Section II - Introduction and Purpose

Texas is one of the most ecologically diverse states in the Union. According to NatureServe's 2002 States of the Union: Ranking America's Biodiversity, Texas is second only to California in terms of its biodiversity. Texas has the highest number of birds and reptiles and the second highest number of plants and mammals in the United States. It has the third largest rate of endemism in the country (TPWD 2002). Much of Texas biodiversity is due to sheer size. It covers approximately 267,000 sq. mi. of land and inland waters and lies adjacent to four states, Mexico and the Gulf of Mexico. It the second largest state in the Union and the largest of the lower 48 states. There are 10 ecoregions within the state ranging from the Pineywoods of East Texas to the deserts and mountain ranges of West Texas. The Gulf of Mexico lines 367 mi. of the Texas coast and provides important habitat for a variety of fish, invertebrates, birds and mammals.

Texas species are as diverse and the Texas landscape. There are 5,500 species of plant in Texas, and greater than 425 of those species are endemics. There have been over 600 bird species identified within the borders of Texas and 184 known mammal species, including marine species that inhabit Texas' coastal waters (Schmidly 2004). It is estimated that there are approximately 29,000 insect species in Texas that take up residence in every conceivable habitat, including rocky outcroppings, pitcher plant bogs and on individual species of plants (Riley in publication).

Overall, Texas has tens of thousands of species that fall under the loose-fitting title "nongame". These species are vital to the ecology of Texas. To help track and manage many of these nongame species, Texas has one of the strongest Wildlife Diversity programs in the country. In addition to our Wildlife Diversity program biologists, Texas also has the largest Urban Wildlife program in the country. With 80% of the Texas' population living in or around the major cities of Texas, it is imperative that the conservation education and opportunity be brought to the city. The Texas Parks and Wildlife Urban Biology program does this by offering landowner workshops, volunteer opportunities and technical guidance to urbanites, absentee landowners, youth and conservation organizations. In addition to our dedicated Wildlife Diversity staff, TPWD also has field Wildlife Biologists who provide technical guidance on wildlife management, provide assistance in regulatory programs and provide educational opportunities primarily to rural residents.

All of the biological branches of the TPWD as well as our myriad of ecological partners spend a great deal of time, effort and resources tracking many of the nongame species and ensuring their future in Texas. The State Wildlife Grants program has offered an opportunity for states like Texas to access and maintain a consistent source of funding that will help to secure a bright future for Texas wildlife and the people who enjoy it. In order to maintain these funds, TPWD, as well as every state fish and wildlife agency in the United States, has been tasked with drafting a comprehensive strategy to address the habitat and species needs of Texas as well as promote and advance relationships with our partners within the state. The strategy must include the following eight elements to be approved:

1^{st} Element: Information on the distribution and abundance of species of wildlife, including low and declining populations as the State fish and wildlife agency deems appropriate, that are indicative of the diversity and health of the State's wildlife.

2^{nd} Element: Descriptions of locations and relative condition of key habitats and community types essential to the conservation of species identified in the 1^{st} element.

3^{rd} Element: Descriptions of problems which may adversely affect species identified in the 1^{st} element or their habitats, and priority research and survey efforts needed to identify factors which may assist in restoration and improved conservation of these species and habitats.

4th Element: Descriptions of conservation actions determined to be necessary to conserve the identified species and habitats and priorities for implementing such actions.

5th Element: Descriptions of the proposed plans for monitoring species identified in the 1st element and their habitats, for monitoring the effectiveness of the conservation actions proposed in the 4th element, and for adapting these conservation actions to respond appropriately to new information or changing conditions.

6th Element: Descriptions of procedures to review the Strategy/Plan at intervals not to exceed 10 years.

7th Element: Descriptions of the plans for coordinating, to the extent feasible, the development, implementation, review, and revision of the Plan-Strategy with Federal, State, and local agencies and Indian tribes that manage significant land and water areas within the State or administer programs that significantly affect the conservation of identified species and habitats.

8th Element: Descriptions of the necessary public participation in the development, revision, and implementation of the Plan.

In addition to meeting the criteria and goals set forth to maintain this source of funds, the CWCS will also be a guide for the future of nongame and even some game species efforts. It will help the TPWD and its partners prioritize, evaluate and reevaluate our priorities over the next five to 10 years. Money for conservation is finite, so all sources need to be used in a fashion which takes into account the needs of the state wildlife and the needs of the landscape as well as the input of the people and ecological organizations of the state of Texas. Texas Parks and Wildlife Department has strived to take all of these points into consideration throughout the process of drafting and compiling this document so that the wildlife of Texas enjoys a strong and abundant future.

Organizational Structure – Development, Implementation, Review and Revision of the CWCS

Element 7

To ensure a diversity of opinions and representation within the CWCS, the Texas Parks and Wildlife Department, in conjunction with Texas State University, hosted the *2004 Wildlife Diversity Conference* held at Texas State University, San Marcos in August. This conference was intended to bring together a diversity of professional biologists and interested organizations to provide a forum for dissemination of current biological information by those biologists, and create a workable structure on which to draft the CWCS.

Texas Parks and Wildlife Department staff attempted to contact all Texas state and federal agencies as well as ecological non-governmental organizations (NGO's) working within the state. Out-of-state NGO's with demonstrated interest in Texas wildlife and wildlife issues and potential for influencing future projects based on State Wildlife Grant funding were also contacted. The conference was successful, and 150 professionals attended at least one of the three days of the event. The event highlighted the natural regions (ecoregions) of Texas on the first day and species group breakout sessions were hosted the second day. The final day focused on increasing support for drafting the CWCS and enlisting volunteers to participate in the project.

Prior to the conference, it was decided that creating working groups to draft the strategy would be the most efficient method to attract partners and gain information. Additionally, working groups would potentially provide a faster turnaround in the development of a draft strategy. Working groups were species-based and consisted of a mammal group, bird group, herptile group, terrestrial invertebrate group and an aquatic group. The aquatic group was comprised of a combination of inland, freshwater specialists as well as coastal, saline specialists. Response was excellent, and the working groups included some of the top specialists in the state. All of the organizations represented by the specialists are noted in this document.

Each working group maintained a TPWD chair and one or more co-chairs from outside of the agency. The working groups were tasked with gathering information to meet elements one through four of the CWCS requirements. Each working group met from one to four times with scheduled agendas and deliverables due at the end of each meeting. The first task for each group to accomplish was to create a list of species in greatest conservation need. In order to create a list of species of concern, the following guidelines were used:

Element 1,3,7

1. All native Texas species were candidates for review
2. Listing state or federally listed Endangered and Threatened species was discouraged but not precluded

Identifying a species as belonging to any of the following categories established it as a strong candidate for listing in the CWCS list of species of concern:

1. Imperiled Species
2. Declining Species
3. Vulnerable Species
4. Species with localized "at-risk", or fragmented populations
5. Species with fragmented or isolated populations
6. Species needs not being met by current funding sources
7. Species of economic importance to the state of Texas

These criteria were adapted from the Teaming with Wildlife Committee, September 15, 2003 memo "Identifying Species in Greatest Need of Conservation". Additional criteria were determined during early sessions of the working groups.

Prior to group meetings, a list of known Texas species was sent to each member of the working group. Working groups used available data as well as expert opinion to determine which species fulfilled the listing criteria. Each group member had the opportunity to highlight species they considered strong candidates for listing. Once the list was updated, the working groups met to discuss the species that should remain on the list for final submission.

The bird working group provides an excellent example of this process in that prior to the first meeting, the chair and co-chair created a list of individual bird species that have been documented within Texas. After removing known vagrants and exotics species, it was sent to each member of the working group. If any member of the working group listed or marked a species as being important, that species remained on the list until the first meeting. Of the original list of greater then 600 species, approximately 380 species remained on the list when the first meeting began. At the first meeting members of the working group, with data and references in hand, discussed each remaining species and determined its final status as a species of concern. This was done in a democratic manner where each working group member was allowed to discuss or present information (data) on any species; after which each species was voted on. All of the working group members knew that this list was dynamic and could be altered throughout the course of the working group process. After the final list was prepared, it was sent to all of the working group members, including those that could not attend the first meeting. After reviewing and deliberating on the draft list the subject was briefly opened again at the second meeting and discussion ensued with several species reviewed for a third time. Once the members of the working group spoke on each specific candidate species, the candidate species were voted on again. The final working list was set and the working group moved on to their next assignments. Resources used to create informed decisions for Texas birds included the following:

1. Texas Breeding Bird Surveys, 1966-2002
2. Texas Christmas Count Surveys, yearly
3. Partners in Flight North American Conservation Plan
4. United States Shorebird Conservation Plan, 2nd Edition
5. Water Conservations for the Americas, North American Waterbird Conservation Plan
6. Bald Eagle Nest Surveys
7. Breeding Non-colonial Waterbird Scores and Status for the southeast U.S. Waterbird Conservation Plan
8. Available U.S Fish and Wildlife Service data
9. Heritage global and state scoring and information
10. Expert Opinion

Due to time constraints, species were ranked on a three-tier system. The simple tiers of high, medium and low priority were established within each working group. Species of highest priority were determined to be in the greatest need of conservation. The species chosen consisted of threatened or endangered populations, species in significant decline, or populations at high risk for decline. Disjunct or isolated populations that could be highly impacted by catastrophic events may also have qualified as high priority. Species of medium priority were deemed to be declining or at-risk but not in critical need of immediate support. These species may be declining at a significant rate; however population size is still estimated to be substantial. Species of lowest priority were typical more stable; however the populations may be vulnerable to decline. Low risk species may also have been species with which the working groups required more information on and could not completely asses but did not wish to abandon. These species may be at-risk however more research and knowledge would be required to establish this. Low risk species may also have less vulnerable populations in other states or in Mexico.

Heritage rankings (number 9, above) were used differently by the individual working groups. The greatest contrast was between the terrestrial invertebrate working group and the other groups. There are approximately 28,975 species of terrestrial insects in Texas (Riley, in publication). In order to reduce the number of listed species the Heritage database was employed by looking most closely at species with a global rank of one (G1 - imperiled) or two (G2 - rare). This immediately brought the reviewed number of species into the hundreds. Other terrestrial invertebrate species were considered, especially those that had not yet been placed in the Heritage database. Many species "groupings" such as South Texas palm grove beetle assemblages were also reviewed and eventually placed on the list. Little is known about this group, however habitat fragmentation is placing its habitat type in decline and therefore the assemblage is in greater peril. The bird working group did use the Heritage database to make priority decisions; however just listing G1 species would not have created a comprehensive list. The majority of the species that are on the bird list are G3 (uncommon or restricted) and above. These species were still deemed to have significant detrimental biological factors associated with their survival and are often in decline.

One factor that confounded the review of some species was the lack of information on or the secretive nature of the species. This was most true of invertebrate species. Similarly, survey efforts of mammals have been applied unequally across Texas. Other then lack of time, lack of information on a genus or species was often the driving force behind the liberal use of expert opinion. To create the most comprehensive and appropriate list of species, working groups often relied on the opinions of scientists who have current and historical knowledge of species and are regarded as authorities. Their research and monitoring activities are often the only source of information on a particular species or genus.

Not all working group members could attend each meeting; however the entire working group was invited to review and comment on the output from each of the previous meeting. Most of this was done via e-mail. At least one group decided to conduct much of their correspondence and production via e-mail because of extensive geographical range of working group representatives and the difficulty of travel. Many of the members of the working groups also presented information to species specialists that were not members of the working groups. All of these professionals essentially gained entrance and provided input into the original working groups through the working group member that contacted them. This input was taken very seriously by working group members.

Texas Parks and Wildlife Department had over 50 staff members involved in this process. Each major wildlife region and district associated with TPWD was represented. Each of these regions and districts cover a wide variety of habitat types and communities. The Inland Fisheries Division and Coastal Fisheries Division were also heavily involved with the aquatic working group. Each Division Director as well as the Chief Operating Officer, the Chief of Staff and the Executive Director was kept apprized of the status of the strategy and the working group's progress. Each person was invited to offer input, advice, or general comment at several stages of development. The Communications Division Director and her staff were instrumental in developing and implementing the public input methodology. Overall, the internal work and effort from TPWD staff was unprecedented.

External participation was also unparalleled, with a number of Universities, NGO's and agencies participating in the working groups or having input through the established TPWD Wildlife Diversity Policy Advisory Committee. This is a group of interested agencies, NGO's and landowner groups that help create direction for the Science, Research and Diversity program at TPWD. All of these organizations were eager to assist and added a great deal of important and needed information. Without these organizations the development of this strategy would not have been possible.

Review of the Strategy

The review of the CWCS was handled as part of the public participation process. Partners were encouraged to attend the public meetings that were designed for review of the strategy. Those agencies and organizations that were part of the original working groups were notified through their working group chair people to attend the meetings for a briefing on the strategy. Once the briefing was completed, the individuals were asked to please read the strategy online and make comments on the available forms or send in e-mails with attached comments. Documents were placed on the website, primarily as Word documents so that a tracking function could be used to make comments or amendments to the individual sections of the document. All comments were reviewed and changes to the final strategy were made or documentation was made as to why changes could or should not be made to the final document.

Revisions of the Strategy

All comments derived from federal, state and local agencies, Indian tribes and other conservation entities were used to create the final draft of this strategy. As stated previously, the public comment process of the strategy was intended to gather information from these organizations as well as the general public. The groups will be encouraged to add significant edits to revisions that occur every five years.

Implementation of the Strategy

The TPWD currently uses a grant proposal system to do research or on-the-ground conservation using State Wildlife Grant money. In order to ensure that all conservation organizations can be involved in this process and therefore receive funds from the State Wildlife Grants program, TPWD staff is encourage to find partners to assist with and/or help finance certain projects. Once this strategy is in place and TPWD's partners have had an opportunity to digest the contents of this document, those groups can then contact appropriate TPWD staff and attempt to obtain funds for projects. This will allow for a large portion of the money spent from this grant program to be used with the support of or the direct partnership with state and national conservation entities. In addition, there is the potential for TPWD to simply have a set aside fund or funds for "pass through" grants from State Wildlife Grant appropriations. This would allow universities or conservation organizations to submit grant proposals directly to the State Wildlife Grants administrator for evaluation and possible funding. By doing this, the groups submitting the grant does not need to work with TPWD personnel and could submit without a "sponsor" staff member. This would potentially reduce the partnering aspects of this program but it could increase the number of organizations that would seek funding.

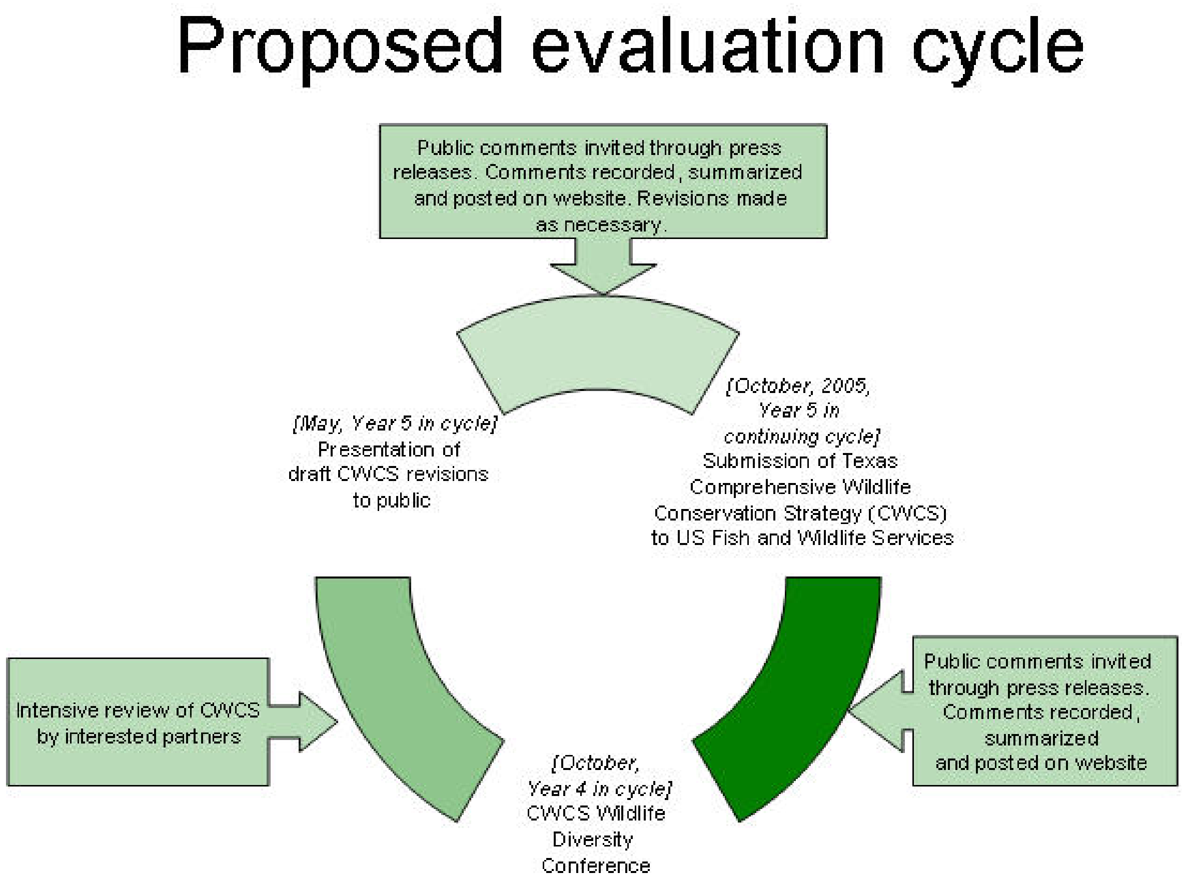
Procedures for Review of the CWCS

Element 6,7,8

Texas Parks and Wildlife has been fortunate to have had the input of multiple conservation organizations during the drafting of the CWCS. Many of these partnerships were developed at the August *2004 Wildlife Diversity Conference*. In order to keep these partnerships active and to create new opportunities for conservation organizations to partner on new projects it is important that the conservation community come together to review and redraft the CWCS at regular and reasonable intervals.

Because of rapid changes in technology and the need to conduct large and long term large conservation projects, it is important to reevaluate nongame conservation progress at intervals not to exceed five years. It is also important that the CWCS be reviewed and evaluated with the input of our conservation partners as well as the public. Throughout the life of each CWCS, a website (http://www.tpwd.state.tx.us/business/grants/wildlife/cwcs/) will be maintained to collect, summarize and post public comments regarding the strategy. Additionally, forums such as the *2004 Wildlife Diversity Conference* are an excellent way to bring biologists together to evaluate individual conservation projects and determine if those projects are meeting the goals of the CWCS and the needs of conservation in Texas. If those goals are not being met, it is important to get input from partners and TPWD staff and make adjustments to ensure quality conservation. Future Wildlife Diversity Conferences should be held at a minimum of every four years after the latest draft of the strategy has been submitted to USFWS. After the conference, changes or adjustments to the goals and objectives of the strategy should be made and a draft of the new document should be presented to the public for final review. The updated document should then be sent to United States Fish and Wildlife Service (USFWS) in the fifth year. This method allows for formalized and scheduled interaction with conservation partners and ample opportunity for the general public to review and comment.

Throughout the life of each draft of the CWCS, it is important for TPWD to continually take public comment on the current strategy and make amendments. Maintaining and updating the website and the electronic and paper comment forms in addition to drafting and releasing press information after each substantial modification of the strategy will allow TPWD to gain feedback at regular intervals. This feedback will permit TPWD to maintain consistent interaction with the public and partners and ensure shorter turn-around on major modifications and resubmissions to USFWS.



Public Involvement and Partnerships

Element 7,8

A relatively recent method for obtaining public comments has been developed by the Texas Department of Transportation (TxDOT) for use in their proposed Trans-Texas Corridor, Oklahoma to Mexico/Gulf Coast (TTC-35) project. The methodology involves a series of public meetings along the proposed corridors, in which TxDOT, their subcontractors and project contributors attend each meeting to discuss a series of poster boards designed to give the public information without overwhelming them. The posters are set up in a manner that allows the public to move from one poster to the next to gather "big picture" ideas, then move to regionally-specific posters with maps that indicate the proposed highway corridors as well as data that supports the need for increased focus on particular traffic-ways. These meetings were advertised six weeks in advance. This methodology lends itself to ease of movement from venue to venue, it is non-confrontational and it allows the public to interact with critical personnel involved in the project. It promotes one-on-one interaction that allows no single person or special-interest group to monopolize a meeting with a specialized agenda.

There are a limited number of seats in the venue to promote movement and flow of the public. In addition to the posters and maps, there are locations within the venue to sit and write comments, a court stenographer is available for those who wish to make verbal statements and television/VCR/DVD combination sets that allow for the posters to be projected through a looping PowerPoint presentation for those attendees that can not stand or walk for great lengths of time. Also available are business card sized handouts that have phone numbers to call, e-mail addresses for commenting electronically, mailing addresses and the active website link for the project. Information is provided in both Spanish and English on the same card. At the entrance of each venue there are personnel available to greet and introduce the process. A large map allows attendees to place a mark in the approximate location of their home so that TxDOT knows how far attendees have traveled.

Texas Parks and Wildlife Department emulated this process with the development of a PowerPoint presentation that can be transferred to poster boards as well as looped on DVD. The PowerPoint Presentation was developed to describe the need for the CWCS, to give information on the required elements of the strategy and to receive comments on the success of meeting the required elements by TPWD and our partners. Our partners and the Wildlife Diversity Policy Advisory Committee representatives are listed in the presentation. Maps associated with the region of interest, based on the location of the meeting, were also available for the public to represent the project scope and the ramifications to their area or ecoregion. The Wildlife Division Planner, the Program Leader for Nongame and Rare and Endangered Species, a cadre of TPWD biologists and partners traveled with the exhibit to the different venues. Regional TPWD employees and partners were available at each meeting to assist in answering questions. These assistants were responsible for discussing biological components of the strategy while the planner answered questions concerning the strategy effort, scope and ramifications of the document.

Copies of the PowerPoint presentation and the complete CWCS were made available to the public so that individuals could comment directly on the text. Prior to the event, sections of the draft strategy could be downloaded from the TPWD-hosted website (http://www.tpwd.state.tx.us/business/grants/wildlife/cwcs/) to allow the public to be more informed about the project. The website and instructions for downloading the project were issued in the press release prior to the public comment sessions.

Public Meetings were held in the following cities and venues:

Austin: July 11, 2005
TPWD Headquarters, 4200 Smith School Road, Austin, Texas

Houston: July 13, 2005
Houston Zoo, 1513 N. MacGregor, Houston, Texas

Dallas: July 14, 2005
Dallas Zoo, 650 South R.L. Thornton Freeway (I35-E), Dallas, Texas

Waco: July 14, 2005
Cameron Park Zoo, 1701 North 4th Street, Waco, Texas

Lufkin: July 18, 2005
Ellen Trout Zoo, 402 Zoo Circle, Lufkin, Texas

Abilene: July 19, 2005
Abilene Zoological Gardens, 2070 Zoo Lane, Nelson Park, Abilene, Texas

Lubbock: July 20, 2005
Science Spectrum, 2579 S. Loop 289, Lubbock, Texas

El Paso: July 21, 2005
Magoffin Home State Historic Site, 1120 Magoffin Ave, El Paso, Texas

San Antonio: July 25, 2005
San Antonio Zoological Gardens and Aquarium, 3903 North St. Mary's Street, San Antonio, Texas

Brownsville: July 26, 2005
Gladys Porter Zoo, 500 Ringgold Street, Brownsville, Texas

Corpus Christi: July 27, 2005
Texas State Aquarium, 2710 North Shoreline, Corpus Christi, Texas

Of the 11 locations that TPWD held public comment sessions, eight were sponsored by American Zoo and Aquarium Association (AZA) accredited zoos and aquariums. Many of these facilities were also involved with the CWCS Working Groups that drafted the comprehensive strategy elements essential to the development of the CWCS. While many zoos are known for their work with exotic species, most also work with species native to their region and engage in strong conservation efforts concerning native fauna.

The strategy website was originally developed for the partners and the CWCS Working Group members to have a centralized location for posting information concerning their meetings and posting resources that might be needed by the teams, including reference materials to help develop the eight required elements of the CWCS. This website was adapted to fit the needs of the public comment session by posting the public comment dates, times and venues as well as posting the PowerPoint presentation developed for the meetings. The individual sections of the CWCS were also posted. The website also included a link that allows citizens to contact the planner and comment directly either in English or in Spanish.

The CWCS for Texas was placed on the website in outline form so that each section or chapter could be opened or downloaded individually. Maps associated with each section were also uploaded to the site so that reviewers and interested parties could review the overall strategy. In addition to the strategy and maps, questionnaires were placed on the website so the citizens, TPWD staff and partnering organizations could comment on the strategy and send their critiques or suggestions directly to the TPWD staff. The sections of the strategy were placed in Microsoft Word documents that could be opened, comments and suggestions made and the edited electronic or printed document could be sent back to TPWD staff for consideration. While the public comment methodology used for the CWCS exploited the advantages of the Internet, list serves, newspapers, newsletters, and other media, this allowed TPWD to reach a greater audience and improve attendance to the public comment sessions held in the cities across Texas. While public attendance was not what was anticipated, there was a large effort to get the public involved and also follow up with the individual meetings by doing further press interviews and general media follow-up.

All comments from the individual sessions or from the website where compiled into one document for scrutiny by TPWD staff. As appropriate, comments were taken and changes were made to the final draft of the strategy up until the strategy was finalized.
Further public involvement was encouraged after the final submission of the CWCS by continuing to accept comments for the first CWCS review, mainly from our website, as well as publicizing our first strategy draft at TPWD's annual Wildlife Expo held in October.

Aside from receiving comment from the general public, the most critically important aspect of the public comment meetings was the forging of new partnerships between TPWD and the ecological partners that attended the meetings. There was a high level of interest in the strategy from several groups including zoos which hosted the CWCS meetings. The partnerships that were developed were worth the time necessary to travel across the state.

Terrestrial Conservation Priorities for Texas Waters based on the Land and Water Resources Conservation and Recreation Plan (Land and Water Plan)

Associated Maps

Ecoregions of Texas………………………...1

Introduction

Texas incorporates habitat types found in the states of Louisiana, Arkansas, Oklahoma, New Mexico and Mexico. It also encompasses habitats found no where else but in Texas. With diversity (and size) come great challenges. These challenges are rooted in the bureaucracy of monitoring an entire State as well as the specific conservation actions that must be enacted to ensure the stability and improvement of habitat for native species. In order to provide a more coordinated and focused approach to habitat and wildlife management, it is imperative that TPWD and other state agencies work with conservation partners to address threats to species and habitats, combining resources for the benefit of Texas wildlife and habitats.

Conservation Threats on Land

Element 3

There are many threats to wildlife habitat and plant communities in the state; some are specific to particular geographic regions, while some occur statewide. The following describes the general threats to natural resources statewide. Specific threats in each ecoregion are described in the Ecoregion Priority Analysis.

Changing Demands on Land Resources

Projected population growth and fragmentation, or the division of single ownership properties into two or more parcels, have had profound effects on the landscape. Land conversion changes natural habitats, which can threaten the viability of those habitats and sustainability of wildlife populations. For example, Texas A&M's *Fragmented Lands: Changing Land Ownership in Texas (Wilkins et al. 2000)* report found that the conversion of rural land to urban use in Texas exceeded 2.6 million ac. from 1982 to 1997. Such changes will increase pressures on natural resources throughout the state, especially near growing metropolitan areas.

Introduced Species in Terrestrial Environments

Non-native plant and animal species introduced into the state can displace native species, threaten habitat integrity and can profoundly alter the landscape. For example, Chinese tallow has invaded woodlands and coastal prairies and, left unchecked, changes these diverse habitats into virtual monocultures. Introduced grass species can create monocultures devoid of quality wildlife forage and of limited useful habitat for young ground nesting birds. For some ground dwelling birds like quail, these dense turf-type grasses cannot be traversed, which fragments their habitats. Imported red fire ants in eastern Texas have profound, but not fully understood, adverse impacts on many wildlife species.

Noxious Brush and Invasive Plant Species

Undesirable or noxious brush, woody and invasive plant species such as mesquite, salt cedar, Chinese tallow and condalia absorb vast quantities of water and provide little or no forage for wildlife or livestock. Many of these plant species are present in excessive quantities on rangelands in Texas today and through improved range management techniques, can be significantly reduced or controlled to benefit water quality and quantity as well as wildlife habitat.

Overgrazing and Fire Suppression

Improper grazing and fire suppression have contributed to a drastic alteration of the historic landscape. Improper grazing results in decreased diversity in forage and cover for nesting as well as other needs of wildlife. In addition, fire suppression has caused native grasslands, savannahs and open woodlands to become overgrown with thickets of woody species.

Limited Understanding of Complex Natural Systems

Research is a critical component of natural resource conservation. Without reliable knowledge and rigorous scientific inquiry, scientists cannot make informed conservation decisions. For instance, some principles of wildlife ecology, such as the early research of edge effects on wildlife, have since been found to inadequately describe natural systems. The decision making process at TPWD must remain grounded in the best science available to assure that policy development, regulatory action and resource management are accurate and effective.

Ecoregion Priority Analysis

Element 2,3,5

Texas is a large and ecologically complex state with deserts, mountains, hills, prairies, forests, karst features, springs, rivers, wetlands and coastal habitats. One of the first challenges in addressing the conservation priorities was to determine what scale to use when describing the diversity found in the state. The scale could range from species-level to population, community, habitat or ecoregion level analysis. Ecologists typically divide the state into ecoregions that categorize the complex, dynamic system of vegetation, climate, geology and soils into a broad and comprehensible form. Given this complexity, the range in scale of the data inputs and the goals, TPWD chose the ecoregion scale as most appropriate for this analysis.

Primary Inputs

Element 2.3

The conserved status in each ecoregion was determined by using the percent of publicly owned land, land owned by non-governmental conservation organizations and large local parkland designated for conservation as well as the percentage of the region operated under TPWD wildlife management plans. This evaluation takes into account the probability of private and public lands being conserved in the future. The analysis assumes that all public lands are protected into perpetuity and that the conservation value of private lands managed under wildlife management plans is currently stable. However, TPWD recognizes that public and private lands can be sold or converted to other purposes and the conservation value of both depends on the quality of management.

The percentage of land converted to urban or agricultural use, fragmentation and population growth projections were used to determine the primary level of threat of each ecoregion. Texas Parks and Wildlife Department recognizes that urban lands can provide limited habitat for some species, though many native wildlife habitats have been negatively impacted by these conversions. The biological value was determined by the total vertebrate species richness, or actual number of species, as well as the vascular plant species richness occurring within the ecoregion.

Secondary Inputs

In determining a final ranking for the 10 ecoregions, a number of secondary factors were also considered.

The conservation value of Conservation Reserve Program (CRP) land, pastureland, commercial timberland and rangeland falls between that of undisturbed, natural habitats and crop and urban lands. The percentage of land under each of these human managed systems in each ecoregion was considered as a secondary input in the analysis.

This evaluation considered miles of roads per acre in each ecoregion as a secondary indicator of land fragmentation.

The evaluation also considered the percentage of vertebrate species of concern (e.g. threatened, endangered, candidate and other species) as well as the number of rare plants in each ecoregion. Though rarity is a natural aspect of the biology of some species, TPWD recognizes that it is an appropriate value to use for broad generalizations with regard to threat and vulnerability.

Texas Parks and Wildlife Department weighted the conserved status, primary level of threat and biological value equally and used these values to rank the ecoregions. Considering the secondary inputs, TPWD categorized the ecoregions of the state into three tiers: high, secondary and tertiary ecoregions. Within each tier, the ecoregions are listed in alphabetical order.

Texas Parks and Wildlife Department will continue with existing efforts in the secondary and tertiary ecoregions, but will focus more resources to increase the number of technical guidance biologists, increase lands under wildlife management plans and other conservation actions in the high priority ecoregions. In addition, the Department will evaluate other methods, such as building partnerships with local and nonprofit organizations, to improve water availability and conserve wildlife habitat in these sensitive ecoregions.

Element* *2,3,6,7,8

Texas Parks and Wildlife Department also identified high priority habitat types that occur across all ecoregions, which are described in detail following the Priority Ecoregions for TPWD Conservation Efforts. The Department will focus its efforts to conserve, restore, or enhance these habitats over the next 10 years through acquisitions, partnerships with other entities, wildlife management plans, education and other TPWD programs.

Tier I – High Priority Ecoregions for TPWD Efforts

Blackland Prairie

Conserved Status: This ecoregion ranked medium in conserved status because there is only a small percentage of public and non-profit conservation land and private property operated under wildlife management plans.

Element* *1,2,3,4

Threats: This is the most severely altered of Texas' ecoregions, since most of the Blackland Prairie has been converted for cropland or urban development. Only an estimated 5,000 ac. remain in their historic condition in terms of plant species. All habitats in this ecoregion are threatened by rapid population growth and accompanying conversion to urban areas and pastureland, fragmentation and decreased land parcel size.

Rare Plants and Communities: This ecoregion ranks lowest in number of rare plant species and seventh in number of endemics, but all four native Blackland Prairie grass communities are rare.

Rare Animals: Many tall grass prairie birds have declined drastically due to land conversion and fragmentation. This region is an important stopover habitat for migrant songbirds and wintering raptors.

Priorities: Protection and restoration of remnant prairies is a high priority.

Gulf Coast Prairies and Marshes

Conserved Status: Overall, this ecoregion ranked relatively high in conserved status second only to the Trans-Pecos ecoregion, although conservation efforts are not evenly distributed across the region. The coastal marshes and barrier islands are relatively well conserved, whereas the inland prairies, coastal woodlands and some beach habitats are not.

Threats: All factors considered this is among the most threatened of the 10 ecoregions and the more threatened of the two high diversity ecoregions. The increased population growth and associated development along the coast have fragmented land, converted prairies, changed river flows, decreased water quality and increased sediment loads and pollutants within marsh and estuarine systems. Projections indicate continued high growth and increased fragmentation in most parts of this ecoregion.

Rare Plants and Communities: The region ranked high in rare plant species and endemism including five rare plant communities. All of the region's 24 rare plants occur inland where the conserved status is lowest.

Rare Animals: Attwater's prairie chicken, whooping crane, aplomado falcon, white-tailed hawk, Gulf Coast hog-nosed and eastern spotted skunks are all in need of attention, as are many bird species that depend on this important migratory stopover area.

Priorities: Protection efforts should focus on inland prairies and coastal woodlands. Many beach areas and mud flats need additional protection.

South Texas Plains

Conserved Status: This ecoregion ranked relatively high in conserved status overall. The South Texas Plains consists mostly of level to rolling terrain characterized by dense brush. Little of the brush country is conserved on public lands, but a relatively high percentage is in large stable ownerships and operated under wildlife management plans. Much of the high quality brush habitat that still exists in the Lower Rio Grande Valley (LRGV) is in public ownership, but it is insufficient to sustain many of the region's threatened plants, animals and communities.

Threats: Overall, this region ranked relatively high. Threats are concentrated in the LRGV due to the expanding human population, fragmentation, conversion to croplands, urban development, insufficient river flow and introduction of exotic plants.

Rare Plants and Communities: Rare plant communities include the Texas ebony-anacua, Texas palmetto and Texas ebony-snake-eyes assemblages. Rare species include Walker's manioc, star cactus, Texas ayenia and Zapata bladderpod.

Rare Animals: The LRGV has particularly rich bird and butterfly faunas as well as the endangered ocelot and jaguarundi.

Priorities: The remaining fragments of brush in the LRGV should be protected and corridors between these habitats should be protected and restored.

Tier II – Secondary Priority Ecoregions for TPWD Efforts

Cross Timbers and Prairies

Conserved Status: This ecoregion, along with the High Plains, rank the lowest in conserved status. There is little public land, few private preserves and a low percentage of private land under wildlife management plans.

Threats: The Cross Timbers and Prairies ecoregion ranked medium in terms of land conversion, but the potential for rapid conversion and fragmentation in the future is suggested by high projected population growth. Threats in this region include fragmentation and land conversion of prairies, forests and savannahs, mesquite invasion of degraded grasslands and proliferation of exotic grasses. Rivers and streams have been altered by an extensive reservoir system. Hundreds of miles of riparian, or river, forests have been inundated and downstream flows reduced. Most ground nesting birds, grassland mammals, amphibians and egg-laying reptiles are also threatened by fire ant invasion.

Rare Plants and Communities: This ecoregion harbors only one rare plant and has relatively low endemism. Patches of Blackland Prairie grasslands within the Cross Timbers are made up of threatened communities similar to those described for other ecoregions.

Rare Animals: The region provides nesting habitat for the federally endangered black-capped vireo and the golden-cheeked warbler.

Priorities: Protecting the ecoregion's prairies, woodlands and remaining river corridors should be a priority.

Edwards Plateau

Conserved Status: Despite a small amount of public and non-profit conservation land, the region ranked medium due to the relatively high percentage of private land managed under wildlife management plans.

Threats: Land conversion values for the ecoregion, overall, were relatively low. However, projected population growth and subdivisions of large tracts of land are high, particularly in the eastern portion where intense development and fragmentation threatens the biodiversity and the region's unique hydrology.

Rare Plants and Communities: The Edwards Plateau is internationally recognized for its unique flora and its karst systems. It has the highest number of plant endemism of any ecoregion in the state and ranks third in number of rare plants. Of the 29 plant communities found here, three occur nowhere else in Texas and two are found nowhere else in the world.

Rare Animals: Karst habitats support many species of salamanders and cave insects, many of which are restricted to only a few sites. This is the most important ecoregion for herpetological and invertebrate species due to high endemism, sensitive habitats and intense threats. Black-capped vireos and golden-cheeked warblers are the two bird species of greatest concern.

Priorities: The sheltered canyons, springs, caves and river systems are home to most of the biological diversity and should be priorities for public and private conservation efforts. Conserving relatively intact grasslands and maintaining sufficient old growth juniper habitat for the golden-cheeked warbler, especially in the western hill country, are also a priority.

<u>High Plains</u>

Conserved Status: This ecoregion is the least conserved because there is a low percentage of public and non-profit conserved land and wildlife management plans for lands located in the High Plains.

Threats: This ecoregion experienced a high rate of conversion to crops, but a considerable portion of it is now enrolled in the USDA's Conservation Reserve Program that has higher conservation value than cropland. Threats include fragmentation and land management practices that are harmful to species such as lesser prairie chickens. Other threats include the damming of springs, streams and rivers, the draining and conversion of playa lakes and surface mining.

Rare Plants and Communities: Plant endemism is low, but there are two rare species, five endemics and several distinct plant communities.

Rare Animals: Birds of concern in this region include ferruginous and Swainson's hawks, burrowing owls, mountain plovers and lesser prairie chickens. The black-tailed prairie dog, swift fox and pronghorn need conservation attention as well.

Priorities: Increasing the percentage of conserved land to support several important game species and threatened animals is a priority.

Pineywoods

Conserved Status: This ecoregion ranked medium in conserved status because of the relatively high percentage of publicly owned land and medium percentage of land under wildlife management plans. The northern half of the ecoregion is not well conserved and has unique habitats and rare species of plants and reptiles.

Threats: The Pineywoods ranked relatively low in terms of land conversion, but high in terms of projected population growth. Much of the longleaf pine and hardwood forest habitats have been converted to loblolly plantations, which have limited conservation value. The primary threats are fragmentation and land conversion. For instance, the consolidation of timber interests around the country has led to sales of large timber tracts in east Texas which may be converted to other uses. Fire suppression, fire ant and Chinese tallow invasion are also threats. Much of the best remaining bottomland hardwood habitat is threatened by potential reservoir construction.

Rare Plants and Communities: Plant endemism ranks relatively low, though the region supports 22 rare species and 27 endemics. The longleaf pine savannahs have been reduced from approximately 1.5 million ac. historically to 50,000 ac. today.
Many of the acid seeps and pitcher plant bogs have been converted for other uses. The federal and state listed Houston toad exists in a confined area located in the spatially separated Pineywoods habitat near Central Texas (Bastrop County) known as the Lost Pines.

Rare Animals: The Gulf Coast Prairies and Marshes and Pineywoods ecoregions share one of the world's most diverse and highly threatened mussel populations. Reptiles of concern include the Louisiana pine snake, alligator snapping turtle and timber rattlesnake. In general amphibians are declining. Birds of concern are the red-cockaded woodpecker, Bachman's sparrow and other grassland savannah nesters and winterers. The endangered Louisiana black bear may be attempting to naturally recolonize the area and the conservation of bottomland forests is critical to their return.

Priorities: Longleaf pine savannahs and other unique plant communities, including bogs, hardwood slope forests, and baygalls, should be preserved and restored wherever possible. Conservation and restoration of remaining bottomland hardwood habitats, such as in the San Bernard River Basin, is also important for many wildlife species.

Tier III –Tertiary Priority Ecoregions for TPWD Efforts

<u>Post Oak Savannah</u>

Conserved Status: The Post Oak Savannah ecoregion ranked medium in conserved status because only a small percentage is public or non-profit conservation land.

Threats: This ecoregion ranked relatively low in threats overall. The primary threats are fragmentation and land conversion, especially from the damming of springs, streams and rivers. Other threats include fire ant infestation and fire suppression in both oak savannahs and pitcher plant bogs.

Rare Plants and Communities: Endemism in the plants of this ecoregion ranks lower than in others, though the area supports 17 rare species and 65 endemics. Many highly specialized plant habitats such as blowout sandhills, clay-pan savannahs, pitcher plant bogs, Catahoula and Oakville sandstone outcrops, chalk glades and limestone prairies support numerous rare plants, which are not found on public land.

Rare Animals: There are several species of concern in the region including loggerhead shrike, painted bunting, spotted skunk and the Brazos water snake.

Priorities: Conservation efforts in this region should focus on areas that support many of the region's unique species and communities such as mesic hardwood woodlands, bogs, sandhills and bottomland hardwoods.

Rolling Plains

Conserved Status: The ecoregion ranked low in conserved status with a relatively small amount of public and non-profit conservation land and a medium percentage of land under wildlife management plans.

Threats: This region ranked medium in threats including land fragmentation and conversion. Exotic species such as salt cedar exist along many miles of riverbank.

Rare Plants and Communities: The only rare plant endemic to this region, the Texas poppy-mallow, is associated with the mesquite grasslands and Havard shin oak communities.

Rare Animals: Low forests on limestone out-pockets are important habitat for the endangered black-capped vireo. Both the federally listed Concho and Brazos water snakes occur here. The state listed Texas kangaroo rat also survives in this region.

Priorities: This region is a prime candidate for restoration efforts and many species would benefit from restoration of grasslands and riparian forests. Protection of the Texas poppy-mallow and high quality examples of communities such as Harvard oak-tallgrass, sandsage-midgrass and cottonwood-tallgrass grasslands and woodlands are also important.

Trans-Pecos

Conserved Status: This ecoregion is the most conserved of all ecoregions, but the conserved lands are not evenly distributed across the region. The desert grasslands of the region are poorly conserved, as are much of the forests along the Rio Grande and plant communities around springs.

Threats: Threats in this region are the lowest of any ecoregion but include persistent drought and groundwater withdrawals that have damaged many existing spring-associated communities. Expansion of human activities in the El Paso region will negatively impact habitats in the surrounding areas.

Rare Plants and Communities: The region is one of Texas' botanically richest and most unique. Approximately one of every 12 plant species occur nowhere else in Texas. The Trans-Pecos supports three times the number of rare plants than any other region. Much of the banks of the Rio Grande are choked with salt cedar, making the protection of the rare patches of cottonwood-willow and velvet ash-willow communities important. Many springs and their associated cienegas and creeks once contained numerous rare plants, but most have dried out. Of the few springs that remain, only three are permanently conserved.

Rare Animals: This region has the highest percentage of vertebrate species of concern. The bird, mammal and insect faunas are rich and unique. Rare birds include the golden eagle, the common black hawk, elf and flammulated owls, peregrine falcon, Montezuma quail and others. Mammals include the black-tailed prairie dog, kit fox, desert bighorn, pronghorn, Mexican black bear and hooded skunk. This is by far the most herpetologically diverse ecoregion. Species of concern include the Chihuahuan mud turtle and the dunes sagebrush lizard.

Priorities: The high desert grasslands, spring communities and riparian woodlands along the Rio Grande need additional conservation action.

High Priority Habitats

Despite the many benefits associated with studying at the ecoregion scale, the very real and often critical conservation needs of some habitats, communities and species can be missed by this approach. Every ecoregion in Texas is home to important game species, threatened and endangered species, significant habitats and communities. The Priority Ecoregion Analysis showed that native prairies and grasslands, riparian habitats that cross ecoregion boundaries, are the most important wildlife habitats, contain the highest numbers of rare species and are often the most threatened. These habitat types will be a priority for the department in the future.

Native Prairie and Grassland Habitat

Native prairies and grasslands once covered Texas from the shortgrass prairies in the Panhandle; to the coastal marshes of the Gulf; to the desert and montane grasslands of the west; and even to small openings within the Pineywoods. These habitats supported a vast array of species including bison, prairie dogs, eastern meadowlarks, northern bobwhites, big bluestem and Indiangrass. Without native prairies and grasslands, cattle ranching and cotton production would not have been successful in the state; but relatively little native habitat remains today. Even those patches of prairies and grasslands that have not been altered or converted to other uses often support fewer species due to fragmentation, fire suppression, overgrazing and woody plant invasion. Nevertheless, with proper management, native prairie and grassland habitats are resilient and many can be restored.

Riparian Habitats

Riparian habitats include vegetation found along the banks and on the floodplains of rivers, creeks and streams. Riparian forests that cover broad floodplains are often referred to as bottomland hardwood forests. In arid regions, and in times of drought, riparian corridors are often the only place where trees and wildlife species are able to survive. These corridors support highly diverse wildlife because they are critical feeding areas and serve as valuable refuges. Riparian forests improve water quality and quantity and provide important nutrients to the streams and rivers. Riparian vegetation also holds water by slowing the rate at which water moves from the land into streams and shaded waterways lose much less water to evaporation.

Element 4

Goals for Terrestrial Conservation

<u>Goal: Increase Support for Conservation on Private Lands</u>

Objectives:

Increase lands under Wildlife Management Plans (WMP).

- Double lands under Wildlife Management Plans to 28 million ac.

- Increase percentages of WMP's in high priority ecoregions identified in the Land and Water Plan (South Texas, Gulf Coast and Blackland Prairies)
- Increase percentage of ecoregion under WMP’s in the High Plains, Pineywoods and Cross Timbers where lowest percentages currently exist
- Increase WMP’s focused on high priority habitats (native prairies, riparian areas) identified in this Plan and for priority wildlife species (priority birds, bighorn sheep, white-tailed deer, lesser prairie chickens, pronghorn, mule deer and quail)
- Support the establishment of a purchase of development rights program in Texas that is consistent with the TPWD’s mission in the conservation of natural resources

Goal: Improve Science and Data Collection

Objectives:

Undertake a complete review of all scientific and conservation programs.

- Review, assessment and monitoring functions for fish and wildlife populations
- Complete an independent programmatic peer review
- Establish a systematic review process

Develop an integrated GIS database of fish, wildlife and water data to assure that decisions are based on sound science and the best available data.

- Annually develop Internet accessible data and analytical capability as well as provisions for continuous updating and coordination with other state agencies to access pertinent data
- Complete formal agreements with state and federal resource agencies where necessary
- Expanded efforts should be made with private landowners to improve water quality and quantity through watershed management and conserve important wildlife habitat

Tier I – High Priority: Blackland Prairie Ecoregion

Associated Maps

Ecoregions of Texas………………………...1

Blackland Prairie Ecoregion……………….. 2

Element 1

Associated Section IV Documents

The Texas Priority Species List…………….733

Supplemental Mammal Information……….. 897

Supplemental Herptile Information………... 988

Priority Species

Group	Species Name	Common Name	State/Federal Status
Birds	*Aimophila cassinii*	Cassin's sparrow	SC
	Aimophila ruficeps	Rufous-crowned sparrow	SC
	Amazilia yucatanensis	Buff-bellied hummingbird	SC
	Ammodramus savannarum	Grasshopper sparrow	SC
	Anas acuta	Northern pintail	SC
	Anthus spragueii	Sprague's pipit	SC
	Aquila chrysaetos	Golden eagle	SC
	Asio flammeus	Short-eared owl	SC
	Athene cunicularia	Burrowing owl	SC
	Aythya affinis	Lesser scaup	SC
	Aythya americana	Redhead	SC
	Aythya valisineria	Canvasback	SC
	Bartramia longicauda	Upland sandpiper	SC
	Botaurus lentiginosus	American bittern	SC
	Buteo lineatus	Red-shouldered hawk	SC
	Buteo regalis	Ferruginous hawk	SC
	Buteo swainsoni	Swainson's hawk	SC

Calcarius mccownii	McCown's longspur	SC
Calidris himantopus	Stilt sandpiper	SC
Calidris mauri	Western sandpiper	SC
Caprimulgus carolinensis	Chuck-will's-widow	SC
Chaetura pelagica	Chimney swift	SC
Charadrius alexandrinus	Snowy plover	SC
Charadrius melodus	**Piping plover	FT/ST
Charadrius montanus	Mountain plover	SC
Chondestes grammacus	Lark sparrow	SC
Chordeiles minor	Common nighthawk	SC
Circus cyaneus	Northern harrier	SC
Cistothorus platensis	Sedge wren	SC
Coccyzus americanus	Yellow-billed cuckoo	SC
Colinus virginianus	Northern bobwhite	SC
Contopus virens	Eastern wood-pewee	SC
Coturnicops noveboracensis	Yellow rail	SC
Dendroica cerulea	Cerulean warbler	SC
Dendroica discolor	Prairie warbler	SC
Dendroica dominica	Yellow-throated warbler	SC
Dryocopus pileatus	Pileated woodpecker	SC
Egretta caerulea	Little blue heron	SC
Egretta thula	Snowy egret	SC
Egretta tricolor	Tri-colored heron	SC
Elanoides forficatus	Swallow-tailed kite	ST
Elanus leucurus	White-tailed kite	SC
Empidonax virescens	Acadian flycatcher	SC
Eremophila alpestris	Horned lark	SC
Falco columbarius	Merlin	SC
Falco mexicanus	Prairie falcon	SC

Falco peregrinus tundrius	Arctic peregrine falcon	ST
Falco sparverius	American kestrel (southeastern)	SC
Gallinago delicata	Wilson's snipe (formerly common snipe)	SC
Grus americana	**Whooping crane	FE/SE
Haliaeetus leucocephalus	Bald Eagle	FT/ST
Helmitheros vermivorum	Worm-eating warbler	SC
Himantopus mexicanus	Black-necked stilt	SC
Hylocichla mustelina	Wood thrush	SC
Icterus spurius	Orchard oriole	SC
Ictinia mississippiensis	Mississippi kite	SC
Ixobrychus exilis	Least bittern	SC
Lanius ludovicianus	Loggerhead shrike	SC
Limnodromus griseus	Short-billed dowitcher	SC
Limnothlypis swainsonii	Swainson's warbler	SC
Limosa haemastica	Hudsonian godwit	SC
Melanerpes aurifrons	Golden-fronted woodpecker	SC
Melanerpes erythrocephalus	Red-headed woodpecker	SC
Mycteria americana	**Wood stork	ST
Myiarchus crinitus	Great crested flycatcher	SC
Numenius americanus	Long-billed curlew	SC
Nyctanassa violacea	Yellow-crowned night-heron	SC
Oporornis formosus	Kentucky warbler	SC
Passerina ciris	Painted bunting	SC
Pegadis chihi	White-faced ibis	ST
Pelecanus erythrorhynchos	American white pelican	SC
Platalea ajaja	Roseate spoonbill	SC
Pluvialis dominica	American golden-plover	SC
Phalaropus tricolor	Wilson's phalarope	SC
Picoides scalaris	Ladder-backed woodpecker	SC

Podiceps auritus	Horned grebe	SC
Podiceps nigricollis	Eared grebe	SC
Protonotaria citrea	Prothonotary warbler	SC
Rallus limicola	Virginia rail	SC
Rallus elegans	King rail	SC
Recurvirostra americana	American avocet	SC
Scolopax minor	American woodcock	SC
Seiurus motacilla	Louisiana waterthrush	SC
Spiza americana	Dickcissel	SC
Spizella pusilla	Field sparrow	SC
Sterna antillarum	**Least tern (interior)	FE/SE
Sterna forsteri	Forster's tern	SC
Sturnella magna	Eastern meadowlark	SC
Sturnella neglecta	Western meadowlark	SC
Thryomanes bewickii	Bewick's wren (eastern)	SC
Toxostoma curvirostre	Curve-billed thrasher	SC
Toxostoma rufum	Brown thrasher	SC
Tringa flavipes	Lesser yellowlegs	SC
Tringa melanoleuca	Greater yellowlegs	SC
Tringa solitaria	Solitary sandpiper	SC
Tryngites subruficollis	Buff-breasted sandpiper	SC
Tympanuchus cupido attwateri	**Greater prairie-chicken (Attwater's)	FE/SE
Tyrannus forficatus	Scissor-tailed flycatcher	SC
Tyrannus tyrannus	Eastern kingbird	SC
Vermivora chrysoptera	Golden-winged warbler	SC
Vermivora pinus	Blue-winged warbler	SC
Vireo atricapillus	**Black-capped vireo	FE/SE
Vireo bellii	Bell's vireo	SC
Vireo flavifrons	Yellow-throated vireo	SC

	Vireo gilvus	Warbling vireo	SC
	Wilsonia citrina	Hooded warbler	SC
	Zenaida macroura	Mourning dove	SC
	Zonotrichia querula	Harris's sparrow	SC
Mammals	*Blarina hylophaga plumblea*	Elliot's short-tailed shrew	SC
	Geomys attwateri	Attwaters pocket gopher	SC
	Lutra canadensis	River otter	SC
	Mustela frenata	Long-tailed weasel	SC
	Myotis austroriparius	Southeastern myotis	SC
	Myotis velifer	Cave myotis	SC
	Puma concolor	Mountain lion	SC
	Spilogale putorius	Eastern spotted skunk	SC
	Sylvilagus aquaticus	Swamp rabbit	SC
	Tadarida brasiliensis	Brazilian free-tailed bat	SC
	Taxidea taxus	American badger	SC
Reptiles	*Bufo houstonensis*	**Houston toad	FE/SE
	Crotalus horridus	Timber rattlesnake	ST
	Deirochelys reticularia	Chicken turtle	SC
	Ophisaurus attenuatus	Slender glass lizard	SC
	Phrynosoma cornutum	Texas horned lizard	ST
	Scaphiopus hurterii	Hurter's spadefoot	SC
	Sistrurus catenatus	Massasauga	SC
	Terrapene spp.	Box turtles	SC

Group	Family	Species Name	Federal Status
Invertebrates			
	Symphyla (Myriapoda)		
	Scolopendrellidae	*Symphyllela texana*	SC
	Scolopendrellidae	*Symphyllela pusilla*	SC
	Polydesmida (Myriapoda)		
	Polydesmidae	*Speodesmus castellanus*	SC
	Polydesmidae	*Speodesmus falcatus*	SC
	Polydesmidae	*Speodesmus ivyi*	SC
	Polydesmidae	*Speodesmus reddelli*	SC
	Araneae (Arachnida)		
	Dictynidae	*Cicurina baronia*	FE
	Dictynidae	*Cicurina gatita*	SC
	Dictynidae	*Cicurina madla*	FE
	Dictynidae	*Cicurina medina*	SC
	Dictynidae	*Cicurina minorata (Gersch and Davis)*	SC
	Dictynidae	*Cicurina venii*	FE
	Dictynidae	*Cicurina vespera*	FE
	Leptonetidae	*Neoleptoneta new species*	SC
	Nesticidae	*Eidmannella nasuta (Gertsch)*	SC
	Dictynidae	*Cicurina armadillo*	SC
	Dictynidae	*Cicurina bandida*	SC
	Dictynidae	*Cicurina cueva*	SC
	Dictynidae	*Cicurina elliotti*	SC
	Dictynidae	*Cicurina reddelli*	SC
	Dictynidae	*Cicurina reyesi*	SC
	Dictynidae	*Cicurina travisae*	SC
	Dictynidae	*Cicurina wartoni*	SC

Leptonetidae	*Neoleptoneta concinna (Gertsch)*	SC
Leptonetidae	*Neoleptoneta devia (Gertsch)*	SC
Linyphiidae	*Meioneta llanoensis (Gertsch and Davis)*	SC
Nesticidae	*Eidmannella nasuta (Gertsch)*	SC
Nesticidae	*Eidmannella reclusa (Gertsch)*	SC
Dictynidae	*Cicurina aenigma*	SC
Dictynidae	*Cicurina ezelli*	SC
Dictynidae	*Cicurina russeli*	SC
Dictynidae	*Cicurina ubicki*	SC
Leptonetidae	*Neoleptoneta new species*	SC
Dictynadae	*Cicurina (Cicurella) caliga*	SC
Dictynadae	*Cicurina (Cicurella) hoodensis*	SC
Dictynidae	*Cicurina bowni*	SC
Dictynidae	*Cicurina vibora*	SC
Leptonetidae	*Neoleptoneta anopica (Gertsch)*	SC
Leptonetidae	*Neoleptoneta paraconcinna*	SC
Opiliones (Arachnida)		
Phalangodidae	*Texella mulaiki (Goodnight and Goodnight)*	SC
Pseudoscorpiones (Arachnida)		
Neobisiidae	*Tartarocreagris infernalis (Muchmore)*	SC
Neobisiidae	*Tartarocreagris texana (Muchmore)*	FE
Neobisiidae	*Tartarocreagris Comanche (Muchmore)*	SC
Neobisiidae	*Tartarocreagris cookei*	SC
Neobisiidae	*Tartarocreagris hoodensis*	SC
Neobisiidae	*Tartarocreagris reyesi*	SC
Coleoptera (Insecta)		
Carabidae	*Rhadine exilis*	FE
Carabidae	*Rhadine infernalis*	FE
**Carabidae	*Rhadine persephone*	FE

Carabidae	*Rhadine reyesi*	SC
**Silphidae	*Nicrophorus americanus*	FE
Staphylinidae (Pselaphidae)	*Batrisodes (Babnormodes) gravesi (Chandler and Reddell)*	SC
Staphylinidae (Pselaphidae)	*Batrisodes (Babnormodes) uncicornis (Casey)*	SC
Staphylinidae (Pselaphidae)	*Batrisodes (Excavodes) cryptotexanus (Chandler and Reddell)*	SC
Staphylinidae (Pselaphidae)	*Texamaurops reddelli (Barr and Steeves)*	SC
Lepidoptera (Insecta)		
Hesperiidae	*Megathymus streckeri texanus*	SC
Hymenoptera (Insecta)		
Apoidea	*Andrena (Tylandrena) scotoptera (Cockerell)*	SC
Apoidea	*Colletes bumeliae (Neff)*	SC
Apoidea	*Colletes inuncantipedis (Neff)*	SC
Apoidea	*Eucera (Synhalonia) birkmanniella (Cockerell)*	SC
Apoidea	*Eucera (Synhalonia) texana (Timberlake)*	SC
Apoidea	*Hesperapis (Carinapis) sp. B*	SC
Apoidea	*Megachile (Megachiloides) parksi (Mitchell)*	SC
Apoidea	*Osmia (Diceratosmia) botitena (Cockerell)*	SC
Apoidea	*Stelis (Protostelis) texana (Thorp)*	SC

Location and Condition of the Blackland Prairie Ecoregion

Element 2

Taking their name from the fertile, dark clay soil, the Blackland Prairies constitute a true prairie ecosystem and have some of the richest, naturally fertile soils in the world. Characterized by gently rolling to nearly level topography, the land is well dissected and marked by rapid surface drainage. Pecan, cedar elm, various oaks, soapberry, honey locust, hackberry and osage orange dot the landscape, with some mesquite invading from the south. A true tall-grass prairie, the dominant grass is little bluestem. Other important grasses include big bluestem, Indiangrass, eastern gammagrass, switchgrass and sideoats grama. While elevations from 300 to more than 800 ft. above MSL match those of the Post Oak Savannah, the annual rainfall varies from 30-40 in. west to east, and the average annual temperatures range from approximately 66°F to 70°F. Described as "black velvet" when freshly plowed and moistened from a good rain, true blackland soils are deep, dark, calcareous deposits renowned for their high productivity (Wasowski 1988). Scientists believe the richness of the prairie soils is derived from the abundant invertebrate fauna and fungal flora found in the soils themselves. The Blackland Prairies of today are almost entirely brought under the plow, with only 5,000 ac. of the original 12 million remaining uncultivated. For this reason, many authorities believe that the Blackland Prairies represent some of the rarest landscapes in Texas.

Like many of the prairie communities comprising the Great Plains of North America, the Blackland Prairies harbor few rare plants or animals. What is special and unique about this ecosystem today, are the grassland communities themselves. This ecoregion can be broken down into seven main habitat classes consisting of grassland, forest, native and introduced grasses, parkland, parkland woodland mosaic, woodland, forest and grassland mosaic, and urban.

Blackland Prairie Forest

The Blackland Prairie forest consists of deciduous or evergreen trees that dominate the landscape. These species are mostly greater than 30 ft. tall with closed crowns or nearly so (71-100% canopy cover). The midstory is generally apparent except in managed monocultures (McMahan et al. 1984, Bridges et al. 2002). One plant association dominates this habitat class.

The *water oak-elm-hackberry* association includes cedar elm, American elm, willow oak, southern red oak, white oak, black willow, cottonwood, red ash, sycamore, pecan, bois d'arc (osage orange), flowering dogwood, dewberry, coral-berry, dallisgrass, switchgrass, rescuegrass, Bermuda grass, eastern gamagrass, Virginia wildrye, Johnsongrass, giant ragweed and Leavenworth eryngo. This association typically occurs in the upper flood plains of the Sabine, Sulphur and Trinity rivers and tributaries (McMahan et al. 1984). Cross-referenced communities: 1) water oak-post oak floodplain forests (Bezanson 2000). This community is considered of low priority for further protection since this community is generally unthreatened even though not many examples of this association are protected (Bezanson 2000).

Blackland Prairie Grassland

Grasslands consist of herbs (grasses, forbs and grass-like plants) which are dominant. Woody vegetation is lacking or nearly so (generally 10% or less woody canopy cover) (McMahan et al.1984). There is one plant association still found in scattered patches within the Blackland Prairie grassland.

The *silver bluestem-Texas wintergrass* association includes little bluestem, sideoats grama, Texas grama, three-awn, hairy grama, tall dropseed, buffalograss, windmillgrass, hairy tridens, tumblegrass, western ragweed, broom snakeweed, Texas bluebonnet, live oak, post oak and mesquite. This association is found primarily in the Cross Timbers and Prairies ecoregion; however, tiny scattered areas still exist in the Blackland Prairie ecoregion (McMahan et al. 1984). Cross-referenced communities: 1) little bluestem-Indiangrass series (Diamond 1993), 2) upland mollisol tall grassland (Bezanson 2000), and 3) little bluestem-sideoats grama herbaceous alliance (Weakley et al. 2000). This association is considered imperiled, or very rare, throughout the state. Approximately 6-20 occurrences are documented, therefore this association is considered vulnerable to extirpation within the state (Diamond 1993). According to Bezanson (2000) this should be a community of high priority for further protection.

Blackland Prairie Native and Introduced Grasses

A mixture of native and introduced grasses which includes herbs (grasses, forbs and grass-like plants) that are dominant with woody vegetation lacking or nearly so (generally 10% or less woody canopy cover). These associations typically result from the invasion of non-native grass species originating from the planting of these non-natives (e.g. Bermuda, KR bluestem, etc.) for roadsides and rangelands. The clearing of woody vegetation is another factor and is sometimes associated with the early stages of a young forest. This community can quickly change as removed brush begins to regrow (McMahan et al. 1984, Bridges et al. 2002).

Blackland Prairie Parkland

In the Blackland Prairie parkland, a majority of the woody plants are equal to or greater than nine feet tall. They are generally dominant and grow as clusters, or as scattered individuals within continuous grass or forbs (11-70% woody canopy cover overall) (McMahan et al. 1984, Bridges et al. 2002). Only one plant association dominates this habitat class.

Huisache, huisachillo, whitebrush, granjeno, lotebush, Berlandier wolfberry, blackbrush, desert yaupon, Texas prickly pear, woollybucket bumelia, tasajillo, agarito, Mexican persimmon, purple three-awn, Roemer three-awn, pink pappusgrass, Halls panicum, slimlobe poppymallow, sensitive briar, two-leaved senna and mat euphorbia are species commonly linked to the *mesquite-live oak-bluewood* association. Typically, this association is found on loamy or sandy upland soils in the South Texas Plains. However, a small patch occurs in the southern most tip of the Blackland Prairie ecoregion. Cross-referenced communities: 1) mesquite-granjeno shrubland/dry woodland (McLendon 1991), 2) mesquite-granjeno series (Diamond 1993), 3) upland mesquite savannas (Bezanson 2000), and 4) honey mesquite woodland alliance (Weakley et al. 2000). This community is considered demonstrably secure globally and within the state of Texas (Diamond 1993). It is suggested that this community is of low priority for further protection (Bezanson 2000).

Blackland Prairie Parkland Woodland Mosaic

The parkland woodland mosaic can be best described by pastures or fields with widely scattered vegetation (trees and/or shrubs) covering 10-25% of the ground (Bridges et al. 2002). Only one plant association relates to this habitat class.

The *elm-hackberry* association includes mesquite, post oak, woollybucket bumelia, honey locust, coral-berry, pasture haw, elbowbush, Texas prickly pear, tasajillo, dewberry, silver bluestem, buffalograss, western ragweed, giant ragweed, goldenrod, frostweed, ironweed, prairie parsley and broom snakeweed. Mesic slopes and floodplains are what this broadly defined deciduous forest prefers. This association typically occurs within the Blackland Prairie ecoregion, primarily in Ellis, Navarro and Limestone counties (McMahan et al. 1984). Cross-reference communities: 1) sugarberry-elm series (Diamond 1993), 2) sugarberry-elm floodplain forests (Bezanson 2000), and 3) sugarberry-cedar elm temporarily flooded forest alliance (Weakley et al. 2000). This community is considered demonstrably secure globally and within the state of Texas (Diamond 1993). It is suggested that this community is of low priority for further protection (Bezanson 2000).

Blackland Prairie Woodland, Forest and Grassland Mosaic

The Blackland Prairie woodland, forest and grassland mosaic is a combination of a few characters from each individual habitat class. Woody plants that are mostly 9-30 ft. tall are growing with deciduous or evergreen trees that are dominant and mostly greater than 30 ft. tall. Between patches of woody vegetation grow herbs (grasses, forbs and grass-like plants) where woody vegetation is lacking or nearly so (generally 10% or less woody canopy cover). In this mosaic habitat, there is a mix between absent canopy cover and areas with closed crowns or nearly so (71-100% canopy cover). In the areas with canopy cover, there ranges a lack of midstory to a midstory that is generally apparent except in managed monocultures (McMahan et al. 1984, Bridges et al. 2002). Only one plant association dominates this habitat class.

Blackjack oak, eastern red cedar, mesquite, black hickory, live oak, sandjack oak, cedar elm, hackberry, yaupon, poison oak, American beautyberry, hawthorn, supplejack, trumpet creeper, dewberry, coral-berry, little bluestem, silver bluestem, sand lovegrass, beaked panicum, three-awn, spranglegrass and tickclover are species commonly associated with the *post oak* association. This community is most common in sandy soils within the Post Oak Savannah but is also found almost entirely around the perimeter of the Blackland Prairie ecoregion (McMahan et al 1984). Cross-referenced communities: 1) post oak-blackjack oak series (Diamond 1993), 2) post oak-blackjack oak upland forest and woodlands (Bezanson 2000), and 3) post oak-blackjack oak forest alliance, post oak-blackjack oak woodland alliance (Weakley et al. 2000). This community is considered demonstrably secure globally and within the state of Texas (Diamond 1993). It is suggested that this community is of low priority for further protection (Bezanson 2000).

Blackland Prairie Urban Community

Urban habitats are cities or towns which are areas dominated by human dwellings including the fences, shrub rows, windbreaks and roads associated with their presence (Bridges at al. 2002).

The Blackland Prairie ecoregion is located primarily in north Central Texas. Historically it is found throughout the eastern side of the Dallas/Fort Worth (DFW) Metroplex. The biggest city in this community is Dallas and its associated suburbs. The next largest city is San Antonio. Smaller prominent cities include Austin, New Braunfels, Lockhart, Taylor Robinson, Retreat, Corsicana, Terrell, Greenville, Howe and Sulphur Springs. This area would have been dominated by various herbaceous plants, dependent on the local geology, of bluestem species, eastern gammagrass, Indiangrass and switchgrass. Very few woody species would be present due to the frequency of fire and grazing pressure by bison.

Now, this particular ecosystem type in considered endangered, or as some ecologists feel, functionally extinct. Currently, there are no functioning Blackland Prairie ecosystems in the area. There are a number small remnants, and “restored” prairie areas, but these are all artificially maintained. In some areas, like the White Rock Lake area, it has been found that a functional seedbank of native plant seed may still exist. When allowed to grow and compete, these areas will often show a high plant biodiversity in a short period of time, and subsequently see an increase in animal biodiversity.

High Priority Communities: A Further Emphasis

Before the 1800’s, *tallgrass prairies* covered approximately 20 million ac. of Texas. A continuous extent of this grassland community ranged from San Antonio to the Red River. Since then, 98% of these prairies have been converted for agricultural uses and urban development. This is potentially the “most dramatic loss of habitat in Texas” (Bezanson and Wolfe 2001). These tallgrass prairies are composed of dark clay soils which are very fertile. Wildflowers and native grasses such as bluestem, grama grasses, dropseed, tridens, switchgrass and Indiangrass dominate this community in the spring and summer months (Bezanson and Wolfe 2001).

Presently, approximately 95% of the original *blackland prairies* have been converted for agricultural uses and urban cities. Only 3,000 ac. of an original 12 million acre range of Blackland Prairie remains in the Dallas/Fort Worth Metroplex (predominately White Rock Lake and Cedar Hills SP) and San Antonio area. The remaining acreages of prairie are in small patches and threatened by various types of development. Many of these are the result of restoration attempts, or are protected on publicly held land. Presently, most of this acreage is used for hay production by private landowners who help to stimulate production without harming diversity and health (Bezanson and Wolfe 2001).

The *ephemeral wetlands* are especially important to many of our amphibian species. Historically, this area had very few natural wetlands, with the exception of oxbows in the areas around the Trinity River. What we did have historically was low-lying prairie areas that would stay wet for varying amounts of time. As the wet prairie/ephemeral pool components were developed, those wetlands were not protected by federal law and have been drained for a variety of reasons such as agricultural fields, development and mosquito control.

Problems Affecting the Blackland Prairie

See the Texas Priority Species List……………………733

Element 3

The key problems facing the *blackland prairie* are agriculture, development, public perception and invasive species. Historically, the blackland prairies soils were highly sought after for agricultural production. Within the urban areas this isn’t so much of a problem, but with the urban sprawl trend, we are potentially developing in former agricultural areas that have potential for restoration efforts. The combination of agriculture and development has created a unique challenge for restoration efforts due to the heavy soil modification that has occurred. Many of the plants associated with this area are very sensitive to specific soil conditions. The second challenge presented by development is the “open, grassy” areas that are easier to build on, and the developer does not have to mitigate nearly as much compared to tree removal. This is where the challenge of public perception and awareness comes into play. Trees are more highly valued than tall grass in this urban area. Areas of tall grasses are perceived as “weedy” and “unkept”, so city ordinances often discourage the growth of tall grasses. The final problem that needs to be addressed is invasive, exotic species. The Dallas area is a major source of Johnsongrass and Bermuda grasses, both of which are very invasive in the blackland prairie, and quickly develop a monoculture of little use to wildlife. Most prairie restoration projects in this area require extensive treatment to remove these two species before native planting can begin.

In areas that are being allowed to grow as a prairie, constraints such as fire bans are causing the remaining Blackland Prairie to be shaded by the encroachment of woody species. This trend is also seen in the rural areas outside to the DFW Metroplex.

The wet prairie areas are all but gone. There are a few locations that are cleared areas along the Trinity River, but few if any are present in the uplands. As these ephemeral wetlands have disappeared, seemingly so has a number of our native amphibian species. The two main issues are development in the area and perceived public health risk. Currently, the ephemeral wetlands in question are not protected under the Wetlands Act, so there are few restrictions to development. As development gets close to these areas they are typically drained in some manner to reduce mosquito populations in the area.

Element 5

High Priority Research and Monitoring Efforts for the Blackland Prairie

See Monitoring and Adaptive Management…..……. 559

See the Texas Priority Species List……………………733

- Baseline Determination and Monitoring - Ascertain the current conditions of those remnants of Blackland Prairie that are left. Determine habitat availability and monitor those locations
- Further Research and Monitoring of Plants - Seed analysis of the seedbanks in the remaining remnants to determine what seed mixes are the “most natural”.

Monitor various mixes, and habitat and environmental combinations to see what works the best

- Further Research and Monitoring of Wildlife - Determine effects of various management practices on species, populations and habitats (e.g. prescribed burning, discing). Once a baseline of present and absent species is established, continue to monitor the size of populations, the seasonal fluctuations in population size, long term trends in population size, determine date of most recent occurrence in the region, document reasons for and date of incidental take, determine habitat range of species or population, and monitor dispersal and movement patterns as well as determine the species or population's historical range
- Survey - A public survey of the perceptions about trees and grasses for a better understanding of the public mentality. Monitor the change in public perception and opinion

High Priority Conservation Actions for the Blackland Prairie

See High Priority Conservation Strategies…………..517

See the Texas Priority Species List…………………….. 733

Element 4

- State level - In this region, we should consider mitigating to grass before mitigating to trees. We need to, and currently are, working with cities to write ordinances that allow for taller grass and forbs species to grow. It is difficult to do restoration when a large number of the plants are going to be restricted
- Regionally or Statewide - Consider shifting priorities for mitigation. Recently, the Texas Department of Transportation (TxDOT) has considered working with Texas Parks and Wildlife on a prairie restoration and maintenance project to mitigate for tree removal on one of their own projects. The initial proposal called for planting trees in the "open space", better known as the blackland prairie remnant. Currently, we have more trees in Dallas than we ever had before, historically, and often they are not even native to the area

- Regionally - Educate the general public of the ecological importance of prairie ecosystems. As it stands, much of the general public views tall grass, and especially tall wet grass, as areas with little purpose or function. This leads to very little protection being provided to grassland areas. Currently, developers are required to mitigate if they remove certain tree species or disrupt wetland areas (not including ephemeral wetland)
- Encourage cities to modify mowing regimes and start prairie restoration projects. Currently we have proposed several prairie restoration projects. One involves training science teachers from the Dallas Independent School District about the importance of prairies, and basic restoration techniques
- Work with federal, state and private organizations to promote (incentives) leaving some cover for wildlife. The economic benefits of wildlife can sometimes equal or surpass the agricultural value of land
- Determine public awareness and perception of prairies in general
- Identify, map and ground truth locations and habitats

Gulf Coast Prairies and Marshes Ecoregion

Associated Maps

Ecoregions of Texas……………………….. 1

Gulf Coast Prairies and Marshes Ecoregion.. 3

Associated Section IV Documents

Element 1

The Texas Priority Species List…………….733

Supplemental Mammal Information……….. 897

Supplemental Herptile Information……….. 988

Priority Species

Group	Species Name	Common Name	State/Federal Status
Birds	*Aimophila aestivalis*	Bachman's sparrow	ST
	Aimophila cassinii	Cassin's sparrow	SC
	Amazilia yucatanensis	Buff-bellied hummingbird	SC
	Ammodramus henslowii	Henslow's sparrow	SC
	Ammodramus leconteii	Le Conte's sparrow	SC
	Ammodramus maritimus	Seaside sparrow	SC
	Ammodramus nelsoni	Nelson's sharp-tailed sparrow	SC
	Ammodramus savannarum	Grasshopper sparrow	SC
	Anas acuta	Northern pintail	SC
	Anas fulvigula	Mottled duck	SC
	Anthus spragueii	Sprague's pipit	SC
	Arenaria interpres	Ruddy turnstone	SC
	Asio flammeus	Short-eared owl	SC
	Athene cunicularia	Burrowing owl	SC
	Aythya affinis	Lesser scaup	SC
	Aythya americana	Redhead	SC

Aythya valisineria	Canvasback	SC
Bartramia longicauda	Upland sandpiper	SC
Botaurus lentiginosus	American bittern	SC
Buteo albicaudatus	White-tailed hawk	ST
Buteo lineatus	Red-shouldered hawk	SC
Buteo regalis	Ferruginous hawk	SC
Buteo swainsoni	Swainson’s hawk	SC
Calcarius mccownii	McCown’s longspur	SC
Calidris alba	Sanderling	SC
Calidris canutus	Red knot	SC
Calidris himantopus	Stilt sandpiper	SC
Calidris mauri	Western sandpiper	SC
Caprimulgus carolinensis	Chuck-will’s-widow	SC
Cardinalis sinuatus	Pyrrhuloxia	SC
Chaetura pelagica	Chimney swift	SC
Charadrius alexandrinus	Snowy plover	SC
Charadrius melodus	**Piping plover	FT/ST
Charadrius wilsonia	Wilson’s plover	SC
Chloroceryle americana	Green kingfisher	SC
Chondestes grammacus	Lark sparrow	SC
Chordeiles minor	Common nighthawk	SC
Circus cyaneus	Northern harrier	SC
Cistothorus platensis	Sedge wren	SC
Coccyzus americanus	Yellow-billed cuckoo	SC
Colinus virginianus	Northern bobwhite	SC
Contopus virens	Eastern wood-pewee	SC
Coturnicops noveboracensis	Yellow rail	SC
Dendrocygna bicolor	Fulvous whistling duck	SC
Dendroica cerulea	Cerulean warbler	SC

Dendroica discolor	Prairie warbler	SC
Dendroica dominica	Yellow-throated warbler	SC
Dryocopus pileatus	Pileated woodpecker	SC
Egretta caerulea	Little blue heron	SC
Egretta rufescens	Reddish egret	ST
Egretta thula	Snowy egret	SC
Egretta tricolor	Tricolored heron	SC
Elanoides forficatus	Swallow-tailed kite	ST
Elanus leucurus	White-tailed kite	SC
Empidonax virescens	Acadian flycatcher	SC
Eremophila alpestris	Horned lark	SC
Falco columbarius	Merlin	SC
Falco femoralis	Aplomado falcon	FE/SE
Falco mexicanus	Prairie falcon	SC
Falco peregrinus tundrius	Arctic peregrine falcon	ST
Falco sparverius	American kestrel (southeastern)	SC
Gallinago delicata	Wilson's snipe (formerly common snipe)	SC
Grus americana	**Whooping crane	FE/SE
Haematopus palliatus	American oystercatcher	SC
Haliaeetus leucocephalus	Bald eagle	FT/ST
Helmitheros vermivorum	Worm-eating warbler	SC
Himantopus mexicanus	Black-necked stilt	SC
Hylocichla mustelina	Wood thrush	SC
Icterus cucullatus	Hooded oriole (both Mexican and Sennett's)	SC
Icterus graduacauda	Audubon's oriole	SC
Icterus spurius	Orchard oriole	SC
Ictinia mississippiensis	Mississippi kite	SC
Ixobrychus exilis	Least bittern	SC

Lanius ludovicianus	Loggerhead shrike	SC
Herpailurus yaguarondi	Jaguarundi	FE/SE
Laterallus jamaicensis	Black rail	SC
Limnodromus griseus	Short-billed dowitcher	SC
Limnothlypis swainsonii	Swainson's warbler	SC
Limosa fedoa	Marbled godwit	SC
Limosa haemastica	Hudsonian godwit	SC
Melanerpes aurifrons	Golden-fronted woodpecker	SC
Melanerpes erythrocephalus	Red-headed woodpecker	SC
Mycteria americana	**Wood stork	ST
Myiarchus crinitus	Great crested flycatcher	SC
Numenius americanus	Long-billed curlew	SC
Numenius phaeopus	Whimbrel	SC
Nyctanassa violacea	Yellow-crowned night-heron	SC
Oporornis formosus	Kentucky warbler	SC
Parabuteo unicinctus	Harris's hawk	SC
Parus articristatus	Black-crested titmouse	SC
Passerina ciris	Painted bunting	SC
Pegadis chihi	White-faced ibis	ST
Pelecanus erythrorhynchos	American white pelican	SC
Pelecanus occidentalis	**Brown pelican	FT/SE
Phalaropus tricolor	Wilson's phalarope	SC
Picoides scalaris	Ladder-backed woodpecker	SC
Platalea ajaja	Roseate spoonbill	SC
Pluvialis dominica	American golden-plover	SC
Podiceps auritus	Horned grebe	SC
Podiceps nigricollis	Eared grebe	SC
Porphyrio martinica	Purple gallinule	SC
Protonotaria citrea	Prothonotary warbler	SC

Rallus elegans	King rail	SC
Rallus limicola	Virginia rail	SC
Rallus longirostris	Clapper rail	SC
Recurvirostra americana	American avocet	SC
Rynchops niger	Black skimmer	SC
Scolopax minor	American woodcock	SC
Seiurus motacilla	Louisiana waterthrush	SC
Setophaga ruticilla	American redstart	SC
Sitta pusilla	Brown-headed nuthatch	SC
Spiza americana	Dickcissel	SC
Spizella pusilla	Field sparrow	SC
Sterna forsteri	Forster’s tern	SC
Sterna nilotica	Gull-billed tern	SC
Sturnella magna	Eastern meadowlark	SC
Sturnella neglecta	Western meadowlark	SC
Thryomanes bewickii	Bewick’s wren (eastern)	SC
Toxostoma curvirostre	Curve-billed thrasher	SC
Toxostoma longirostre	Long-billed thrasher	SC
Toxostoma rufum	Brown thrasher	SC
Tringa flavipes	Lesser yellowlegs	SC
Tringa melanoleuca	Greater yellowlegs	SC
Tringa solitaria	Solitary sandpiper	SC
Tryngites subruficollis	Buff-breasted sandpiper	SC
Tympanuchus cupido attwateri	**Greater prairie-chicken (Attwater’s)	FE/SE
Tyrannus forficatus	Scissor-tailed flycatcher	SC
Tyrannus tyrannus	Eastern kingbird	SC
Vermivora chrysoptera	Golden-winged warbler	SC
Vermivora pinus	Blue-winged warbler	SC
Vireo bellii	Bell’s vireo	SC

	Vireo flavifrons	Yellow-throated vireo	SC
	Vireo gilvus	Warbling vireo	SC
	Wilsonia citrina	Hooded warbler	SC
	Zenaida macroura	Mourning dove	SC
	Zonotrichia querula	Harris's sparrow	SC
Mammals	*Blarina hylophaga plumblea*	Elliot's short-tailed shrew	SC
	Conepatus leuconotus	Hog-nosed skunk	SC
	Dipodomys compactus compactus	Padre Island kangaroo rat	SC
	Geomys attwateri	Attwaters pocket gopher	SC
	Geomys personatus maritimus	Maritime pocket gopher	SC
	Geomys personatus personatus	Barrier Island Texas pocket gopher	SC
	Lasiurus ega	Southern yellow bat	ST
	Leopardus pardalis	**Ocelot	FE/SE
	Lutra canadensis	River otter	SC
	Mustela frenata	Long-tailed weasel	SC
	Nasua narica	White-nosed coati	ST
	Nyctinomops macrotis	Big free-tailed bat	SC
	Oryzomys couesi	Coues rice rat	ST
	Puma concolor	Mountain lion	SC
	Spilogale putorius	Eastern spotted skunk	SC
	Sylvilagus aquaticus	Swamp rabbit	SC
	Tadarida brasiliensis	Brazilian free-tailed bat	SC
	Taxidea taxus	American badger	SC
	Trichechus manatus	**West Indian manatee	FE/SE
Reptiles	*Alligator mississippiensis*	American alligator (4 sp.)	SC
	Amphiuma tridactylum	Three-toed amphiuma	SC
	Caretta caretta	Loggerhead sea turtle	FT/ST

Cemophora lineri	Texas scarlet snake	ST
Chelonia mydas	**Green sea turtle	FT/ST
Deirochelys reticularia	Chicken turtle	SC
Dermochelys coriacea	**Leatherback sea turtle	FE/SE
Drymarchon corais	Western indigo snake	ST
Drymobius margaritiferus	Speckled racer	ST
Eretmochelys imbricate	Hawksbill sea turtle	FE/SE
Gopherus berlandieri	Texas tortoise	ST
Holbrookia lacerata	Spot-tailed earless lizard	SC
Hypopachus variolosus	Sheep frog	ST
Lepidochelys kempii	**Kemp's ridley sea turtle	FE/SE
Macrochelys temminckii	Alligator snapping turtle	ST
Malaclemys terrapin	Diamond-backed terrapin	SC
Necturus beyeri	Gulf Coast waterdog	SC
Nerodia clarkia	Saltmarsh snake	SC
Notophthalmus meridionalis	Black-spotted newt	ST
Ophisaurus attenuatus	Slender glass lizard	SC
Phrynosoma cornutum	Texas horned lizard	ST
Rana areolata	Crawfish frog	SC
Rana grylio	Pig frog	SC
Scaphiopus hurterii	Hurter's spadefoot	SC
Siren sp.	Rio Grande (lesser) siren	ST
Sistrurus catenatus	Massasauga	SC
Sistrurus miliarius	Pygmy rattlesnake	SC
Terrapene spp.	Box turtles	SC

Group	Family	Species Name	Federal Status
Invertebrates			
	Araneae (Arachnida)		
	Dictynidae	*Cicurina rudimentops (Chamberlin and Ivie)*	SC
	Dictynidae	*Cicurina sintonia*	SC
	Coleoptera (Insecta)		
	Anobiidae	*Ptinus tumidus (Fall)*	SC
	Anobiidae	*Trichodesma pulchella (Schaeffer)*	SC
	Anobiidae	*Trichodesma sordida (Horn)*	SC
	Anobiidae	*Trichodesma texana (Schaeffer)*	SC
	Anobiidae	*Tricorynus texanus (White)*	SC
	Anthribidae	*Neoxenus versicolor (Valentine)*	SC
	Anthribidae	*Ormiscus albofasciatus (Schaeffer)*	SC
	Anthribidae	*Ormiscus irroratus (Schaeffer)*	SC
	Anthribidae	*Phoenicobiella schwarzii (Schaeffer)*	SC
	Anthribidae	*Toxonotus penicellatus (Schaeffer)*	SC
	Brentidae	*Apion aculeatum (Fall)*	SC
	Brentidae	*Apion buchanani (Kissinger)*	SC
	Brentidae	*Heterobrenthus texanus (Schaeffer)*	SC
	Buprestidae	*Agrilus dollii (Schaeffer)*	SC
	Buprestidae	*Agrilus subtropicus (Schaeffer)*	SC
	Buprestidae	*Pachyschelus fisheri (Vogt)*	SC
	Buprestidae	*Spectralia prosternalis (Schaeffer)*	SC
	Buprestidae	*Trigonogya reticulaticollis (Schaeffer)*	SC
	Carabidae	*Agra oblongopunctata oblongopunctata (Chevrolat)*	SC
	Carabidae	*Apenes sp. UASM 11*	SC
	Carabidae	*Calleida fimbriata (Bates)*	SC

Carabidae	*Galerita aequinoctialis (Chaudoir)*	SC
Carabidae	*Nemotarsus rhombifer (Bates)*	SC
Cerambycidae	*Adetus sp. EGR 1*	SC
Cerambycidae	*Agallissus lepturoides (Chevrolat)*	SC
Cerambycidae	*Ataxia tibialis (Schaeffer)*	SC
Cerambycidae	*Cacostola lineata (Hamilton)*	SC
Cerambycidae	*Callipogonius cornutus (Linsley)*	SC
Cerambycidae	*Desmiphora aegrota (Bates)*	SC
Cerambycidae	*Dihammaphora dispar (Chevrolat)*	SC
Cerambycidae	*Ecyrus penicillatus (Bates)*	SC
Cerambycidae	*Hemierana marginata suturalis (Linell)*	SC
Cerambycidae	*Sphaenothecus trilineatus (Dupont)*	SC
Chrysomelidae	*Baliosus sp. EGR 1*	SC
Chrysomelidae	*Brucita marmorata (Jacoby)*	SC
Chrysomelidae	*Chaetocnema rileyi (White)*	SC
Chrysomelidae	*Chlamisus maculipes (Chevrolat)*	SC
Chrysomelidae	*Dibolia championi (Jacoby)*	SC
Chrysomelidae	*Disonycha barberi (Blake)*	SC
Chrysomelidae	*Disonycha stenosticha (Schaeffer)*	SC
Chrysomelidae	*Epitrix sp. EGR 1*	SC
Chrysomelidae	*Heptispa sp. EGR 1*	SC
Chrysomelidae	*Malacorhinus acaciae (Schaeffer)*	SC
Chrysomelidae	*Megascelis texana (Linell)*	SC
Chrysomelidae	*Octotoma championi (Baly)*	SC
Chrysomelidae	*Pachybrachis duryi (Fall)*	SC
Chrysomelidae	*Pachybrachis sp. EGR 2*	SC
Chrysomelidae	*Pachybrachis sp. EGR 6*	SC
Chrysomelidae	*Parchicola sp. EGR 1*	SC
Chrysomelidae	*Pentispa distincta (Baly)*	SC

Chrysomelidae	*Plagiodera thymaloides (Stal)*	SC
Coccinellidae	*Diomus pseudotaedatus (Gordon)*	SC
Coccinellidae	*Hyperaspis rotunda (Casey)*	SC
Curculionidae	*Allopentarthrum sp. TAC 1*	SC
Curculionidae	*Allopentarthrum sp. TAC 2*	SC
Curculionidae	*Andranthobius sp. TAC 1*	SC
Curculionidae	*Apteromechus texanus (Fall)*	SC
Curculionidae	*Brachystylus microphthalmus (Champion)*	SC
Curculionidae	*Chalcodermus semicostatus (Schaeffer)*	SC
Curculionidae	*Chalcodermus serripes (Fahraeus)*	SC
Curculionidae	*Conotrachelus rubescens (Schaeffer)*	SC
Curculionidae	*Elleschus sp. TAC 1*	SC
Curculionidae	*Eubulus sp. TAC 1*	SC
Curculionidae	*Haplostethops sp. TAC 1*	SC
Curculionidae	*Notolomus sp. TAC 1*	SC
Curculionidae	*Notolomus sp. TAC 2*	SC
Curculionidae	*Platyomus flexicaulis (Schaeffer)*	SC
Curculionidae	*Plocetes versicolor (Clark)*	SC
Elateridae	*Anchastus augusti (Candeze)*	SC
Languriidae	*Hapalips texanus (Schaeffer)*	SC
Languriidae	*Loberus ornatus (Schaeffer)*	SC
Languriidae	*Toramus chamaeropis (Schaeffer)*	SC
Mycetophagidae	*Berginus sp. EGR 1*	SC
Phengodidae	*Cenophengus pallidus (Schaeffer)*	SC
Ptilodactylidae	*Lachnodactyla texana (Schaeffer)*	SC
Salpingidae	*Dacoderus n. sp. (Aalbu and Andrews, ms.)*	SC
Scarabaeidae	*Deltochilum scabriusculum scabriusculum (Bates)*	SC
Scarabaeidae	*Malagoniella astyanax yucateca (Harold)*	SC
Scarabaeidae	*Onthophagus batesi (Howden and Cartwright)*	SC

Scarabaeidae	*Phanaeus adonis (Harold)*	SC
Tenebrionidae	*Rhypasma sp. EGR 1*	SC
Tenebrionidae	*Strongylium aulicum (Maklin)*	SC
Tenebrionidae	*Strongylium championi (Gebien)*	SC
Tenebrionidae	*Talanus mecoselis (Triplehorn)*	SC
Lepidoptera (Insecta)		
Hesperiidae	*Euphyes bayensis*	SC
Hesperiidae	*Stallingsia maculosus*	SC
Saturniidae	*Agapema galbina*	SC
Saturniidae	*Sphingicampa blanchardi*	SC
Hymenoptera (Insecta)		
Apoidea	*Andrena (Micrandrena) micheneri (Ribble)*	SC
Apoidea	*Brachynomada (Melanomada) sp. A*	SC
Apoidea	*Colletes saritensis (Stephen)*	SC
Apoidea	*Perdita (Cockerellia) fraticincta (Timberlake)*	SC
Apoidea	*Perdita (Cockerellia) tricincta (Timberlake)*	SC
Apoidea	*Perdita (Perdita) crotonis decipiens (Timberlake)*	SC
Apoidea	*Perdita (Perdita) fidissima (Timberlake)*	SC

Location and Condition of the Gulf Coast Prairies and Marshes Ecoregion

Element 2

Following the line of the Texas Coast, and extending inland approximately 60 mi., are the Gulf Coast Prairies and Marshes. This 9,500,000-acre swath of land traces a broad arc along the coast from the Sabine River to Baffin Bay. Elevations range from near sea level to almost 150 ft. above MSL, while annual average temperatures range from 70°F to 74°F. Soils of the marshy areas include acid sands, sandy loams and clay. Soils of the Gulf Prairies contain more clay than the marsh areas and are very rich in nutrients (Simpson 1988). The character of the coastline is shaped by the long and continuous confrontation with the sea, wind and rain. Storms shape this ecoregion, creating a tapestry of shallow bays, estuaries, salt marshes, dunes and tidal flats. Because of the proximity to the Gulf of Mexico, many plants are highly salt tolerant or halophytic. The

Coastal Bend begins at mid-coast near Corpus Christi where the shoreline is edged by Mustang and Padre Islands, described as part of the longest chain of barrier islands in the world. Here, island dunes are spotted with sea oats, glasswort, beach evening primrose and railroad vine, hardy colonizers of the shifting beach-head sands. Sandy soils of the Coastal Bend also support distinctive Chenier woodlands of scrub oaks, yaupon, red-bay and wax-myrtle. Tallgrass and midgrass prairies, as well as spartina marshes, make up a major portion of the coastal vegetation. Much of the upland areas are dissected by numerous sluggish rivers, bayous, creeks and sloughs. Between the rivers, extensive open prairies are dominated by little bluestem, Indiangrass and various sedges. At one time the coastal river bottoms of this area were clothed in woodlands of sugarberry, pecan, elms and coastal live oaks. Few such areas remain today, as most of these prairies are farmed, or absorbed into urban areas. Much of the remaining native sod of the Gulf Coast Prairies and Marshes has been invaded by exotics such as Macartney rose and Chinese tallow or native woody species including mesquite, prickly-pear, acacias and scrub oaks (Gould 1975). Today rich coastal prairie soils are grazed for cattle production or farmed in rice, corn, grain sorghum and cotton, while the northeastern end of this region is intensively devoted to the oil and petrochemical industries (Winkler 1982).

Coastal areas are rich in wildlife with coastal marshes harboring hundreds of thousands of wintering geese and ducks and providing critical landfall in the spring for Neotropical migratory birds. The area is home to important wildlife sanctuaries and refuges, notably those protecting the endangered Attwater's prairie-chicken and the whooping crane. In the fall, coastal dunes serve as sentry roosts for northward-bound migrating peregrine falcons, while at any season there are lone willets, mini battalions of sanderling and congregations of gulls, terns and black skimmers feeding or loafing near the surf.

This ecoregion can be broken down into eight main habitat classes consisting of brushland, grassland, forest, marsh barrier island, native and introduced grasses, parkland, parkland woodland mosaic, and urban.

Gulf Coast Prairies and Marshes Brushland

The Gulf Coast Prairies and Marshes brushland consists of woody plants mostly less than nine feet tall which are dominant and growing as closely spaced individuals, clusters or closed canopied stands (greater than 10% canopy cover). Typically there are continuous, impenetrable shrubs covering over 75% of the ground (McMahan et al. 1984, Bridges et al. 2002). Only one plant association dominates this habitat class.

The *mesquite-blackbrush* association comprises the following plants: lotebush, ceniza, guajillo, desert olive, allthorn, whitebrush, bluewood, granjeno, guayacan, leatherstem, Texas prickly pear, tasajillo, kidneywood, yucca, desert yaupon, goatbush, purple three-awn, pink pappusgrass, hairy tridens, slim tridens, hairy grama, mat euphorbia, coldenia, dogwood, knotweed leafflower and two-leaved senna. This association is typically found on upland shallow, loamy or gravelly soils in the South Texas Plains ecoregion, although it barely extends into the Gulf Coast Prairies and Marshes ecoregion (McMahan et al. 1984). Cross-referenced communities: 1) freer mixed brush (Davis and Spicer 1965), 2) barretal (USFWS 1983), 3) blackbrush-twisted acacia (McLendon 1991), 4) blackbrush series (Diamond 1993), 5) blackbrush xerophytic brush (Bezanson 2000), and 6) blackbrush-cenizo-guajillo shrubland alliance (Weakley et al. 2000). The *mesquite-blackbrush* association is demonstratably secure globally and within the state of Texas (Diamond 1993). As a whole, this community is stable and common, however, there are a few plants found within this association that are rare and should have selective protection (USFWS 1983, Weakley et al. 2000). This community is considered low priority for further protection, excluding the discriminatory protection of a few rare species (Bezanson 2000).

Gulf Coast Prairies and Marshes Grassland

Grasslands consist of herbs (grasses, forbs and grass-like plants) which are dominant. Woody vegetation is lacking or nearly so (generally 10% or less woody canopy cover) (McMahan et al. 1984). There are three dominant plant associations found in the Gulf Coast Prairies and Marshes grassland.

The *blue grama-buffalograss* association is a shortgrass grassland which is most commonly found in the central and northwestern High Plains. However, there are scattered, isolated patches in the Gulf Coast Prairies and Marshes ecoregion. It is recognized by dominant upland soils (McMahan et al. 1984, Diamond 1993). Common plants associated with this subclass include sideoats grama, hairy grama, sand dropseed, cholla cactus, grassland prickly pear cactus, narrowleaf yucca, western ragweed, broom snakeweed, zinnia, rushpea, scurfpea, catclaw sensitive briar, wild buckwheat and woollywhite (McMahan et al. 1984). Cross-referenced communities: 1) mixed prairie climax (Rowell 1967), 2) blue grama-buffalograss (Diamond 1993), 3) blue grama-buffalograss short grasslands (Bezanson 2000), and 4) blue grama herbaceous alliance (Weakley et al. 2000). The *blue grama-buffalograss* community is considered secure globally. Statewide, this community is considered rare or uncommon. Non-native grasses, such as kleingrass, have been seeded on millions of acres throughout this community. Mesquite, narrowleaf yucca, juniper species and other brushy species have invaded these once treeless prairies. Broomweed species and other weedy forbs now dominate grazed pastures (Bezanson 2000). Approximately 21-100 occurrences are documented within the state (Diamond 1993). Due to these concerns, this community is considered of medium priority for further protection.

The *bluestem* association includes these plants: bushy bluestem, slender bluestem, little bluestem, silver bluestem, three-awn, buffalograss, Bermuda grass, brownseed paspalum, single-spike paspalum, smutgrass, sacahuista, windmillgrass, southern dewberry, live oak, mesquite, huisache, baccharis and Macartney rose (McMahan et al. 1984). This community is found on loamy upland soils over most of the Gulf Coast Prairies and Marshes ecoregion (McMahan et al. 1984, Diamond 1993). It is most prevalent in the grassland area of Goliad, Victoria and Refugio counties and also the areas between Refugio and Victoria (McMahan et al. 1984). Cross-reference communities: 1) little bluestem-trichloris grassland (McLendon 1991), 2) little bluestem-brownseed paspalum series (Diamond 1993), 3) upland tall grasslands (Coastal Prairies) (Bezanson 2000), and 4) little bluestem-brownseed paspalum herbaceous (Weakley et al. 2000). The *bluestem* community is considered imperiled and highly vulnerable to extinction throughout its global range. Within the state, this community is considered imperiled and is highly vulnerable to extirpation due to its rare occurrences. Globally and statewide there are only 6-20 occurrences documented (Diamond 1993).

The *seaoats-seacoast bluestem* association includes croton species, single-spike paspalum, Pan American balsamscale, flat sedge, sea purslane, cenicilla, bulrush, beach morning glory, goatfoot morning glory, sea rocket and lime pricklyash (McMahan et al. 1984). This is a mid to tallgrass association which occurs on stable sand dunes and prefers excessively drained soils (Diamond 1993). These sandy coastal barrier islands are located from the high tide mark to the leeward marshes, and are also found on the mainland Gulf shoreline in patches (McMahan et al. 1984). Cross-referenced communities: 1) sea oats-bitter panicum series (Diamond 1993), 2) beaches and active coastal dunes (Bezanson 2000), 3) cenicilla-beach morning glory series (Diamond et al. 1987), and 4) railroad-vine herbaceous alliance, sea oats temperate herbaceous alliance (Weakley et al. 2000). The *seaoats-seacoast bluestem* community is apparently secure globally with over 100 occurrences documented. There are areas in this community's range where it is considered rare, especially at the periphery. This community is considered rare or uncommon within the state with only 21-100 known occurrences (Diamond 1993).

Gulf Coast Prairies and Marshes Forest

The Gulf Coast Prairies and Marshes forest consists of deciduous or evergreen trees that are dominant in the landscape. These species are mostly greater than 30 ft. tall with closed crowns or nearly so (71-100% canopy cover). The midstory is generally apparent except in managed monocultures (McMahan et al. 1984, Bridges et al. 2002). Three plant associations dominate this habitat class.

The *bald cypress-water tupelo swamp* association is found in acidic, hydric soils in the swampy flatlands of the Pineywoods, barely extending into the northeastern most portion of the Gulf Coast Prairies and Marshes ecoregion**.** Commonly association plants include **w**ater oak, water hickory, swamp blackgum, red maple, swamp privit, buttonbush, possum haw, water elm, black willow, eardrop vine, supplejack, trumpet creeper, climbing hempweed, bog hemp, water fern, duckweed, water hyacinth, bladderwort, beggar-ticks, water paspalum and St. John's wort (McMahan et al. 1984). Cross-referenced communities: 1) cypress-tupelo sloughs and swamps (Watson 1979), 2) bald cypress (SAF #101), bald cypress-water tupelo (SAF #102) (Eyre 1980), 3) bald cypress tupelo series (Diamond 1993), 4) swamp cypress-tupelo forest (Marks and Harcombe 1981), 5) bald cypress-tupelo inundated forests (Bezanson 2000), and 6) bald cypress semipermanently flooded forest alliance, water-tupelo-(bald cypress) semipermanently flooded forest alliance, bald cypress (water tupelo, swamp blackgum, ogeechee tupelo) semipermanently flooded forest alliance, (water tupelo, swamp blackgum, ogeechee tupelo) pond seasonally flooded forest alliance (Weakley et al. 2000). The *bald cypress-water tupelo swamp* association is apparently secure globally with more than 100 known occurrences. It is possible for this community to be rare in parts of its range, especially in the periphery. Statewide, this community is considered rare or uncommon. Only 21-100 known occurrences exist (Diamond 1993).

American elm, cedar elm, cottonwood, sycamore, black willow, live oak, Carolina ash, bald cypress, water oak, hackberry, virgin's bower, yaupon, greenbriar, mustang grape, poison oak, Johnsongrass, Virginia wildrye, Canada wildrye, rescuegrass, frostweed and western ragweed are species commonly found in the *pecan-elm* association (McMahan et al 1984). This community is a broadly defined deciduous forest typically found along major rivers, bottomlands and mesic slopes where soils are often heavily textured and calcareous (Diamond 1993). This community is found along the Brazos, Colorado, Guadalupe, San Antonio and Frio river basins as well as the areas of the Navidad, San Bernard and Lavaca rivers (McMahan et al 1984). Cross-referenced communities: 1) sugarberry-elm series, pecan-sugarberry series (Diamond 1993), 2) sugarberry-elm floodplain forests (South Texas Plains) (Bezanson 2000), and 3) plateau oak-sugarberry woodland alliance, sugarberry-cedar elm temporarily flooded forest alliance, pecan-(sugarberry) temporarily flooded forest alliance (Weakley et al. 2000). The *pecan-elm* community is apparently secure within the state as well as globally (Diamond 1993). However, there are very few mature examples of the dominant plants in this community. The locations in south Texas that do exist are not very well protected but there are many examples of this community in other ecoregions. Due to this, Bezanson (2000) ranks this community as a medium priority for further protection in south Texas.

The *willow oak-water oak-blackgum* association includes beech, overcup oak, chestnut oak, cherrybark oak, elm, sweetgum, sycamore, southern magnolia, white oak, black willow, bald cypress, swamp laurel oak, hawthorn, bush palmetto, common elderberry, southern arrowwood, poison oak, supplejack, trumpet creeper, crossvine, greenbriar, blackberry, rhomboid copperleaf and St. Andrew's Cross (McMahan et al. 1984). This is a broadly defined community made up of deciduous vegetation that prefers bottomlands floodplains of major streams (Diamond 1993). This community is most commonly found in the lower flood plains of the Sulphur, Neches, Angelina, Trinity and Sabine rivers in the Pineywoods; however it extends into the northernmost portion of the Gulf Coast Prairies and Marshes ecoregion (McMahan et al. 1984). Cross-referenced communities: 1) sweetgum-willow oak (SAF #92) (Eyre 1980), 2) floodplain hardwood forest (Marks and Harcombe 1981), 3) water oak-willow oak series (Diamond 1993), 4) loblolly pine/water oak ridges (Mundorff 1998), 5) wet floodplain forests, wet flatland forests (Turner 1999), 6) floodplain hardwood forests (Bezanson 2000), and 7) (willow oak, water oak, diamondleaf oak) temporarily flooded forest alliance (Weakley et al. 2000). The *willow oak-water oak-blackgum* community is apparently secure globally with over 100 occurrences documented. There are areas in this community's range where it is considered rare, especially at the periphery. This community is considered rare or uncommon within the state with only 21-100 known occurrences (Diamond 1993).

Gulf Coast Prairies and Marshes/Marsh Barrier Island Community

The Marsh Barrier Island Community consists of emergent herbaceous plants which are dominant in inundated or periodically inundated areas. Woody vegetation is typically lacking or nearly so (generally 10% or less woody canopy cover). Smooth sloping accumulations of sand, shell and gravel along sea and bay shores are scattered with exposed unvegetated or sparsely vegetated wetlands and dunes (McMahan et al. 1984).

<u>Fresh</u>: The *maidencane-alligator weed marsh* (subtype 1) is a freshwater lowland that is on the landward of brackish marshes. Commonly associated plants include water hyacinth, cattail, water-pennywort, pickerelweed, arrowhead, white waterlily, cabomba, coontail and duckweed (McMahan et al. 1984). Cross-referenced communities: 1) *Typha-Scirpus* consocies and *Mariscus* consocies (Penfound and Hathaway 1938), 2)

semipermanent freshwater wetlands (Bezanson 2000), and 3) giant bulrush semipermanently flooded herbaceous alliance, maidencane seasonally flooded temperate herbaceous alliance, lanceleaf arrowhead semipermanently flooded herbaceous alliance, (narrowleaf cattail, common cattail)-(bulrush species) semipermanently flooded herbaceous alliance, soft rush seasonally flooded herbaceous alliance, southern wild rice seasonally flooded temperate herbaceous alliance (Weakley et al. 2000). The *maidencane-alligator weed marsh* community has an estimated 10,000 ac. that are already protected; however this community is still considered a medium priority for further protection due to its importance for sustaining wildlife species in this ecoregion and the potential for destruction from various threats (Bezanson 2000).

Brackish: The *marshay cordgrass-olneyi three-square-leafy three-square marsh* (subtype 2) is a discontinuous brackish lowland that is typically on the landward side of normal to storm tidelands (McMahan et al. 1984, Diamond 1993). Commonly associated plants include big cordgrass, widgeongrass, California bulrush, seashore paspalum, sacahuista and common reed (McMahan et al. 1984). Cross-referenced communities: 1) marshhay cordgrass series, saltgrass-cordgrass series (Diamond 1993), 2) intermediate marshes, brackish marshes (Bezanson 2000), and 3) saltmeadow cordgrass seasonally flooded herbaceous alliance, saltmeadow cordgrass-(saltgrass) tidal herbaceous alliance, groundsel-tree-maritime marsh-elder tidal shrubland alliance, olney threesquare semipermanently flooded herbaceous alliance, black needlerush tidal herbaceous alliance, beaked ditch-grass permanently flooded-tidal temperate herbaceous alliance (Weakley et al. 2000). The *marshay cordgrass-olneyi three-square-leafy three-square marsh* community is apparently secure within the state as well as globally (Diamond 1993). This community is common and widespread; therefore, it is considered a fairly low priority for further protection (Bezanson 2000).

Saline: The *smooth cordgrass-marsh saltgrass-sea ox-eye marsh* (subtype 3) is a saline lowland that is located where there are tidally-inundated shores of bays. Commonly associated plants include black rush, vidrillos, black mangrove, glasswort, seashore paspalum and shoalgrass. Cross-referenced communities: 1) *Spartina alterniflora* consocies, *Distichlis* consocies (Penfound and Hathaway 1938), 2) smooth cordgrass series (Diamond 1993), 3) tidal salt marshes (Bezanson 2000), and 4) saltmarsh cordgrass tidal herbaceous alliance, saltgrass tidal herbaceous alliance (Weakley et al. 2000). The *smooth cordgrass-marsh saltgrass-sea ox-eye marsh* community is apparently secure within the state as well as globally (Diamond 1993). This community is common and widespread; therefore, it is considered a fairly low priority for further protection (Bezanson 2000).

Gulf Coast Prairies and Marshes Native and Introduced Grasses

A mixture of native and introduced grasses which includes herbs (grasses, forbs and grass-like plants) that are dominant with woody vegetation lacking or nearly so (generally 10% or less woody canopy cover). These associations typically result from the invasion of non-native grass species originating from the planting of these non-natives (e.g. Bermuda, KR bluestem, etc.) for roadsides and rangelands. The clearing of woody vegetation is another factor and is sometimes associated with the early stages of a young forest. This community can quickly change as removed brush begins to regrow (McMahan et al. 1984, Bridges et al. 2002).

Gulf Coast Prairies and Marshes Parkland

In the Gulf Coast Prairies and Marshes parkland, a majority of the woody plants are equal to or greater than nine feet tall. They are generally dominant and grow as clusters, or as scattered individuals within continuous grass or forbs (11-70% woody canopy cover overall) (McMahan et al. 1984, Bridges et al. 2002). Only one plant association dominates this habitat class.

The *mesquite-granejo* association is most commonly found on loamy or sandy upland soils in the South Texas Plains. However, it barely extends into the Gulf Coast Prairies and Marshes ecoregion. Commonly associated plants include bluewood, lotebush, coyotillo, guayacan, Texas colubrina, tasajillo, Texas prickly pear, Pan American balsamscale, single-spike paspalum, hooded windmillgrass, tanglehead, Roemer three-awn, purple three-awn, tumble lovegrass, Lindheimer tephrosia, bullnettle, croton species, slender evolvulus, Texas lantana, silverleaf nightshade and firewheel. Cross-referenced communities: 1) mesquite-granjeno shrubland/dry woodland (McLendon

1991), 2) mesquite-granjeno series (Diamond 1993), 3) upland mesquite savannas (Bezanson 2000), and 4) honey mesquite woodland alliance (Weakley et al. 2000). The *mesquite-granejo* community is considered demonstrably secure globally and within the state of Texas (Diamond 1993). It is suggested that these communities are of low priority for further protection (Bezanson 2000).

Gulf Coast Prairies and Marshes Parkland Woodland Mosaic

The parkland woodland mosaic can be best described by pastures or fields with widely scattered vegetation (trees and/or shrubs) covering 10-25% of the ground (Bridges et al. 2002). There is only one plant association related to this habitat class.

The *live oak* association is principally on sandy soils in Brooks and Kenedy counties. Commonly related plants include the following: Texas prickly pear, lime pricklyash, greenbriar, bushsunflower, tanglehead, crinkleawn, single-spike paspalum, fringed signalgrass, Lindheimer tephrosia, croton, silverleaf nightshade, bullnettle, Texas lantana, dayflower, silverleaf sunflower and shrubby oxalis. Cross-referenced communities: 1) live oak savannas (South Texas Sand Sheet) (Bezanson 2000). The *live oak* community is stable however it is considered of medium priority for further protection since this community is primarily located on private lands (Bezanson 2000).

Gulf Coast Prairies and Marshes Urban Community

Urban habitats are cities or towns which are areas dominated by human dwellings including the fences, shrub rows, windbreaks and roads associated with their presence (Bridges at al. 2002). The biggest city in the Gulf Coast Prairies and Marshes community is by far Houston and its suburbs. The next largest city is Corpus Christi. Smaller prominent cities include Orange, Port Arthur, Port Neches, Groves, Richwood, Clute, Victoria, Port Lavaca, Rockport, Fulton and Brownsville.

Problems Affecting the Gulf Coast and Prairies

See the Texas Priority Species List……………………733

Element 3

- Fragmentation – Wetlands, marshes and prairies function best as large ecosystems. Remaining tracts of these habitats are being broken up, divided and impacted from development of roads for commerce, development for housing and businesses, and for agricultural purposes. This is highly detrimental to species that are less mobile
- Commercialization – Sand deposits are being sold for commercial resale out of wetland and riparian areas and impacting water quality downstream and in the bays
- Off-Road Vehicles – Off-road recreation has taken hold as an active outdoor pastime. There are off-roaders taking their four-wheelers into wetlands and these actions are impacting the effectiveness of the wetlands to function properly
- Prairie Conversion – Prairies are being converted into monocultures and are changing to urban environments. Within the Parklands and Woodlands, the slow growth of post oak trees, due to a loss of prairie grass species (which offer protection from wildlife), its slow growth from reduced succession of acorn saplings (from browsing of over-populated white-tailed deer), and its inability to handle construction impaction reduces post oak growth outside of natural areas. Also, because of this species slow growth, most commercial nurseries do not sell them
- Fire suppression – The suppression of wildfire has changed local prairie communities and this suppression supports the growth of invasive and exotic species
- Salt Water Intrusion – Navigation traffic introduces saltwater into freshwater marshes, causes drastic changes in native local plant communities and loss of habitat for many other species in this ecoregion
- Urbanization – Changing from vegetative environments to those of asphalt and concrete are reducing wildlife species, producing monocultures of grass that do

not benefit wildlife, fragmenting native plant communities and increasing pesticide and herbicide use

- Disturbance - the effects of disturbance in some coastal habitats to a number of coastal wildlife species, particularly certain groups of birds, (waterfowl, colonial waterbirds, shorebirds) is largely unquantified and merits investigation

Element 5

High Priority Research and Monitoring Efforts for the Gulf Coast and Prairies

See Monitoring and Adaptive Management………… 559

See the Texas Priority Species List……………………733

- Study the benefit of using constructed wetlands to purify wastewater
- Determine the effects of disturbance in some coastal habitats to a number of coastal wildlife species, particularly certain groups of birds, (waterfowl, colonial waterbirds, shorebirds)
- Monitor impacts of feral and domestic pets on wildlife
- Study the benefits of re-irrigating trapped water collected in retention ponds to provide habitat for wildlife (e.g. reduce flooding, putting water back into soil, etc.)
- Monitor highway bridges that provide man-made habitat for wildlife (e.g. swallows and bats) and the adoption of construction parameters that benefit wildlife
- Determine impacts of high fences on wildlife populations and monitor these trends
- Start an invasive plant committee to monitor and create regulations to stop importation and selling of exotic plants that are invasive and noxious

High Priority Conservation Actions for the Gulf Coast and Prairies

See High Priority Conservation Strategies…………..517

See the Texas Priority Species List……………………733

Element 4

- In this region, we should consider mitigating to grass before mitigating to trees. We need to, and currently are, working with cities to write ordinances that allow for taller grass and forbs species to grow. It is difficult to do restoration when a large number of the plants are going to be restricted
- Encourage cities to modify mowing regimes and start prairie restoration projects
- Educate the general public of the ecological importance of prairie ecosystems. As it stands, much of the general public views tall grass, and especially tall wet grass, as areas with little purpose or function. This leads to very little protection being provided to grassland areas. Currently, developers are required to mitigate if they remove certain tree species or disrupt wetland areas (not including ephemeral wetland)
- Educate the general public on human and wildlife interactions (i.e. coyotes in urban areas)
- Educate cities to enforce covering trash cans in urban areas for commercial properties to limit unwanted feeding of wildlife species
- Emphasize the importance of proper grazing. Work with state, federal and private agencies to continue to develop cost-effective means to balance grazing and wildlife
- Work with federal, state and private organizations to promote (incentives) leaving some cover for wildlife. The economic benefits of wildlife can sometimes equal or surpass the agricultural value of land

South Texas Plains Ecoregion

Associated Maps

Ecoregions of Texas………………………...1

South Texas Plains Ecoregion……………... 4

Element 1

Associated Section IV Documents

The Texas Priority Species List…………….733

Supplemental Mammal Information……….. 897

Supplemental Herptile Information………... 988

Priority Species

Group	Species Name	Common Name	State/Federal Status
Birds	*Aimophila botterii*	Botteri's sparrow	SC
	Aimophila cassinii	Cassin's sparrow	SC
	Aimophila ruficeps	Rufous-crowned sparrow	SC
	Amazilia yucatanensis	Buff-bellied hummingbird	SC
	Amazona viridigenalis	Red-crowned parrot	SC
	Ammodramus bairdii	Baird's sparrow (42 accepted state records)	SC
	Ammodramus maritimus	Seaside sparrow	SC
	Ammodramus nelsoni	Nelson's sharp-tailed sparrow	SC
	Ammodramus savannarum	Grasshopper sparrow	SC
	Amphispiza bilineata	Black-throated sparrow	SC
	Anas acuta	Northern pintail	SC
	Anas fulvigula	Mottled duck	SC
	Anthus spragueii	Sprague's pipit	SC
	Aquila chrysaetos	Golden eagle	SC
	Arenaria interpres	Ruddy turnstone	SC
	Asio flammeus	Short-eared owl	SC
	Asturina nitidus	Gray hawk	ST

Athene cunicularia	Burrowing owl	SC
Aythya affinis	Lesser scaup	SC
Aythya americana	Redhead	SC
Aythya valisineria	Canvasback	SC
Bartramia longicauda	Upland sandpiper	SC
Botaurus lentiginosus	American bittern	SC
Buteo albicaudatus	White-tailed hawk	ST
Buteo albontatus	Zone-tailed hawk	ST
Buteo lineatus	Red-shouldered hawk	SC
Buteo regalis	Ferruginous hawk	SC
Buteo swainsoni	Swainson's hawk	SC
Buteogallus anthracinus	Common black-hawk	ST
Calcarius mccownii	McCown's longspur	SC
Calidris alba	Sanderling	SC
Calidris canutus	Red knot	SC
Calidris himantopus	Stilt sandpiper	SC
Calidris mauri	Western sandpiper	SC
Callipepla squamata	Scaled quail	SC
Camptostoma imberbe	Northern beardless-tyrannulet	ST
Campylorhynchus brunneicapillus	Cactus wren	SC
Caprimulgus carolinensis	Chuck-will's-widow	SC
Cardinalis sinuatus	Pyrrhuloxia	SC
Chaetura pelagica	Chimney swift	SC
Charadrius alexandrinus	Snowy plover	SC
Charadrius montanus	Mountain plover	SC
Charadrius wilsonia	Wilson's plover	SC
Chloroceryle americana	Green kingfisher	SC
Chondestes grammacus	Lark sparrow	SC
Chondrohierax uncinatus	Hook-billed kite	SC

Chordeiles minor	Common nighthawk	SC
Circus cyaneus	Northern harrier	SC
Cistothorus platensis	Sedge wren	SC
Coccyzus americanus	Yellow-billed cuckoo	SC
Colinus virginianus	Northern bobwhite	SC
Columba flavirostris	Red-billed pigeon	SC
Contopus virens	Eastern wood-pewee	SC
Corvus imparatus	Tamaulipas crow	SC
Coturnicops noveboracensis	Yellow rail	SC
Cyanocorax morio	Brown jay	SC
Dendrocygna bicolor	Fulvous whistling-duck	SC
Dendroica dominica	Yellow-throated warbler	SC
Egretta caerulea	Little blue heron	SC
Egretta thula	Snowy egret	SC
Egretta tricolor	Tricolored heron	SC
Elanoides forficatus	Swallow-tailed kite	ST
Elanus leucurus	White-tailed kite	SC
Empidonax virescens	Acadian flycatcher	SC
Eremophila alpestris	Horned lark	SC
Falco columbarius	Merlin	SC
Falco femoralis	Aplomado falcon	FE/SE
Falco peregrinus tundrius	Arctic peregrine falcon	ST
Falco sparverius	American kestrel (southeastern)	SC
Gallinago delicata	Wilson's snipe (formerly common snipe)	SC
Geothlypis trichas	Common yellowthroat (Brownsville)	SC
Glaucidium brasilianum	Ferruginous pygmy-owl	ST
Haematopus palliatus	American oystercatcher	SC
Haliaeetus leucocephalus	Bald Eagle	FT/ST
Himantopus mexicanus	Black-necked stilt	SC

Hylocichla mustelina	Wood thrush	SC
Icterus cucullatus	Hooded oriole (both Mexican and Sennett's)	SC
Icterus graduacauda	Audubon's oriole	SC
Icterus gularis	Altamira oriole	SC
Icterus spurius	Orchard oriole	SC
Ictinia mississippiensis	Mississippi kite	SC
Ixobrychus exilis	Least bittern	SC
Lanius ludovicianus	Loggerhead shrike	SC
Laterallus jamaicensis	Black rail	SC
Limnodromus griseus	Short-billed dowitcher	SC
Limosa fedoa	Marbled godwit	SC
Limosa haemastica	Hudsonian godwit	SC
Melanerpes aurifrons	Golden-fronted woodpecker	SC
Micrathene whitneyi	Elf owl	SC
Mycteria americana	**Wood stork	ST
Myiarchus crinitus	Great crested flycatcher	SC
Numenius americanus	Long-billed curlew	SC
Numenius phaeopus	Whimbrel	SC
Nyctanassa violacea	Yellow-crowned night-heron	SC
Ortalis vetula	Plain chachalaca	SC
Pachyramphus aglaiae	Rose-throated becard (30 accepted state records)	ST
Parabuteo unicinctus	Harris's hawk	SC
Parula pitiayumi	Tropical parula	ST
Parus atricristatus	Black-crested titmouse	SC
Passerina ciris	Painted bunting	SC
Passerina versicolor	Varied bunting	SC
Pegadis chihi	White-faced ibis	ST
Pelecanus erythrorhynchos	American white pelican	SC
Pelecanus occidentalis	**Brown pelican	FT/SE

Phalaropus tricolor	Wilson's phalarope	SC
Picoides scalaris	Ladder-backed woodpecker	SC
Platalea ajaja	Roseate spoonbill	SC
Pluvialis dominica	American golden-plover	SC
Podiceps nigricollis	Eared grebe	SC
Polioptila melanura	Black-tailed gnatcatcher	SC
Porphyrio martinica	Purple gallinule	SC
Protonotaria citrea	Prothonotary warbler	SC
Rallus elegans	King rail	SC
Rallus limicola	Virginia rail	SC
Recurvirostra americana	American avocet	SC
Rynchops niger	Black skimmer	SC
Scolopax minor	American woodcock	SC
Spiza americana	Dickcissel	SC
Spizella breweri	Brewer's sparrow	SC
Spizella pusilla	Field sparrow	SC
Sporophila torqueola	White-collared seedeater	SC
Sterna antillarum	**Least tern (interior)	FE/SE
Sterna forsteri	Forster's tern	SC
Sterna nilotica	Gull-billed tern	SC
Sturnella magna	Eastern meadowlark	SC
Sturnella neglecta	Western meadowlark	SC
Toxostoma curvirostre	Curve-billed thrasher	SC
Toxostoma longirostre	Long-billed thrasher	SC
Toxostoma rufum	Brown thrasher	SC
Tringa flavipes	Lesser yellowlegs	SC
Tringa melanoleuca	Greater yellowlegs	SC
Tringa solitaria	Solitary sandpiper	SC
Tryngites subruficollis	Buff-breasted sandpiper	SC

	Tyrannus forficatus	Scissor-tailed flycatcher	SC
	Tyrannus tyrannus	Eastern kingbird	SC
	Tyto alba	Barn owl	SC
	Vermivora pinus	Blue-winged warbler	SC
	Vireo atricapillus	**Black-capped vireo	FE/SE
	Vireo bellii	Bell's vireo	SC
	Vireo flavifrons	Yellow-throated vireo	SC
	Vireo gilvus	Warbling vireo	SC
	Wilsonia citrina	Hooded warbler	SC
	Zenaida macroura	Mourning dove	SC
	Zonotrichia querula	Harris's sparrow	SC
Mammals	*Conepatus leuconotus*	Hog-nosed skunk	SC
	Geomys attwateri	Attwaters pocket gopher	SC
	Geomys personatus davisi	Texas (Davis') Pocket Gopher	SC
	Geomys personatus maritimus	Maritime pocket gopher	SC
	Geomys streckerii	Strecker's pocket gopher	SC
	Geomys texensis bakeri	Frio pocket gopher	SC
	Herpailurus yaguarondi	Jaguarundi	FE/SE
	Lasiurus ega	Southern yellow bat	ST
	Lasiurus xanthinus	Western yellow bat	SC
	Leopardus pardalis	**Ocelot	FE/SE
	Mormoops megalophylla	Ghost-faced bat	SC
	Mustela frenata	Long-tailed weasel	SC
	Myotis velifer	Cave myotis	SC
	Myotis yumanensis	Yuma myotis	SC
	Nasua narica	White-nosed coati	ST
	Notisorex crawfordii	Desert shrew	SC
	Nyctinomops macrotis	Big free-tailed bat	SC

	Oryzomys couesi	Coues rice rat	ST
	Puma concolor	Mountain lion	SC
	Spilogale gracilis	Western spotted skunk	SC
	Spilogale putorius	Eastern spotted skunk	SC
	Tadarida brasiliensis	Brazilian free-tailed bat	SC
	Taxidea taxus	American badger	SC
	Alligator mississippiensis	American alligator (4 sp.)	SC
Reptiles	*Cemophora coccinea*	Scarlet snake	ST
	Crotaphytus reticulatus	Reticulate collared lizard	ST
	Drymarchon corais	Western indigo snake	ST
	Drymobius margaritiferus	Speckled racer	ST
	Gopherus berlandieri	Texas tortoise	ST
	Heterodon nasicus gloydi	Dusty hog-nosed snake	SC
	Holbrookia lacerata	Spot-tailed earless lizard	SC
	Holbrookia propinqua	Keeled earless lizard	SC
	Hypopachus variolosus	Sheep frog	ST
	Macrochelys temminckii	Alligator snapping turtle	ST
	Notophthalmus meridionalis	Black-spotted newt	ST
	Ophisaurus attenuatus	Slender glass lizard	SC
	Phrynosoma cornutum	Texas horned lizard	ST
	Phrynosoma modestum	Round-tailed horned lizard	SC
	Scaphiopus hurterii	Hurter's spadefoot	SC
	Siren sp.	Rio Grande (lesser) siren	ST
	Sistrurus catenatus	Massasauga	SC
	Syrrhophus cystignathoides	Rio Grande chirping frog	SC
	Terrapene spp.	Box turtles	SC

Group	Family	Species Name	Federal Status
Invertebrates			
	Stylommatophora (Gastropoda)		
	Polygyridae	*Euchemotrema leai cheatumi*	SC
	Schizomida (Myriapoda)		
	Protoschizomidae	*?Agastoschizomus n.sp.*	SC
	Polydesmida (Myriapoda)		
	Polydesmidae	*Speodesmus falcatus*	SC
	Polydesmidae	*Speodesmus ivyi*	SC
	Polydesmidae	*Speodesmus reddelli*	SC
	Araneae (Arachnida)		
	Dictynidae	*Cicurina baronia*	FE
	Dictynidae	*Cicurina gatita*	SC
	Dictynidae	*Cicurina madla*	FE
	Dictynidae	*Cicurina medina*	SC
	Dictynidae	*Cicurina minorata (Gersch and Davis)*	SC
	Dictynidae	*Cicurina pablo*	SC
	Dictynidae	*Cicurina patei*	SC
	Dictynidae	*Cicurina porteri*	SC
	Dictynidae	*Cicurina riogrande (Gertsch and Mulaik)*	SC
	Dictynidae	*Cicurina rudimentops (Chamberlin and Ivie)*	SC
	Dictynidae	*Cicurina selecta*	SC
	Dictynidae	*Cicurina serena*	SC
	Dictynidae	*Cicurina sintonia*	SC
	Dictynidae	*Cicurina uvalde*	SC
	Dictynidae	*Cicurina venii*	FE
	Dictynidae	*Cicurina vespera*	FE
	Dictynidae	*Cicurina watersi*	SC
	Leptonetidae	*Neoleptoneta new species*	SC

Leptonetidae	*Neoleptoneta valverde (Gertsch)*	SC
Nesticidae	*Eidmannella nasuta (Gertsch)*	SC
Opiliones (Arachnida)		
Phalangodidae	*Texella homi*	SC
Pseudoscorpiones (Arachnida)		
Bochidae	*Leucohya texana*	SC
Neobisiidae	*Tartarocreagris cookei*	SC
Neobisiidae	*Tartarocreagris reyesi*	SC
Coleoptera (Insecta)		
Anobiidae	*Ptinus tumidus (Fall)*	SC
Anobiidae	*Trichodesma pulchella (Schaeffer)*	SC
Anobiidae	*Trichodesma sordida (Horn)*	SC
Anobiidae	*Trichodesma texana (Schaeffer)*	SC
Anobiidae	*Tricorynus texanus (White)*	SC
Anthribidae	*Neoxenus versicolor (Valentine)*	SC
Anthribidae	*Ormiscus albofasciatus (Schaeffer)*	SC
Anthribidae	*Ormiscus irroratus (Schaeffer)*	SC
Anthribidae	*Phoenicobiella schwarzii (Schaeffer)*	SC
Anthribidae	*Toxonotus penicellatus (Schaeffer)*	SC
Brentidae	*Apion aculeatum (Fall)*	SC
Brentidae	*Apion buchanani (Kissinger)*	SC
Brentidae	*Heterobrenthus texanus (Schaeffer)*	SC
Buprestidae	*Agrilus dollii (Schaeffer)*	SC
Buprestidae	*Agrilus subtropicus (Schaeffer)*	SC
Buprestidae	*Pachyschelus fisheri (Vogt)*	SC
Buprestidae	*Spectralia prosternalis (Schaeffer)*	SC
Buprestidae	*Trigonogya reticulaticollis (Schaeffer)*	SC
Carabidae	*Agra oblongopunctata oblongopunctata (Chevrolat)*	SC

Carabidae	*Apenes sp. UASM 11*	SC
Carabidae	*Calleida fimbriata (Bates)*	SC
Carabidae	*Galerita aequinoctialis (Chaudoir)*	SC
Carabidae	*Nemotarsus rhombifer (Bates)*	SC
Carabidae	*Rhadine exilis*	FE
Carabidae	*Rhadine infernalis*	FE
Cerambycidae	*Adetus sp. EGR 1*	SC
Cerambycidae	*Agallissus lepturoides (Chevrolat)*	SC
Cerambycidae	*Ataxia tibialis (Schaeffer)*	SC
Cerambycidae	*Cacostola lineata (Hamilton)*	SC
Cerambycidae	*Callipogonius cornutus (Linsley)*	SC
Cerambycidae	*Desmiphora aegrota (Bates)*	SC
Cerambycidae	*Dihammaphora dispar (Chevrolat)*	SC
Cerambycidae	*Ecyrus penicillatus (Bates)*	SC
Cerambycidae	*Hemierana marginata suturalis (Linell)*	SC
Cerambycidae	*Sphaenothecus trilineatus (Dupont)*	SC
Chrysomelidae	*Baliosus sp. EGR 1*	SC
Chrysomelidae	*Brucita marmorata (Jacoby)*	SC
Chrysomelidae	*Chaetocnema rileyi (White)*	SC
Chrysomelidae	*Chlamisus maculipes (Chevrolat)*	SC
Chrysomelidae	*Dibolia championi (Jacoby)*	SC
Chrysomelidae	*Disonycha barberi (Blake)*	SC
Chrysomelidae	*Disonycha stenosticha (Schaeffer)*	SC
Chrysomelidae	*Epitrix sp. EGR 1*	SC
Chrysomelidae	*Heptispa sp. EGR 1*	SC
Chrysomelidae	*Malacorhinus acaciae (Schaeffer)*	SC
Chrysomelidae	*Megascelis texana (Linell)*	SC
Chrysomelidae	*Octotoma championi (Baly)*	SC
Chrysomelidae	*Pachybrachis duryi (Fall)*	SC

Chrysomelidae	*Pachybrachis sp. EGR 2*	SC
Chrysomelidae	*Pachybrachis sp. EGR 6*	SC
Chrysomelidae	*Parchicola sp. EGR 1*	SC
Chrysomelidae	*Pentispa distincta (Baly)*	SC
Chrysomelidae	*Plagiodera thymaloides (Stal)*	SC
Cicindelidae	*Cicindela cazieri*	SC
Coccinellidae	*Diomus pseudotaedatus (Gordon)*	SC
Coccinellidae	*Hyperaspis rotunda (Casey)*	SC
Curculionidae	*Allopentarthrum sp. TAC 1*	SC
Curculionidae	*Allopentarthrum sp. TAC 2*	SC
Curculionidae	*Andranthobius sp. TAC 1*	SC
Curculionidae	*Apteromechus texanus (Fall)*	SC
Curculionidae	*Brachystylus microphthalmus (Champion)*	SC
Curculionidae	*Chalcodermus semicostatus (Schaeffer)*	SC
Curculionidae	*Chalcodermus serripes (Fahraeus)*	SC
Curculionidae	*Conotrachelus rubescens (Schaeffer)*	SC
Curculionidae	*Elleschus sp. TAC 1*	SC
Curculionidae	*Eubulus sp. TAC 1*	SC
Curculionidae	*Haplostethops sp. TAC 1*	SC
Curculionidae	*Notolomus sp. TAC 1*	SC
Curculionidae	*Notolomus sp. TAC 2*	SC
Curculionidae	*Platyomus flexicaulis (Schaeffer)*	SC
Curculionidae	*Plocetes versicolor (Clark)*	SC
Elateridae	*Anchastus augusti (Candeze)*	SC
Languriidae	*Hapalips texanus (Schaeffer)*	SC
Languriidae	*Loberus ornatus (Schaeffer)*	SC
Languriidae	*Toramus chamaeropis (Schaeffer)*	SC
Mycetophagidae	*Berginus sp. EGR 1*	SC
Phengodidae	*Cenophengus pallidus (Schaeffer)*	SC

Ptilodactylidae	*Lachnodactyla texana (Schaeffer)*	SC
Salpingidae	*Dacoderus n. sp. (Aalbu and Andrews, ms.)*	SC
Scarabaeidae	*Deltochilum scabriusculum scabriusculum (Bates)*	SC
Scarabaeidae	*Malagoniella astyanax yucateca (Harold)*	SC
Scarabaeidae	*Onthophagus batesi (Howden and Cartwright)*	SC
Scarabaeidae	*Phanaeus adonis (Harold)*	SC
Staphylinidae (Pselaphinae)	*Batrisodes (Babnormodes) uncicornis (Casey)*	SC
Tenebrionidae	*Rhypasma sp. EGR 1*	SC
Tenebrionidae	*Strongylium aulicum (Maklin)*	SC
Tenebrionidae	*Strongylium championi (Gebien)*	SC
Tenebrionidae	*Talanus mecoselis (Triplehorn)*	SC
Lepidoptera (Insecta)		
Hesperiidae	*Megathymus streckeri texanus*	SC
Hesperiidae	*Stallingsia maculosus*	SC
Saturniidae	*Agapema galbina*	SC
Saturniidae	*Sphingicampa blanchardi*	SC
Hymenoptera (Insecta)		
Apoidea	*Andrena (Micrandrena) micheneri (Ribble)*	SC
Apoidea	*Andrena (Scrapteropsis) flaminea (LaBerge)*	SC
Apoidea	*Anthophorula (Anthophorisca) ignota (Timberlake)*	SC
Apoidea	*Brachynomada (Melanomada) sp. A*	SC
Apoidea	*Calliopsis (Verbenapis) michenerella (Shinn and Engel)*	SC
Apoidea	*Coelioxys (Xerocoelioxys) piercei (Crawford)*	SC
Apoidea	*Colletes saritensis (Stephen)*	SC
Apoidea	*Holcopasites (Holcopasites) jerryrozeni (Neff)*	SC

Apoidea	*Macrotera (Cockerellula) lobata (Timberlake)*	SC
Apoidea	*Macrotera (Cockerellula) robertsi (Timberlake)*	SC
Apoidea	*Megachile (Megachiloides) parksi (Mitchell)*	SC
Apoidea	*Osmia (Diceratosmia) botitena (Cockerell)*	SC
Apoidea	*Perdita (Cockerellia) fraticincta (Timberlake)*	SC
Apoidea	*Perdita (Cockerellia) tricincta (Timberlake)*	SC
Apoidea	*Perdita (Epimacrotera) dolanensis (Neff)*	SC
Apoidea	*Perdita (Hexaperdita) agasta (Timberlake)*	SC
Apoidea	*Perdita (Perdita) fidissima (Timberlake)*	SC
Apoidea	*Protandrena (Heterosarus) subglaber (Timberlake)*	SC

Element 2

Location and Condition of the South Texas Plains Ecoregion

Bounded on the west by the Rio Grande and Mexico and on the north by the Balcones Escarpment, the South Texas Plains is vast, serene and unpopulated (Winkler 1982). Elevations range from sea level to 1,000 ft. above MSL and rainfall varies from 30 in. in the east to 16 in. in the west. Soils are varied and highly complex. Generally extremely basic to slightly acidic, they range from deep sands to tight clays and clay loams. With average annual temperatures around 73°F, the South Texas Plains boast the longest growing season in Texas, lasting up to 365 days in some years in Brownsville (Simpson 1988). This warm region is, however, a land of recurrent droughts, a factor which distinctly marks the landscape. Nearly everything that grows here is drought-tolerant, as rainfall is well below the amount needed for conventional forest trees (Wasowski 1988). Sporadic rains, however, will trigger wildflowers to bloom unexpectedly at almost any time of year.

The South Texas region owes its diversity to the convergence of the Chihuahuan Desert to the west, the Tamaulipan thornscrub and subtropical woodlands along the Rio Grande to the south, and the coastal grasslands to the east. Essentially a gently rolling plain, the region is cut by arroyos and streams, and is blanketed with low-growing vegetation such as mesquite, granjeno, huisache, catclaw, blackbrush, cenizo and guayacan. Wherever conditions are suitable, there is a dense understory of smaller trees and shrubs such as coyotillo, paloverde, Mexican olive and various species of cacti. The woody vegetation of the South Texas Plains is so distinctive that the area is also referred to as the "brush country".

The Lower Rio Grande Valley is a highly distinctive subregion of the South Texas Plains. Usually defined as Cameron, Willacy, Hidalgo and Starr counties, it contains the only subtropical area in Texas. Once supporting majestic groves of Texas palmetto, Montezuma cypress, tall ebony-anacua woodlands and jungle-like expanses of Tamaulipan thorn scrub, today much of it has been bulldozed, plowed or paved. In fact, the once extensive groves of the native sabal palm which used to flourish here are now reduced to only a few stands near Brownsville. Soils in this subtropical region range from sands to heavy clays. Clays and extremely poor drainage dominate the resaca areas (old meandering paths of the Rio Grande) (Wasowski 1988).

Despite the oldest land use history in the state, the Rio Grande Plain harbors many rare species of plants and animals (Texas General Land Office 1984). It is here that a few wild tropical cats, ocelots and jaguarundis, still take refuge. Other special animals include ferruginous pygmy-owl, green jay, elf owl, Texas tortoise, indigo snake and Mexican burrowing toad. There are also a surprising number of plants that occur here and nowhere else, especially among the cactus family, like Albert's black lace cactus, star cactus and Runyon's cory cactus.

This ecoregion can be broken down into eight main habitat classes consisting of brushland, forest, native and introduced grasses, parkland, woodland, woodland, forest and grassland mosaic, parkland woodland mosaic, and urban.

South Texas Plains Brushland

The South Texas Plains brushland consists of woody plants mostly less than nine feet tall which are dominant and grow as closely spaced individuals, clusters or closed canopied stands (greater than 10% canopy cover). Typically there are continuous, impenetrable shrubs covering over 75% of the ground (McMahan et al. 1984, Bridges et al. 2002). Two plant associations dominate this habitat class.

The *ceniza-blackbrush-creosote* association is normally found on the slopes of the Rio Grande basin, Stockton Plateau and South Texas plains which occur from Val Verde County, in the city of Langtry, to Zapata County near San Ygnacio (McMahan et al. 1984, Diamond 1993). This community typically grows on shallow soils (Diamond 1993). Commonly associated plants include guajillo, lotebush, mesquite, guayacan, Texas prickly pear, paloverde, goatbush, yucca, sotol, desert yaupon, catclaw acacia, kidneywood, allthorn, curly mesquite, Texas grama, hairy tridens, slim tridens, pink pappusgrass and two-leaved senna (McMahan et al. 1984). Cross-referenced communities: 1) ceniza series (Diamond 1993), 2) cenizo-blackbrush xerophytic brush (Bezanson 2000), and 3) blackbrush-cenizo-guajillo shrubland alliance (Weakley et al. 2000). The *ceniza-blackbrush-creosote* community is apparently secure within the state as well as globally (Diamond 1993). This community is common and widespread, therefore, it is considered a fairly low priority for further protection (Bezanson 2000).

The *mesquite-blackbrush* association comprises the following plants: lotebush, ceniza, guajillo, desert olive, allthorn, whitebrush, bluewood, granjeno, guayacan, leatherstem, Texas prickly pear, tasajillo, kidneywood, yucca, desert yaupon, goatbush, purple three-awn, pink pappusgrass, hairy tridens, slim tridens, hairy grama, mat euphorbia, coldenia, dogwood, knotweed leafflower and two-leaved senna. This association is typically found on upland shallow, loamy or gravelly soils in the South Texas Plains ecoregion (McMahan et al. 1984). Cross-referenced communities: 1) freer mixed brush (Davis and Spicer 1965), 2) barretal (USFWS 1983), 3) blackbrush-twisted acacia (McLendon 1991), 4) blackbrush series (Diamond 1993), 5) blackbrush xerophytic brush (Bezanson 2000), and 6) blackbrush-cenizo-guajillo shrubland alliance (Weakley et al. 2000). The *mesquite-blackbrush* association is demonstratably secure globally and within the state of

Texas (Diamond 1993). As a whole, this community is stable and common, however, there are a few plants found within this association that are rare and should have selective protection (USFWS 1983, Weakley et al. 2000). This community is considered low priority for further protection, excluding the discriminatory protection of a few rare species (Bezanson 2000).

South Texas Plains Forest

The South Texas Plains forest consists of deciduous or evergreen trees that are dominant in the landscape. These species are mostly greater than 30 ft. tall with closed crowns or nearly so (71-100% canopy cover). The midstory is generally apparent except in managed monocultures (McMahan et al. 1984, Bridges et al. 2002). Only one plant association dominates this habitat class.

American elm, cedar elm, cottonwood, sycamore, black willow, live oak, Carolina ash, bald cypress, water oak, hackberry, virgin's bower, yaupon, greenbriar, mustang grape, poison oak, Johnsongrass, Virginia wildrye, Canada wildrye, rescuegrass, frostweed and western ragweed are species commonly found in the *pecan-elm* association (McMahan et al 1984). This community is a broadly defined deciduous forest typically found along major rivers, bottomlands and mesic slopes where soils are often heavily textured and calcareous (Diamond 1993). This community is found along the San Antonio and Frio river basins which are found mainly in the South Texas Plains ecoregion (McMahan et al 1984). Cross-referenced communities: 1) sugarberry-elm series, pecan-sugarberry series (Diamond 1993), 2) sugarberry-elm floodplain forests (South Texas Plains) (Bezanson 2000), and 3) plateau oak-sugarberry woodland alliance, sugarberry-cedar elm temporarily flooded forest alliance, pecan-(sugarberry) temporarily flooded forest alliance (Weakley et al. 2000). The *pecan-elm* community is apparently secure within the state as well as globally (Diamond 1993). However, there are very few mature examples of the dominant plants in this community. The locations in south Texas that do exist are not very well protected but there are many examples of this community in other ecoregions. Due to this, Bezanson (2000) suggests to rank this community as a medium priority for further protection in south Texas.

South Texas Plains Native and Introduced Grasses

A mixture of native and introduced grasses which includes herbs (grasses, forbs and grass-like plants) that are dominant with woody vegetation lacking or nearly so (generally 10% or less woody canopy cover). These associations typically result from the invasion of non-native grass species originating from the planting of these non-natives (e.g. Bermuda, KR bluestem, etc.) for roadsides and rangelands. The clearing of woody vegetation is another factor that is sometimes associated with the early stages of a young forest. This community can quickly change as removed brush begins to regrow (McMahan et al. 1984, Bridges et al. 2002).

South Texas Plains Parkland

In the South Texas Plains parkland, a majority of the woody plants are equal to or greater than nine feet tall. They are generally dominant and grow as clusters, or as scattered individuals within continuous grass or forbs (11-70% woody canopy cover overall) (McMahan et al. 1984, Bridges et al. 2002). Two plant associations dominate this habitat class.

The *mesquite-granejo* association is found mainly on loamy or sandy upland soils in the South Texas Plains. Commonly associated plants include bluewood, lotebush, coyotillo, guayacan, Texas colubrina, tasajillo, Texas prickly pear, Pan American balsamscale, single-spike paspalum, hooded windmillgrass, tanglehead, Roemer three-awn, purple three-awn, tumble lovegrass, Lindheimer tephrosia, bullnettle, croton species, slender evolvulus, Texas lantana, silverleaf nightshade and firewheel. Cross-referenced communities: 1) mesquite-granjeno shrubland/dry woodland (McLendon 1991), 2) mesquite-granjeno series (Diamond 1993), 3) upland mesquite savannas (Bezanson 2000), and 4) honey mesquite woodland alliance (Weakley et al. 2000). The *mesquite-granejo* community is considered demonstrably secure globally and within the state of Texas (Diamond 1993). It is suggested that this community is of low priority for further protection (Bezanson 2000).

Huisache, huisachillo, whitebrush, granjeno, lotebush, Berlandier wolfberry, blackbrush, desert yaupon, Texas prickly pear, woollybucket bumelia, tasajillo, agarito, Mexican persimmon, purple three-awn, Roemer three-awn, pink pappusgrass, Halls panicum, slimlobe poppymallow, sensitive briar, two-leaved senna and mat euphorbia are species commonly linked to the *mesquite-live oak-bluewood* association. Typically, this association is found on loamy or sandy upland soils in the South Texas Plains. Locations of this community are primarily found in Uvalde, Bee and Medina counties in the South Texas Plains. Cross-referenced communities: 1) mesquite-granjeno shrubland/dry woodland (McLendon 1991), 2) mesquite-granjeno series (Diamond 1993), 3) upland mesquite savannas (Bezanson 2000), and 4) honey mesquite woodland alliance (Weakley et al. 2000). The *mesquite-live oak-bluewood* community is considered demonstrably secure globally and within the state of Texas (Diamond 1993). It is suggested that this community is of low priority for further protection (Bezanson 2000).

South Texas Plains Woodland

In the South Texas Plains woodland, a majority of the woody plants are mostly 9-30 ft. tall with closed crowns or nearly so (71-100% canopy cover). Typically the midstory is usually lacking any vegetation (McMahan et al. 1984, Bridges et al. 2002). One plant association dominates this habitat class.

The *mesquite-granejo* association is located primarily in Jim Wells and Kleberg counties in the South Texas Plains. Commonly associated plants include whitebrush, virgin's bower, desert olive, retama, Texas prickly pear, bluewood, lotebush, desert yaupon, tasajillo, guayacan, woollybucket bumelia, Berlandier wolfberry, catclaw acacia, Halls panicum, pink pappusgrass, purple three-awn, woodsorrel and field ragweed. Typically, this association is found on loamy or sandy upland soils in the South Texas Plains. Cross-referenced communities: 1) mesquite-granjeno shrubland/dry woodland (McLendon 1991), 2) mesquite-granjeno series (Diamond 1993), 3) upland mesquite savannas (Bezanson 2000), and 4) honey mesquite woodland alliance (Weakley et al. 2000). The *mesquite-granejo* community is considered demonstrably secure globally and within the state of Texas (Diamond 1993). It is suggested that this community is of low priority for further protection (Bezanson 2000).

South Texas Plains Woodland, Forest and Grassland Mosaic

The South Texas Plains woodland, forest and grassland mosaic is a combination of a few characters from each individual habitat class. Woody plants that are mostly 9-30 ft. tall are growing with deciduous or evergreen trees that are dominant and mostly greater than 30 ft. tall. Between patches of woody vegetation grow herbs (grasses, forbs and grass-like plants) where woody vegetation is lacking or nearly so (generally 10% or less woody canopy cover). In this mosaic habitat, there is a mix between absent canopy cover and areas with closed crowns or nearly so (71-100% canopy cover). In the areas with canopy cover, there ranges a lack of midstory to a midstory that is generally apparent except in managed monocultures (McMahan et al. 1984, Bridges et al. 2002).

Blackjack oak, eastern red cedar, mesquite, black hickory, live oak, sandjack oak, cedar elm, hackberry, yaupon, poison oak, American beautyberry, hawthorn, supplejack, trumpet creeper, dewberry, coral-berry, little bluestem, silver bluestem, sand lovegrass, beaked panicum, tree-awn, spranglegrass and tickclover are species commonly associated with the *post oak* association. This community is most commonly found in sandy soils in the Post Oak Savannah but is also found in the northeastern most portions of the South Texas Plains (McMahan et al 1984). Cross-referenced communities: 1) post oak-blackjack oak series (Diamond 1993), 2) post oak-blackjack oak upland forest and woodlands (Bezanson 2000), and 3) post oak-blackjack oak forest alliance, post oak-blackjack oak woodland alliance (Weakley et al. 2000). The *post oak* community is considered demonstrably secure globally and within the state of Texas (Diamond 1993). It is suggested that this community is of low priority for further protection (Bezanson 2000).

South Texas Plains Parkland Woodland Mosaic

The parkland woodland mosaic can be best described by pastures or fields with widely scattered vegetation (trees and/or shrubs) covering 10-25% of the ground (Bridges et al. 2002). There is only one plant association in this habitat class (McMahan et al. 1984, Bridges et al. 2002).

The *live oak* association is principally on sandy soils in Brooks and Kenedy counties. Commonly related plants include the following: Texas prickly pear, lime pricklyash, greenbriar, bushsunflower, tanglehead, crinkleawn, single-spike paspalum, fringed signalgrass, Lindheimer tephrosia, croton, silverleaf nightshade, bullnettle, Texas lantana, dayflower, silverleaf sunflower and shrubby oxalis. Cross-referenced communities: 1) live oak savannas (South Texas Sand Sheet) (Bezanson 2000). The *live oak* community is stable, however it is considered a medium priority for further protection since this community it located on private lands (Bezanson 2000).

South Texas Plains Urban Community

Urban habitats are cities or towns which are areas dominated by human dwellings including the fences, shrub rows, windbreaks and roads associated with their presence (Bridges at al. 2002). The two statistically important metropolitan areas of the Valley (Harlingen/San Benito/Brownsville and McAllen/Mission/Edinburg) are amongst the 10 fastest growing in the country. Smaller, prominent cities include the surrounding suburbs of McAllen such as Kingsville, Laredo, Freer, Eagle Pass, Pleasanton, Del Rio and Hondo. Economic development is a priority and urban sprawl continues being a major cause of habitat loss. The effect of non-native, invasive plants on wildlife (birds, butterflies, small reptiles) might be better understood by conducting science-based research and surveys.

As much as 97% of the native south Texas Tamaulipan thorn scrub ecosystem has been lost, primarily to agriculture and urban development. The urban landscape consists mainly of exotic, high maintenance plants that provide little or no habitat for both resident and migratory wildlife.

The remaining pockets of sabal palm trees and the abundance of other non-native palm trees are important elements of the urban landscape. Their importance resides in the fact that they provide roosting/nesting opportunities for birds (owls, orioles, etc), and at least two species of bats.

High Priority Communities: A Further Emphasis

The *Lower Rio Grande valley brushland* is considered an ecological transition zone between Mexico and the United States. This key community is not only home to many rare, threatened and endangered species but it is also a stop-over for migrating Neotropical birds. This rare habitat only occurs in the southernmost portion of Texas and is found no where else in the nation (Bezanson and Wolfe 2001). It is a high priority to protect more of the *Lower Rio Grande valley brushland* community. Since 1970 this area has tripled in population and is expected to double again within 20 years. Presently, there are small conservation areas in this community but not enough continuous land to preserve wildlife species such as the endangered ocelot (Bezanson and Wolfe 2001).

In the *Lower Rio Grande valley brushland habitat* there is significant growth in the human population. Approximately 90% of the Rio Grande Valley floodplain has been converted to agricultural land. General use, dams and upstream diversions of the Rio Grande waters are reducing this river to a trickle in many points. Near the mouth of this river it is almost dry, especially during the summer months. It is a high priority that private landowner involvement and preservation of land by various organizations occur for the preservation of this key community. Education is also necessary to build public awareness and to involve them in the preservation of this rare and fragile community (Bezanson and Wolfe 2001).

Element 3

Problems Affecting the South Texas Plains

See the Texas Priority Species List……………………733

The common practice of trimming palm trees for aesthetical purposes effectively takes roosting/nesting opportunities away from the wildlife species found in the South Texas Plains ecoregion (e.g. bat populations).

The demographic make-up of the area is predominantly Hispanic. Traditionally, less advantage is taken of nature-related outdoor recreation opportunities as a whole. Increasing awareness and involvement within these communities should be a priority.

High Priority Research and Monitoring Efforts for the South Texas Plains

See Monitoring and Adaptive Management………....559
See the Texas Priority Species List……………………733

Element 5

- Identification of undisturbed palm tree sites or "islands" (e.g. urban bat populations) and monitoring their populations
- Bat monitoring plan - Surveys could be conducted quarterly to capture presence/absence of resident and migratory species throughout the year and especially during spring and fall migration. In light of the recent incursion of Neotropical birds to south Texas the documentation of accidental species, particularly those new to the United States, is especially important
- Educational materials - Simple, easy to read, bilingual brochures and presentations can be distributed to city planners, home builders, landscaping companies, nurseries, home improvement stores, etc. Monitor their acceptance and usefulness
- Conservation and management workshops - Partnerships with local home/land owner organizations may assist in improved urban conservation
- Landowner incentive program (LIP) - Urban landowners would be more likely to buy into urban conservation actions when technical/economic assistance is provided
- Promote and monitor outdoor recreational and educational opportunities that are family oriented. This would likely recruit more Hispanics into nature/wildlife conservation

High Priority Conservation Actions for the South Texas Plains

See High Priority Conservation Strategies…………...517
See the Texas Priority Species List……………………733

Element 4

- Produce educational materials (brochure, presentations, etc) on the pros and cons of palm tree trimming

- Environmental education programs that address cultural/language barriers may assist in restoration and improved conservation
- Promote urban/suburban land/wildlife conservation and management workshops
- Promote a landowner incentive program for urban landowners
- Promote outdoor recreational and educational opportunities that are family oriented.
- Encourage cities to modify mowing regimes and start prairie restoration projects.
- Emphasize the importance of proper grazing. Work with state, federal and private agencies to continue to develop cost-effective means to balance grazing and wildlife. Patch grazing appears to be very promising. Support Farm Bill programs which encourage proper grazing management
- Work with federal, state and private organizations to promote (incentives) leaving some cover for wildlife. The economic benefits of wildlife can sometimes equal or surpass the agricultural value of land

Tier II – Secondary Priority: Cross Timbers and Prairies Ecoregion

Element 1

Associated Maps

Ecoregions of Texas………………………...1

Cross Timbers and Prairies Ecoregion……...5

Associated Section IV Documents

The Texas Priority Species List…………….733

Supplemental Mammal Information……….. 897

Supplemental Herptile Information………... 988

Priority Species

Group	Species Name	Common Name	State/Federal Status
Birds	*Aimophila cassinii*	Cassin's sparrow	SC
	Aimophila ruficeps	Rufous-crowned sparrow	SC
	Ammodramus bairdii	Baird's sparrow (42 accepted state records)	SC
	Ammodramus henslowii	Henslow's sparrow	SC
	Ammodramus leconteii	Le Conte's sparrow	SC
	Ammodramus savannarum	Grasshopper sparrow	SC
	Amphispiza bilineata	Black-throated sparrow	SC
	Anas acuta	Northern pintail	SC
	Anthus spragueii	Sprague's pipit	SC
	Asio flammeus	Short-eared owl	SC
	Athene cunicularia	Burrowing owl	SC
	Aythya affinis	Lesser scaup	SC
	Aythya americana	Redhead	SC
	Aythya valisineria	Canvasback	SC
	Bartramia longicauda	Upland sandpiper	SC
	Botaurus lentiginosus	American bittern	SC

Buteo lineatus	Red-shouldered hawk	SC
Buteo swainsoni	Swainson's hawk	SC
Calcarius mccownii	McCown's longspur	SC
Calcarius pictus	Smith's longspur	SC
Calidris canutus	Red knot	SC
Calidris himantopus	Stilt sandpiper	SC
Calidris mauri	Western sandpiper	SC
Callipepla squamata	Scaled quail	SC
Campylorhynchus brunneicapillus	Cactus wren	SC
Caprimulgus carolinensis	Chuck-will's-widow	SC
Catherpes mexicanus	Canyon wren	SC
Chaetura pelagica	Chimney swift	SC
Charadrius alexandrinus	Snowy plover	SC
Charadrius melodus	**Piping plover	FT/ST
Chondestes grammacus	Lark sparrow	SC
Chordeiles minor	Common nighthawk	SC
Circus cyaneus	Northern harrier	SC
Coccyzus americanus	Yellow-billed cuckoo	SC
Colinus virginianus	Northern bobwhite	SC
Contopus virens	Eastern wood-pewee	SC
Coturnicops noveboracensis	Yellow rail	SC
Dendroica cerulea	Cerulean warbler	SC
Dendroica discolor	Prairie warbler	SC
Dendroica dominica	Yellow-throated warbler	SC
Dryocopus pileatus	Pileated woodpecker	SC
Egretta caerulea	Little blue heron	SC
Egretta thula	Snowy egret	SC
Egretta tricolor	Tri-colored heron	SC

Empidonax virescens	Acadian flycatcher	SC
Eremophila alpestris	Horned lark	SC
Falco peregrinus tundrius	Arcitic peregrine falcon	ST
Gallinago delicata	Wilson's snipe (formerly common snipe)	SC
Haliaeetus leucocephalus	Bald Eagle	FT/ST
Helmitheros vermivorum	Worm-eating warbler	SC
Himantopus mexicanus	Black-necked stilt	SC
Hylocichla mustelina	Wood thrush	SC
Icterus spurius	Orchard oriole	SC
Ictinia mississippiensis	Mississippi kite	SC
Ixobrychus exilis	Least bittern	SC
Lanius ludovicianus	Loggerhead shrike	SC
Limnodromus griseus	Short-billed dowitcher	SC
Limosa fedoa	Marbled godwit	SC
Limosa haemastica	Hudsonian godwit	SC
Melanerpes aurifrons	Golden-fronted woodpecker	SC
Melanerpes erythrocephalus	Red-headed woodpecker	SC
Mycteria americana	**Wood stork	ST
Myiarchus crinitus	Great Crested flycatcher	SC
Numenius americanus	Long-billed curlew	SC
Numenius phaeopus	Whimbrel	SC
Nyctanassa violacea	Yellow-crowned night-heron	SC
Oporornis formosus	Kentucky warbler	SC
Parus atricristatus	Black-crested titmouse	SC
Passerina ciris	Painted bunting	SC
Pegadis chihi	White-faced ibis	ST
Pelecanus erythrorhynchos	American white pelican	SC
Phalaropus tricolor	Wilson's phalarope	SC
Picoides scalaris	Ladder-backed woodpecker	SC

Picoides villosus	Hairy woodpecker	SC
Pluvialis dominica	American golden-plover	SC
Podiceps auritus	Horned grebe	SC
Podiceps nigricollis	Eared grebe	SC
Protonotaria citrea	Prothonotary warbler	SC
Rallus elegans	King rail	SC
Rallus limicola	Virginia rail	SC
Recurvirostra americana	American avocet	SC
Scolopax minor	American woodcock	SC
Seiurus motacilla	Louisiana waterthrush	SC
Spiza americana	Dickcissel	SC
Spizella pusilla	Field sparrow	SC
Sterna antillarum	**Least tern (interior)	FE/SE
Sterna forsteri	Forster's tern	SC
Sturnella magna	Eastern meadowlark	SC
Sturnella neglecta	Western meadowlark	SC
Thryomanes bewickii	Bewick's wren (eastern)	SC
Toxostoma rufum	Brown thrasher	SC
Tringa flavipes	Lesser yellowlegs	SC
Tringa melanoleuca	Greater yellowlegs	SC
Tringa solitaria	Solitary sandpiper	SC
Tryngites subruficollis	Buff-breasted sandpiper	SC
Tympanuchus cupido attwateri	**Greater prairie-chicken (Attwater's)	FE/SE
Tyrannus forficatus	Scissor-tailed flycatcher	SC
Tyrannus tyrannus	Eastern kingbird	SC
Vermivora chrysoptera	Golden-winged warbler	SC
Vermivora pinus	Blue-winged warbler	SC
Vireo bellii	Bell's vireo	SC
Vireo flavifrons	Yellow-throated vireo	SC

	Vireo gilvus	Warbling vireo	SC
	Wilsonia citrina	Hooded warbler	SC
	Zenaida macroura	Mourning dove	SC
	Zonotrichia querula	Harris's sparrow	SC
Mammals	*Conepatus leuconotus*	Hog-nosed skunk	SC
	Dipodomys elator	Texas kangaroo rat	ST
	Lutra canadensis	River otter	SC
	Mustela frenata	Long-tailed weasel	SC
	Mustela nigripes	Black-footed ferret	FE/SE
	Myotis velifer	Cave myotis	SC
	Puma concolor	Mountain lion	SC
	Spilogale putorius	Eastern spotted skunk	SC
	Sylvilagus aquaticus	Swamp rabbit	SC
	Tadarida brasiliensis	Brazilian free-tailed bat	SC
	Taxidea taxus	American badger	SC
Reptiles	*Deirochelys reticularia*	Chicken turtle	SC
	Ophisaurus attenuatus	Slender glass lizard	SC
	Scaphiopus hurterii	Hurter's spadefoot	SC
	Terrapene spp.	Box turtles	SC

Group	Family	Species Name	Federal Status
Invertebrates			
	Symphyla (Myriapoda)		
	Scolopendrellidae	*Symphyllela pusilla*	SC
	Scolopendrellidae	*Symphyllela texana*	SC
	Polydesmida (Myriapoda)		
	Polydesmidae	*Speodesmus castellanus*	SC

Araneae (Arachnida)

Dictynadae	*Cicurina (Cicurella) caliga*	SC
Dictynadae	*Cicurina (Cicurella) coryelli (Gertsch)*	SC
Dictynadae	*Cicurina (Cicurella) hoodensis*	SC
Dictynidae	*Cicurina armadillo*	SC
Dictynidae	*Cicurina bandida*	SC
Dictynidae	*Cicurina bowni*	SC
Dictynidae	*Cicurina cueva*	SC
Dictynidae	*Cicurina elliotti*	SC
Dictynidae	*Cicurina machete*	SC
Dictynidae	*Cicurina marmorea*	SC
Dictynidae	*Cicurina microps (Chamberlin and Ivie)*	SC
Dictynidae	*Cicurina reddelli*	SC
Dictynidae	*Cicurina reyesi*	SC
Dictynidae	*Cicurina sansaba*	SC
Dictynidae	*Cicurina travisae*	SC
Dictynidae	*Cicurina vibora*	SC
Dictynidae	*Cicurina wartoni*	SC
Leptonetidae	*Neoleptoneta anopica (Gertsch)*	SC
Leptonetidae	*Neoleptoneta concinna (Gertsch)*	SC
Leptonetidae	*Neoleptoneta devia (Gertsch)*	SC
Leptonetidae	*Neoleptoneta paraconcinna*	SC
Linyphiidae	*Meioneta llanoensis (Gertsch and Davis)*	SC
Nesticidae	*Eidmannella reclusa (Gertsch)*	SC

Opiliones (Arachnida)

Phalangodidae	*Texella mulaiki (Goodnight and Goodnight)*	SC
**Phalangodidae – Bone Cave Harvestman	*Texella reyesi*	FE

Pseudoscorpiones (Arachnida)

Neobisiidae	*Tartarocreagris comanche (Muchmore)*	SC
Neobisiidae	*Tartarocreagris hoodensis*	SC
Neobisiidae	*Tartarocreagris texana (Muchmore)*	FE
Neobisiidae	*Tartarocreagris infernalis (Muchmore)*	SC
Coleoptera (Insecta)		
**Carabidae	*Rhadine persephone*	FE
Carabidae	*Rhadine reyesi*	SC
Pselaphidae	*Batrisodes (Excavodes) texanus*	FE
Staphylinidae	*Batrisodes (Babnormodes) feminiclypeus*	SC
Staphylinidae	*Batrisodes (Babnormodes) gravesi (Chandler and Reddell)*	SC
Staphylinidae	*Batrisodes (Babnormodes) uncicornis (Casey)*	SC
Staphylinidae	*Batrisodes (Babnormodes) wartoni (Chandler and Reddell)*	SC
Staphylinidae	*Batrisodes (Excavodes) cryptotexanus (Chandler and Reddell)*	SC
Staphylinidae	*Batrisodes (Excavodes) globosus (LeConte)*	SC
Staphylinidae	*Batrisodes (Excavodes) reyesi (Chandler)*	SC
Staphylinidae	*Texamaurops reddelli (Barr and Steeves)*	SC
Hymenoptera (Insecta)		
Apoidea	*Andrena (Tylandrena) scotoptera (Cockerell)*	SC
Apoidea	*Anthophorula (Anthophorisca) ignota (Timberlake)*	SC
Apoidea	*Colletes inuncantipedis (Neff)*	SC
Apoidea	*Eucera (Synhalonia) texana (Timberlake)*	SC
Apoidea	*Protandrena (Protandrena) maurula (Cockerell)*	SC
Apoidea	*Stelis (Protostelis) texana (Thorp)*	SC

Element 2

Location and Condition of the Cross Timbers and Prairies Ecoregion

The Cross Timbers and Prairies contain approximately 17,000,000 ac. represented by alternating bands of wooded habitat scattered throughout a mostly prairie region. Elevations range from about 600 to almost 1,700 ft. above MSL while rainfall varies from about 25 in. in the west to 35 in. in the east. The average annual temperature is 67°F. The Cross Timbers share many of the same species with the Post Oak Savannah. Grassland species such as little bluestem, Indiangrass and big bluestem are common to both, but there are a few notable differences in floral composition. Yaupon, sassafras and dogwood which form dense understory thickets in the Post Oak Savannah are almost nonexistent in the eastern Cross Timbers. Texas mulberry, American elm and osage orange become more common. In the understory are rusty blackhaw viburnum, American beautyberry, Arkansas yucca and smooth sumac. In the western Cross Timbers, which is drier still, live oak becomes more important, replacing the post oaks as one proceeds westward. The decrease in moisture discourages trees from growing close together except along streams resulting in more expansive pockets of prairies separating isolated stands of trees. Here flameleaf sumac, redbud, Mexican plum, rusty blackhaw viburnum and eastern red cedar become more prevalent. Fragrant sumac appears for the first time, a common shrub in the western Cross Timbers, and further west. Wildlife consists of a mixture of eastern forest and prairie species.

This ecoregion can be broken down into nine main habitat classes consisting of brushland, grassland, native and introduced grasses, parkland, parkland woodland mosaic, shrubland, woodland, woodland forest and grassland mosaic, and urban.

Cross Timbers and Prairies Brushland

The Cross Timbers and Prairies brushlands consist of woody plants mostly less than nine feet tall which are dominant and growing as closely spaced individuals, clusters or closed canopied stands (greater than 10% canopy cover). Typically there are continuous, impenetrable shrubs which cover over 75% of the ground (McMahan et al. 1984, Bridges et al. 2002). Two plant associations dominate this habitat class.

The *cottonwood-hackberry-salt cedar* association is the most prominent in the Guadalupe Mountains of Culberson County in the Trans-Pecos, however it is also prominent along the Red River in the Cross Timbers and Prairies ecoregion. It is a deciduous forest community that was occupied by floodplains of perennial streams which have since subsided due to disturbances (Diamond 1993). Commonly associated plants include Lindheimer's black willow, buttonbush, groundsel-tree, rough-leaf dogwood, Panhandle grape, heartleaf ampelopsis, false climbing buckwheat, cattail, switchgrass, prairie cordgrass, saltgrass, alkali sacaton, spikesedge, horsetail, bulrush, coarse sumpweed and Maximilian sunflower (McMahan et al. 1984). Cross-referenced communities: 1) floodplain forest and savannah (Kuchler 1974), 2) cottonwood-tallgrass series (Diamond 1993), 3) cottonwood-willow riparian woodlands (Bezanson 2000), and 4) eastern cottonwood temporarily flooded alliance woodland (Weakley et al. 2000). The C*ottonwood-hackberry-salt cedar* community is considered imperiled, or very rare, globally. It is endangered throughout its range. It is determined that 6-20 occurrences are documented (Diamond 1993) and that this association is considered imperiled, or very rare, throughout the state; therefore, this association is considered vulnerable to extirpation within the state (Diamond 1993).

The *mesquite* association is found principally in the Rolling Plains, however, small isolated patches are also found in the Cross Timbers and Prairies ecoregion. The plants commonly found with this association includes narrow-leaf yucca, grassland prickly pear, juniper, red grama, Texas grama, sideoats grama, hairy grama, purple three-awn, Roemer three-awn, buffalograss, red lovegrass, gummy lovegrass, sand dropseed, tobosa, western ragweed, James rushpea, scurfpea and wild buckwheat (McMahan et al. 1984). This association is found on typical upland soils which are sandy and shallow with influences from caliche or limestone (Diamond 1993). Cross-referenced communities: 1) mesquite-midgrass series (Diamond 1993), 2) upland mesquite-midgrass savannahs (Bezanson 2000), and 3) honey mesquite woodland alliance (Weakley et al. 2000). This community is considered secure globally and throughout the state with more than 100 occurrences documented. Occurrences may be rare in part of its range with associations becoming infrequent at the periphery (Diamond 1993).

Cross Timbers and Prairies Grassland

Grasslands consist of herbs (grasses, forbs and grass-like plants) which are dominant. Woody vegetation is lacking or nearly so (generally 10% or less woody canopy cover) (McMahan et al.1984). There are two dominant plant associations found in the Cross Timbers and Prairies grassland.

The *bluestem* association includes these plants: bushy bluestem, slender bluestem, little bluestem, silver bluestem, three-awn, buffalograss, Bermuda grass, brownseed paspalum, single-spike paspalum, smutgrass, sacahuista, windmillgrass, southern dewberry, live oak, mesquite, huisache, baccharis, Macartney rose (McMahan et al. 1984). This community is common in loamy upland soils over most of the Gulf Coast Prairies and Marshes ecoregion, most prevalent in the grassland area of Goliad, Victoria and Refugio counties and also the areas between Refugio and Victoria. However, it is also dominant in the central portion of the Cross Timbers and Prairies ecoregion (McMahan et al. 1984, Diamond 1993). Cross-reference communities: 1) little bluestem-trichloris grassland (McLendon 1991), 2) little bluestem-brownseed paspalum series (Diamond 1993), 3) upland tall grasslands (Coastal Prairies) (Bezanson 2000), and 4) little bluestem-brownseed paspalum herbaceous (Weakley et al. 2000). The *bluestem* community is considered imperiled and highly vulnerable to extinction throughout its global range. Within the state, this community is considered imperiled and is highly vulnerable to extirpation due to its rare occurrences. Globally and statewide there are only 6-20 occurrences documented (Diamond 1993).

The *silver bluestem-Texas wintergrass* association includes little bluestem, sideoats grama, Texas grama, three-awn, hairy grama, tall dropseed, buffalograss, windmillgrass, hairy tridens, tumblegrass, western ragweed, broom snakeweed, Texas bluebonnet, live oak, post oak and mesquite. This association is found primarily in the Cross Timbers and Prairies ecoregion; however, a small section crosses into the Post Oak Savannah ecoregion (McMahan et al. 1984). Cross-referenced communities: 1) little bluestem-Indiangrass series (Diamond 1993), 2) upland mollisol tall grassland (Bezanson 2000), and 3) little bluestem-sideoats grama herbaceous alliance (Weakley et al. 2000). This community is considered imperiled, or very rare, globally. It is endangered throughout its range. Approximately 6-20 occurrences have been documented, therefore, this association is considered vulnerable to extirpation within the state (Diamond 1993). According to Bezanson (2000) this should be a community of high priority for further protection.

Cross Timbers and Prairies Native and Introduced Grasses

A mixture of native and introduced grasses which includes herbs (grasses, forbs and grass-like plants) that are dominant with woody vegetation lacking or nearly so (generally 10% or less woody canopy cover). These associations typically result from the invasion of non-native grass species originating from the planting of these non-natives (e.g. Bermuda, KR bluestem, etc.) for roadsides and rangelands. The clearing of woody vegetation is another factor and is sometimes associated with the early stages of a young forest. This community can quickly change as removed brush begins to regrow (McMahan et al. 1984, Bridges et al. 2002).

Cross Timbers and Prairies Parkland

In the Cross Timbers and Prairies parkland, a majority of the woody plants are equal to or greater than nine feet tall. They are generally dominant and grow as clusters, or as scattered individuals within continuous grass or forbs (11-70% woody canopy cover overall) (McMahan et al. 1984, Bridges et al. 2002). Two plant associations dominate this habitat class.

The *live oak-mesquite-Ashe juniper* and *live oak-Ashe juniper* associations consist of Texas oak, shin oak, cedar elm, netleaf hackberry, flameleaf sumac, agarito, Mexican persimmon, Texas prickly pear, kidneywood, greenbriar, Texas wintergrass, little bluestem, curly mesquite, Texas grama, Halls panicum, purple three-awn, hairy tridens, cedar sedge, two-leaved senna, mat euphorbia and rabbit tobacco. These two associations are typically found on level to gently rolling uplands and ridge tops in the Edwards Plateau, which are limestone-dominated, although it is also found dominate in the south and western central areas of the Cross Timbers and Prairies ecoregion (McMahan et al. 1984). Cross-referenced communities: Cross-referenced communities: 1) plateau live oak series (Diamond 1993), 2) upland plateau live oak savannas

(Bezanson 2000), and 3) plateau oak woodland alliance (Weakley et al. 2000). The *live oak-mesquite-Ashe juniper* and *live oak-Ashe juniper* communities are apparently secure globally and throughout the state with more than 100 occurrences documented. Occurrences may be rare in part of its range with associations becoming infrequent at the periphery (Diamond 1993).

Cross Timbers and Prairies Parkland Woodland Mosaic

The parkland woodland mosaic can be best described by pastures or fields with widely scattered vegetation (trees and/or shrubs) covering 10-25% of the ground (Bridges et al. 2002). There are three plant associations related to this habitat class.

The *Ashe juniper* association includes live oak, Texas oak, cedar elm, mesquite, agarito, tasajillo, western ragweed, scurfpea, little bluestem, sideoats grama, Texas wintergrass, silver bluestem, hairy tridens, tumblegrass and red three-awn. This association is typically found on the slopes of hills in small isolated patches within Stephens and Palo Pinto counties found in the Cross Timbers and Prairies ecoregion (McMahan et al. 1984). Cross-referenced communities: 1) Ashe juniper-oak series (Diamond 1993), 2) Ashe juniper low forests (Bezanson 2000), and 3) Ashe's juniper woodland alliance (Weakley et al. 2000). The *Ashe juniper* community is considered apparently secure globally and within the state. More than 100 occurrences are known both globally and statewide, however this community can be rare in parts of its natural global range, especially the periphery. It can also be rare in some areas of Texas especially around the perimeter of its range (Diamond 1993).

The *oak-mesquite-juniper* association includes post oak, Ashe juniper, shin oak, Texas oak, blackjack oak, live oak, cedar elm, agarito, soapberry, sumac, hackberry, Texas prickly pear, Mexican persimmon, purple three-awn, hairy grama, Texas grama, sideoats grama, curly mesquite and Texas wintergrass. This community type occurs as associations or as a mixture of individual (woody) species stands on uplands in the Cross Timbers and Prairies (McMahan et al. 1984). This community most closely resembles the limestone dominated soil of the *live oak-Ashe juniper parkland* and the *live oak-mesquite-Ashe juniper parkland*. These associations typically occur on level to gently rolling uplands and ridge tops in the Edwards Plateau but are also found in the Cross Timbers and Prairies ecoregion (McMahan et al. 1984). Cross-referenced communities: 1) plateau live oak series (Diamond 1993), 2) upland plateau live oak savannas (Bezanson 2000), and 3) plateau oak woodland alliance (Weakley et al. 2000). This community is considered secure globally and throughout the state with more than 100 occurrences documented. Occurrences may be rare in part of its range with associations becoming infrequent at the periphery (Diamond 1993).

Blackjack oak, eastern red cedar, mesquite, black hickory, live oak, sandjack oak, cedar elm, hackberry, yaupon, poison oak, American beautyberry, hawthorn, supplejack, trumpet creeper, dewberry, coral-berry, little bluestem, silver bluestem, sand lovegrass, beaked panicum, three-awn, spranglegrass and tickclover are species commonly associated with the *post oak* association. This community is most commonly found in sandy soils in the Post Oak Savannah but is also found in the northwestern-most portion of the Cross Timbers and Prairies ecoregion (McMahan et al 1984). Cross-referenced communities: 1) post oak-blackjack oak series (Diamond 1993), 2) post oak-blackjack oak upland forest and woodlands (Bezanson 2000), and 3) post oak-blackjack oak forest alliance, post oak-blackjack oak woodland alliance (Weakley et al. 2000). This community is considered demonstrably secure globally and within the state of Texas (Diamond 1993). It is suggested that this community is of low priority for further protection (Bezanson 2000).

Cross Timbers and Prairies Shrubland

Shrublands consist of individual woody plants generally less than nine feet tall scattered throughout arid or semi-arid regions where the vegetation is evenly spaced covering over 75% of the ground (Bridges et al. 2002). Typically there is less than 30% woody canopy cover overhead (McMahan et al. 1984). The Cross Timbers and Prairies shrubland includes one plant association.

The *mesquite-lotebush* association is most commonly found in the central and southern portion of the Rolling Plains and is also found in the northwestern most corner of the Cross Timbers and Prairies ecoregion. This association is typically deciduous and it is normal to find this association growing on upland soils which are sandy and shallow with influences from caliche or limestone (Diamond 1993). Commonly associated plants include yucca species, skunkbush sumac, agarito, elbowbush, juniper, tasajillo, cane bluestem, silver bluestem, little bluestem, sand dropseed, Texas grama, sideoats grama, hairy grama, red grama, tobosa, buffalograss, Texas wintergrass, purple three-awn, Roemer three-awn, Engelmann daisy, broom snakeweed and bitterweed (McMahan et al. 1984). Cross-referenced communities: 1) mesquite-midgrass series (Diamond 1993), 2) upland mesquite-midgrass savannahs (Bezanson 2000), and 3) honey mesquite woodland alliance (Weakley et al. 2000). This community is considered secure globally and throughout the state with more than 100 occurrences documented. Occurrences may be rare in part of its range with associations becoming infrequent at the periphery (Diamond 1993).

Cross Timbers and Prairies Woodland

In the Cross Timbers and Prairies woodland, a majority of the woody plants are mostly 9-30 ft. tall with closed crowns or nearly so (71-100% canopy cover). Typically the midstory is usually lacking any vegetation (McMahan et al. 1984, Bridges et al. 2002). Only one plant association dominates this habitat class.

The *live oak-Ashe juniper* association includes Texas oak, shin oak, cedar elm, evergreen sumac, escarpment cherry, saw greenbriar, mescal bean, poison oak, twistleaf yucca, elbowbush, cedar sedge, little bluestem, Neally grama, Texas grama, meadow dropseed, Texas wintergrass, curly mesquite, pellitory, noseburn, spreading sida, woodsorrel and mat euphorbia. This community is found chiefly on shallow limestone soils on the hills and escarpment of the Edwards Plateau, but is also found in a few small patches in the southeastern most corner of the Cross Timbers and Prairies ecoregion (McMahan et al. 1984). Cross-referenced communities: 1) Ashe juniper-oak series (Diamond 1993), 2) Ashe juniper low forests (Bezanson 2000), and 3) Ashe's juniper woodland alliance (Weakley et al. 2000). This community is considered apparently secure globally and within the state. More than 100 occurrences are known both globally and statewide, however this community can be rare in parts of its natural global range, especially the periphery. It can also be rare in some areas of Texas especially around the border of its range (Diamond 1993).

Cross Timbers and Prairies Woodland, Forest and Grassland Mosaic

The Cross Timbers and Prairies woodland, forest and grassland mosaic is a combination of a few characters from each individual habitat class. Woody plants that are mostly 9-30 ft. tall are growing with deciduous or evergreen trees that are dominant and mostly greater than 30 ft. tall. Between patches of woody vegetation grow herbs (grasses, forbs and grass-like plants) where woody vegetation is lacking or nearly so (generally 10% or less woody canopy cover). In this mosaic habitat, there is a mix between absent canopy cover and areas with closed crowns or nearly so (71-100% canopy cover). In the areas with canopy cover, there ranges a lack of midstory to a midstory that is generally apparent except in managed monocultures (McMahan et al. 1984, Bridges et al. 2002). Only one plant association dominates this habitat class.

Blackjack oak, eastern red cedar, mesquite, black hickory, live oak, sandjack oak, cedar elm, hackberry, yaupon, poison oak, American beautyberry, hawthorn, supplejack, trumpet creeper, dewberry, coral-berry, little bluestem, silver bluestem, sand lovegrass, beaked panicum, three-awn, spranglegrass and tickclover are species commonly associated with the *post oak* association. This community is most common in sandy soils within the Post Oak Savannah but is also found in the northern half of the Cross Timbers and Prairies ecoregion (McMahan et al 1984). Cross-referenced communities: 1) post oak-blackjack oak series (Diamond 1993), 2) post oak-blackjack oak upland forest and woodlands (Bezanson 2000), and 3) post oak-blackjack oak forest alliance, post oak-blackjack oak woodland alliance (Weakley et al. 2000). This community is considered demonstrably secure globally and within the state of Texas (Diamond 1993). It is suggested that this community is of low priority for further protection (Bezanson 2000).

Cross Timbers and Prairies Urban Community

Urban habitats are cities or towns which are areas dominated by human dwellings including the fences, shrub rows, windbreaks and roads associated with their presence (Bridges at al. 2002).

The Cross Timbers and Prairies ecoregion is located in north Central Texas. It extends east to west from Ft. Worth to Mineral Wells and north to south from the Red River down to Hamilton County. The biggest city in the Cross Timbers and Prairies community is Fort Worth and its associated suburbs. The next largest cities include Wichita Falls, Temple, Waco and the western side of Austin. Smaller prominent cities include Denison, Sherman, Gainesville, Decatur, Mineral Wells, Weatherford, Ranger, Brownwood and McGregor. Typically this ecoregion is divided into the eastern and western Cross Timber regions, split by the Grand Prairie. The dominant plant species are post and blackjack oaks in the upland woodlands, and little bluestem grass in the open "pocket prairies". Historically, this region was known for having incredibly dense forests with occasional open prairies.

In the rural setting this system is functioning and doing relatively well. In the urban areas around Ft. Worth the conditions are not nearly as favorable. The undeveloped areas surrounding Ft. Worth are relatively attractive to housing developments, especially upper end subdivisions. The "pocket prairies" are relatively easy and popular to build in. These prairie openings are also experiencing problems with woody species encroachment by various invasive plants, both native and exotic. The upland wooded areas are often left as park areas, but from a wildlife standpoint the habitat quality is greatly diminished. Typically, in the park areas, the woodland is significantly thinned, the underbrush removed and the overstory trees low limbed, resulting in very little layering of the habitat. In many if of the parks with cross timbers habitat, the trees are slowly dying due to little root protection caused by the fore mentioned practices.

Element 3

Problems Affecting the Cross Timbers and Prairies

See the Texas Priority Species List……………………733

Currently, most of the development in the cross timbers is of traditional nature which encourages urban sprawl. The growth of "ranchet" style subdivisions is very popular in the outlying urban areas in this ecoregion. Conservation subdivision or cluster design is encouraged, but it still slow to catch on. A second issue with development is the use of heavy machinery around the trees. Post and blackjack oaks are very sensitive to soil compaction and root damage. Though the trees may not appear damaged, it is not uncommon for the trees to start dying shortly after an area is built up. Both of these species are also very sensitive to over watering.

In the developed urban area there are pockets of cross timber habitat, usually located in city parks. Due to the general perception of visual aesthetics and perceived safety benefits, the wooded areas are typically thinned out and the underbrush removed. The larger oaks are typically left, but most small trees and brush are cleared. To discourage the regrowth of woody species, some cities mow as often as twice a year. This creates two main problems, no layering of habitat and little root protection for the larger trees. Frequent mowing will also discourage growth of beneficial grass and forb species.

Due to the lack of fire, previous or current heavy grazing, and introduction from urban development, invasive plant species are a major concern in urban cross timbers areas. In areas that were historically open prairie areas, there is the threat of woody species encroachment. The most noted species is the honey mesquite and in some areas the Ashe juniper is also a concern. In the wooded areas, where understory is allowed to grow, there is an increase in the amount nandina (*Nadina domestica*), various privets (*Ligustrum sp*.) and Japanese honeysuckle (*Lonicera japonica*). Any of these species can quickly create a monoculture in the understory.

High Priority Research and Monitoring Efforts for the Cross Timbers and Prairies

See Monitoring and Adaptive Management………… 559
See the Texas Priority Species List……………………733

- Further Baseline Research - Identify foraging habitat requirements, quantify diet, determine habitat availability and monitor locations, monitor size of population, seasonal fluctuations in population size, long term trends in population size, determine date of most recent occurrence in the region, minimum viable population size, habitat range, dispersal and movement patterns, historical range and monitor successful survey techniques (e.g. Texas horned lizard)

Element 5

- Researching invasive species control is important. (i.e. many of the techniques commonly used on horned lizards and harvester ants are not conducted in an urban setting)
- Amphibian Watch surveys
- Surveys of invasive species prevalence. Using data from such surveys we could potentially determine the success or failure of our management strategies
- Determine affects of various management practices on species, populations and habitats (e.g. prescribed burning, discing)
- Identify, map and ground truth locations and habitats

Element 4

High Priority Conservation Actions for the Cross Timbers and Prairies

See High Priority Conservation Strategies…………..517

See the Texas Priority Species List……………………733

- Value Understory – For those areas that are left undeveloped, like parks, one of the greatest needs is a greater appreciation and understanding of the understory. This understanding starts with the general public, up through the various park departments and even extends to the police departments. Currently, we are actively involved in this aspect through technical guidance work with various cities on park management updates. Without an understory, we simply see very little wildlife in the parks. This same concept needs to be applied to subdivision "common" areas
- Conservation Development – Encouraging conservation subdivision design within the ecoregion would be beneficial. Currently, Texas Parks and Wildlife provides technical guidance to developers that request assistance in this concept. To date, our main method of educating developers in this technique is through various workshops. At the regional and city levels, there needs to be a concerted effort to encourage coding that allows for this type of development. As it stands, many municipalities have coding that will not allow for this type development technique
- Invasive species control – On all management levels, we must become more diligent in the control of invasive species. Without some sort of control, we will

lose the pocket prairies to woody encroachment and potentially develop monocultures in the understory

- Encourage cities to modify mowing regimes and start prairie restoration projects
- Emphasize the importance of proper grazing. Work with state, federal and private agencies to continue to develop cost-effective means to balance grazing and wildlife. Patch grazing appears to be very promising
- Work with federal, state and private organizations to promote (incentives) leaving some cover for wildlife. The economic benefits of wildlife can sometimes equal or surpass the agricultural value of land

Edwards Plateau Ecoregion

Associated Maps

Ecoregions of Texas………………………...1

Edwards Plateau Ecoregion………………... 6

Element 1

Associated Section IV Documents

The Texas Priority Species List…………….733

Supplemental Mammal Information……….. 897

Supplemental Herptile Information………... 988

Priority Species

Group	Species Name	Common Name	State/Federal Status
Birds	*Aimophila cassinii*	Cassin's sparrow	SC
	Aimophila ruficeps	Rufous-crowned sparrow	SC
	Ammodramus bairdii	Baird's sparrow (42 accepted state records)	SC
	Ammodramus leconteii	Le Conte's sparrow	SC
	Ammodramus savannarum	Grasshopper sparrow	SC
	Amphispiza bilineata	Black-throated sparrow	SC
	Anas acuta	Northern pintail	SC
	Aquila chrysaetos	Golden eagle	SC
	Athene cunicularia	Burrowing owl	SC
	Aythya affinis	Lesser scaup	SC
	Aythya americana	Redhead	SC
	Aythya valisineria	Canvasback	SC
	Bartramia longicauda	Upland sandpiper	SC
	Buteo albontatus	Zone-tailed hawk	ST
	Buteo lineatus	Red-shouldered hawk	SC
	Buteo swainsoni	Swainson's hawk	SC
	Calcarius mccownii	McCown's longspur	SC

Calidris canutus	Red knot	SC
Calidris himantopus	Stilt sandpiper	SC
Calidris mauri	Western sandpiper	SC
Callipepla squamata	Scaled quail	SC
Campylorhynchus brunneicapillus	Cactus wren	SC
Caprimulgus carolinensis	Chuck-will's-widow	SC
Cardinalis sinuatus	Pyrrhuloxia	SC
Catherpes mexicanus	Canyon wren	SC
Chaetura pelagica	Chimney swift	SC
Charadrius alexandrinus	Snowy plover	SC
Charadrius montanus	Mountain plover	SC
Chloroceryle americana	Green kingfisher	SC
Chondestes grammacus	Lark sparrow	SC
Chordeiles minor	Common nighthawk	SC
Circus cyaneus	Northern harrier	SC
Coccyzus americanus	Yellow-billed cuckoo	SC
Colinus virginianus	Northern bobwhite	SC
Contopus virens	Eastern wood-pewee	SC
Cyrtonyx montezumae	Montezuma quail	SC
Dendroica chrysoparia	**Golden-cheeked warbler	FE/SE
Dendroica dominica	Yellow-throated warbler	SC
Dryocopus pileatus	Pileated woodpecker	SC
Egretta thula	Snowy egret	SC
Empidonax virescens	Acadian flycatcher	SC
Falco peregrinus tundrius	Arctic peregrine falcon	ST
Gallinago delicata	Wilson's snipe (formerly common snipe)	SC
Haliaeetus leucocephalus	Bald eagle	FT/ST
Helmitheros vermivorum	Worm-eating warbler	SC
Himantopus mexicanus	Black-necked stilt	SC

Hylocichla mustelina	Wood thrush	SC
Icterus cucullatus	Hooded oriole (both Mexican and Sennett's)	SC
Icterus parisorum	Scott's oriole	SC
Icterus spurius	Orchard oriole	SC
Ictinia mississippiensis	Mississippi kite	SC
Ixobrychus exilis	Least bittern	SC
Lanius ludovicianus	Loggerhead shrike	SC
Limnodromus griseus	Short-billed dowitcher	SC
Limosa fedoa	Marbled godwit	SC
Limosa haemastica	Hudsonian godwit	SC
Melanerpes aurifrons	Golden-fronted woodpecker	SC
Melanerpes erythrocephalus	Red-headed woodpecker	SC
Micrathene whitneyi	Elf owl	SC
Myiarchus crinitus	Great crested flycatcher	SC
Numenius americanus	Long-billed curlew	SC
Nyctanassa violacea	Yellow-crowned night-heron	SC
Oporornis formosus	Kentucky warbler	SC
Parabuteo unicinctus	Harris's hawk	SC
Parus atricristatus	Black-crested titmouse	SC
Passerina ciris	Painted bunting	SC
Passerina versicolor	Varied bunting	SC
Pelecanus erythrorhynchos	American white pelican	SC
Phalaropus tricolor	Wilson's phalarope	SC
Picoides scalaris	Ladder-backed woodpecker	SC
Picoides villosus	Hairy woodpecker	SC
Pluvialis dominica	American golden-plover	SC
Podiceps auritus	Horned grebe	SC
Podiceps nigricollis	Eared grebe	SC
Protonotaria citrea	Prothonotary warbler	SC

	Rallus elegans	King rail	SC
	Rallus limicola	Virginia rail	SC
	Recurvirostra americana	American avocet	SC
	Seiurus motacilla	Louisiana waterthrush	SC
	Spiza americana	Dickcissel	SC
	Spizella breweri	Brewer's sparrow	SC
	Spizella pusilla	Field sparrow	SC
	Sterna antillarum	**Least tern (interior)	FE/SE
	Sterna forsteri	Forster's tern	SC
	Sturnella magna	Eastern meadowlark	SC
	Sturnella neglecta	Western meadowlark	SC
	Toxostoma crissale	Crissal thrasher	SC
	Toxostoma curvirostre	Curve-billed thrasher	SC
	Toxostoma rufum	Brown thrasher	SC
	Tringa flavipes	Lesser yellowlegs	SC
	Tringa melanoleuca	Greater yellowlegs	SC
	Tringa solitaria	Solitary sandpiper	SC
	Tryngites subruficollis	Buff-breasted sandpiper	SC
	Tyrannus forficatus	Scissor-tailed flycatcher	SC
	Tyrannus tyrannus	Eastern kingbird	SC
	Vireo atricapillus	**Black-capped vireo	FE/SE
	Vireo bellii	Bell's vireo	SC
	Vireo flavifrons	Yellow-throated vireo	SC
	Vireo gilvus	Warbling vireo	SC
	Vireo vicinior	Gray vireo	SC
	Wilsonia citrina	Hooded warbler	SC
	Zenaida macroura	Mourning dove	SC
Mammals	*Antrozous pallidus*	Pallid bat	SC

	Conepatus leuconotus	Hog-nosed skunk	SC
	Corynorhinus townsendii	**Townsend's big-eared bat	SC
	Cynomys ludovicianus	Black-tailed prairie dog	SC
	Erethizon dorsatum	Porcupine	SC
	Geomys aurenarius	Desert pocket gopher	SC
	Geomys texensis bakeri	Frio pocket gopher	SC
	Geomys texensis texensis	Llano pocket gopher	SC
	Lutra canadensis	River otter	SC
	Mormoops megalophylla	Ghost-faced bat	SC
	Mustela frenata	Long-tailed weasel	SC
	Mustela nigripes	Black-footed ferret	FE/SE
	Myotis velifer	Cave myotis	SC
	Myotis yumanensis	Yuma myotis	SC
	Nasua narica	White-nosed coati	ST
	Puma concolor	Mountain lion	SC
	Spilogale gracilis	Western spotted skunk	SC
	Spilogale putorius	Eastern spotted skunk	SC
	Sylvilagus aquaticus	Swamp rabbit	SC
	Tadarida brasiliensis	Brazilian free-tailed bat	SC
	Taxidea taxus	American badger	SC
	Ursus americanus	Black bear	ST
	Vulpes velox	Swift fox (Kit fox)	SC
Reptiles	*Crotalus horridus*	Timber rattlesnake	ST
	Drymarchon corais	Western indigo snake	ST
	Eurycea chisholmensis	Salado salamander	SC
	Eurycea latitans	Cascade caverns salamander	ST
	Eurycea nana	**San Marcos salamander	FT/ST
	Eurycea naufragia	Georgetown salamander	SC

Eurycea neotenes	Texas salamander	SC
Eurycea pterophila	Fern bank salamander	SC
Eurycea rathbuni	**Texas blind salamander	FE/SE
Eurycea robusta	Blanco blind salamander	ST
Eurycea sosorum	Barton springs salamander	FE/SE
Eurycea spp.	Central Texas spring salamanders	FE/SE/FT/ST
Eurycea tonkawae	Jollyville Plateau salamander	SC
Eurycea tridentifera	Comal blind salamander	ST
Eurycea troglodytes	Valdina Farms salamander (2 sp.)	SC
Eurycea waterlooensis	Austin blind salamander	SC
Graptemys spp.	**Map turtles	FC/ST
Heterodon nasicus gloydi	Dusty hog-nosed snake	SC
Holbrookia lacerata	Spot-tailed earless lizard	SC
Macrochelys temminckii	Alligator snapping turtle	ST
Nerodia paucimaculata	**Concho watersnake	ST
Ophisaurus attenuatus	Slender glass lizard	SC
Phrynosoma cornutum	Texas horned lizard	ST
Scaphiopus hurterii	Hurter's spadefoot	SC
Syrrhophus cystignathoides	Rio Grande chirping frog	SC
Terrapene spp.	Box turtles	SC

Group	Family	Species Name	Federal Status
Invertebrates			
	Symphyla (Myriapoda)		
	Scolopendrellidae	*Symphyllela pusilla*	SC
	Scolopendrellidae	*Symphyllela reddelli*	SC
	Scolopendrellidae	*Symphyllela texana*	SC
	Scutigerellidae	*Scutigerella linsleyi (Michelbacher)*	SC
	Scutigerellidae	*Scutigerella palmonii (Michelbacher)*	SC

Scutigerellidae	*Scutigerella silvestrii (Michelbacher)*	SC
Schizomida (Myriapoda)		
Protoschizomidae	*?Agastoschizomus n.sp.*	SC
Polydesmida (Myriapoda)		
Polydesmidae	*Speodesmus echinourus*	SC
Polydesmidae	*Speodesmus falcatus*	SC
Polydesmidae	*Speodesmus ivyi*	SC
Polydesmidae	*Speodesmus reddelli*	SC
Araneae (Arachnida)		
**Leptonetidae	*Neoleptoneta myopica (Gertsch)*	FE
Dictynidae	*Cicurina aenigma*	SC
Dictynidae	*Cicurina armadillo*	SC
Dictynidae	*Cicurina bandera*	SC
Dictynidae	*Cicurina bandida*	SC
Dictynidae	*Cicurina baronia*	FE
Dictynidae	*Cicurina barri*	SC
Dictynidae	*Cicurina blanco*	SC
Dictynidae	*Cicurina caverna*	SC
Dictynidae	*Cicurina cueva*	SC
Dictynidae	*Cicurina delrio*	SC
Dictynidae	*Cicurina dorothea*	SC
Dictynidae	*Cicurina elliotti*	SC
Dictynidae	*Cicurina ezelli*	SC
Dictynidae	*Cicurina gatita*	SC
Dictynidae	*Cicurina gruta*	SC
Dictynidae	*Cicurina hexops (Chamberlin and Ivie)*	SC
Dictynidae	*Cicurina holsingeri*	SC
Dictynidae	*Cicurina joya*	SC
Dictynidae	*Cicurina machete*	SC

Dictynidae	*Cicurina madla*	FE
Dictynidae	*Cicurina mckenziei*	SC
Dictynidae	*Cicurina medina*	SC
Dictynidae	*Cicurina menardia*	SC
Dictynidae	*Cicurina microps (Chamberlin and Ivie)*	SC
Dictynidae	*Cicurina minorata (Gersch and Davis)*	SC
Dictynidae	*Cicurina mirifica*	SC
Dictynidae	*Cicurina modesta*	SC
Dictynidae	*Cicurina obscura*	SC
Dictynidae	*Cicurina orellia*	SC
Dictynidae	*Cicurina pablo*	SC
Dictynidae	*Cicurina pampa (Chamberlin and Ivie)*	SC
Dictynidae	*Cicurina pastura*	SC
Dictynidae	*Cicurina patei*	SC
Dictynidae	*Cicurina porteri*	SC
Dictynidae	*Cicurina puentecilla*	SC
Dictynidae	*Cicurina rainesi*	SC
Dictynidae	*Cicurina reclusa*	SC
Dictynidae	*Cicurina reddelli*	SC
Dictynidae	*Cicurina reyesi*	SC
Dictynidae	*Cicurina rosae*	SC
Dictynidae	*Cicurina russeli*	SC
Dictynidae	*Cicurina sansaba*	SC
Dictynidae	*Cicurina selecta*	SC
Dictynidae	*Cicurina serena*	SC
Dictynidae	*Cicurina sheari*	SC
Dictynidae	*Cicurina sprousei*	SC
Dictynidae	*Cicurina stowersi*	SC
Dictynidae	*Cicurina suttoni*	SC

Dictynidae	*Cicurina texana (Gertsch)*	SC
Dictynidae	*Cicurina travisae*	SC
Dictynidae	*Cicurina ubicki*	SC
Dictynidae	*Cicurina uvalde*	SC
Dictynidae	*Cicurina venefica*	SC
Dictynidae	*Cicurina venii*	FE
Dictynidae	*Cicurina vespera*	FE
Dictynidae	*Cicurina wartoni*	SC
Dictynidae	*Cicurina watersi*	SC
Leptonetidae	*Neoleptoneta concinna (Gertsch)*	SC
Leptonetidae	*Neoleptoneta devia (Gertsch)*	SC
Leptonetidae	*Neoleptoneta microps (Gertsch)*	FE
Leptonetidae	*Neoleptoneta new species*	SC
Leptonetidae	*Neoleptoneta new species*	SC
Leptonetidae	*Neoleptoneta valverde (Gertsch)*	SC
Linyphiidae	*Meioneta llanoensis (Gertsch and Davis)*	SC
Nesticidae	*Eidmannella delicata (Gertsch)*	SC
Nesticidae	*Eidmannella nasuta (Gertsch)*	SC
Nesticidae	*Eidmannella reclusa (Gertsch)*	SC
Opiliones (Arachnida)		
Phalangodidae	*Texella bilobata*	SC
Phalangodidae	*Texella brevidenta*	SC
Phalangodidae	*Texella brevistyla*	SC
Phalangodidae	*Texella cokendolpheri*	FE
Phalangodidae	*Texella diplospina*	SC
Phalangodidae	*Texella grubbsi*	SC
Phalangodidae	*Texella hardeni*	SC
Phalangodidae	*Texella jungi*	SC
Phalangodidae	*Texella mulaiki (Goodnight and Goodnight)*	SC

Phalangodidae	*Texella renkesae*	SC
Phalangodidae	*Texella spinoperca*	SC
**Phalangodidae – Bee Creek Cave Harvestman	*Texella reddelli (Goodnight and Goodnight)*	FE
**Phalangodidae – Bone Cave Harvestman	*Texella reyesi*	FE
Pseudoscorpiones (Arachnida)		
Bochicidae	*Leucohya texana (Muchmore)*	SC
Bochidae	*Leucohya texana*	SC
Cheiridiidae	*Apocheiridium reddelli*	SC
Cheiridiidae	*Cheiridium reyesi*	SC
Chernetidae	*Dinocheirus cavicolus*	SC
Chernetidae	*Dinocheirus texanus (Hoff and Clawson)*	SC
Chernetidae	*Dinocheirus venustus (Hoff and Clawson)*	SC
Chernetidae	*Hesperochernes molestus (Hoff)*	SC
Chernetidae	*Hesperochernes occidentalis (Hoff and Bolsterli)*	SC
Chernetidae	*Hesperochernes riograndensis (Hoff and Clawson)*	SC
Chernetidae	*Hesperochernes unicolor (Banks)*	SC
Chernetidae	*Neoallochernes stercoreus (Turk)*	SC
Chthoniidae	*Tyrannochtonius texanus*	SC
Chthoniidae	*Tyrannochtonius troglodytes (Muchmore)*	SC
Chtoniidae	*Tyrannochtonius troglodytes*	SC
Neobisiidae	*Tartarocreagris altimana*	SC
Neobisiidae	*Tartarocreagris amblyopa*	SC
Neobisiidae	*Tartarocreagris attenuata*	SC
Neobisiidae	*Tartarocreagris comanche (Muchmore)*	SC
Neobisiidae	*Tartarocreagris cookei*	SC
Neobisiidae	*Tartarocreagris domina*	SC

Neobisiidae	*Tartarocreagris grubbsi*	SC
Neobisiidae	*Tartarocreagris proserpina*	SC
Neobisiidae	*Tartarocreagris reyesi*	SC
Neobisiidae	*Tartarocreagris texana (Muchmore)*	FE
Neobisiidae	*Microbisium parvulum (Banks)*	SC
Neobisiidae	*Tartarocreagris infernalis (Muchmore)*	SC
Neobisiidae	*Tartarocreagris intermedia (Muchmore)*	SC
Neobisiidae	*Tartarocreagris reddelli (Muchmore)*	SC
Syarinidae	*Chitrella elliotti*	SC
Syarinidae	*Chitrella major*	SC
Coleoptera (Insecta)		
Carabidae	*Rhadine exilis*	FE
Carabidae	*Rhadine infernalis*	FE
**Carabidae	*Rhadine persephone*	FE
Staphylinidae	*Batrisodes (Babnormodes) uncicornis (Casey)*	SC
Staphylinidae	*Batrisodes (Excavodes) clypeonotus (Brendel)*	SC
Staphylinidae	*Batrisodes (Excavodes) globosus (LeConte)*	SC
Staphylinidae	*Batrisodes (Excavodes) grubbsi Chandler)*	SC
Staphylinidae	*Batrisodes (Excavodes) reyesi (Chandler)*	SC
Staphylinidae	*Texamaurops reddelli (Barr and Steeves)*	SC
Lepidoptera (Insecta)		
Hesperiidae	*Agathymus remingtoni valverdiensis*	SC
Hesperiidae	*Megathymus streckeri texanus*	SC
Riodinidae	*Apodemia chisosensis*	SC
Sphingidae	*Sphinx eremitoides*	SC
Hymenoptera (Insecta)		
Apoidea	*Andrena (Tylandrena) scotoptera (Cockerell)*	SC
Apoidea	*Colletes bumeliae (Neff)*	SC
Apoidea	*Colletes inuncantipedis (Neff)*	SC

Apoidea	*Holcopasites (Holcopasites) jerryrozeni (Neff)*	SC
Apoidea	*Macrotera (Cockerellula) parkeri (Timberlake)*	SC
Apoidea	*Macrotera (Cockerellula) robertsi (Timberlake)*	SC
Apoidea	*Megachile (Megachiloides) parksi (Mitchell)*	SC
Apoidea	*Osmia (Diceratosmia) botitena (Cockerell)*	SC
Apoidea	*Perdita (Epimacrotera) dolanensis (Neff)*	SC
Apoidea	*Protandrena (Heterosarus) subglaber (Timberlake)*	SC
Apoidea	*Protandrena (Protandrena) maurula (Cockerell)*	SC
Apoidea	*Pseudopanurgus bradleyi (Timberlake)*	SC
Apoidea	*Stelis (Protostelis) texana (Thorp)*	SC

Location and Condition of the Edwards Plateau Ecoregion

Element 2

Semi-arid, rocky and rugged, the Edwards Plateau comprises nearly 24 million ac. of land dominated by Ashe juniper, various oaks and occasionally, honey mesquite (Winkler 1982). Much of the region overlays a foundation of honey-combed Cretaceous limestone and an immense underground reservoir called the Edwards Aquifer that spills into many clear springs. Caliche slopes, limestone escarpments and thin clay soils are riddled with fossil remains of microscopic marine creatures, bearing testimony to the once massive sea that covered most of the state. Topography is generally rough with elevations ranging from slightly less than 1,000 ft. to over 3,000 ft. above MSL and average annual rainfall varying from 15 in. in the west to more than 33 in. in the east (Gould 1975). Droughts can be prolonged, frequent and often unpredictable. Sporadic flash floods can be devastating near rivers and creeks. Average temperatures range from 64°F to 67°F. Soils range from neutral to slightly acidic sands and sandy loams in the Llano Uplift, to thin, rocky, highly calcareous clays and clay loams over the rest of the Plateau (Simpson 1988). Floristically, it is a region of great diversity, with 100 of the 400 Texas endemic plants occurring only here, including Texas snowbells, bracted twist-flower, Texabama croton, Texas wildrice and rock quillworts. Tucked away in protected valleys, are relict populations of Texas madrone, Texas smoke tree, witch hazel and bigtooth maples: trees normally found far to the northeast in Arkansas, to the west in the Trans-Pecos mountains or to the south in the mountains of Mexico (Wasowski 1988). The moist river corridors of the Colorado, Guadalupe, Blanco and Nueces are lined with majestic bald cypress, pecan, hackberry and sycamores. Wildflowers in the Edwards Plateau are extremely prevalent in the spring, with some of the more common varieties including bluebonnets, Indian paintbrush, gaillardia and golden-wave.

The region also hosts a number of terrestrial vertebrates. The white-tailed deer is extremely common and sometimes found in overabundance. Other common denizens of the Hill Country include armadillo, black-tailed jackrabbit, opossum and Texas earless lizard. Springs in the Edwards Plateau are also very common. The purity and constant temperature of the waters provide ideal habitat for specialized spring dwellers such as the Clear Creek gambusia, the San Marcos gambusia, the fountain darter and the San Marcos salamander. Within the larger rivers can be found the unique Guadalupe bass and the Cagle's map turtle. Thousands of caves of all sizes harbor cave shrimp and blind salamanders which live only within the confines of these underground systems. Rare invertebrates like blind spiders, pseudoscorpions, mold beetles and harvestmen are also found in caves, as well as Mexican free-tailed bats which establish summer nursery colonies within several larger caves throughout the region. The Edwards Plateau also provides habitat for birds typical of both eastern and western regions. The green kingfisher, cave swallow, black-capped vireo and golden-cheeked warbler nest more commonly here than in any other region in the state (Fisher 1984).

This ecoregion can be broken down into seven main habitat classes consisting of brushland, forest, parkland, parkland woodland mosaic, shrubland, woodland, and urban.

Edwards Plateau Brushland

The Edwards Plateau brushlands consist of woody plants mostly less than nine feet tall which are dominant and growing as closely spaced individuals, clusters or closed canopied stands (greater than 10% canopy cover). Typically there are continuous, impenetrable shrubs covering over 75% of the ground (McMahan et al. 1984, Bridges et al. 2002). A total of seven plant associations dominate this habitat class.

The *mesquite* association is found principally in the Rolling Plains, however, larger patches are also found in the northern portion of the Edwards Plateau. The plants commonly found with this association includes narrow-leaf yucca, grassland prickly pear, juniper, red grama, Texas grama, sideoats grama, hairy grama, purple three-awn, Roemer three-awn, buffalograss, red lovegrass, gummy lovegrass, sand dropseed, tobosa, western ragweed, James rushpea, scurfpea and wild buckwheat (McMahan et al. 1984). This association is found on typical upland soils which are sandy and shallow with influences from caliche or limestone (Diamond 1993). Cross-referenced communities: 1) mesquite-midgrass series (Diamond 1993), 2) upland mesquite-midgrass savannahs (Bezanson 2000), and 3) honey mesquite woodland alliance (Weakley et al. 2000). The *mesquite* community is considered secure globally and throughout the state with more than 100 occurrences documented. Occurrences may be rare in part of its range with associations becoming infrequent at the periphery (Diamond 1993).

The *mesquite-lotebush* association is most commonly found in the northwestern portion of the Edwards Plateau and is typically deciduous. It is normal to find this association growing on upland soils which are sandy and shallow with influences from caliche or limestone (Diamond 1993). Commonly associated plants include yucca species, skunkbush sumac, agarito, elbowbush, juniper, tasajillo, cane bluestem, silver bluestem, little bluestem, sand dropseed, Texas grama, sideoats grama, hairy grama, red grama, tobosa, buffalograss, Texas wintergrass, purple three-awn, Roemer three-awn, Engelmann daisy, broom snakeweed and bitterweed (McMahan et al. 1984). Cross-referenced communities: 1) mesquite-midgrass series (Diamond 1993), 2) upland mesquite-midgrass savannahs (Bezanson 2000), and 3) honey mesquite woodland alliance (Weakley et al. 2000). The *mesquite-lotebush* community is considered secure globally and throughout the state with more than 100 occurrences documented. Occurrences may be rare in part of its range with associations becoming infrequent at the periphery (Diamond 1993).

The *mesquite-juniper* association is naturally found on mesas and hillsides of the western portion of the Edwards Plateau. This association is commonly found on rocky slopes and follows disturbed areas with plant types varying depending on soil, slope and past history (Diamond 1993). Plants found in this group include lotebush, shin oak, sumac species, Texas prickly pear cactus, guajillo, tasajillo, kidneywood, agarito, redbud, yucca species, Lindheimer silktassel, sotol, catclaw acacia, Mexican persimmon, sideoats grama, three-awn, Texas grama, hairy grama, curly mesquite, buffalograss and hairy tridens (McMahan et al. 1984). Cross-referenced communities: 1) upland juniper-mesquite savannahs (Bezanson 2000), and 2) redberry juniper woodland alliance, one-seed juniper woodland alliance (Weakley et al. 2000). The *mesquite-juniper* community is considered secure globally and throughout the state with more than 100 occurrences documented. Occurrences may be rare in part of its range with associations becoming infrequent at the periphery (Diamond 1993).

Plants commonly related to the *mesquite-hackberry* association include walnut, live oak, juniper, lotebush, catclaw acacia, woollybucket bumelia, tasajillo, agarito, whitebrush, switchgrass, vine-mesquite, silver bluestem, Johnsongrass, Lindheimer muhly, western ragweed and silverleaf nightshade. This association is found along creeks, drainages and canyon bottoms in the Rolling Plains and the western portion of the Edwards Plateau ecoregions (McMahan et al. 1984). Cross-referenced communities: 1) mesquite floodplain brush. The *mesquite-hackberry* community is of low priority for further protection (Bezanson 2000).

The *mesquite-juniper-live oak* association is found mostly on mesas and hillsides of the western portion of the Edwards Plateau. This association is commonly found on rocky slopes and follows disturbed areas with plant types varying depending on soil, slope and past history (Diamond 1993). Associated plants include the following: lotebush, shin oak, sumac species, Texas prickly pear, tasajillo, kidneywood, agarito, redbud, yucca species, Lindheimer silktassel, sotol, catclaw acacia, Mexican persimmon, sideoats grama, three-awn, Texas grama, hairy grama, curly mesquite, buffalograss and hairy tridens (McMahan et al. 1984). Cross-referenced communities: 1) upland juniper-mesquite savannahs (Bezanson 2000), and 2) redberry juniper woodland alliance, one-seed juniper woodland alliance (Weakley et al. 2000). The *mesquite-juniper-live oak* community is considered secure globally and throughout the state with more than 100 occurrences documented. Occurrences may be rare in part of its range with associations becoming infrequent at the periphery (Diamond 1993).

The *ceniza-blackbrush-creosote* association is normally found on the slopes of the Rio Grande basin, Stockton Plateau and South Texas Plains (McMahan et al. 1984, Diamond 1993). Within the Edwards Plateau ecoregion it is found along the Rio Grande Valley to each side of the Pecos and Devil's rivers. This community typically grows on shallow soils (Diamond 1993). Commonly associated plants include guajillo, lotebush, mesquite, guayacan, Texas prickly pear, paloverde, goatbush, yucca, sotol, desert yaupon, catclaw acacia, kidneywood, jessamine, curly mesquite, Texas grama, hairy tridens, slim tridens, pink pappusgrass and two-leaved senna (McMahan et al. 1984). Cross-referenced communities: 1) ceniza series (Diamond 1993), 2) cenizo-blackbrush xerophytic brush (Bezanson 2000), and 3) blackbrush-cenizo-guajillo shrubland alliance (Weakley et al. 2000). The *ceniza-blackbrush-creosote* community is apparently secure within the state as well as globally (Diamond 1993). This community is common and widespread, therefore, it is considered a fairly low priority for further protection (Bezanson 2000).

The *mesquite-blackbrush* association comprises the following plants: lotebush, ceniza, guajillo, desert olive, allthorn, whitebrush, bluewood, granjeno, guayacan, leatherstem, Texas prickly pear, tasajillo, kidneywood, yucca, desert yaupon, goatbush, purple three-awn, pink pappusgrass, hairy tridens, slim tridens, hairy grama, mat euphorbia, coldenia, dogwood, knotweed leafflower and two-leaved senna. This association is typically found on upland shallow, loamy or gravelly soils in the South Texas Plains ecoregion (McMahan et al. 1984). In the Edwards Plateau ecoregion it occurs along the southernmost fringe which borders the South Texas Plains. Cross-referenced communities: 1) freer mixed brush (Davis and Spicer 1965), 2) barretal (USFWS 1983), 3) blackbrush-twisted acacia (McLendon 1991), 4) blackbrush series (Diamond 1993), 5) blackbrush xerophytic brush (Bezanson 2000), and 6) blackbrush-cenizo-guajillo shrubland alliance (Weakley et al. 2000). The *mesquite-blackbrush* association is demonstrably secure globally and within the state of Texas (Diamond 1993). As a whole, this community is stable and common, however, there are a few plants found within this association that are rare and should have selective protection (USFWS 1983, Weakley et al. 2000). This community is considered low priority for further protection, excluding the discriminatory protection of a few rare species (Bezanson 2000).

Edwards Plateau Forest

The Edwards Plateau forest consists of deciduous or evergreen trees that are dominant in the landscape. These species are mostly greater than 30 ft. tall with closed crowns or nearly so (71-100% canopy cover). The midstory is generally apparent except in managed monocultures (McMahan et al. 1984, Bridges et al. 2002). Only one plant association dominates this habitat class.

American elm, cedar elm, cottonwood, sycamore, black willow, live oak, Carolina ash, bald cypress, water oak, hackberry, virgin's bower, yaupon, greenbriar, mustang grape, poison oak, Johnsongrass, Virginia wildrye, Canada wildrye, rescuegrass, frostweed and western ragweed are species commonly found in the *pecan-elm* association (McMahan et al 1984). This community is a broadly defined deciduous forest typically found along major rivers, bottomlands and mesic slopes where soils are often heavily textured and calcareous (Diamond 1993). This community is found along the Brazos, Colorado, Guadalupe, San Antonio and Frio river basins as well as the areas of the Navidad, San Bernard and Lavaca rivers (McMahan et al 1984). Cross-referenced communities: 1) sugarberry-elm series, pecan-sugarberry series (Diamond 1993), 2) sugarberry-elm floodplain forests (South Texas Plains) (Bezanson 2000), and 3) plateau oak-sugarberry woodland alliance, sugarberry-cedar elm temporarily flooded forest alliance, pecan-(sugarberry) temporarily flooded forest alliance (Weakley et al. 2000). The *pecan-elm* community is apparently secure within the state as well as globally (Diamond 1993). However, there are very few mature examples of the dominant plants in this community. The locations in south Texas that do exist are not very well protected but there are many examples of this community in other ecoregions. Due to this, Bezanson (2000) suggests to rank this community as a medium priority for further protection in south Texas.

Edwards Plateau Parkland

In the Edwards Plateau parkland, a majority of the woody plants are equal to or greater than nine feet tall. They are generally dominant and grow as clusters, or as scattered individuals within continuous grass or forbs (11-70% woody canopy cover overall) (McMahan et al. 1984, Bridges et al. 2002). A total of three plant associations dominate this habitat class.

The *live oak-mesquite-Ashe juniper* and *live oak-Ashe juniper* associations consist of Texas oak, shin oak, cedar elm, netleaf hackberry, flameleaf sumac, agarito, Mexican persimmon, Texas prickly pear, kidneywood, greenbriar, Texas wintergrass, little bluestem, curly mesquite, Texas grama, Halls panicum, purple three-awn, hairy tridens, cedar sedge, two-leaved senna, mat euphorbia and rabbit tobacco. These two associations are typically found on level to gently rolling uplands and ridge tops in the Edwards Plateau, which are limestone dominated (McMahan et al. 1984). Cross-referenced communities: Cross-referenced communities: 1) plateau live oak series (Diamond 1993), 2) upland plateau live oak savannas (Bezanson 2000), and 3) plateau oak woodland alliance (Weakley et al. 2000). The *live oak-mesquite-Ashe juniper* and *live oak-Ashe juniper* communities are apparently secure globally and throughout the state with more than 100 occurrences documented. Occurrences may be rare in part of its range with associations becoming infrequent at the periphery (Diamond 1993).

The *live oak-mesquite* association includes post oak, blackjack oak, cedar elm, black hickory, whitebrush, agarito, Mexican persimmon, woollybucket bumelia, elbowbush, buffalograss, curly mesquite, Texas grama, sideoats grama, hairy grama, little bluestem, Texas wintergrass, purple three-awn, Indian mallow, Texas bluebonnet and firewheel. This association is typically found on granite soils of the Edwards Plateau (Central Mineral Region) (McMahan at al. 1984). The *live oak-mesquite* community is apparently secure globally and throughout the state with more than 100 occurrences documented. Occurrences may be rare in part of its range with associations becoming infrequent at the periphery (Diamond 1993).

Edwards Plateau Parkland Woodland Mosaic

The parkland woodland mosaic can be best described by pastures or fields with widely scattered vegetation (trees and/or shrubs) covering 10-25% of the ground (Bridges et al. 2002). There are two plant associations in this habitat class.

The *oak-mesquite-juniper* association includes post oak, Ashe juniper, shin oak, Texas oak, blackjack oak, live oak, cedar elm, agarito, soapberry, sumac, hackberry, Texas prickly pear, Mexican persimmon, purple three-awn, hairy grama, Texas grama, sideoats grama, curly mesquite and Texas wintergrass. This community most closely resembles the limestone dominated soil of the *live oak-Ashe juniper parkland* and the *live oak-mesquite-Ashe juniper parkland*. These associations typically occur on level to gently rolling uplands and ridge tops in the Edwards Plateau (McMahan et al. 1984). Cross-referenced communities: Cross-referenced communities: 1) plateau live oak series (Diamond 1993), 2) upland plateau live oak savannas (Bezanson 2000), and 3) plateau oak woodland alliance (Weakley et al. 2000). The *oak-mesquite-juniper* community is considered secure globally and throughout the state with more than 100 occurrences documented. Occurrences may be rare in part of its range with associations becoming infrequent at the periphery (based on: Diamond 1993).

The *gray oak-pinyon pine-alligator juniper* association typically found in sheltered canyons, at cliff bases and north-facing slopes occurring from 4,500 to 7,500 ft. in elevation. Typically this community is found in the major mountain ranges such as the Davis, Guadalupe and Chisos Mountain ranges (McMahan et al. 1984, Plumb 1988, Diamond 1993, Bezanson 2000). However, a small segment falls into the Edwards Plateau at the southwestern most tip. This association is mostly evergreen and typically found in alluvial soils in mountain valleys. Deciduous gray oak-oak series also occur in these areas but are restricted to the bottomlands of mesic mountain canyons. Many of the associated plants are very distinctive and restricted to this plant association alone (Diamond 1993). These plants include Emory oak, silverleaf oak, Gambel's oak, mountain mahogany, evergreen sumac, mountain snowberry, Texas madrone, southwestern chokecherry, bullgrass, Pringle needlegrass, finestem needlegrass, pine dropseed, sideoats grama, blue grama, pine muhly, pinyon ricegrass, largeleaf oxalis, heartleaf groundcherry and Torrey antherium (McMahan et al. 1984). Cross-referenced communities: 1) pinyon-juniper-oak savannah/woodland (Wauer 1971), 2) oak woodlands (Henrickson and Johnston 1986), 3) mixed oak, pinyon-oak-juniper assemblages (Plumb 1988), 4) gray oak-oak series (Diamond 1993), 5) montane oak-juniper-pinyon woodlands (Bezanson 2000), and 6) Mexican pinyon-Chisos red oak forest alliance, gray oak woodland alliance, Emory oak woodland alliance (Weakley et al. 2000). The *gray oak-pinyon pine-alligator juniper* is fairly common throughout the southwestern United States. However, in Texas this community only occurs in a few isolated mountain ranges, mostly within the Trans-Pecos with extensions into the Edwards Plateau ecoregion, making it fairly rare throughout the state. This community is considered apparently secure statewide and globally (Diamond 1993). A medium priority for further protection is suggested by Bezanson (2000).

Edwards Plateau Shrubland

Shrublands consist of individual woody plants generally less than nine feet tall scattered throughout arid or semi-arid regions where the vegetation is evenly spaced covering over 75% of the ground (Bridges et al. 2002). Typically there is less than 30% woody canopy cover overhead (McMahan et al. 1984). The Edwards Plateau shrubland includes four different plant associations, some being very unique and limited in range within Texas.

The *mesquite* association consists of narrow-leaf yucca, tasajillo, juniper, grassland prickly pear, cholla, blue grama, hairy grama, purple three-awn, Roemer three-awn, buffalograss, little bluestem, western wheatgrass, Indiangrass, switchgrass, James rushpea, scurfpea, lemon scurfpea, sandlily, plains beebalm, scarlet gaura, yellow evening primrose, sandsage and wild buckwheat (McMahan et al. 1984). This association is found on typical upland soils which are sandy and shallow with influences from caliche or limestone. At more mesic sites, and also locations maintaining good quality rangeland, this community type is seen grading into a midgrass community (Diamond 1993). Cross-referenced communities: 1) mesquite-midgrass series (Diamond 1993), 2) upland mesquite-midgrass savannahs (Bezanson 2000), and 3) honey mesquite woodland alliance (Weakley et al. 2000). The *mesquite* community is apparently secure across the globe and also within the state with more than 100 occurrences documented. Occurrences may be rare in part of its range with associations becoming infrequent at the periphery (Diamond 1993).

The *fourwing saltbush-creosote* association is found principally in washes and alluvium of the Pecos River in Reeves, Ward and Crane counties (McMahan et al. 1984).

However, a few patches occur on the central northwestern boundary of the Edwards Plateau ecoregion. The soil they prefer is typically saline and plant composition can vary depending on the magnitude of salinity, water availability and amount of disturbance (Diamond 1993). The associated plants include mesquite, salt cedar, tarbush, grassland prickly pear cactus, tasajillo, alkali sacaton, Wright's sacaton, tobosa, black grama, mesa dropseed, purple three-awn, two-flowered trichloris, jimmyweed, broom snakeweed and James rushpea (McMahan et al. 1984). Cross-referenced communities: 1) saline bolson (Burgess and Northington 1979), 2) *Prosopis-Atriplex* scrub (Henrickson and Johnston 1986), 3) mesquite-saltbush series (Diamond 1993), 4) mesquite-saltbush saline brush (Bezanson 2000), and 5) fourwing saltbush shrubland alliance (Weakley et al. 2000). The *fourwing saltbush-creosote* community is apparently secure globally; however, it was once fairly rare or uncommon throughout the state with less than 100 known occurrences (Diamond 1993). According to Bezanson (2000), it is no longer considered rare or uncommon but now widespread. It is currently unthreatened and occurs in Guadalupe Mountains National Park and other locations throughout the Trans-Pecos. Therefore, this association is ranked as a fairly low priority for suggested protection (Bezanson 2000).

The *creosote-lechuguilla* association includes mesquite, yucca species, lotebush, ocotillo, javelina bush, catclaw acacia, whitethorn acacia, whitebrush, ceniza, jessamine, guayacan, prickly pear cactus, pitaya, tasajillo, chino grama, black grama, fluffgrass, range ratany, skeletonleaf goldeneye, tarbush and mariola (McMahan et al. 1984). These associated plants are often found in the lower slopes (3,500 ft.) and intermountain valleys of the Trans-Pecos ecoregion, especially in Jeff Davis, Presidio and Brewster counties (Diamond 1993). However, this community is also found in the southwestern most portion of the Edwards Plateau ecoregion. Cross-referenced communities: 1) creosote-ocotillo-mesquite association, creosote-lechuguilla association, sotol-lechuguilla association (Denyes 1956), 2) chino grama-lechuguilla, chino grama-candelilla (Warnock and Kittams 1970), 3) shrub desert (Wauer 1971), 4) limestone Chihuahuan Desert (Burgess and Northington 1979), 5) mixed desert scrub, lechuguilla scrub (Henrickson and Johnston 1986), 6) lechuguilla-grass-prickly pear, creosote-lechuguilla, lechuguilla-grass-candelilla, lechuguilla-grass-hechtia assemblages (Plumb 1988), 7) lechuguilla-sotol series (Diamond 1993), 8) Chihuahuan Desert scrub (Bezanson 2000), and 9) ocotillo shrubland alliance, creosote shrubland alliance, smooth sotol (lechuguilla, skeletonleaf goldeneye) shrubland (Weakley et al. 2000). The *creosote-lechuguilla* community is demonstrably secure globally and statewide. These five communities are considered the most extensively protected community types in Texas and are considered a low to fairly low priority for further protection (Bezanson 2000).

The *creosote-tarbush* association consists of range ratany, cholla, fourwing saltbush, sotol, mesquite, whitethorn acacia, catclaw acacia, lechuguilla, chino grama, gyp grama, alkali sacaton, false nightshade, false broomweed and jimmyweed (McMahan et al. 1984) . This association is typically found in Pecos and Reeves counties in fairly level, arid, non-saline alluvial plains (bajadas) below 3,800 ft. (Bezanson 2000). However, there is one large isolated community in the southwestern portion of it in the Edwards Plateau ecoregion. Cross-referenced communities: 1) mesquite-creosote bush association (Webster 1950), 2) creosote-tarbush association, creosote-tasajillo association (Denyes 1956), 3) shrub desert (Whitson 1970), 4) creosote, creosote-tarbush (Warnock and Kittams 1970), 5) creosote flats (Burgess and Northington 1979), 6) *Larrea* scrub (Henrickson and Johnston 1986), 7) creosote series (Diamond 1993), 8) creosote flats, creosote-grass, lechuguilla-tarbush assemblages (Plumb 1988), 9) creosote open shrub deserts, and 10) creosote shrubland alliance, tarbush shrubland alliance (Weakley et al. 2000). The *creosote-tarbush* community is apparently secure across the globe and also within the state with more than 100 occurrences documented. Occurrences may be rare in part of its range with associations becoming infrequent at the periphery (Diamond 1993).

Edwards Plateau Woodland

In the Edwards Plateau woodland, a majority of the woody plants are mostly 9-30 ft. tall with closed crowns or nearly so (71-100% canopy cover). Typically the midstory is usually lacking any vegetation (McMahan et al. 1984, Bridges et al. 2002). Only one plant association dominates this habitat class.

The *live oak-Ashe juniper* association includes Texas oak, shin oak, cedar elm, evergreen sumac, escarpment cherry, saw greenbriar, mescal bean, poison oak, twistleaf yucca, elbowbush, cedar sedge, little bluestem, Neally grama, Texas grama, meadow dropseed, Texas wintergrass, curly mesquite, pellitory, noseburn, spreading sida, woodsorrel and mat euphorbia. This community is found chiefly on shallow limestone soils on the hills and escarpment of the Edwards Plateau (McMahan et al. 1984). Cross-referenced communities: 1) Ashe juniper-oak series (Diamond 1993), 2) Ashe juniper low forests (Bezanson 2000), and 3) Ashe's juniper woodland alliance (Weakley et al. 2000). The *live oak-Ashe juniper* community is considered apparently secure globally and within the state. More than 100 occurrences are known both globally and statewide, however this community can be rare in parts of its natural global range, especially the periphery. It can also be rare in some areas of Texas especially around the border of its range (Diamond 1993).

Edwards Plateau Urban Community

Urban habitats are cities or towns which are areas dominated by human dwellings including the fences, shrub rows, windbreaks and roads associated with their presence (Bridges at al. 2002).

The largest city in this ecoregion is San Antonio and Austin is the next largest. These two cities barely cross over the boundary into the Edwards Plateau ecoregion. Bulverde, Boerne, Kerrville, Fredericksburg, Mason and Brady are the next largest cities. The city of San Antonio is in Bexar County in Central Texas at the junction of the Edwards Plateau, Post Oak Savannah, Blackland Prairie and South Texas Plains ecoregions. Much of the Post Oak Savannah and Blackland Prairie ecoregions have been affected so much in and around San Antonio that only marginal associations of the historic vegetation communities remain. Much of the southern half of San Antonio is characteristic of the South Texas Plains ecoregion, while the rocky soil and rolling elevation in the western and northwestern parts of the city are characteristic of the Edwards Plateau ecoregion. The northeastern parts of the city fall within the historic range of the Blackland Prairie. Fragments of Post Oak Savannah can be found in the east and southeast.

San Antonio is currently the most rapidly developing area in the nation. Due to prevailing livestock management practices and historic fire suppression, the Edwards Plateau has become largely dominated by Ashe Juniper, reducing prevalence of native grasses, valuable understory and diversity within riparian corridors. Due to the poor reputation of Ashe Juniper, current development and urban landscape practices in San Antonio tend to select against Ashe Juniper and other understory components such that only small stands of live oak remain. These monocultures are vulnerable to the threat of oak wilt (*Ceratocystis facacearum*), which endangers the few remaining parcels of urban wildlife habitat. Despite its poor reputation, Ashe Juniper remains an important source of food and cover for many valuable wildlife species, including two endangered Neotropical songbirds, the golden-cheeked warbler (*Dendroica chrysoparia*) and the black-capped vireo (*Vireo atricapillus*). The integrity of the Edwards Plateau continues to be compromised by urban expansion, habitat fragmentation as San Antonio residents seek a "place in the country", and a proliferation of non-native ungulates in rural areas. Furthermore, rapid development within the city has allowed for large isolated populations of white-tailed deer (*Odocoileus virginianus*) to create what has become a divisive issue for many San Antonio communities.

In southern San Antonio most of the traditional South Texas Plains vegetation has been altered by agricultural production on small farms. Those lands not altered by row-crop or hay production are affected by urban expansion. In these communities, the desire for development and urban improvements take precedence over conservation issues and natural resource protection. Urban development on the south side is generally large-scale projects subsidized by the city that offer educational or work-force opportunities for south side residents.

High Priority Communities: A Further Emphasis

Karst habitats are the caves, sinkholes, springs and underground streams formed in Central Texas through eroded limestone. A variety of wildlife use these karst systems; some invertebrates are specialized to karst caves and four endangered cave invertebrates are found in the Central Texas metropolitan caves (Campbell 1995). The endangered Barton Creek salamander, as well as other salamander, fish and even eel species, require the specialized habitat provided by karst springs. Many species of bat including the cave myotis, Brazilian free-tail and little brown bat utilize karst caves as nurseries and for roosting. *Caves* have historically been undervalued and have often served as refuse dumps. Caves have been found filled with trash, toxic chemicals and motor oil, and even construction refuse or fill dirt. *Karst* springs are prized features of the Texas Hill Country.

There are many *Hill Country rivers and springs* throughout the Edwards Plateau ecoregion. Bald cypress and American sycamore line the banks of these rivers, often creating small rapids. Springs well up from local aquifers and dot the ecoregion creating many creeks, streams, waterfalls and rivers. Since many of the rivers are fed by aquifer generated springs, they typically run year-round, serving as a constant water source for local wildlife. In the Edwards Plateau, surface water drains back into the aquifer to be recirculated (Bezanson and Wolfe 2001). *Hill Country rivers and springs* are already highly threatened by population growth and subdivision expansion. Over-application of fertilizers, erosion from construction and channel erosion from increased but intermittent creek flow and general non-point-source pollution decrease the value of these springs for both humans and wildlife. Approximately 2,000 ac. are protected at this time, however preserving these riparian areas does not address the issue of unregulated pumping from the local aquifers causing loss of water for both wildlife and human use (Bezanson and Wolfe 2001).

Hill Country forests, woodlands and savannahs are located in the Edwards Plateau where limestone is the main soil base for vegetative communities. The limestone terraces and balconies found along the Balcones escarpment of Central Texas support a mosaic of *Ashe juniper and oak forests and woodlands*. This area is dominated by live oak, grasses and juniper with canyons containing Spanish oak, black cherry and Texas mountain-laurel. This key habitat is home to many rare and endemic species such as Texas snowbells and canyon mock-orange. The *canyon forests and woodlands* are known for isolated springs and sheltered canyon walls where oases of bigtooth maple, Texas madrone, oaks and walnuts grow as large as eastern US hardwood forests (Bezanson and Wolfe 2001). The woodlands host a variety of species, including the federally endangered golden-cheeked warbler. The warbler is a specialist of this habitat and requires oak species as a substrate for forage and shreds the mature juniper bark for its nest.

Many of the larger hardwood trees of this community were cut in the mid 1900's. Over-browsing by goats and sheep is very destructive to the native vegetation in this area. The over-population of white-tailed deer, and the destruction from their browsing, prevents successional growth of the more mature forested canyon areas. Over-browsing prevents the growth of seedlings and the replacement of mature hardwood species in the future. General development, harvest of juniper for fenceposts and other constructions and the fear of juniper as a water-depleting species has reduced the amount of contiguous and mature oak-juniper woodland. The steep limestone slopes that have been historically avoided by ranching and construction development remain valuable for the warblers and other wildlife.

Presently, there are still large ranches in the western portion of the Edwards Plateau which preserve these key communities. There are also a few nature preserves and state parks which preserve these communities. Less than 500 ac. of bigtooth maple forest is protected in the Texas Hill Country (Bezanson and Wolfe 2001). *Hill Country savannahs* were historically maintained by a natural fire regime. The oak-shrub *savannah* of Central Texas consists of primarily warm grasses interspersed with live oak, shin oak and red oak mottes. This early to mid-successional stage habitat is key for the federally listed black-capped vireo. Because of the suitability of the terrain and ease of development, these savannahs were often the earliest areas to be ranched and developed. Ranched savannahs are generally "improved" with the addition of exotic cool season grasses which are less valuable to native wildlife and prohibit some grassland-nesting species such as bobwhite quail. In urban areas where the savannah remains, suppression of fire has allowed the land to continue successional development into a more mature woodland. Over-browsing by white-tailed deer, often at more dense populations than desired, has produced mature woodlands with few saplings to regenerate the habitat.

The *Llano Uplift granite country* is made of metamorphic and volcanic rock and is considered by many as an "island" in the middle of the Edwards Plateau ecoregion. Rock found in this location includes schist, marble and pink crystalline granite. Llano, Mason and surrounding counties are home to this ancient exposed rock. This uplift boasts many plant and wildlife species that are found no where else. These granite outcrops are dotted with stunted oaks, cacti, sheltering crevices which grow ferns and wildflowers and shallow ephemeral pools (Bezanson and Wolfe 2001). *Llano Uplift granite country* is fairly well protected at this time. These granite outcrops are inaccessible to cattle and other livestock and many of these areas are located on private ranches. Therefore, the granite country has been fairly well preserved (Bezanson and Wolfe 2001).

Element 3

Problems Affecting the Edwards Plateau

See the Texas Priority Species List………….………733

The density of the human population contributes to the increase of non-permeable and heat-reflective materials used in structural construction, which produces a heat-island effect. Non-permeable surfaces and channelization of watercourses contribute to the speeding of water, which reduces its ability to nourish area vegetation, increases the watershed's susceptibility to erosion and decreases the amount of water available to recharge the Edward's Aquifer. Water within Central Texas' urban areas will have increased turbidity, lower dissolved oxygen, increased temperature and increased chemical pollution as urbanization increases (Barret and Charbeneau 1996).

Because of the fragmented and disturbed nature of land in an urban system, exotic and invasive plant species have become introduced into even the least developed areas. In Central Texas, the exotic species that appear to be most disruptive to the native ecosystem are ligustrum (*Ligustrum* spp.), Bermuda grass, chinaberry (*Melia azedarach*), Johnsongrass, KR bluestem, elephant ear (*Colocasia* spp.), giant reed and wild mustard. Along with fragmentation there is an increase in the price of Hill Country land and many larger ranches are being reduced in size for planned subdivisions.

Feral cats, increasingly prevalent around human populations, cause intense and non-native predation pressure to native wildlife. Cats have the potential to exterminate entire species (notably see Galbreath and Brown 2004), and so their increase in urban outdoor areas should be deterred.

Generalist predators are also on the rise in urban areas. Raccoon, jessamine, blue jay (egg predators) and coyote populations all appear to be increasing. These generalist predators, while important to the ecosystem, can sometimes be deleterious to other native populations.

White-tailed deer, historically an important species of the Central Texas ecosystem, are now over-abundant in our cities. The overpopulation of deer has put incredible pressure on available food resources resulting in smaller and less healthy deer. Additionally, the dense population of deer has increased hazards for humans such as vehicle/deer collisions and Lyme's disease, as well as produced annoyances such as loss of landscape vegetation.

The habitat fragmentation prevalent in all urban areas has put Central Texas wildlife species in jeopardy because of the reduction of corridors available for wildlife to find food, water and shelter. The City of Austin is aggressive in purchasing land for water recharge and habitat (Trust for Public Land 2005) and has received extensive public comment on its activities. These activities should decrease the effect of habitat fragmentation in Central Texas.

While native landscaping has increased in popularity, many Central Texas home landscapes exhibit a disconcerting similarity to the landscaped areas found throughout America. The reduced diversity of plants and vegetation structure found in traditional landscaping has been shown to result in a decrease in the diversity of avian species (Hunter and Simpson 2002). While much of urban Central Texas retains some of the vegetation diversity present in the rural areas surrounding it, it appears that non-native and cosmopolitan vegetation is becoming more prevalent, particularly in the larger "master planned" communities in the suburban ring surrounding most Central Texas cities.

Hill Country rivers and springs are threatened by unregulated over-pumping of aquifer water for water supplies as well as changes in land use. Presently, there are already springs which have already dried up due to a drop in water level of subsurface aquifers. Population expansion will put a great deal of pressure on groundwater resources and the clearing of land for subdivisions is creating more problems (Bezanson and Wolfe 2001).

Element 5

High Priority Research and Monitoring Efforts for the Edwards Plateau

See Monitoring and Adaptive Management………… 559
See the Texas Priority Species List…………..……….733

- Coordinate with City of Austin, LCRA, TCEQ and others to continue water quality monitoring efforts. Publish results on the internet (as is currently done). Publish list of corporate violators on the same website
- Create a statewide survey to be issued once every five years to track the infestation of weedy species established by the statewide weed control board. Survey should be issued to all public lands, be relatively simple to complete and provide a vehicle for reporting new invasions, track pre-existing infestation and monitor removal efforts
- Results of efforts to increase customer demand of native plants should be evident in the supply of plants provided to retailers, since retailers generally respond quickly to public demand. Support research that investigates plant species stocked at home improvement and nursery retailers
- Support research that investigates effectiveness of wildlife corridors that are established in the Central Texas area
- Create permanent survey transects throughout the metropolitan area on which to monitor key wildlife species or groups and vegetation. Establish relationships with volunteer organizations such as Texas Master Naturalists to consistently monitor these routes. Suggest protocol similar to the Breeding Bird Survey or Christmas Bird Count

- Monitor populations of some generalist predators, such as raccoons and coyotes. Support research examining effect of generalist predator populations on other native wildlife
- Determine sources of point-source and non-point-source pollution entering the aquifers and reduce its prevalence through education, regulation and incentives. City of Austin, LCRA, TCEQ and others are already involved in these activities. Coordination with and support of these entities is recommended
- Enhance, enforce and continue monitoring water-slowing efforts already in effect (e.g. retention ponds, erosion control)
- Map current or potential wildlife corridor options and work to encourage permanent easements or purchase development rights for critical land. Monitor current efforts by the City of Austin to acquire and support studies to investigate the effect of these land purchases on wildlife habitat
- Install native landscapes in highly visible public places, including retail shopping malls and strip centers, to introduce native landscape plants into citizens' landscaping vocabulary. Survey and monitor perceptions and personal use of ideas

High Priority Conservation Actions for the Edwards Plateau

See High Priority Conservation Strategies.…….……..517

See the Texas Priority Species List………….………733

Element 4

- Provide legal incentives and remove code impediments for conservation development within the city and municipal areas
- Implement and enforce stringent erosion-reducing requirements for development within watersheds. These regulations and incentives should particularly address construction, agriculture, or landscaping activities that affect stream bank stability
- Create a statewide weed control board to list and coordinate efforts regarding invasive plant sale and distribution within and into the state
- Coordinate with Agriculture personnel (Texas Coop Extension Service and Agriculture programs in high schools, colleges and universities) to provide

education regarding best management practices for small and medium (1/2 ac. to 300 ac.) parcels for wildlife

- Coordinate with home-improvement retailers to:
    - Offer more organic options for pest control and plant fertilization
    - Offer less toxic options for pest control and plant fertilization
    - Provide sales personnel that are educated about best management practices
    - Offer more native plant options for landscaping
    - Eliminate invasive species from garden inventory
    - Provide education about native landscaping
    - Provide education on using chemical pesticides correctly and integrating best management practices
- Initiate dialogue with county and municipal development boards to begin process of reconciling outdated code with current standards of conservation development. Sponsor graduate studies that examine the effect of conservation development on wildlife habitat, property value and other factors determined valuable to citizens
- Support efforts to reduce or eliminate outdoor feral cats. Minimally, support enforcement of leash laws and education/clinics for spaying and neutering pets and feral cats and dogs
- Emphasize the importance of proper grazing. Work with state, federal and private agencies to continue to develop cost-effective means to balance grazing and wildlife
- Work with federal, state and private organizations to promote (incentives) leaving some cover for wildlife. The economic benefits of wildlife can sometimes equal or surpass the agricultural value of land

High Plains Ecoregion

Associated Maps

Ecoregions of Texas………………………...1

High Plains Ecoregion………………………7

Associated Section IV Documents

The Texas Priority Species List…………….733

Supplemental Mammal Information……….. 897

Supplemental Herptile Information………... 988

Element 1

Priority Species

Group	Species Name	Common Name	State/Federal Status
Birds	*Aimophila cassinii*	Cassin's sparrow	SC
	Ammodramus bairdii	Baird's sparrow (42 accepted state records)	SC
	Ammodramus savannarum	Grasshopper sparrow	SC
	Amphispiza bilineata	Black-throated sparrow	SC
	Anas acuta	Northern pintail	SC
	Anthus spragueii	Sprague's pipit	SC
	Asio flammeus	Short-eared owl	SC
	Athene cunicularia	Burrowing owl	SC
	Aythya affinis	Lesser scaup	SC
	Aythya americana	Redhead	SC
	Aythya valisineria	Canvasback	SC
	Bartramia longicauda	Upland sandpiper	SC
	Botaurus lentiginosus	American bittern	SC
	Buteo lagopus	Rough-legged hawk	SC
	Buteo regalis	Ferruginous hawk	SC
	Buteo swainsoni	Swainson's hawk	SC

Calcarius mccownii	McCown's longspur	SC
Calidris alba	Sanderling	SC
Calidris canutus	Red knot	SC
Calidris himantopus	Stilt sandpiper	SC
Calidris mauri	Western sandpiper	SC
Callipepla squamata	Scaled quail	SC
Calothorax lucifer	Lucifer hummingbird	SC
Campylorhynchus brunneicapillus	Cactus wren	SC
Caprimulgus carolinensis	Chuck-will's-widow	SC
Chaetura pelagica	Chimney swift	SC
Charadrius alexandrinus	Snowy plover	SC
Charadrius montanus	Mountain plover	SC
Chondestes grammacus	Lark sparrow	SC
Chordeiles minor	Common nighthawk	SC
Circus cyaneus	Northern harrier	SC
Coccyzus americanus	Yellow-billed cuckoo	SC
Contopus virens	Eastern wood-pewee	SC
Coturnicops noveboracensis	Yellow rail	SC
Dendroica cerulea	Cerulean warbler	SC
Dendroica discolor	Prairie warbler	SC
Dendroica dominica	Yellow-throated warbler	SC
Egretta thula	Snowy egret	SC
Egretta tricolor	Tricolored heron	SC
Elanoides forficatus	Swallow-tailed kite	ST
Empidonax virescens	Acadian flycatcher	SC
Eremophila alpestris	Horned lark	SC
Falco femoralis	Aplomado falcon	FE/SE
Falco mexicanus	Prairie falcon	SC

Falco peregrinus tundrius	Arctic peregrine falcon	ST
Gallinago delicata	Wilson's snipe (formerly common snipe)	SC
Haliaeetus leucocephalus	Bald Eagle	FT/ST
Helmitheros vermivorum	Worm-eating warbler	SC
Himantopus mexicanus	Black-necked stilt	SC
Icterus parisorum	Scott's oriole	SC
Icterus spurius	Orchard oriole	SC
Ictinia mississippiensis	Mississippi kite	SC
Ixobrychus exilis	Least bittern	SC
Lanius ludovicianus	Loggerhead shrike	SC
Limnodromus griseus	Short-billed dowitcher	SC
Limosa fedoa	Marbled godwit	SC
Limosa haemastica	Hudsonian godwit	SC
Melanerpes aurifrons	Golden-fronted woodpecker	SC
Myiarchus crinitus	Great crested flycatcher	SC
Numenius americanus	Long-billed curlew	SC
Numenius phaeopus	Whimbrel	SC
Nyctanassa violacea	Yellow-crowned night-heron	SC
Oporornis formosus	Kentucky warbler	SC
Parabuteo unicinctus	Harris's hawk	SC
Parus atricristatus	Black-crested titmouse	SC
Passerina ciris	Painted bunting	SC
Pegadis chihi	White-faced ibis	ST
Pelecanus erythrorhynchos	American white pelican	SC
Phalaropus tricolor	Wilson's phalarope	SC
Picoides scalaris	Ladder-backed woodpecker	SC
Picoides villosus	Hairy woodpecker	SC
Pluvialis dominica	American golden-plover	SC
Podiceps auritus	Horned grebe	SC

Podiceps nigricollis	Eared grebe	SC
Protonotaria citrea	Prothonotary warbler	SC
Rallus elegans	King rail	SC
Rallus limicola	Virginia rail	SC
Recurvirostra americana	American avocet	SC
Scolopax minor	American woodcock	SC
Seiurus motacilla	Louisiana waterthrush	SC
Spiza americana	Dickcissel	SC
Spizella breweri	Brewer's sparrow	SC
Spizella pusilla	Field sparrow	SC
Sterna antillarum	**Least tern (interior)	FE/SE
Sterna forsteri	Forster's tern	SC
Sturnella magna	Eastern meadowlark	SC
Sturnella neglecta	Western meadowlark	SC
Toxostoma curvirostre	Curve-billed thrasher	SC
Tringa flavipes	Lesser yellowlegs	SC
Tringa melanoleuca	Greater yellowlegs	SC
Tringa solitaria	Solitary sandpiper	SC
Tryngites subruficollis	Buff-breasted sandpiper	SC
Tympanuchus pallidicinctus	Lesser prairie-chicken	SC
Tyrannus forficatus	Scissor-tailed flycatcher	SC
Tyrannus tyrannus	Eastern kingbird	SC
Tyrannus vociferans	Cassin's kingbird	SC
Vermivora chrysoptera	Golden-winged warbler	SC
Vermivora pinus	Blue-winged warbler	SC
Vermivora virginiae	Virginia's warbler	SC
Vireo atricapillus	**Black-capped vireo	FE/SE
Vireo bellii	Bell's vireo	SC
Vireo flavifrons	Yellow-throated vireo	SC

	Vireo gilvus	Warbling vireo	SC
	Vireo vicinior	Gray vireo	SC
Mammals	*Antilocapra americana*	Pronghorn	SC
	Antrozous pallidus	Pallid bat	SC
	Conepatus leuconotus	Hog-nosed skunk	SC
	Corynorhinus townsendii	**Townsend's big-eared bat	SC
	Cratogeomys castanops	Yellow-faced pocket gopher	SC
	Cynomys ludovicianus	Black-tailed prairie dog	SC
	Dipodomys spectabilis	Banner-tailed kangaroo rat	SC
	Erethizon dorsatum	Porcupine	SC
	Microtus ochrogaster	Prairie vole	SC
	Mustela frenata	Long-tailed weasel	SC
	Mustela nigripes	Black-footed ferret	FE/SE
	Myotis velifer	Cave myotis	SC
	Notisorex crawfordii	Desert shrew	SC
	Nyctinomops macrotis	Big free-tailed bat	SC
	Peromyscus truei comanche	Palo duro mouse	ST
	Puma concolor	Mountain lion	SC
	Spilogale gracilis	Western spotted skunk	SC
	Spilogale putorius	Eastern spotted skunk	SC
	Tadarida brasiliensis	Brazilian free-tailed bat	SC
	Taxidea taxus	American badger	SC
	Vulpes velox	Swift fox (Kit fox)	SC
Reptiles	*Crotalus viridis*	Prairie rattlesnake	SC
	Deirochelys reticularia	Chicken turtle	SC
	Gambelia wislizeni	Long-nosed leopard lizard	SC
	Graptemys spp.	**Map turtles	FC/ST

Nerodia harteri	Brazos watersnake	ST
Nerodia paucimaculata	**Concho watersnake	ST
Ophisaurus attenuatus	Slender glass lizard	SC
Phrynosoma cornutum	Texas horned lizard	ST
Phrynosoma modestum	Round-tailed horned lizard	SC
Sceloporus arenicolus	Dunes sagebrush lizard	SC
Sistrurus catenatus	Massasauga	SC
Terrapene spp.	Box turtles	SC

Group	Family	Species Name	Federal Status
Invertebrates			
	Araneae (Arachnida)		
	Linyphiidae	*Islandiana unicornis Ivie*	SC

Element 2

Location and Condition of the High Plains Ecoregion

Described as a sea of waving grasslands, the High Plains extends from the Panhandle south to the Pecos River. This 20,000,000 ac. region fills most of the "handle portion" of the state and consists of a relatively high and level plateau of sandy to heavy, dark, calcareous clay soils lying over an impervious layer of caliche. Soils consist mainly of outwash sediments from the Rocky Mountains. Elevations range from 3,000 to 4,700 ft. above MSL, with an average annual temperature of approximately 59°F. Winters here are the coldest in Texas. Rainfall averages from 21 in. on the eastern edge of the region to as low as 12 in. on the southwestern edge. Sun and wind rob the soil of what little moisture it receives. Today, an arid, treeless plain, much of the High Plains is irrigated from the vast Ogallala formation. Classified as mixed-prairie and short-grass prairie, the vegetation varies as a function of location. Hardlands, mixed lands, sandy lands, draws or caliche lakes give rise to distinct differences in plant communities (Correll and Johnston 1979). Though characteristically free from trees or brush, honey mesquite and yucca have invaded some areas, while sandsage and shinnery oak have spread through the sandylands. Playa lakes play an essential role in this region, as they are among the prime waterfowl wintering grounds for the North American Central Flyway. The region's other name, Llano Estacado or "Staked Plains", is thought to derive from the first European settlers to traverse the High Plains who drove stakes into the ground to help guide them across the flat, featureless plain. These early pioneers found a vast carpet of short grasses, home to enormous herds of buffalo and pronghorn. This was also home to the Comanches, "Lords of the South Plains". While the original character of the High Plains has been forever changed by the plow and the barbed wire fence, unique areas still remain, including scattered sand dunes cloaked with Havard shin-oak, sandsage and little bluestem. Tallgrass meadows still exist along the Canadian River and its tributaries, nourished by underground water flowing through the sands. While few rivers actually cross the High Plains, the thin ribbons of water along the Canadian and Red rivers once sustained luxuriant growth of tall willows and cottonwoods. Now two Old World exotic plants, Russian olive and tamarisk, have supplanted the native trees that line the banks, providing alternate homes for versatile phoebes and kingbirds. Grasses still provide cover and nesting habitat for other birds and belts of trees planted back in the 1930's provide shelter to an amazing diversity of wildlife. Whereas gray wolves, grizzly bears and elk no longer occur on the High Plains, mountain lions, the adaptable coyote, red-tailed hawk and the diminutive swift fox now sit at the top of the food chain. And while the once vast populations of prairie dogs have dwindled, flocks of wintering waterfowl still frequent the ephemeral playa lakes, as do sandhill cranes and shorebirds that forage along the playa margins. Scattered bunches of lesser prairie-chickens still boom on the prairies, though their numbers are greatly reduced, while migrating flocks of lark buntings and horned larks still fly the skies.

This ecoregion can be broken down into four main habitat classes consisting of brushland, grassland, shrubland, and urban.

High Plains Brushland

The High Plains brushland consists of woody plants mostly less than nine feet tall which are dominant and growing as closely spaced individuals, clusters or closed canopied stands (greater than 10% canopy cover). Typically there are continuous, impenetrable shrubs covering over 75% of the ground (McMahan et al. 1984, Bridges et al. 2002). A total of six plant associations dominate this habitat class.

The *mesquite-lotebush association* is most commonly found in the southern fringe of the High Plains ecoregion and is typically deciduous. Commonly associated plants include yucca species, skunkbush sumac, agarito, elbowbush, juniper, tasajillo, cane bluestem, silver bluestem, little bluestem, sand dropseed, Texas grama, sideoats grama, hairy grama, red grama, tobosa, buffalograss, Texas wintergrass, purple three-awn, Roemer three-awn, Engelmann daisy, broom snakeweed and bitterweed (McMahan et al. 1984). Cross-referenced communities: 1) mesquite-midgrass series (Diamond 1993), 2) upland mesquite-midgrass savannahs (Bezanson 2000), and 3) honey mesquite woodland alliance (Weakley et al. 2000). The *mesquite-lotebush* community is considered secure globally and throughout the state with more than 100 occurrences documented. Occurrences may be rare in part of its range with associations becoming infrequent at the periphery (Diamond 1993).

The *mesquite-salt cedar* association is typically found in ephemeral drainages in the southern High Plains drainage areas where saline, sandy soils occur. It can also be found around sub-irrigated swales and ephemeral creek bottoms as well as between dunes occasionally, in the panhandle (Diamond 1993). Commonly associated plants include creosote, cottonwood, desert willow, giant reed, seepwillow, common buttonbush, burrobush, whitethorn acacia, Australian saltbush, fourwing saltbush, lotebush, wolfberry, tasajillo, guayacan, alkali sacaton, Johnsongrass, saltgrass, cattail, bushy bluestem, chino grama and Mexican devil-weed (McMahan et al. 1984). Cross-referenced communities: 1) floodplain forest and savannah (Kuchler 1974), 2) cottonwood-tallgrass series (Diamond 1993), 3) cottonwood-willow riparian woodlands (Bezanson 2000), and 4) eastern cottonwood temporarily flooded alliance woodland (Weakley et al. 2000). This community is considered imperiled, or very rare, globally and statewide. It is endangered throughout its range globally and it is considered vulnerable to extirpation within the state. It is determined that 6-20 occurrences are documented (Diamond 1993).

The *sandsage-Harvard shin oak* association is broadly defined and includes mostly evergreen brush or grasses. This association is typically isolated on sandy soils, many times stabilized sand dunes and usually occurs in the northwestern portion, or panhandle, of the High Plains. Skunkbush sumac, Chickasaw plum, Indiangrass, switchgrass, sand bluestem, little bluestem, sand lovegrass, big sandreed, sideoats grama, hairy grama, sand dropseed, sand paspalum, lead plant, scurfpea, scarletpea, slickseed bean, wild blue indigo, wild buckwheat and bush morning glory include a few of the commonly associated plants found within this plant community. The community composition can vary with the depth and level of stabilization of the dunes and also the amount and reliability of precipitation. Cross-referenced communities: 1) Harvard shin oak-tallgrass series (Diamond 1993), 2) Harvard shin oak brush (Bezanson 2000), and 3) Harvard shin oak shrubland alliance (Weakley et al. 2000). The *sandsage-Harvard shin oak* community is considered secure globally and throughout the state with more than 100 occurrences documented. Occurrences may be rare in part of its range with associations becoming infrequent at the periphery (Diamond 1993).

The *Harvard shin oak-mesquite* association occurs primarily on sandy soils and include plants such as sandsage, catclaw acacia, yucca species, giant dropseed, sand dropseed, Indiangrass, silver bluestem, sand bluestem, little bluestem, feather plume, Illinois bundleflower, foxglove and yellow evening primrose (McMahan et al. 1984). This association is widespread and deciduous occurring primarily on limestone or caliche soils (Diamond 1993). It typically occurs in the southwestern portion of the High Plains ecoregion and is also indicative of the Rolling Plains ecoregion (McMahan et al. 1984). Cross-referenced communities: 1) Harvard shin oak-tallgrass series (Diamond 1993), 2) Harvard shin oak brush (Bezanson 2000), and 3) Harvard shin oak shrubland alliance (Weakley et al. 2000). The *Harvard shin oak-mesquite* community is considered secure globally and throughout the state with more than 100 occurrences documented. Occurrences may be rare in part of its range with associations becoming infrequent at the periphery (Diamond 1993).

The *Harvard shin oak* association is found chiefly on sandy soils and degraded sand sheet in the High Plains ecoregion, which is typically associated with the counties of Andrews, Crane, Ward and Winkler (McMahan et al. 1984, Diamond 1993, Bezanson 2000). Isolated patches of this community are also found within the High Plains counties of Lynn, Howard, Dawson, Cochran, Terry and Yoakum. This is a broadly-defined, evergreen vegetation association typically restricted to stabilized sand dunes. Composition is dependent on precipitation and factors relating to the disturbance of the sand dunes such as depth and degree of stabilization (Diamond 1993). Plants found in this association include catclaw acacia, bush morning glory, southwest rabbitbrush, sandsage, mesquite, hooded windmillgrass, sand bluestem, big sandreed, false buffalograss, spike dropseed, giant dropseed, mesa dropseed, narrowleaf sand verbena, sweet sand verbena, bull nettle, sand dune spurge, prairie spurge, firewheel and plains sunflower (McMahan et al. 1984). Cross-referenced communities: 1) Harvard shin oak low shrublands (Bezanson 2000), and 2) Harvard oak shrubland alliance (Weakley et al. 2000). *Harvard shin oak* communities are considered rare or uncommon. They are typically only found locally in restricted areas throughout its range with less than 100 occurrences within the state (Diamond 1993). The best protected location of this community occurs at the Monahans Sandhills State Park (Bezanson 2000). On a global scale it is considered very rare and local within its range or found locally within a restricted range. Sometimes they are found in a single physiographic region. There are fewer than 100 occurrences documented and due to various threats these communities are vulnerable to extinction throughout their global range (Diamond 1993).

The *cottonwood-hackberry-salt cedar* association is the most prominent in the Canadian and Red River basins. It is a deciduous forest community that was occupied by floodplains of perennial streams which have since subsided due to disturbances (Diamond 1993). Commonly associated plants include Lindheimer's black willow, buttonbush, groundsel-tree, rough-leaf dogwood, Panhandle grape, heartleaf ampelopsis, false climbing buckwheat, cattail, switchgrass, prairie cordgrass, saltgrass, alkali sacaton, spikesedge, horsetail, bulrush, coarse sumpweed and Maximilian sunflower (McMahan et al. 1984). Cross-referenced communities: 1) floodplain forest and savannah (Kuchler 1974), 2) cottonwood-tallgrass series (Diamond 1993), 3) cottonwood-willow riparian woodlands (Bezanson 2000), and 4) eastern cottonwood temporarily flooded alliance woodland (Weakley et al. 2000). The *Cottonwood-hackberry-salt cedar* community is considered imperiled, or very rare, globally and statewide. It is endangered throughout its range globally and it is considered vulnerable to extirpation within the state. It is determined that 6-20 occurrences are documented (Diamond 1993).

High Plains Grassland

Grasslands consist of herbs (grasses, forbs and grass-like plants) which are dominant. Woody vegetation is lacking or nearly so (generally 10% or less woody canopy cover) (McMahan et. at 1984). There is one dominant plant association found in the High Plains grasslands.

The *blue grama-buffalograss* plant association is a shortgrass grassland. It is most commonly found in the central and northwestern High Plains although there are patches in the Trans-Pecos and Rolling Plains ecoregions. It is recognized by dominant upland soils (McMahan et al. 1984, Diamond 1993). Common plants associated with this subclass include sideoats grama, hairy grama, sand dropseed, cholla cactus, grassland prickly pear cactus, narrowleaf yucca, western ragweed, broom snakeweed, zinnia, rushpea, scurfpea, catclaw sensitive briar, wild buckwheat and woollywhite (McMahan et al. 1984). Cross-referenced communities: 1) mixed prairie climax (Rowell 1967), 2) blue grama-buffalograss (Diamond 1993), 3) blue grama-buffalograss short grasslands (Bezanson 2000), and 4) blue grama herbaceous alliance (Weakley et al. 2000). The *blue grama-buffalograss* community is considered secure globally. Statewide, this community is considered rare or uncommon. Non-native grasses, such as kleingrass, have been seeded on millions of acres throughout this community. Mesquite, narrowleaf yucca, juniper species and other brushy species have invaded these once treeless prairies. Broomweed species and other weedy forbs now dominate grazed pastures (Bezanson 2000). Approximately 21-100 occurrences are documented within the state (Diamond 1993). Due to these concerns, this community is considered of medium priority for further protection.

High Plains Shrubland

Shrublands consist of individual woody plants generally less than nine feet tall scattered throughout arid or semi-arid regions where the vegetation is evenly spaced covering over 75% of the ground (Bridges et al. 2002). Typically there is less than 30% woody canopy cover overhead (McMahan et al. 1984). The High Plains shrubland consists of one main plant association.

The *mesquite* association consists of narrow-leaf yucca, tasajillo, juniper, grassland prickly pear, cholla, blue grama, hairy grama, purple three-awn, Roemer three-awn, buffalograss, little bluestem, western wheatgrass, Indiangrass, switchgrass, James rushpea, scurfpea, lemon scurfpea, sandlily, plains beebalm, scarlet gaura, yellow evening primrose, sandsage and wild buckwheat (McMahan et al. 1984). This association is found on typical upland soils which are sandy and shallow with influences from caliche or limestone. At more mesic sites, and also locations maintaining good quality rangeland, this community type is seen grading into a midgrass community (Diamond 1993). Cross-referenced communities: 1) mesquite-midgrass series (Diamond 1993), 2) upland mesquite-midgrass savannahs (Bezanson 2000), and 3) honey mesquite woodland alliance (Weakley et al. 2000). The *mesquite* community is considered secure globally and throughout the state with more than 100 occurrences documented. Occurrences may be rare in part of its range with associations becoming infrequent at the periphery (Diamond 1993). Bezanson (2000) also considers this community to be of low priority for further protection.

High Plains Urban Community

Urban habitats are cities or towns which are areas dominated by human dwellings including the fences, shrub rows, windbreaks and roads associated with their presence (Bridges at al. 2002). The biggest cities in the High Plains are Amarillo and Lubbock with Midland and Odessa ranked as the third and fourth largest cities. Other prominent but smaller cities include Big Spring, Levelland, Hereford, Plainview, Dumas, Brownfield and Pampa.

High Priority Communities **(Portions of the following information were used with permission from the Playa Lakes Joint Venture (PLJV))**

There are approximately 19,000 *playa lakes* between the High Plains and the Rolling Plains ecoregions which are home to roughly 37 mammal species, more than 200 bird species, 13 amphibian species, 124 aquatic invertebrate taxa and greater than 340 species of plant. These communities are one of the most numerous wetland types in the High and Rolling Plains ecoregions. Playas are shallow, depressional wetlands that are generally round and small, averaging 17 ac. in size. There is very little rainfall in the High Plains ecoregion averaging 20 in. or less, therefore, most of the water sources for wildlife are available only in these seasonal lakes. Water from spring rainstorms is trapped in shallow depressions scattered throughout the High and Rolling Plains ecoregions which eventually recharge the Ogallala Aquifer. These depressions have clay bottoms which are impermeable and can hold water for long time periods (Bezanson and Wolfe 2001). Presently, it is undetermined as to what condition the *playa lakes* of the High and Rolling plains are in. More than 99% of playas are privately owned with the majority of playa lakes located in or adjacent to farms, grazing lands and feedlots. The Natural Area Preservation Association and Environmental Defense currently protect five sites which contain playa lakes (Bezanson and Wolfe 2001).

There are about 100 s*aline lakes* located in the southern portions of the High Plains. They are closed systems which are fed by freshwater springs, several exceeding 1,000 ac. *Saline lakes* are generally ice-free in the winter and host large concentrations of migratory birds, especially when other sources of water are frozen. *Saline lakes* are important roost sites for sandhill cranes and support large numbers during migration and winter. Many species breed on the shores of *saline lakes* with snowy plovers being the highest priority for conservation. Seeps found in association with saline lakes are used by a variety of birds throughout the year.

Riparian woodlands and sandhills were once numerous in the High and Rolling Plains. They are typically found along rivers and are home to cottonwoods and tall grasses. These areas are extremely important for many types of wildlife, especially migrating and breeding birds (Bezanson and Wolfe 2001). Presently, there are a few sites on private ranch lands which accommodate *riparian woodland and sandhill* communities. Native tall grass species and cottonwoods are found at these locations. Helping private land owners protect these sites is considered a high priority (Bezanson and Wolfe 2001).

Element 3

Problems Affecting the High Plains

See the Texas Priority Species List……………..………733

Playa lakes are extremely important for migrating, breeding and local wildlife species yet there are not many protected specifically for wildlife. Agricultural (pesticides, fertilizers and contaminants from feedlots) runoff, conversion of surrounding lands from shortgrass prairie to cropland, the conversion of the playa lakes themselves to other uses and sedimentation are large threats to this key community type of the High Plains (Bezanson and Wolfe 2001). Sedimentation is the primary threat to playa lakes. Sediment runoff into playa basins reduces the volume of water they can hold and may disrupt the wet-dry cycles necessary for vegetation growth. Additional impacts on playas include: development, oil field water dumping, improper grazing techniques and altered water cycles and basin structure. Most playa basins have been manipulated to increase storage capacity for irrigation purposes. The presence of additional water from irrigation runoff also alters natural playa hydrology.

Major threats to *saline lakes* are lowering of water tables due to irrigation and an increasing population in larger cities and oil and gas development.

Riparian woodlands and sandhills face isolation from agricultural practices. Dams and detrimental irrigation practices have decreased streamflows. Poor grazing practices have altered the natural state of these communities. The most detrimental incidence is from the invasion of exotic species such as salt cedar. Many native species of the High Plains have disappeared, except from isolated areas, because of from invasive species (Bezanson and Wolfe 2001).

High Priority Research and Monitoring Efforts for the High Plains

See Monitoring and Adaptive Management………. 559

See the Texas Priority Species List………..………733

Element 5

- Evaluation of the effectiveness of playa buffer techniques (e.g. buffer size, buffer mix, or species represented) as they relate to hydrology, runoff, sedimentation, wetland quality and land bird use
- Monitoring birds during migration, their chronology, numbers and/or stopover times for species identified
- Evaluation of playa restoration techniques, such as sediment removal or back-filling "pits", on bird use, plant response, playa hydrology and other playa functions
- Monitoring identified species of birds as well as their habitat quality and quantity.
- Efficacy of habitat management strategies (e.g. different grazing regimes, exotic vegetation control methods) on priority bird species, particularly abundance and/or distribution objectives of those species or other measures that are indicative of bird response (e.g. change in vital rates)
- Landscape-scale comparison of bird use on well-utilized and non well-utilized wetlands. (Questions might focus on intrinsic and extrinsic habitat quality, surrounding land use or wetland complex value)
- Bird use of non-playa wetlands (examples of other wetland types are saline lakes, stock ponds, reservoirs, riparian areas, beaver ponds, wet meadows, etc.)
- Annual and seasonal availability of priority foraging habitats
- Estimating availability/nutrient content of foods available in croplands, and the potential importance (contribution) of croplands to birds that may rely heavily on them

Element 4

High Priority Conservation Actions for the High Plains

See High Priority Conservation Strategies…………..517

See the Texas Priority Species List………..………733

- Increase the amount of protected habitats including playas, wetlands, shortgrass, sandsage and shinnery prairie
- Waterfowl and shorebird habitat conservation efforts should be directed at providing habitat to support approximately 686 million additional foraging use-days for waterfowl and two million for shorebirds, which represent the current shortfalls. This could be accomplished by enhancing 162,494 ac. of playas through moist-soil management for maximum waterfowl food production. Of these, 11,383 ac. should also be managed for optimum shorebird foraging suitability (very shallow water with minimal emergent cover). Because only a small portion of existing wetland habitat is suitable for foraging shorebirds (too deep, too densely vegetated, etc.), alternative conservation strategies could involve improving suitability of existing wetlands for foraging shorebirds through management actions such as grazing, brush removal, water level management, etc. For example, if the suitability of the existing habitat for shorebirds could be tripled, the population goal would nearly be met. However, this strategy requires management of more acres than the strategy described above
- Protect and restore playas wherever they occur
- Maintain wetland habitats surrounding reservoirs and ponds
- Ensure all CRP is planted with native and area appropriate grasses and include shrubs in the mixture when on sandy soils
- Encourage the elimination of invasive exotics, such as salt cedar, in riparian areas in conjunction with native replanting
- Increase the number of large blocks of shortgrass by 28,700 ac. all concentrated in the far northwestern panhandle. Increase the amount of large blocks of shinnery by a minimum of 256,410 ac. Find lesser prairie-chicken in sandsage in this region
- Be creative in the maintenance and increase of prairie-dog colonies in shortgrass. Work to achieve an additional 249,000 ac. of prairie-dog colonies to reach

objective levels for the burrowing owl

- Encourage maximum enrollment (136,700 ac.) in Farm Bill programs to increase block size of native grasslands, buffer playas and protect groundwater sources near saline lakes. Consider programs not beholden to the CRP county cap
- Protect all saline lakes and look for opportunities to protect groundwater sources which may feed the lake (i.e. places to target CRP or other programs to bring cropland out of irrigated production)
- Protect known colonial waterbird colonies and areas where marsh birds breed
- Work with federal, state and private organizations to promote (incentives) leaving some cover for wildlife. The economic benefits of wildlife can sometimes equal or surpass the agricultural value of land
- Emphasize the importance of proper grazing. Work with state, federal and private agencies to continue to develop cost-effective means to balance grazing and wildlife. Patch grazing appears to be very promising. Support Farm Bill programs which encourage proper grazing management
- Encourage cities to modify mowing regimes and start prairie restoration projects

Pineywoods Ecoregion

Associated Maps

Ecoregions of Texas…………………………1

Pineywoods Ecoregion………………………8

Element 1

Associated Section IV Documents

The Texas Priority Species List…………….733

Supplemental Mammal Information……….. 897

Supplemental Herptile Information……….. 988

Priority Species

Group	Species Name	Common Name	State/Federal Status
Birds	*Aimophila aestivalis*	Bachman's sparrow	ST
	Ammodramus henslowii	Henslow's sparrow	SC
	Ammodramus leconteii	Le Conte's sparrow	SC
	Ammodramus savannarum	Grasshopper sparrow	SC
	Anas acuta	Northern pintail	SC
	Anthus spragueii	Sprague's pipit	SC
	Aquila chrysaetos	Golden eagle	SC
	Asio flammeus	Short-eared owl	SC
	Aythya affinis	Lesser scaup	SC
	Aythya americana	Redhead	SC
	Aythya valisineria	Canvasback	SC
	Bartramia longicauda	Upland sandpiper	SC
	Botaurus lentiginosus	American bittern	SC
	Buteo lineatus	Red-shouldered hawk	SC
	Buteo swainsoni	Swainson's hawk	SC
	Calcarius pictus	Smith's longspur	SC

Calidris mauri	Western sandpiper	SC
Caprimulgus carolinensis	Chuck-will's-widow	SC
Chaetura pelagica	Chimney swift	SC
Chondestes grammacus	Lark sparrow	SC
Chordeiles minor	Common nighthawk	SC
Circus cyaneus	Northern harrier	SC
Cistothorus platensis	Sedge wren	SC
Coccyzus americanus	Yellow-billed cuckoo	SC
Colinus virginianus	Northern bobwhite	SC
Contopus virens	Eastern wood-pewee	SC
Dendroica cerulea	Cerulean warbler	SC
Dendroica discolor	Prairie warbler	SC
Dendroica dominica	Yellow-throated warbler	SC
Dryocopus pileatus	Pileated woodpecker	SC
Egretta caerulea	Little blue heron	SC
Egretta thula	Snowy egret	SC
Egretta tricolor	Tri-colored heron	SC
Elanoides forficatus	Swallow-tailed kite	ST
Elanus leucurus	White-tailed kite	SC
Empidonax virescens	Acadian flycatcher	SC
Eremophila alpestris	Horned lark	SC
Euphagus carolinus	Rusty blackbird	SC
Falco columbarius	Merlin	SC
Falco peregrinus tundrius	Arctic peregrine falcon	ST
Falco sparverius	American kestrel (southeastern)	SC
Gallinago delicata	Wilson's snipe (formerly common snipe)	SC
Haliaeetus leucocephalus	Bald eagle	FT/ST
Helmitheros vermivorum	Worm-eating warbler	SC
Himantopus mexicanus	Black-necked stilt	SC

Hylocichla mustelina	Wood thrush	SC
Icterus spurius	Orchard oriole	SC
Ictinia mississippiensis	Mississippi kite	SC
Ixobrychus exilis	Least bittern	SC
Lanius ludovicianus	Loggerhead shrike	SC
Limnothlypis swainsonii	Swainson's warbler	SC
Melanerpes erythrocephalus	Red-headed woodpecker	SC
Mycteria americana	**Wood stork	ST
Myiarchus crinitus	Great crested flycatcher	SC
Numenius americanus	Long-billed curlew	SC
Nyctanassa violacea	Yellow-crowned night-heron	SC
Oporornis formosus	Kentucky warbler	SC
Passerina ciris	Painted bunting	SC
Pegadis chihi	White-faced ibis	ST
Pelecanus erythrorhynchos	American white pelican	SC
Phalaropus tricolor	Wilson's phalarope	SC
Picoides borealis	**Red-cockaded woodpecker	FE/SE
Picoides villosus	Hairy woodpecker	SC
Platalea ajaja	Roseate spoonbill	SC
Pluvialis dominica	American golden-plover	SC
Podiceps auritus	Horned grebe	SC
Podiceps nigricollis	Eared grebe	SC
Porphyrio martinica	Purple gallinule	SC
Protonotaria citrea	Prothonotary warbler	SC
Rallus elegans	King rail	SC
Rallus limicola	Virginia rail	SC
Recurvirostra americana	American avocet	SC
Scolopax minor	American woodcock	SC
Seiurus motacilla	Louisiana waterthrush	SC

	Setophaga ruticilla	American redstart	SC
	Sitta pusilla	Brown-headed nuthatch	SC
	Spiza americana	Dickcissel	SC
	Spizella pusilla	Field sparrow	SC
	Sterna forsteri	Forster's tern	SC
	Sturnella magna	Eastern meadowlark	SC
	Sturnella neglecta	Western meadowlark	SC
	Toxostoma rufum	Brown thrasher	SC
	Tringa flavipes	Lesser yellowlegs	SC
	Tringa melanoleuca	Greater yellowlegs	SC
	Tringa solitaria	Solitary sandpiper	SC
	Tryngites subruficollis	Buff-breasted sandpiper	SC
	Tyrannus forficatus	Scissor-tailed flycatcher	SC
	Tyrannus tyrannus	Eastern kingbird	SC
	Vermivora chrysoptera	Golden-winged warbler	SC
	Vermivora pinus	Blue-winged warbler	SC
	Vireo bellii	Bell's vireo	SC
	Vireo flavifrons	Yellow-throated vireo	SC
	Vireo gilvus	Warbling vireo	SC
	Wilsonia citrina	Hooded warbler	SC
	Zenaida macroura	Mourning dove	SC
	Zonotrichia querula	Harris's sparrow	SC
Mammals	*Blarina carolinensis*	Southern short-tailed shrew	SC
	Corynorhinus rafinesquii	Rafinesque's big-eared bat	ST
	Lutra canadensis	River otter	SC
	Microtus ochrogaster	Prairie vole	SC
	Mustela frenata	Long-tailed weasel	SC
	Myotis austroriparius	Southeastern myotis	SC

	Puma concolor	Mountain lion	SC
	Spilogale putorius	Eastern spotted skunk	SC
	Sylvilagus aquaticus	Swamp rabbit	SC
	Tadarida brasiliensis	Brazilian free-tailed bat	SC
	Ursus americanus luteolus	**Louisiana black bear	FT/ST
Reptiles	*Alligator mississippiensis*	American alligator (4 sp.)	SC
	Ambystoma talpoideum	Mole salamander	SC
	Amphiuma tridactylum	Three-toed amphiuma	SC
	Cemophora coccinea	Scarlet snake	ST
	Crotalus horridus	Timber rattlesnake	ST
	Deirochelys reticularia	Chicken turtle	SC
	Eumeces anthracinus	Coal skink	SC
	Graptemys spp.	**Map turtles	FC/ST
	Macrochelys temminckii	Alligator snapping turtle	ST
	Necturus beyeri	Gulf Coast waterdog	SC
	Ophisaurus attenuatus	Slender glass lizard	SC
	Pituophis ruthveni	Louisiana pine snake	FC/ST
	Rana areolata	Crawfish frog	SC
	Rana grylio	Pig frog	SC
	Scaphiopus hurterii	Hurter's spadefoot	SC
	Sistrurus miliarius	Pygmy rattlesnake	SC
	Terrapene spp.	Box turtles	SC

Group	Family	Species Name	Federal Status
Invertebrates			
	Lepidoptera (Insecta)		
	Hesperiidae	*Euphyes bayensis*	SC

Location and Condition of the Pineywoods Ecoregion

Element 2

Mostly deep, dark and evergreen, the Pineywoods region of East Texas is an extension of the rich pine/hardwood forests of the southeastern United States. Gently rolling hills cloaked with pines and oaks and rich bottomlands with tall hardwoods characterize these forests, while intermittent pockets of evergreen shrub bogs, open seepage slopes and cypress-tupelo swamps form a patchwork quilt throughout. Frequent long-term flooding plays an essential role in maintaining these bottomland hardwood communities. The region's 35 to 60 in. of rain each year support not only pines (loblolly, shortleaf and longleaf) but also swamp and streamside stands of hardwoods (beech oaks, elm and magnolia) and a myriad of woodland specialties (flowering dogwood, sphagnum mosses, ferns, pitcher plants, sundews, pipeworts and orchids) (Winkler 1982).

Elevations range from near sea level to almost 500 ft. above MSL with an average annual temperature of 66°F. The growing season approaches 250 days in the south and 230 days near the Red River in the north. Highly weathered soils are sandy or loamy and very deep. As most of the 15.8 million ac. of the region is prime timber land, conversion of these woodlands to plantations of loblolly or slash pine has permanently altered many of the natural forest communities.

East Texas boasts a rich diversity of wildlife. Fifteen species of Texas breeding birds nest predominantly in this eco-region. Three of these species, including the pine warbler, brown-headed nuthatch and the endangered red-cockaded woodpecker are confined almost exclusively, in Texas, to the Pineywoods forest for breeding. The Bachman's sparrow nests locally in Texas only in the longleaf pine uplands of this region, while wintering bald eagles set up winter roosts in undisturbed woodlands near rivers and lakes. Other avian specialties of the Pineywoods include the wood thrush, hooded warbler, prothonotary warbler and barred owl. Characteristic mammals of the region include river otter, gray squirrel, flying squirrel and the Louisiana black bear. Although the Louisiana black bear is currently thought to be absent from the Texas Pineywoods, suitable habitat still exists to support future populations of this East Texas specialty.

This ecoregion can be broken down into four main habitat classes consisting of forest, native and introduced grasses, woodland forest and parkland mosaic, and urban.

Pineywoods Forest

The Pineywoods forest consists of deciduous or evergreen trees that are dominant in the landscape. These species are mostly greater than 30 ft. tall with closed crowns or nearly so (71-100% canopy cover). The midstory is generally apparent except in managed monocultures (McMahan et al. 1984, Bridges et al. 2002). Only one plant association dominates this habitat class.

The *bald cypress-water tupelo swamp* association is found in acidic, hydric soils in the swampy flatlands of the Pineywoods, barely extending into the northeastern most portion of the Gulf Coast Prairies and Marshes ecoregion**.** Commonly associated plants include water oak, water hickory, swamp blackgum, red maple, swamp privet, buttonbush, posssam haw, water elm, black willow, eardrop vine, supplejack, trumpet creeper, climbing hempweed, bog hemp, water fern, duckweed, water hyacinth, bladderwort, beggar-ticks, water paspalum and St. John's wort (McMahan et al. 1984). Cross-referenced communities: 1) cypress-tupelo sloughs and swamps (Watson 1979), 2) bald cypress (SAF #101), bald cypress-water tupelo (SAF #102) (Eyre 1980), 3) bald cypress tupelo series (Diamond 1993), 4) swamp cypress-tupelo forest (Marks and Harcombe 1981), 5) bald cypress-tupelo inundated forests (Bezanson 2000), and 6) bald cypress semipermanently flooded forest alliance, water-tupelo-(bald cypress) semipermanently flooded forest alliance, bald cypress (water tupelo, swamp blackgum, ogeechee tupelo) semipermanently flooded forest alliance, (water tupelo, swamp blackgum, ogeechee tupelo) pond seasonally flooded forest alliance (Weakley et al. 2000). The *bald cypress-water tupelo swamp* community is apparently secure globally with more than 100 known occurrences. It is possible for this community to be rare in parts of its range, especially in the periphery. Statewide, this community is considered rare or uncommon. Only 21-100 known occurrences exist (Diamond 1993).

<u>Pine hardwood</u> – The *loblolly pine-sweetgum* association (subtype 1) includes shortleaf pine, water oak, white oak, southern red oak, winged elm, beech, blackgum, magnolia,

American beautyberry, American hornbeam, flowering dogwood, yaupon, hawthorn, supplejack, Virginia creeper, wax myrtle, red bay, sassafras, southern arrowwood, poison oak, greenbriar and blackberry (McMahan et al. 1984). Soils tend to be sandy or loamy and fairly acidic (Diamond 1993). This association is an upland mainly deciduous community that typically occurs throughout the Pineywoods ecoregion (McMahan et al. 1984). Cross-referenced communities: 1) loblolly pine-hardwood (SAF #82) (Eyre 1980), 2) mid slope oak pine forest (Marks and Harcombe 1981), 3) loblolly pine-oak series (Diamond 1993), 4) eastern dry-mesic upland forests, western dry-mesic upland forests (Turner 1999), 5) pine-hardwood dry-mesic forests, and 6) loblolly pine forest alliance, loblolly pine-shortleaf pine forest alliance, loblolly pine-(white oak, southern red oak, post oak) forest alliance (Weakley et al. 2000). The *loblolly pine-sweetgum* community is considered a fairly low priority for further protection. This community is secure globally and throughout the state with more than 100 occurrences documented. Occurrences can be rare in part of its range with associations becoming infrequent at the periphery (Diamond 1993).

Pine hardwood (subtype 2) – The *shortleaf pine-post oak-southern red oak* association includes loblolly Pine, black hickory, sandjack oak, flowering dogwood, common persimmon, sweetgum, sassafras, greenbriar, yaupon, wax myrtle, American beautyberry, hawthorn, supplejack, winged elm, beaked panicum, spranglegrass, Indiangrass, switchgrass, three-awn, bushclover and tickclover (McMahan et al. 1984). Soils are typically either sandy or loamy and range from deep to shallow, with the pines occurring in the more shallow areas (Diamond 1993). This association is found in the northeastern Texas counties of Bowie, Red River, Lamar, Cass, Camp, Titus, Franklin, Marion, Harrison, Upshur, Gregg, Smith, Wood and Morris. It continues to extend into the southeastern portion of the Pineywoods, typically along deep sand ridges (McMahan et al. 1984). Cross-referenced communities: 1) upper slope pine oak forest (Marks and Harcombe 1981), 2) shortleaf pine-oak series, post oak-black hickory series (Diamond 1993), 3) upland hardwood-pine forests (Bezanson 2000), and 4) shortleaf pine-(white oak, southern red oak, post oak, black oak) forest alliance, loblolly pine-(blackjack oak, southern red oak, post oak) forest alliance, shortleaf pine forest alliance (Weakley et al. 2000). The *shortleaf pine-post oak-southern red oak* community is considered a fairly low priority for further protection. Approximately 10,000 ac. of the *shortleaf pine-post oak-southern red oak* community is protected presently (Bezanson 2000). This community is secure globally and throughout the state with more than 100 occurrences documented. Occurrences can be rare in part of its range with associations becoming infrequent at the periphery (Diamond 1993).

Pine hardwood (subtype 3) – The *loblolly pine-post oak* association includes Black hickory, blackjack oak, eastern red cedar, cedar elm, hackberry, greenbriar, yaupon, elbowbush, purpletop, sand lovegrass, broomsedge bluestem, little bluestem, brownseed paspalum, bushclover, tickclover, gay feather, yellow neptunia, bitter sneezeweed and velvet bundleflower (McMahan et al. 1984). Soils are typically sandy and shallow (Diamond 1993). This community is associated with the "Lost Pines" in Bastrop County and westward of the pine producing region of East Texas (McMahan et al. 1984). Cross-referenced communities: 1) loblolly pine-post oak upland forest (Bezanson 2000). The *loblolly pine-post oak* community is considered a fairly low priority for further protection. Over 6,000 ac. of the *loblolly pine-post oak* community is protected presently (Bezanson 2000). This community is secure globally and throughout the state with more than 100 occurrences documented. Occurrences can be rare in part of its range with associations becoming infrequent at the periphery (Diamond 1993).

Pine hardwood – The *longleaf pine-sandjack oak* association includes loblolly pine, shortleaf pine, blackjack oak, sand post oak, southern red oak, flowering dogwood, sweetgum, sassafras, American beautyberry, wax myrtle, yaupon, hawthorn, yellow jessamine, slender bluestem, broomsedge bluestem and little bluestem (McMahan et al. 1984). Soils range from sandy to loamy and are very acidic (Diamond 1993). This association is an upland evergreen community that is found mainly in the southeastern portion of the Pineywoods ecoregion (McMahan et al. 1984). Cross-referenced communities: 1) upland pine forest (Marks and Harcombe 1981), 2) longleaf pine uplands (Watson 1979), 3) longleaf pine-little bluestem series (Diamond 1993), 4) mesic woodlands, southern dry woodlands, northern dry woodlands (Turner 1999), 5) longleaf pine open forests (Bezanson 2000), and 6) longleaf pine-(slash pine) forest alliance, longleaf pine-oak species woodland alliance, longleaf pine woodland alliance (Weakley et al. 2000). The *longleaf pine-sandjack oak* association is considered a high priority for further protection (Bezanson 2000). This community is found as rare and local throughout its global range or locally in a restricted range such as a single physiographic region. Only 21-100 occurrences are known and various factors cause this community to be vulnerable to extinction globally. Statewide, there are less than 6-20 known occurrences. Therefore, it is considered imperiled and vulnerable to extirpation due to its rareness (Diamond 1993).

The *willow oak-water oak-blackgum* association includes beech, overcup oak, chestnut oak, cherrybark oak, elm, sweetgum, sycamore, southern magnolia, white oak, black willow, bald cypress, swamp laurel oak, hawthorn, bush palmetto, common elderberry, southern arrowwood, poison oak, supplejack, trumpet creeper, crossvine, greenbriar, blackberry, rhomboid copperleaf and St. Andrew's Cross (McMahan et al. 1984). This is a broadly defined community made up of deciduous vegetation that prefers bottomlands floodplains of major streams (Diamond 1993). This community is most commonly found in the lower flood plains of the Sulphur, Neches, Angelina, Trinity and Sabine rivers in the Pineywoods; however, it extends into the northernmost portion of the Gulf Coast Prairies and Marshes ecoregion (McMahan et al. 1984). Cross-referenced communities: 1) sweetgum-willow oak (SAF #92) (Eyre 1980), 2) floodplain hardwood forest (Marks and Harcombe 1981), 3) water oak-willow oak series (Diamond 1993), 4) loblolly pine/water oak ridges (Mundorff 1998), 5) wet floodplain forests, wet flatland forests (Turner 1999), 6) floodplain hardwood forests (Bezanson 2000), and 7) (willow oak, water oak, diamondleaf oak) temporarily flooded forest alliance (Weakley et al. 2000). The *willow oak-water oak-blackgum* community is apparently secure globally with more than 100 known occurrences. It is possible for this community to be rare in parts of its range, especially in the periphery. Statewide, this community is considered rare or uncommon. Only 21-100 known occurrences exist (Diamond 1993).

Pineywoods Native and Introduced Grasses

A mixture of native and introduced grasses which includes herbs (grasses, forbs and grass-like plants) that are dominant with woody vegetation lacking or nearly so (generally 10% or less woody canopy cover). These associations typically result from the invasion of non-native grass species originating from the planting of these non-natives (e.g. Bermuda, KR bluestem, etc.) for roadsides and rangelands. The clearing of woody vegetation is another factor and is sometimes associated with the early stages of a young forest. This community can quickly change as removed brush begins to regrow (McMahan et al. 1984, Bridges et al. 2002).

Pineywoods Woodland, Forest and Grassland Mosaic

The Pineywoods woodland, forest and grassland mosaic is a combination of a few characters from each individual habitat class. Woody plants that are mostly 9-30 ft. tall are growing with deciduous or evergreen trees that are dominant and mostly greater than 30 ft. tall. Between patches of woody vegetation grow herbs (grasses, forbs and grass-like plants) where woody vegetation is lacking or nearly so (generally 10% or less woody canopy cover). In this mosaic habitat there is a mix between absent canopy cover and areas with closed crowns or nearly so (71-100% canopy cover). In the areas with canopy cover, there ranges a lack of midstory to a midstory that is generally apparent except in managed monocultures (McMahan et al. 1984, Bridges et al. 2002). Only one plant association dominates this habitat class.

The *young forest and/or grassland* association includes various combinations and age classes of pine and regrowth southern red oak, sweetgum, post oak, white oak, black hickory, blackgum, elm, hackberry and water oak resulting from recent harvesting of pine or pine-hardwood forest and subsequent establishment of young pine plantation or young pine-hardwood forests. Typical associated shrubby vegetation includes hawthorn, poison oak, sumac, holly, wax myrtle, blueberry, blackberry and red bay. This community may also portray grasslands resulting from the clearing of forests (McMahan et al. 1984). This association is most commonly found throughout the Pineywoods ecoregion.

Urban Pineywoods Community

Urban habitats are cities or towns which are areas dominated by human dwellings including the fences, shrub rows, windbreaks and roads associated with their presence (Bridges at al. 2002). The biggest city in the Pineywoods is northern Houston and its associated suburbs. The next largest cities include Beaumont and Longview and their associated suburbs. Smaller prominent cities include Marshall, Texarkana, Nash, Wake Village, Atlanta, Queen City, Henderson, Jacksonville, Nacogdoches, Lufkin, Livingston, Conroe and Jasper.

High Priority Communities: A Further Emphasis

Weches glades consist of rock outcrops and occur in only a few locations within only two counties in the Pineywoods ecoregion. The soil is shallow therefore this community does not support much plant life. There are hardly any trees and the sites are very dry which is unique considering the wetter areas that surround these communities. These sites are home to mosses, grasses and two rare flowers that are found no where else in the world. The *weches glades* compare with the limestone outcrops of central and western Texas (Bezanson and Wolfe 2001). Presently, the *weches glades* are not protected for conservation and all sites are located on private lands (Bezanson and Wolfe 2001).

Longleaf pine forests and savannahs once covered millions of acres. Today, remnant stands are located in the southern portion of the Pineywoods ecoregion. *Longleaf pine forest* soils are typically sandy and thick with rock outcrops scattered throughout. Commonly associated species include dogwood, oak, pawpaw trees, grasses and wildflowers such as the rare trailing phlox. *Longleaf wetland savannah* soils are normally claypan, trapping water in wet conditions and drying out during the summer months. Species such as orchids, grasses, sedges, evergreen shrub species and carnivorous plants (sundew and pitcher plants) grow underneath scattered stands of longleaf pines. Today, a few examples of this community exist in the "Big Thicket" region of the Pineywoods ecoregion (Bezanson and Wolfe 2001). *Longleaf pine forests* are currently represented by only a few stands (the best examples in Angelina and Jasper counties), protected by timber companies and public agencies. By the mid-twentieth century most of the mature tress in this community were logged. Trees were replanted but only as monocultures of fast growing pine species. Approximately 95% of these original forests are now gone. *Longleaf wetland savannahs* are considered one of the rarest habitat communities and are also one of the most florally diverse of any other ecoregion (Bezanson and Wolfe 2001).

East Texas hardwood forests are found throughout the Pineywoods ecoregion. Many of these forests are the result of commercial pine plantations created from monoculture plantings, however there are still natural stands of forest existing. Natural forests are typically devoid of a midstory and commonly associated species include maple, hickory, elm, oak, redbud, dogwood, beech, blackgum, azalea, magnolia, hornbeam and pines (Bezanson and Wolfe 2001). The *East Texas hardwood-dominated upland and slope forests* are highly threatened as only a few small remaining areas of natural forests, located in parks and wildlife management areas, have been protected. There are more examples of *bottomland forests*, especially along the Neches River, that are managed by hunting clubs and timber companies. Presently, there are still large, natural tracts of bottomlands in this area (Bezanson and Wolfe 2001).

East Texas bogs are found in small isolated patches all over the eastern portion of Texas. These bogs are created from a clay base and sandy surface layer which prevents water from reaching the water table. Acidic soil conditions are formed because of the leaching of these saturated soils. Unique plants such as mosses, ferns, orchids and various carnivorous plants are found in these bogs. In the acidic soils of *baygalls and forested seeps* one can find wild azalea, orchids, ferns, epiphyte species and the rare and endangered Texas trillium. These communities are formed from seep-fed streams that drain boggy areas, then filling forested swamps (Bezanson and Wolfe 2001). Most *East Texas bogs* are not protected from logging, grazing, or other potentially detrimental activities, even those located in National Forests. These boggy areas are very small and scattered throughout East Texas, making them highly susceptible to unfavorable changes. *Baygalls and forested seeps* are present in even smaller numbers, found in only a few locations in East Texas such as the Big Thicket. It is estimated that less than 1,000 ac. of these acidic bogs and baygalls are protected for conservation (Bezanson and Wolfe 2001).

Problems Affecting the Pineywoods

See the Texas Priority Species List……………………733

Element 3

Longleaf pine forests and savannahs are threatened by overgrowth of midstory species and lack of natural fire, or fire management. This prevents sunlight from reaching grasses, wildflowers and lower-growing species, thus shading these species out of nutrients. It is estimated that only 5,000 ac. of *longleaf pine forests* are protected today (Bezanson and Wolfe 2001).

East Texas hardwood forest bottomlands are highly threatened by the proposition of reservoir construction to sustain the growing human population of surrounding cities and suburbs. *East Texas hardwood-dominated upland and slope forests* are even more threatened, and rare, since the majority has already been clear-cut and are now stands of monoculture forest. It is estimated that less than 10,000 ac. of hardwood-dominated slope forest are protected for conservation (Bezanson and Wolfe 2001).

East Texas bogs, baygalls and forested seeps are threatened by unsuitable logging and grazing practices and from the changes in local aquifers and watersheds which support a large number of these boggy areas. The suppression of fire is another detrimental factor. This creates overgrowth of brushy species, in turn smothering out these bog species (Bezanson and Wolfe 2001).

High Priority Research and Monitoring Efforts for the Pineywoods

See Monitoring and Adaptive Management………… 559
See the Texas Priority Species List……………………733

Element 5

- At this time, major community types in the Pineywoods forests are poorly represented. There is a need for the determination of suitable habitat sites for reintroduction of underrepresented flora in these communities
- Research on response of production and species diversity by season, frequency and environmental conditions (soil moisture, humidity, temperature, etc) of most effective prescribed fire

- Continue inventory and identification of important sites for diversity and protect those areas that remain

Element 4

High Priority Conservation Actions for the Pineywoods

See High Priority Conservation Strategies…………..517
See the Texas Priority Species List……………………733

- Fund broad coalition (environmental and agricultural, industry and private foundations) support for water conservation policies that have applications to insure instream flows to coastal estuaries and bays and healthy riparian ecosystems. Fund Joint Ventures and other partners that leverage resources to purchase or obtain conservation easements on critical or high priority sites (surface or water rights) vulnerable to loss or degradation
- Using current GIS; analyze the landscape and identify critical corridors with high conservation needs, support additional acquisition of lands for conservation, continue to promote LIP and Partners for Wildlife (PFW) programs for private landowners and actively pursue identification of funding sources for these conservation purchases
- Emphasize the importance of periodic prescribed fire and adopt/implement fire policies that mimic natural fire regimes in frequency, size, intensity, etc. Work with and support the Texas Forest Service and the National Forest Service in their prescribed burning programs. Support legislation that facilitates prescribed burning on private lands. Support private prescribed burning associations and promulgate right to burn laws
- Encourage small tract clear cuts rather than total area clear cuts
- Encourage the use of artificial habitats (e.g. artificial hollow trees, buildings, bat houses, replica hollow trees and caves)
- Encourage non-traditional forest management practices modeled after the south Georgia and north Florida quail hunting plantations (www.talltimbers.org) such as uneven-aged management and singletree selection harvest methods that maintain

southern pine stands in an open, park-like structure with less than 50% tree canopy cover

- Work to conserve wilderness areas by removing fire suppression policies
- Education through Technical Guidance – TAES/NRCS Seminars, Field Days, BW Brigade Summer Camps, 4-H Projects, literature on advantages of stock tanks and water for wildlife, offer SWG for challenge-cost share with NRCS for wetland reserve program and riparian buffers
- Continue educating landowners concerning best management practices for forest management, work with Texas Forestry Association to communicate the value of bottomland hardwood forests both ecologically and economically, work with Texas Logging Council to continue improvement of logging operations in bottomland hardwoods and continue to educate landowners concerning programs to restore bottomland hardwoods like LIP, PFW and Farm Bill programs
- Work with state, federal and private agencies to continue developing cost-effective means for removal of invasive species
- Educate and inform landowners about the effects of exotics on wildlife
- Fund research on invasive species such as with the Texas Invasive Species Monitoring Committee to assess risks and recommend policies that regulate importation of exotics
- Work with federal, state and private organizations to promote (incentives) leaving some cover for wildlife. The economic benefits of wildlife can sometimes equal or surpass the agricultural value of land
- Seek to prohibit or minimize grazing in riparian forests, fencing and develop alternative water sources for livestock

Tier III – Tertiary Priority: Post Oak Savannah Ecoregion

Associated Maps

Ecoregions of Texas………………………...1

Post Oak Savannah Ecoregion……………... 9

Element 1

Associated Section IV Documents

The Texas Priority Species List…………….733

Supplemental Mammal Information……….. 897

Supplemental Herptile Information……….... 988

Priority Species

Group	Species Name	Common Name	State/Federal Status
Birds	*Aimophila cassinii*	Cassin's sparrow	SC
	Aimophila ruficeps	Rufous-crowned sparrow	SC
	Amazilia yucatanensis	Buff-bellied hummingbird	SC
	Ammodramus savannarum	Grasshopper sparrow	SC
	Anas acuta	Northern pintail	SC
	Anthus spragueii	Sprague's pipit	SC
	Aquila chrysaetos	Golden eagle	SC
	Asio flammeus	Short-eared owl	SC
	Athene cunicularia	Burrowing owl	SC
	Aythya affinis	Lesser scaup	SC
	Aythya americana	Redhead	SC
	Aythya valisineria	Canvasback	SC
	Bartramia longicauda	Upland sandpiper	SC
	Botaurus lentiginosus	American bittern	SC
	Buteo lineatus	Red-shouldered hawk	SC
	Buteo regalis	Ferruginous hawk	SC

Buteo swainsoni	Swainson's hawk	SC
Calcarius mccownii	McCown's longspur	SC
Calidris himantopus	Stilt sandpiper	SC
Calidris mauri	Western sandpiper	SC
Caprimulgus carolinensis	Chuck-will's-widow	SC
Chaetura pelagica	Chimney swift	SC
Charadrius alexandrinus	Snowy plover	SC
Charadrius melodus	**Piping plover	FT/ST
Charadrius montanus	Mountain plover	SC
Chondestes grammacus	Lark sparrow	SC
Chordeiles minor	Common nighthawk	SC
Circus cyaneus	Northern harrier	SC
Cistothorus platensis	Sedge wren	SC
Coccyzus americanus	Yellow-billed cuckoo	SC
Colinus virginianus	Northern bobwhite	SC
Contopus virens	Eastern wood-pewee	SC
Coturnicops noveboracensis	Yellow rail	SC
Dendroica cerulea	Cerulean warbler	SC
Dendroica discolor	Prairie warbler	SC
Dendroica dominica	Yellow-throated warbler	SC
Dryocopus pileatus	Pileated woodpecker	SC
Egretta caerulea	Little blue heron	SC
Egretta thula	Snowy egret	SC
Egretta tricolor	Tri-colored heron	SC
Elanoides forficatus	Swallow-tailed kite	ST
Elanus leucurus	White-tailed kite	SC
Empidonax virescens	Acadian flycatcher	SC
Eremophila alpestris	Horned lark	SC
Falco columbarius	Merlin	SC

Falco mexicanus	Prairie falcon	SC
Falco peregrinus tundrius	Arctic peregrine falcon	ST
Falco sparverius	American kestrel (southeastern)	SC
Gallinago delicata	Wilson's snipe (formerly common snipe)	SC
Grus americana	**Whooping crane	FE/SE
Haliaeetus leucocephalus	Bald Eagle	FT/ST
Helmitheros vermivorum	Worm-eating warbler	SC
Himantopus mexicanus	Black-necked stilt	SC
Hylocichla mustelina	Wood thrush	SC
Icterus spurius	Orchard oriole	SC
Ictinia mississippiensis	Mississippi kite	SC
Ixobrychus exilis	Least bittern	SC
Lanius ludovicianus	Loggerhead shrike	SC
Limnodromus griseus	Short-billed dowitcher	SC
Limnothlypis swainsonii	Swainson's warbler	SC
Limosa haemastica	Hudsonian godwit	SC
Melanerpes aurifrons	Golden-fronted woodpecker	SC
Melanerpes erythrocephalus	Red-headed woodpecker	SC
Mycteria americana	**Wood stork	ST
Myiarchus crinitus	Great crested flycatcher	SC
Numenius americanus	Long-billed curlew	SC
Nyctanassa violacea	Yellow-crowned night-heron	SC
Oporornis formosus	Kentucky warbler	SC
Passerina ciris	Painted bunting	SC
Pegadis chihi	White-faced ibis	ST
Pelecanus erythrorhynchos	American white pelican	SC
Picoides scalaris	Ladder-backed woodpecker	SC
Picoides villosus	Hairy woodpecker	SC

Platalea ajaja	Roseate spoonbill	SC
Pluvialis dominica	American golden-plover	SC
Podiceps auritus	Horned grebe	SC
Podiceps nigricollis	Eared grebe	SC
Porphyrio martinica	Purple gallinule	SC
Protonotaria citrea	Prothonotary warbler	SC
Rallus elegans	King rail	SC
Rallus limicola	Virginia rail	SC
Recurvirostra americana	American avocet	SC
Scolopax minor	American woodcock	SC
Seiurus motacilla	Louisiana waterthrush	SC
Spiza americana	Dickcissel	SC
Spizella pusilla	Field sparrow	SC
Sterna antillarum	**Least tern (interior)	FE/SE
Sterna forsteri	Forster's tern	SC
Sturnella magna	Eastern meadowlark	SC
Sturnella neglecta	Western meadowlark	SC
Thryomanes bewickii	Bewick's wren (eastern)	SC
Toxostoma curvirostre	Curve-billed thrasher	SC
Toxostoma rufum	Brown thrasher	SC
Tringa flavipes	Lesser yellowlegs	SC
Tringa melanoleuca	Greater yellowlegs	SC
Tringa solitaria	Solitary sandpiper	SC
Tryngites subruficollis	Buff-breasted sandpiper	SC
Tympanuchus cupido attwateri	**Greater prairie-chicken (Attwater's)	FE/SE
Tyrannus forficatus	Scissor-tailed flycatcher	SC
Tyrannus tyrannus	Eastern kingbird	SC
Vermivora chrysoptera	Golden-winged warbler	SC
Vermivora pinus	Blue-winged warbler	SC

	Vireo atricapillus	**Black-capped vireo	FE/SE
	Vireo bellii	Bell's vireo	SC
	Vireo flavifrons	Yellow-throated vireo	SC
	Vireo gilvus	Warbling vireo	SC
	Wilsonia citrina	Hooded warbler	SC
	Wilson's Phalarope	Wilson's phalarope	SC
	Zenaida macroura	Mourning dove	SC
	Zonotrichia querula	Harris's sparrow	SC
Mammals	*Blarina carolinensis*	Southern short-tailed shrew	SC
	Blarina hylophaga plumblea	Elliot's short-tailed shrew	SC
	Geomys attwateri	Attwaters pocket gopher	SC
	Mustela frenata	Long-tailed weasel	SC
	Myotis austroriparius	Southeastern myotis	SC
	Puma concolor	Mountain lion	SC
	Sylvilagus aquaticus	Swamp rabbit	SC
	Tadarida brasiliensis	Brazilian free-tailed bat	SC
	Taxidea taxus	American badger	SC
Reptiles	*Bufo houstonensis*	**Houston toad	FE
	Crotalus horridus	Timber rattlesnake	ST
	Deirochelys reticularia	Chicken turtle	SC
	Ophisaurus attenuatus	Slender glass lizard	SC
	Phrynosoma cornutum	Texas horned lizard	ST
	Scaphiopus hurterii	Hurter's spadefoot	SC
	Sistrurus catenatus	Massasauga	SC
	Terrapene spp.	Box turtles	SC

Group	Family	Species Name	Federal Status
Invertebrates			
	Stylommatophora (Gastropoda)		
	Polygyridae	*Euchemotrema leai cheatumi*	SC
	Polydesmida (Myriapoda)		
	Polydesmidae	*Speodesmus falcatus*	SC
	Polydesmidae	*Speodesmus ivyi*	SC
	Polydesmidae	*Speodesmus reddelli*	SC
	Araneae (Arachnida)		
	Dictynidae	*Cicurina baronia*	FE
	Dictynidae	*Cicurina gatita*	SC
	Dictynidae	*Cicurina madla*	FE
	Dictynidae	*Cicurina medina*	SC
	Dictynidae	*Cicurina minorata (Gersch and Davis)*	SC
	Dictynidae	*Cicurina venii*	FE
	Dictynidae	*Cicurina vespera*	FE
	Leptonetidae	*Neoleptoneta new species*	SC
	Nesticidae	*Eidmannella nasuta (Gertsch)*	SC
	Pseudoscorpiones (Arachnida)		
	Neobisiidae	*Tartarocreagris cookei*	SC
	Neobisiidae	*Tartarocreagris reyesi*	SC
	Coleoptera (Insecta)		
	Carabidae	*Rhadine exilis*	FE
	Carabidae	*Rhadine infernalis*	FE
	**Silphidae	*Nicrophorus americanus*	FE
	Staphylinidae (Pselaphinae)	*Batrisodes (Babnormodes) uncicornis (Casey)*	SC
	Lepidoptera (Insecta)		

Hesperiidae	*Megathymus streckeri texanus*	SC
Hymenoptera (Insecta)		
Apoidea	*Andrena (Scrapteropsis) flaminea (LaBerge)*	SC
Apoidea	*Colletes bumeliae (Neff)*	SC
Apoidea	*Colletes inuncantipedis (Neff)*	SC
Apoidea	*Eucera (Synhalonia) birkmanniella (Cockerell)*	SC
Apoidea	*Hesperapis (Carinapis) sp. B*	SC
Apoidea	*Megachile (Megachiloides) parksi (Mitchell)*	SC
Apoidea	*Osmia (Diceratosmia) botitena (Cockerell)*	SC
Apoidea	*Perdita (Hexaperdita) alexi (Timberlake)*	SC
Apoidea	*Perdita (Hexaperdita) fedorensis (Cockerell)*	SC
Apoidea	*Perdita (Perdita) atriventris (Timberlake)*	SC
Apoidea	*Perdita (Perdita) crotonis decipiens (Timberlake)*	SC

Location and Condition of the Post Oak Savannah Ecoregion

Element 2

Lying immediately west of the East Texas Pineywoods, the Post Oak Savannah emerges and changes almost imperceptibly in soils and vegetation. Occupying approximately 8,500,000 ac., the area's topography is gently rolling to hilly with elevations ranging from 300 to 800 ft. above MSL, and rainfall averages from 35 to 45 in. per year from west to east. Annual average temperatures range from 65°F to 70°F. Soils of the Post Oak Savannah are interesting and complex. They are usually acidic, with sands and sandy loams occurring on the uplands, clay to clay loams on the bottomlands and with dense clay pan underlying all soil types. Because of this peculiarity, the Post Oak Savannah is sometimes referred to as the "Clay Pan Savannah". Clay pan soils are nearly impervious to water and underlie the surface layers of soil at depths of only a few feet. As a consequence, the moisture available for plant growth is limited making the habitat surprisingly arid at times. One curious exception to the clay pan soils occurs in Bastrop

County, home of the Lost Pines. The Carrizo Sands, a sandy inclusion of moist soils, harbor a unique community of loblolly pine, post oak and blackjack oak and are also home to sphagnum bogs with ferns and pitcher plants.

The Post Oak Savannah is punctuated by scattered oaks, mainly post and blackjack oaks (Wasowski 1988). Black hickory may also be locally abundant. Widespread trees of lesser importance include cedar elm, sugarberry, eastern red cedar and common persimmon. Other important species of the region are southern red oak, sassafras, flowering dogwood, yaupon and winged elm. Some authorities believe that this region was once predominantly a tall-grass prairie, but trees, mostly oaks and brushy shrubs proliferated with the suppression of fires and the conversion of the land to farming and grazing. When fires were frequent, the land was not as it appears today. Historically, wide vistas of tallgrasses such as little bluestem, Indiangrass, switchgrass and a myriad of wildflowers, broken only by the occasional motte of venerable "giants", lent a park-like appearance to the landscape. Peat bogs, like the ones found in the Pineywoods, are also found here, mingled amongst stands of flowering dogwood, sassafras, bumelia and yaupon.

Early European settlers were especially attracted to the Post Oak Savannah because it was clearly transitional between woodland and prairies (Wasowski 1988). Today, the Post Oak Savannah is used largely for improved pasture, with vast acreages seeded to introduce grasses such as Bahia grass or Bermuda grass (Simpson 1988). Mostly prairie animals with some woodland species abound in the Post Oak Savannah region. The distinctive sandy inclusion of the Lost Pines area also harbors one of the last refuges for the endangered Houston toad.

This ecoregion can be broken down into six main habitat classes consisting of grassland, forest, native and introduced grasses, parkland woodland mosaic, woodland, forest and grassland mosaic, and urban.

Post Oak Savannah Grassland

Grasslands consist of herbs (grasses, forbs and grass-like plants) which are dominant. Woody vegetation is lacking or nearly so (generally 10% or less woody canopy cover) (McMahan et al.1984). There is only one dominant plant association found in the Post Oak Savannah grassland.

The *silver bluestem-Texas wintergrass* association includes little bluestem, sideoats grama, Texas grama, three-awn, hairy grama, tall dropseed, buffalograss, windmillgrass, hairy tridens, tumblegrass, western ragweed, broom snakeweed, Texas bluebonnet, live oak, post oak and mesquite (McMahan et al. 1984). This is a broadly defined association where secondary species vary with the type of soil encountered, such as loamy Alfisols or clay Vertisols (Diamond 1993). This association is found primarily in the Cross Timbers and Prairies ecoregion, however a small section crosses into the Post Oak Savannah ecoregion (McMahan et al. 1984). Cross-referenced communities: 1) little bluestem-Indiangrass series (Diamond 1993), 2) upland mollisol tall grassland (Bezanson 2000), and 3) little bluestem-sideoats grama herbaceous alliance (Weakley et al. 2000). The *silver-bluestem-Texas wintergrass* association is considered imperiled, or very rare, globally and it is endangered throughout its range. It is determined that 6-20 occurrences are documented (Diamond 1993). This association is also considered imperiled, or very rare, throughout the state and therefore this it is considered vulnerable to extirpation within the state (Diamond 1993). According to Bezanson (2000) this community is a high priority for further protection.

Post Oak Savannah Forest

The Post Oak Savannah forest consists of deciduous or evergreen trees that are dominant in the landscape. These species are mostly greater than 30 ft. tall with closed crowns or nearly so (71-100% canopy cover). The midstory is generally apparent except in managed monocultures (McMahan et al. 1984, Bridges et al. 2002). Four plant associations, one with two subtypes, dominate this habitat class.

American elm, cedar elm, cottonwood, sycamore, black willow, live oak, Carolina ash, bald cypress, water oak, hackberry, virgin's bower, yaupon, greenbriar, mustang grape, poison oak, Johnsongrass, Virginia wildrye, Canada wildrye, rescuegrass, frostweed and western ragweed are species commonly found in the *pecan-elm* association (McMahan et al 1984). This community is a broadly defined deciduous forest typically found along major rivers, bottomlands and mesic slopes where soils are often heavily textured and calcareous (Diamond 1993). This community is found along the Brazos, Colorado, Guadalupe, San Antonio and Frio river basins as well as the areas of the Navidad, San Bernard and Lavaca rivers (McMahan et al 1984). Cross-referenced communities: 1) sugarberry-elm series, pecan-sugarberry series (Diamond 1993), 2) sugarberry-elm floodplain forests (South Texas Plains) (Bezanson 2000), and 3) plateau oak-sugarberry woodland alliance, sugarberry-cedar elm temporarily flooded forest alliance, pecan-(sugarberry) temporarily flooded forest alliance (Weakley et al. 2000). The *pecan-elm* community is apparently secure within the state as well as globally (Diamond 1993). However, there are very few mature examples of the dominant plants in this community. The locations in south Texas that do exist are not very well protected but there are many examples of this community in other ecoregions. Due to this, Bezanson (2000) suggests to rank this community as a medium priority for further protection in south Texas.

<u>Pine hardwood (subtype 2)</u>- The *shortleaf pine-post oak-southern red oak* association includes loblolly pine, black hickory, sandjack oak, flowering dogwood, common persimmon, sweetgum, sassafras, greenbriar, yaupon, wax myrtle, American beautyberry, hawthorn, supplejack, winged elm, beaked panicum, spranglegrass, Indiangrass, switchgrass, three-awn, bushclover and tickclover (McMahan et al. 1984). Soils are typically either sandy or loamy and range from deep to shallow, with the pines occurring in the more shallow areas (Diamond 1993). This association is found in the northeastern Texas counties of Bowie, Red River, Lamar, Cass, Camp, Titus, Franklin, Marion, Harrison, Upshur, Gregg, Smith, Wood and Morris. It continues to extend into the southeastern portion of the Pineywoods, typically along deep sand ridges (McMahan et al. 1984). Cross-referenced communities: 1) upper slope pine oak forest (Marks and Harcombe 1981), 2) shortleaf pine-oak series, post oak-black hickory series (Diamond 1993), 3) upland hardwood-pine forests (Bezanson 2000), and 4) shortleaf pine-(white oak, southern red oak, post oak, black oak) forest alliance, loblolly pine-(blackjack oak, southern red oak, post oak) forest alliance, shortleaf pine forest alliance (Weakley et al.

2000). The *shortleaf pine-post oak-southern red oak* community is considered a fairly low priority for further protection. Approximately 10,000 ac. of this community is protected presently (Bezanson 2000).

Pine hardwood (subtype 3)- The *loblolly pine-post oak* association includes black hickory, blackjack oak, eastern red cedar, cedar elm, hackberry, greenbriar, yaupon, elbowbush, purpletop, sand lovegrass, broomsedge bluestem, little bluestem, brownseed paspalum, bushclover, tickclover, gay feather, yellow neptunia, bitter sneezeweed and velvet bundleflower (McMahan et al. 1984). Soils are typically sandy and shallow (Diamond 1993). This community is associated with the "Lost Pines" in Bastrop County and westward of the pine producing region of East Texas (McMahan et al. 1984). Cross-referenced communities: 1) loblolly pine-post oak upland forest (Bezanson 2000). The *loblolly pine-post oak* community is considered a fairly low priority for further protection. Over 6,000 ac. of the *loblolly pine-post oak* community is protected presently (Bezanson 2000).

The *water oak-elm-hackberry* association includes cedar elm, American elm, willow oak, southern red oak, white oak, black willow, cottonwood, red ash, sycamore, pecan, bois d'arc, flowering dogwood, dewberry, coral-berry, dallisgrass, switchgrass, rescuegrass, Bermuda grass, eastern gamagrass, Virginia wildrye, Johnsongrass, giant ragweed and Leavenworth eryngo. This association typically occurs in the upper flood plains of the Sabine, Neches, Sulphur and Trinity rivers and tributaries (McMahan et al. 1984). Cross-referenced communities: 1) water oak-post oak floodplain forests (Bezanson 2000). The *water oak-elm-hackberry* community is considered of low priority for further protection since this community is generally unthreatened even though not many examples of this association are protected (Bezanson 2000).

The *willow oak-water oak-blackgum* association includes beech, overcup oak, chestnut oak, cherrybark oak, elm, sweetgum, sycamore, southern magnolia, white oak, black willow, bald cypress, swamp laurel oak, hawthorn, bush palmetto, common elderberry, southern arrowwood, poison oak, supplejack, trumpet creeper, crossvine, greenbriar, blackberry, rhomboid copperleaf and St. Andrew's Cross (McMahan et al. 1984). This is a broadly defined community made up of deciduous vegetation that prefers bottomland floodplains of major streams (Diamond 1993). This community is most commonly found in the lower flood plains of the Sulphur, Neches, Angelina, Trinity and Sabine rivers in the Pineywoods; however, it extends into the northernmost portion of the Gulf Coast Prairies and Marshes ecoregion (McMahan et al. 1984). Cross-referenced communities: 1) sweetgum-willow oak (SAF #92) (Eyre 1980), 2) floodplain hardwood forest (Marks and Harcombe 1981), 3) water oak-willow oak series (Diamond 1993), 4) loblolly pine/water oak ridges (Mundorff 1998), 5) wet floodplain forests, wet flatland forests (Turner 1999), 6) floodplain hardwood forests (Bezanson 2000), and 7) (willow oak, water oak, diamondleaf oak) temporarily flooded forest alliance (Weakley et al. 2000). The *willow oak-water oak-blackgum* community is apparently secure globally with over 100 occurrences documented. There are areas in this community's range where it is considered rare, especially at the periphery. This community is considered rare or uncommon within the state with only 21-100 known occurrences (Diamond 1993).

Post Oak Savannah Native and Introduced Grasses

A mixture of native and introduced grasses which includes herbs (grasses, forbs and grass-like plants) that are dominant with woody vegetation lacking or nearly so (generally 10% or less woody canopy cover). These associations typically result from the invasion of non-native grass species originating from the planting of these non-natives (e.g. Bermuda, KR bluestem, etc.) for roadsides and rangelands. The clearing of woody vegetation is another factor and is sometimes associated with the early stages of a young forest. This community can quickly change as removed brush begins to regrow (McMahan et al. 1984, Bridges et al. 2002).

Post Oak Savannah Parkland Woodland Mosaic

The parkland woodland mosaic can be best described by pastures or fields with widely scattered vegetation (trees and/or shrubs) covering 10-25% of the ground (Bridges et al. 2002). There is only one plant association related to this habitat class.

The *elm-hackberry* association includes mesquite, post oak, woollybucket bumelia, honey locust, coral-berry, pasture haw, elbowbush, Texas prickly pear, tasajillo, dewberry, silver bluestem, buffalograss, western ragweed, giant ragweed, goldenrod, frostweed, ironweed, prairie parsley and broom snakeweed. Mesic slopes and floodplains are what this broadly defined deciduous forest prefers. This association typically occurs within the Blackland Prairie ecoregion, primarily in Ellis, Navarro and Limestone counties. However, an extension of this association is found in the Post Oak Savannah as well (McMahan et al. 1984). Cross-reference communities: 1) sugarberry-elm series (Diamond 1993), 2) sugarberry-elm floodplain forests (Bezanson 2000), and 3) sugarberry-cedar elm temporarily flooded forest alliance (Weakley et al. 2000). The *elm-hackberry* community is considered demonstratably secure globally and within the state of Texas (Diamond 1993). It is suggested that this community is of low priority for further protection (Bezanson 2000).

Post Oak Savannah Woodland, Forest and Grassland Mosaic

The Post Oak Savannah woodland, forest and grassland mosaic is a combination of a few characters from each individual habitat class. Woody plants that are mostly 9-30 ft. tall are growing with deciduous or evergreen trees that are dominant and mostly greater than 30 ft. tall. Between patches of woody vegetation grow herbs (grasses, forbs and grass-like plants) where woody vegetation is lacking or nearly so (generally 10% or less woody canopy cover). In this mosaic habitat, there is a mix between absent canopy cover and areas with closed crowns or nearly so (71-100% canopy cover). In the areas with canopy cover, there ranges a lack of midstory to a midstory that is generally apparent except in managed monocultures (McMahan et al. 1984, Bridges et al. 2002). Only one plant association dominates this habitat class.

Blackjack oak, eastern red cedar, mesquite, black hickory, live oak, sandjack oak, cedar elm, hackberry, yaupon, poison oak, American beautyberry, hawthorn, supplejack, trumpet creeper, dewberry, coral-berry, little bluestem, silver bluestem, sand lovegrass, beaked panicum, three-awn, spranglegrass and tickclover are species commonly associated with the *post oak* association. This community is most commonly found in sandy soils in the Post Oak Savannah (McMahan et al 1984). Cross-referenced communities: 1) post oak-blackjack oak series (Diamond 1993), 2) post oak-blackjack oak upland forest and woodlands (Bezanson 2000), and 3) post oak-blackjack oak forest alliance, post oak-blackjack oak woodland alliance (Weakley et al. 2000). The *post oak* community is considered demonstratably secure globally and within the state of Texas (Diamond 1993). It is suggested that this community is of low priority for further protection (Bezanson 2000).

Post Oak Savannah Urban Community

Urban habitats are cities or towns which are areas dominated by human dwellings including the fences, shrub rows, windbreaks and roads associated with their presence (Bridges at al. 2002). The biggest cities in the Post Oak Savannah community are Tyler, Bryan and College Station. Smaller prominent cities include Paris, Mount Pleasant, Mineola, Athens, Palestine, Giddings, Bastrop and Gonzales.

High Priority Communities: A Further Emphasis

East Texas bogs are found in small isolated patches all over the eastern portion of Texas. These bogs are created from a clay base and sandy surface layer, this preventing water to sink to the water table. Acidic soil conditions are formed because of the leaching of these saturated soils. Unique plants such as mosses, ferns, orchids and various carnivorous plants are found in these bogs. In the acidic soils of *baygalls and forested seeps* one can find wild azalea, orchids, ferns, epiphyte species and the rare and endangered Texas trillium. These communities are formed from seep-fed streams that drain boggy areas, then filling forested swamps (Bezanson and Wolfe 2001). Most *East Texas bogs* are not protected from logging, improper grazing techniques, or other potentially detrimental activities, even those located in National Forests. These boggy areas are very tiny and scattered throughout East Texas making them highly susceptible to unfavorable changes. *Baygalls and forested seeps* are present in even smaller numbers, found in only a few locations in East Texas such as the Big Thicket. It is estimated that less than 1,000 ac. of these acidic bogs and baygalls are protected for conservation (Bezanson and Wolfe 2001).

East Texas bogs, baygalls and forested seeps are threatened by unsuitable logging and grazing practices and from the changes in local aquifers and watersheds which support a large number of these boggy areas. The suppression of fire is another detrimental factor.

This creates overgrowth of brushy species, in turn smothering out these bog species (Bezanson and Wolfe 2001).

Before the 1800's *tallgrass prairies* covered approximately 20 million ac. of Texas. A continuous extent of this grassland community ranged from San Antonio to the Red River. Since then, 98% of these prairies have been converted for agricultural uses and urban development. This is potentially the "most dramatic loss of habitat in Texas" (Bezanson and Wolfe 2001). These tallgrass prairies are composed of dark clay soils which are very fertile. Wildflowers and native grasses such as bluestem, grama grasses, dropseed, tridens, switchgrass and Indiangrass dominate this community in the spring and summer months (Bezanson and Wolfe 2001).

Presently, approximately 95% of the original coastal prairies have been converted for agricultural uses and urban cities. Only 3,000 ac. of an original 12 million acre range of blackland prairie remains in the Dallas/Fort Worth and San Antonio metroplexes. The remaining acreages of prairie are in small patches and are too threatened by various types of development. Presently, most of this acreage is used for hay meadows by private landowners who help to stimulate production without harming diversity and health (Bezanson and Wolfe 2001).

The *Eocene sand barrens* of the South Texas Plains are considered a critical habitat for further protection. This key community consists of deep, isolated sand dunes that occur on Eocene sandstone formations. Typically these outcrops are located in post oak woodlands in south and East Texas. These communities are known to support endangered plants such as the large-fruited sand verbena, one of the many rare endemic species located in these "barrens" (Bezanson and Wolfe 2001). According to Bezanson (2000) there are no known *Eocene sand dune* communities that are protected. Since these locations are small it would be very easy for conservation organizations to protect these key communities by buying land or through private landowner agreements.

The *Eocene sand dunes* are most threatened from subdivision growth from an increase in the human population (Bezanson and Wolfe 2001).

Problems Affecting the Post Oak Savannah

See the Texas Priority Species List……………………733

The key problems facing the *tallgrass prairie* are agriculture, development, public perception and invasive species. Historically, the prairie soils were highly sought after for agricultural production. Within the urban areas this isn't so much of a problem, but with the urban sprawl trend, we are potentially developing in former agricultural areas that have potential for restoration efforts. The combination of agriculture and development has created a unique challenge for restoration efforts due to the heavy soil modification that has occurred. Many of the plants associated with this area are very sensitive to specific soil conditions. The second challenge presented by development is the "open, grassy" areas that are easier to build on, and the developer does not have to mitigate nearly as much compared to tree removal. This is where the challenge of public perception and awareness comes into play. Trees are more highly valued than tall grass in this urban area. Areas of tall grasses are perceived as "weedy" and "unkept", so city ordinances often discourage the growth of tall grasses. The final problem that needs to be addressed is invasive, exotic species.

Element 3

In areas that are being allowed to grow as a prairie, constraints such as fire bans, are causing remaining blackland prairie areas to be shaded by the encroachment of woody species. This trend is also seen in the rural areas outside of major cities. *Tallgrass prairies* are most threatened by agricultural land conversion, ranching and urban sprawl (Bezanson and Wolfe 2001).

High Priority Research and Monitoring Efforts for the Post Oak Savannah

See Monitoring and Adaptive Management………… 559
See the Texas Priority Species List……………………733

- Baseline - Ascertain the current condition of those remnants that are left.
- Further Research - Seed analysis of the seedbanks in the remaining remnants to determine what seed mixes are the "most natural"

Element 5

- A public survey of the perceptions about trees and grasses would be nice for a better understanding of the public mentality
- Practicality - Techniques must be easy to understand for individuals without a strong agricultural background, and able to show a relatively high yield in a short amount of time
- Identify, map and ground truth locations and habitats

Element 4

High Priority Conservation Actions for the Post Oak Savannah

See High Priority Conservation Strategies…………..517

See the Texas Priority Species List……………………733

- State level – In this region, we should consider mitigating to grass before mitigating to trees. We need to, and currently are, working with cities to write ordinances that allow for taller grass and forbs species to grow. It is difficult to do restoration when a large number of the plants are going to be restricted
- Regionally or Statewide – Consider shifting priorities for mitigation. Recently, The Texas Department of Transportation (TxDOT) has considered working with Texas Parks and Wildlife on a prairie restoration and maintenance project to mitigate for tree removal on one of their own projects. The initial proposal called for planting trees in the "open space", better known as the blackland prairie remnant
- Regionally - Educate the general public of the ecological importance of prairie ecosystems. As it stands, much of the general public views tall grass, and especially tall wet grass, as areas with little purpose or function. This leads to very little protection being provided to grassland areas. Currently, developers are required to mitigate if they remove certain tree species or disrupt wetland areas (not including ephemeral wetland)
- Encourage cities to modify mowing regimes and start prairie restoration projects.

Rolling Plains Ecoregion

Associated Maps

Ecoregions of Texas………………………...1

Rolling Plains Ecoregion…………………... 10

Associated Section IV Documents

The Texas Priority Species List…………….733

Supplemental Mammal Information……….. 897

Supplemental Herptile Information………... 988

Element 1

Priority Species

Group	Species Name	Common Name	State/Federal Status
Birds	*Aimophila cassinii*	Cassin's sparrow	SC
	Aimophila ruficeps	Rufous-crowned sparrow	SC
	Ammodramus bairdii	Baird's sparrow (42 accepted state records)	SC
	Ammodramus savannarum	Grasshopper sparrow	SC
	Amphispiza bilineata	Black-throated sparrow	SC
	Anas acuta	Northern pintail	SC
	Anthus spragueii	Sprague's pipit	SC
	Aquila chrysaetos	Golden eagle	SC
	Asio flammeus	Short-eared owl	SC
	Athene cunicularia	Burrowing owl	SC
	Aythya affinis	Lesser scaup	SC
	Aythya americana	Redhead	SC
	Aythya valisineria	Canvasback	SC
	Bartramia longicauda	Upland sandpiper	SC
	Botaurus lentiginosus	American bittern	SC
	Buteo lagopus	Rough-legged hawk	SC

Buteo regalis	Ferruginous hawk	SC
Buteo swainsoni	Swainson's hawk	SC
Calcarius mccownii	McCown's longspur	SC
Calidris alba	Sanderling	SC
Calidris canutus	Red knot	SC
Calidris himantopus	Stilt sandpiper	SC
Calidris mauri	Western sandpiper	SC
Callipepla squamata	Scaled quail	SC
Campylorhynchus brunneicapillus	Cactus wren	SC
Caprimulgus carolinensis	Chuck-will's-widow	SC
Catherpes mexicanus	Canyon wren	SC
Chaetura pelagica	Chimney swift	SC
Charadrius alexandrinus	Snowy plover	SC
Charadrius melodus	**Piping plover	FT/ST
Charadrius montanus	Mountain plover	SC
Chondestes grammacus	Lark sparrow	SC
Chordeiles minor	Common nighthawk	SC
Circus cyaneus	Northern harrier	SC
Coccyzus americanus	Yellow-billed cuckoo	SC
Colinus virginianus	Northern bobwhite	SC
Contopus virens	Eastern wood-pewee	SC
Coturnicops noveboracensis	Yellow rail	SC
Dendroica discolor	Prairie warbler	SC
Dendroica dominica	Yellow-throated warbler	SC
Egretta thula	Snowy egret	SC
Eremophila alpestris	Horned lark	SC
Falco columbarius	Merlin	SC
Falco peregrinus tundrius	Arctic peregrine falcon	ST

Gallinago delicata	Wilson's snipe (formerly common snipe)	SC
Haliaeetus leucocephalus	Bald Eagle	FT/ST
Helmitheros vermivorum	Worm-eating warbler	SC
Himantopus mexicanus	Black-necked stilt	SC
Icterus parisorum	Scott's oriole	SC
Icterus spurius	Orchard oriole	SC
Ictinia mississippiensis	Mississippi kite	SC
Ixobrychus exilis	Least bittern	SC
Lanius ludovicianus	Loggerhead shrike	SC
Limnodromus griseus	Short-billed dowitcher	SC
Limosa fedoa	Marbled godwit	SC
Limosa haemastica	Hudsonian godwit	SC
Melanerpes aurifrons	Golden-fronted woodpecker	SC
Melanerpes erythrocephalus	Red-headed woodpecker	SC
Myiarchus crinitus	Great crested flycatcher	SC
Numenius americanus	Long-billed curlew	SC
Numenius phaeopus	Whimbrel	SC
Nyctanassa violacea	Yellow-crowned night-heron	SC
Oporornis formosus	Kentucky warbler	SC
Parus atricristatus	Black-crested titmouse	SC
Passerina ciris	Painted bunting	SC
Pegadis chihi	White-faced ibis	ST
Pelecanus erythrorhynchos	American white pelican	SC
Phalaropus tricolor	Wilson's phalarope	SC
Picoides scalaris	Ladder-backed woodpecker	SC
Picoides villosus	Hairy woodpecker	SC
Pluvialis dominica	American golden-plover	SC
Podiceps auritus	Horned grebe	SC
Podiceps nigricollis	Eared grebe	SC

Protonotaria citrea	Prothonotary warbler	SC
Rallus elegans	King rail	SC
Rallus limicola	Virginia rail	SC
Recurvirostra americana	American avocet	SC
Scolopax minor	American woodcock	SC
Seiurus motacilla	Louisiana waterthrush	SC
Spiza americana	Dickcissel	SC
Spizella pusilla	Field sparrow	SC
Sterna antillarum	**Least tern (interior)	FE/SE
Sterna forsteri	Forster's tern	SC
Sturnella magna	Eastern meadowlark	SC
Sturnella neglecta	Western meadowlark	SC
Toxostoma curvirostre	Curve-billed thrasher	SC
Tringa flavipes	Lesser yellowlegs	SC
Tringa melanoleuca	Greater yellowlegs	SC
Tringa solitaria	Solitary sandpiper	SC
Tryngites subruficollis	Buff-breasted sandpiper	SC
Tympanuchus pallidicinctus	Lesser prairie-chicken	SC
Tyrannus forficatus	Scissor-tailed flycatcher	SC
Tyrannus tyrannus	Eastern kingbird	SC
Tyrannus vociferans	Cassin's kingbird	SC
Vermivora chrysoptera	Golden-winged warbler	SC
Vireo atricapillus	**Black-capped vireo	FE/SE
Vireo bellii	Bell's vireo	SC
Vireo flavifrons	Yellow-throated vireo	SC
Vireo gilvus	Warbling vireo	SC
Vireo vicinior	Gray vireo	SC
Zonotrichia querula	Harris's sparrow	SC

Mammals	*Antilocapra americana*	Pronghorn	SC
	Antrozous pallidus	Pallid bat	SC
	Conepatus leuconotus	Hog-nosed skunk	SC
	Corynorhinus townsendii	**Townsend's big-eared bat	SC
	Cratogeomys castanops	Yellow-faced pocket gopher	SC
	Cynomys ludovicianus	Black-tailed prairie dog	SC
	Dipodomys elator	Texas kangaroo rat	ST
	Erethizon dorsatum	Porcupine	SC
	Microtus ochrogaster	Prairie vole	SC
	Mustela frenata	Long-tailed weasel	SC
	Mustela nigripes	Black-footed ferret	FE/SE
	Myotis velifer	Cave myotis	SC
	Nyctinomops macrotis	Big free-tailed bat	SC
	Peromyscus truei comanche	Palo Duro mouse	ST
	Puma concolor	Mountain lion	SC
	Spilogale gracilis	Western spotted skunk	SC
	Spilogale putorius	Eastern spotted skunk	SC
	Tadarida brasiliensis	Brazilian free-tailed bat	SC
	Taxidea taxus	American badger	SC
	Vulpes velox	Swift fox (Kit fox)	SC
Reptiles	*Crotalus viridis*	Prairie rattlesnake	SC
	Graptemys spp.	**Map turtles	FC/ST
	Holbrookia propinqua	Keeled earless lizard	SC
	Ophisaurus attenuatus	Slender glass lizard	SC
	Phrynosoma cornutum	Texas horned lizard	ST
	Phrynosoma modestum	Round-tailed horned lizard	SC
	Sistrurus catenatus	Massasauga	SC
	Terrapene spp.	Box turtles	SC

Group	Family	Species Name	Federal Status
Invertebrates			
	Araneae (Arachnida)		
	Dictynidae	*Cicurina hexops (Chamberlin and Ivie)*	SC
	Dictynidae	*Cicurina microps (Chamberlin and Ivie)*	SC
	Linyphiidae	*Islandiana unicornis Ivie*	SC
	Hymenoptera (Insecta)		
	Apoidea	*Protandrena (Protandrena) maurula (Cockerell)*	SC

Element 2

Location and Condition of the Rolling Plains Ecoregion

Marking the southern end of the Great Plains of the central United States, the Rolling Plains represents the "last gasp" of a great continental prairie ecosystem. As its name suggests, topography of the Rolling Plains is gently rolling to moderately rough, with elevations ranging from 800 to 3,000 ft. above MSL. Rainfall averages between 30 in. in the east to 22 in. in the west (Correll and Johnston 1979). The average annual temperature is 62 °F. Most of the soils are neutral to slightly basic. Named for the soils, the land is a varied and beautiful assortment of reds, from burnt sienna to the palest of pinks (Wasowski 1984). East of the Cap Rock, on heavier clay soils, the native prairies of the Rolling Plains consisted of midgrass and tallgrass communities nurtured by the intense summer rains and hot summer days. Pristine pockets of prairie are a rarity today, however. Much of what was once a sweeping expanse of sideoats grama, little bluestem and blue grama has been tilled for grain fields or cotton. In many areas, overgrazing has allowed honey mesquite and shinnery oak to spread into the prairies, along with snakeweed and prickly-pear. Trees occurring along waterways and canyons of the Caprock include plains cottonwood, Mohr oak, netleaf hackberry, one-seed juniper and Rocky Mountain juniper.

The gently rolling hills and broad flats of the Rolling Plains are the birthplace of many great Texas rivers including the Colorado, Concho and Red River which originate in the brakes of the Cap Rock Escarpment and in the western reaches of the region. These rivers and their tributaries harbor their own unique inhabitants such as the Concho water snake and Brazos water snake which live only in a few restricted areas of the Colorado and Brazos river systems respectively. Sand bars in the upper reaches of these rivers provide nesting habitat for the rare interior least tern and the snowy plover. Juniper woodlands, on the steep breaks of the canyons, are home to the Palo Duro mouse, a close relative of the pinyon mouse of the Rocky Mountains.

This ecoregion can be broken down into four main habitat classes consisting of brushland, native and introduced grasses, shrubland, and urban.

Rolling Plains Brushland

The Rolling Plains brushland consists of woody plants mostly less than nine feet tall which are dominant and growing as closely spaced individuals, clusters or closed canopied stands (greater than 10% canopy cover). Typically there are continuous, impenetrable shrubs covering over 75% of the ground (McMahan et al. 1984, Bridges et al. 2002). A total of 10 plant associations dominate this habitat class.

The *mesquite* association is found in scattered patches throughout the Rolling Plains. The plants commonly found within this association include narrow-leaf yucca, grassland prickly pear, juniper, red grama, Texas grama, sideoats grama, hairy grama, purple three-awn, Roemer three-awn, buffalograss, red lovegrass, gummy lovegrass, sand dropseed, tobosa, western ragweed, James rushpea, scurfpea and wild buckwheat (McMahan et al. 1984). This association is found on typical upland soils which are sandy and shallow with influences from caliche or limestone (Diamond 1993). Cross-referenced communities: 1) mesquite-midgrass series (Diamond 1993), 2) upland mesquite-midgrass savannahs (Bezanson 2000), and 3) honey mesquite woodland alliance (Weakley et al. 2000). The *mesquite* community is considered secure globally and throughout the state with more than 100 occurrences documented. Occurrences may be rare in part of its range with associations becoming infrequent at the periphery (Diamond 1993).

The *mesquite-lotebush* association is most commonly found in the southwestern fringe of the Rolling Plains ecoregion and is typically deciduous. It is normal to find this association growing on upland soils which are sandy and shallow with influences from caliche or limestone (Diamond 1993). Commonly associated plants include yucca species, skunkbush sumac, agarito, elbowbush, juniper, tasajillo, cane bluestem, silver bluestem, little bluestem, sand dropseed, Texas grama, sideoats grama, hairy grama, red grama, tobosa, buffalograss, Texas wintergrass, purple three-awn, Roemer three-awn, Engelmann daisy, broom snakeweed and bitterweed (McMahan et al. 1984). Cross-referenced communities: 1) mesquite-midgrass series (Diamond 1993), 2) upland mesquite-midgrass savannahs (Bezanson 2000), and 3) honey mesquite woodland alliance (Weakley et al. 2000). The *mesquite-lotebush* community is considered secure globally and throughout the state with more than 100 occurrences documented. Occurrences may be rare in part of its range with associations becoming infrequent at the periphery (Diamond 1993).

The *mesquite-juniper* association is indicative of mesas and hillsides of the western portion of the Edwards Plateau. However, it is found in large patches throughout the Rolling Plains on rocky slopes and follows disturbed areas with plant types varying depending on soil, slope and past history (Diamond 1993). Plants found in this group include lotebush, shin oak, sumac species, Texas prickly pear cactus, guajillo, tasajillo, kidneywood, agarito, redbud, yucca species, Lindheimer silktassel, sotol, catclaw acacia, Mexican persimmon, sideoats grama, three-awn, Texas grama, hairy grama, curly mesquite, buffalograss and hairy tridens (McMahan et al. 1984). Cross-referenced communities: 1) upland juniper-mesquite savannahs (Bezanson 2000), and 2) redberry juniper woodland alliance, one-seed juniper woodland alliance (Weakley et al. 2000). The *mesquite-juniper* community is considered secure globally and throughout the state with more than 100 occurrences documented. Occurrences may be rare in part of its range with associations becoming infrequent at the periphery (Diamond 1993).

The *mesquite-juniper-live oak* association is found mostly on mesas and hillsides of the western portion of the Edwards Plateau. However, it is also found in the southernmost portion of the Rolling Plains ecoregion. This association is commonly found on rocky slopes and follows disturbed areas with plant types varying depending on soil, slope and past history (Diamond 1993). Associated plants include the following: lotebush, shin oak, sumac species, Texas prickly pear, tasajillo, kidneywood, agarito, redbud, yucca species, Lindheimer silktassel, sotol, catclaw acacia, Mexican persimmon, sideoats grama, three-awn, Texas grama, hairy grama, curly mesquite, buffalograss and hairy tridens (McMahan et al. 1984). Cross-referenced communities: 1) upland juniper-mesquite savannahs (Bezanson 2000), and 2) redberry juniper woodland alliance, one-seed juniper woodland alliance (Weakley et al. 2000). The *mesquite-juniper-live oak* community is considered secure globally and throughout the state with more than 100 occurrences documented. Occurrences may be rare in part of its range with associations becoming infrequent at the periphery (Diamond 1993).

Plants commonly related to the *mesquite-hackberry* association include walnut, live oak, juniper, lotebush, catclaw acacia, woollybucket bumelia, tasajillo, agarito, whitebrush, switchgrass, vine-mesquite, silver bluestem, Johnsongrass, Lindheimer muhly, western ragweed and silverleaf nightshade. This association is found along creeks, drainages and canyon bottoms in the Rolling Plains (McMahan et al. 1984). Cross-referenced communities: 1) mesquite floodplain brush (Bezanson 2000). The *mesquite-hackberry* community is of low priority for further protection (Bezanson 2000).

The *mesquite-salt cedar* association is typically found in ephemeral drainages in the central Rolling Plains where saline, sandy soils occur. It can also be found around sub-irrigated swales, ephemeral creek bottoms and occasionally between dunes in the panhandle (Diamond 1993). Commonly associated plants include creosote, cottonwood, desert willow, giant reed, seepwillow, common buttonbush, burrobush, whitethorn acacia, Australian saltbush, fourwing saltbush, lotebush, wolfberry, tasajillo, guayacan, alkali sacaton, Johnsongrass, saltgrass, cattail, bushy bluestem, chino grama and Mexican devil-weed (McMahan et al. 1984). Cross-referenced communities: 1) floodplain forest and savannah (Kuchler 1974), 2) cottonwood-tallgrass series (Diamond 1993), 3) cottonwood-willow riparian woodlands (Bezanson 2000), and 4) eastern cottonwood temporarily flooded alliance woodland (Weakley et al. 2000). This community is considered imperiled, or very rare, globally and statewide. It is endangered throughout its range globally and it is considered vulnerable to extirpation within the state. It is determined that 6-20 occurrences are documented (Diamond 1993).

The *sandsage-Harvard shin oak* association is broadly defined and includes mostly evergreen brush or grasses. This association is typically isolated on sandy soils and many times stabilized sand dunes, and usually occurs in the northern portion, or panhandle, of the Rolling Plains. Skunkbush sumac, Chickasaw plum, Indiangrass, switchgrass, sand bluestem, little bluestem, sand lovegrass, big sandreed, sideoats grama, hairy grama, sand dropseed, sand paspalum, lead plant, scurfpea, scarletpea, slickseed bean, wild blue indigo, wild buckwheat and bush morning glory include a few of the commonly associated plants found within this plant community. The community composition can vary with depth and level of stabilization of the dunes and also the amount and reliability of precipitation. Cross-referenced communities: 1) Harvard shin oak-tallgrass series (Diamond 1993), 2) Harvard shin oak brush (Bezanson 2000), and 3) Harvard shin oak shrubland alliance (Weakley et al. 2000). The *sandsage-Harvard shin oak* community is considered secure globally and throughout the state with more than 100 occurrences documented. Occurrences may be rare in part of its range with associations becoming infrequent at the periphery (Diamond 1993).

Common plants found with the s*andsage mesquite* association include skunkbush sumac, Chickasaw plum, catclaw acacia, little bluestem, sand bluestem, sliver bluestem, sand dropseed, red three-awn, slickseed bean, sensitive briar, wild blue indigo, sandlily, spearleaf ground cherry, wild buckwheat, spinytooth gumweed, common sunflower, spectacle pod and hierba del pollo. This association is typically found on sandy upland soils, especially in Donley and Collingsworth counties in the Rolling Plains. Cross-referenced communities: 1) sandsage prairie (Kuchler 1974), 2) sandsage shrub grassland (Bezanson 2000), and 3) sandsage shrubland alliance (Weakley et al. 2000). The *sandsage-mesquite* community is considered fairly low priority for further protection within Texas. There are approximately 10,000 ac. that are protected within the Gene Howe WMA, Matador WMA and other Texas Parks and Wildlife conservation areas.

The *Harvard shin oak-mesquite* association occurs primarily on sandy soils and include plants such as sandsage, catclaw acacia, yucca species, giant dropseed, sand dropseed, Indiangrass, silver bluestem, sand bluestem, little bluestem, feather plume, Illinois bundleflower, foxglove and yellow evening primrose (McMahan et al. 1984). This association is widespread and deciduous occurring primarily on limestone or caliche soils (Diamond 1993). It typically occurs in the western portion of the Rolling Plains ecoregion (McMahan et al. 1984). Cross-referenced communities: 1) Harvard shin oak-tallgrass series (Diamond 1993), 2) Harvard shin oak brush (Bezanson 2000), and 3) Harvard shin oak shrubland alliance (Weakley et al. 2000). The *Harvard shin oak-mesquite* community is considered secure globally and throughout the state with more than 100 occurrences documented. Occurrences may be rare in part of its range with associations becoming infrequent at the periphery (Diamond 1993).

The *cottonwood-hackberry-salt cedar* association is most prominent in the Canadian and Red River basins. It is a deciduous forest community that was occupied by floodplains of perennial streams which have since subsided due to disturbances (Diamond 1993). Commonly associated plants include Lindheimer's black willow, buttonbush, groundsel-tree, rough-leaf dogwood, Panhandle grape, heartleaf ampelopsis, false climbing buckwheat, cattail, switchgrass, prairie cordgrass, saltgrass, alkali sacaton, spikesedge, horsetail, bulrush, coarse sumpweed and Maximilian sunflower (McMahan et al. 1984). Cross-referenced communities: 1) floodplain forest and savannah (Kuchler 1974), 2) cottonwood-tallgrass series (Diamond 1993), 3) cottonwood-willow riparian woodlands (Bezanson 2000), and 4) eastern cottonwood temporarily flooded alliance woodland (Weakley et al. 2000). The c*ottonwood-hackberry-salt cedar* community is considered imperiled, or very rare, globally and it is endangered throughout its range. This association is also considered imperiled, or very rare, throughout the state. Approximately 6-20 occurrences have been documented, therefore, this association is considered vulnerable to extirpation within the state (Diamond 1993).

Rolling Plains Native and Introduced Grasses

A mixture of native and introduced grasses which includes herbs (grasses, forbs and grass-like plants) that are dominant with woody vegetation lacking or nearly so (generally 10% or less woody canopy cover). These associations typically result from the invasion of non-native grass species originating from the planting of these non-natives (e.g. Bermuda, KR bluestem, etc.) for roadsides and rangelands. The clearing of woody vegetation is another factor and is sometimes associated with the early stages of a young forest. This community can quickly change as removed brush begins to regrow (McMahan et al. 1984, Bridges et al. 2002).

Rolling Plains Parkland

In the Rolling Plains parkland, a majority of the woody plants are equal to or greater than nine feet tall. They are generally dominant and grow as clusters, or as scattered individuals within continuous grass or forbs (11-70% woody canopy cover overall) (McMahan et al. 1984, Bridges et al. 2002). Only one plant associations dominates this habitat class.

The *live oak-mesquite-Ashe juniper* association consists of Texas oak, shin oak, cedar elm, netleaf hackberry, flameleaf sumac, agarito, Mexican persimmon, Texas prickly pear, kidneywood, greenbriar, Texas wintergrass, little bluestem, curly mesquite, Texas grama, Halls panicum, purple three-awn, hairy tridens, cedar sedge, two-leaved senna, mat euphorbia and rabbit tobacco. This association is typically found on level to gently rolling uplands and ridge tops in the Edwards Plateau, which are limestone dominated, although a small section runs up through the southeastern portion of the Rolling Plains ecoregion (McMahan et al. 1984). Cross-referenced communities: 1) plateau live oak series (Diamond 1993), 2) upland plateau live oak savannas (Bezanson 2000), and 3) plateau oak woodland alliance (Weakley et al. 2000). The *live oak-mesquite-Ashe juniper* community is apparently secure globally and throughout the state with more than 100 occurrences documented. Occurrences may be rare in part of its range with associations becoming infrequent at the periphery (Diamond 1993).

Rolling Plains Parkland Woodland Mosaic

The parkland woodland mosaic can be best described by pastures or fields with widely scattered vegetation (trees and/or shrubs) covering 10-25% of the ground (Bridges et al. 2002). There is only one plant association representing this habitat class.

The *oak-mesquite-juniper* association consists of post oak, Ashe juniper, shin oak, Texas oak, blackjack oak, live oak, cedar elm, agarito, soapberry, sumac, hackberry, Texas prickly pear, Mexican persimmon, purple three-awn, hairy grama, Texas grama, sideoats grama, curly mesquite and Texas wintergrass. This community occurs as associations or as a mixture of individual (woody) species stands on uplands in the Cross Timbers and Prairies with a small patch occurring in the southeastern most portion of the Rolling Plains ecoregion (McMahan et al. 1984). Soils tend to range from limestone to sandy and composition of plants varies with the amount of rainfall and substrate type (Diamond 1993). Cross-referenced communities: 1) plateau live oak series (Diamond 1993), 2) upland plateau live oak savannas (Bezanson 2000), and 3) plateau oak woodland alliance (Weakley et al. 2000). The *oak-mesquite-juniper* association is considered rare or uncommon throughout the state with 21-100 known occurrences. This community is also considered rare on a global scale with between 21 and 100 documented occurrences. This community is found locally throughout its range (and sometimes abundant) or it is found locally in a restricted area, in a single state or physiographic region. It is considered rare because it is potentially vulnerable to extinction (Diamond 1993).

Rolling Plains Shrubland

Shrublands consist of individual woody plants generally less than nine feet tall scattered throughout arid or semi-arid regions where the vegetation is evenly spaced covering over 75% of the ground (Bridges et al. 2002). Typically there is less than 30% woody canopy cover overhead (McMahan et al. 1984). The Rolling Plains shrubland consists of two main plant associations.

The *mesquite* association consists of narrow-leaf yucca, tasajillo, juniper, grassland prickly pear, cholla, blue grama, hairy grama, purple three-awn, Roemer three-awn, buffalograss, little bluestem, western wheatgrass, Indiangrass, switchgrass, James rushpea, scurfpea, lemon scurfpea, sandlily, plains beebalm, scarlet gaura, yellow evening primrose, sandsage and wild buckwheat (McMahan et al. 1984). This association is found on typical upland soils which are sandy and shallow with influences from caliche or limestone. At more mesic sites, and also locations maintaining good quality rangeland, this community type is seen grading into a midgrass community (Diamond 1993). Cross-referenced communities: 1) mesquite-midgrass series (Diamond 1993), 2) upland mesquite-midgrass savannahs (Bezanson 2000), and 3) honey mesquite woodland alliance (Weakley et al. 2000). The *mesquite* community is considered secure globally and throughout the state with more than 100 occurrences documented. Occurrences may be rare in part of its range with associations becoming infrequent at the periphery (Diamond 1993).

The *mesquite-lotebush* association is most commonly found in the central and southern portion of the Rolling Plains ecoregion and is typically deciduous. It is normal to find this association growing on upland soils which are sandy and shallow with influences from caliche or limestone (Diamond 1993). Commonly associated plants include yucca species, skunkbush sumac, agarito, elbowbush, juniper, tasajillo, cane bluestem, silver bluestem, little bluestem, sand dropseed, Texas grama, sideoats grama, hairy grama, red grama, tobosa, buffalograss, Texas wintergrass, purple three-awn, Roemer three-awn, Engelmann daisy, broom snakeweed and bitterweed (McMahan et al. 1984). Cross-referenced communities: 1) mesquite-midgrass series (Diamond 1993), 2) upland mesquite-midgrass savannahs (Bezanson 2000), and 3) honey mesquite woodland alliance (Weakley et al. 2000). The *mesquite-lotebush* community is considered secure globally and throughout the state with more than 100 occurrences documented. Occurrences may be rare in part of its range with associations becoming infrequent at the periphery (Diamond 1993).

Rolling Plains Woodland

In the Rolling Plains woodland, a majority of the woody plants are mostly 9-30 ft. tall with closed crowns or nearly so (71-100% canopy cover). Typically the midstory is usually lacking any vegetation (McMahan et al. 1984, Bridges et al. 2002). Only one plant association dominates this habitat class.

The *juniper* association includes live oak, Texas oak, cedar elm, mesquite, agarito, tasajillo, western ragweed, scurfpea, little bluestem, sideoats grama, Texas wintergrass, silver bluestem, hairy tridens, tumblegrass and red three-awn. This association is found on the slopes of hills in Stephens and Palo Pinto counties of the Cross Timbers and Prairies but can also be found in small isolated patches throughout the Rolling Plains ecoregion (McMahan et al. 1984). Soils are typically shallow and of limestone origin and this community can range from an evergreen shrubland to a woodland depending on the amount of disturbance, deepness of the soil and slope (Diamond 1993). Cross-referenced communities: 1) Ashe juniper-oak series (Diamond 1993), 2) Ashe juniper low forests (Bezanson 2000), and 3) Ashe's juniper woodland alliance (Weakley et al. 2000). The *juniper* community is considered apparently secure globally and within the state. More than 100 occurrences are known both globally and statewide, however this community can be rare in parts of its natural global range, especially the periphery. It can also be rare in some areas of Texas especially around the border of its range (Diamond 1993).

Rolling Plains Urban Community

Urban habitats are cities or towns which are areas dominated by human dwellings including the fences, shrub rows, windbreaks and roads associated with their presence (Bridges at al. 2002). The largest city in the Rolling Plains is Abilene. Other prominent but smaller cities include Vernon, Burkburnett, Pleasant Valley, Borger, Sweetwater and San Angelo.

High Priority Communities (information from Playa Lakes Joint Venture (PLJV))

There are approximately 19,000 *playa lakes* between the High Plains and the Rolling Plains ecoregions which are home to approximately 37 mammal species, more than 200 bird species, 13 amphibian species, 124 aquatic invertebrate taxa and greater than 340 species of plants. These communities are one of the most numerous wetland types in the High and Rolling Plains ecoregions. Playas are shallow, depressional wetlands that are generally round and small, averaging 17 ac. in size. There is very little rainfall in this Rolling Plains ecoregion averaging 20 in. or less, therefore, most of the water sources for wildlife are available only in these seasonal lakes. Water from spring rainstorms is trapped in shallow depressions scattered throughout the High and Rolling Plains ecoregions which eventually recharge the Ogallala Aquifer. These depressions have clay bottoms which are impermeable and can hold water for long time periods (Bezanson and Wolfe 2001). Presently, it is undetermined as to what condition the *playa lakes* of the High and Rolling Plains are in. More than 99% of playas are privately owned with the majority of playa lakes located in or adjacent to farms, grazing lands and feedlots. The Natural Area Preservation Association and Environmental Defense currently protect five sites which contain playa lakes (Bezanson and Wolfe 2001).

Riparian woodlands and sandhills were once numerous in the High and Rolling Plains. They are typically found along rivers and are home to cottonwoods and tall grasses. These areas are extremely important for many types of wildlife, especially migrating and breeding birds (Bezanson and Wolfe 2001). Presently, there are a few sites on private ranch lands which accommodate r*iparian woodland and sandhill* communities. Native tall grass species and cottonwood are found at these locations. Helping private land owners protect these sites is considered a high priority (Bezanson and Wolfe 2001).

Element 3

Problems Affecting the Rolling Plains

See the Texas Priority Species List……………………733

Playa lakes are extremely important for migrating, breeding and local wildlife species yet there are not many protected specifically for wildlife. Agricultural (pesticides, fertilizers and contaminants from feedlots) runoff, conversion of surrounding lands from shortgrass prairie to cropland, the conversion of the playa lakes themselves to other uses and sedimentation are large threats to this key community type of the High Plains (Bezanson and Wolfe 2001). Sedimentation is the primary threat to playa lakes. Sediment runoff into playa basins reduces the volume of water they can hold and may disrupt the wet-dry cycles necessary for vegetation growth. Additional impacts on playas include: development, oil field water dumping, overgrazing, altered water cycles and basin structure. Most playa basins have been manipulated to increase storage capacity for irrigation purposes. The presence of additional water from irrigation runoff also alters natural playa hydrology.

Riparian woodlands and sandhills face isolation from agricultural practices. Dams and detrimental irrigation practices have decreased streamflows. Poor grazing practices have altered the natural state of these communities. The most detrimental incidence is from the invasion of exotic species such as salt cedar. Many native species of the High Plains have disappeared, except from isolated areas, due to the encroachment of invasive species (Bezanson and Wolfe 2001).

High Priority Research and Monitoring Efforts for the Rolling Plains

See Monitoring and Adaptive Management………. 559

See the Texas Priority Species List…………………733

Element 5

- Evaluation of the effectiveness of playa buffer techniques (e.g. buffer size, buffer mix, or species represented) as they relate to hydrology, runoff, sedimentation, wetland quality and land bird use.
- Monitoring birds during migration, their chronology, numbers and/or stopover times, for species identified
- Evaluation of playa restoration techniques, such as sediment removal or back-filling "pits", on bird use, plant response, playa hydrology and other playa functions
- Monitoring identified species of birds as well as their habitat quality and quantity.
- Efficacy of habitat management strategies (e.g. different grazing regimes, exotic vegetation control methods) on priority bird species, particularly abundance and/or distribution objectives of those species or other measures that are indicative of bird response (e.g. change in vital rates)
- Landscape-scale comparison of bird use on well-utilized and non well-utilized wetlands. (Questions might focus on intrinsic and extrinsic habitat quality, surrounding land use or wetland complex value)
- Bird use of non-playa wetlands (examples of other wetland types are saline lakes, stock ponds, reservoirs, riparian areas, beaver ponds, wet meadows, etc.
- Annual and seasonal availability of priority foraging habitats
- Estimating availability/ nutrient content of foods available in croplands and the potential importance (contribution) of croplands to birds that may rely heavily on them

Element 4

High Priority Conservation Actions for the Rolling Plains

See High Priority Conservation Strategies…………..517

See the Texas Priority Species List……………………733

- Increase the amount of managed mixed grass prairie and mesquite savannah via protection, restoration, encouragement of proper grazing and regular patch burning
- Increase the amount of CRP by 617,500 ac., especially targeting areas adjacent to native mixed grass, sandsage and shinnery in the northeastern panhandle in order to create large blocks of habitat
- Ensure all CRP land is plant to native and area appropriate grasses. Include shrubs and native forbs in the mixture
- Increase the number of large blocks of mixed grass by 150,000 ac.; increase the amount of shinnery by 100,000 ac. and the amount of sandsage by 6,400 ac.
- Protect early-mid successional oak/juniper woodlands where black-capped vireo has historically occurred in extreme southern counties. If necessary, plan for burns to maintain the habitat in early-mid succession
- Shorebird habitat conservation efforts should emphasize protection and enhancement of existing habitats, as a hedge against future habitat declines
- Waterfowl habitat conservation efforts should be directed at providing habitat to support about 611 million additional foraging use-days, which is the current shortfall. This could be done by converting 144,760 ac. of cropland to moist-soil units and managing for maximum waterfowl food production
- Maintain and increase prairie-dog colonies by 20,800 ac. primarily in the far northern panhandle and where possible in southern areas for Burrowing Owl to reach objective levels
- Maintain wetland habitats around reservoirs and ponds and improve riparian conditions along streams, including the eradication of non-native plants
- Plan for the creation and "maintenance" of wide, braided, stream channels containing unvegetated sandbars. On the sides of these stream channels or in other riparian areas change the percentage of shrub (assumed to be primarily exotics such as salt cedar) to canopy forest

- Encourage maximum enrollment in Farm Bill programs that help recommendations above and are positioned to increase block size of native grasslands
- Protect known colonial waterbird colonies and areas where marsh birds breed
- Emphasize the importance of proper grazing. Work with state, federal and private agencies to continue to develop cost-effective means to balance grazing and wildlife. Patch grazing appears to be very promising. Support Farm Bill programs which encourage proper grazing management.
- Work with federal, state and private organizations to promote (incentives) leaving some cover for wildlife. The economic benefits of wildlife can sometimes equal or surpass the agricultural value of land.

Trans-Pecos Ecoregion

Associated Maps

Ecoregions of Texas……………………………...1

Trans-Pecos Ecoregion…………………….. 11

Element 1

Associated Section IV Documents

The Texas Priority Species List…………….733

Supplemental Mammal Information……….. 897

Supplemental Herptile Information………... 988

Priority Species

Group	Species Name	Common Name	State/Federal Status
Birds	*Aeronautes saxatalis*	White-throated swift	SC
	Aimophila cassinii	Cassin's sparrow	SC
	Aimophila ruficeps	Rufous-crowned sparrow	SC
	Ammodramus bairdii	Baird's sparrow (42 accepted state records)	SC
	Ammodramus savannarum	Grasshopper sparrow	SC
	Amphispiza bilineata	Black-throated sparrow	SC
	Anas acuta	Northern pintail	SC
	Aquila chrysaetos	Golden eagle	SC
	Archilochus alexandri	Black-chinned sparrow	SC
	Asio flammeus	Short-eared owl	SC
	Asturina nitidus	Gray hawk	ST
	Athene cunicularia	Burrowing owl	SC
	Aythya affinis	Lesser scaup	SC
	Aythya americana	Redhead	SC
	Aythya valisineria	Canvasback	SC
	Bartramia longicauda	Upland sandpiper	SC

Botaurus lentiginosus	American bittern	SC
Buteo albontatus	Zone-tailed hawk	ST
Buteo swainsoni	Swainson's hawk	SC
Buteogallus anthracinus	Common black-hawk	ST
Calcarius mccownii	McCown's longspur	SC
Calidris mauri	Western sandpiper	SC
Callipepla squamata	Scaled quail	SC
Calothorax lucifer	Lucifer hummingbird	SC
Campylorhynchus brunneicapillus	Cactus wren	SC
Cardinalis sinuatus	Pyrrhuloxia	SC
Catherpes mexicanus	Canyon wren	SC
Chaetura pelagica	Chimney swift	SC
Charadrius alexandrinus	Snowy plover	SC
Charadrius montanus	Mountain plover	SC
Chloroceryle americana	Green kingfisher	SC
Chondestes grammacus	Lark sparrow	SC
Chordeiles minor	Common nighthawk	SC
Circus cyaneus	Northern harrier	SC
Coccyzus americanus	Yellow-billed cuckoo	SC
Cyrtonyx montezumae	Montezuma quail	SC
Egretta thula	Snowy egret	SC
Eremophila alpestris	Horned lark	SC
Falco columbarius	Merlin	SC
Falco femoralis	Aplomado falcon	FE/SE
Falco mexicanus	Prairie falcon	SC
Falco peregrinus anatum	American peregrine falcon	SE/ST
Falco peregrinus tundrius	Arctic peregrine falcon	ST
Gallinago delicata	Wilson's snipe (formerly common snipe)	SC
Himantopus mexicanus	Black-necked stilt	SC

Icterus parisorum	Scott's oriole	SC
Icterus spurius	Orchard oriole	SC
Ictinia mississippiensis	Mississippi kite	SC
Ixobrychus exilis	Least bittern	SC
Lanius ludovicianus	Loggerhead shrike	SC
Micrathene whitneyi	Elf owl	SC
Numenius americanus	Long-billed curlew	SC
Otus flammeolus	Flammulated owl	SC
Parabuteo unicinctus	Harris’s hawk	SC
Passerina ciris	Painted bunting	SC
Passerina versicolor	Varied bunting	SC
Patagioenas fasciata	Band-tailed pigeon	SC
Pelecanus erythrorhynchos	American white pelican	SC
Phainopepla nitens	Phainopepla	SC
Phalaropus tricolor	Wilson’s phalarope	SC
Picoides scalaris	Ladder-backed woodpecker	SC
Podiceps auritus	Horned grebe	SC
Podiceps nigricollis	Eared grebe	SC
Polioptila melanura	Black-tailed gnatcatcher	SC
Rallus elegans	King rail	SC
Rallus limicola	Virginia rail	SC
Recurvirostra americana	American avocet	SC
Spiza americana	Dickcissel	SC
Spizella breweri	Brewer's sparrow	SC
Spizella pusilla	Field sparrow	SC
Sterna forsteri	Forster's tern	SC
Strix occidentalis	Spotted owl	SC
Sturnella magna	Eastern meadowlark	SC
Sturnella neglecta	Western meadowlark	SC

	Toxostoma crissale	Crissal thrasher	SC
	Toxostoma curvirostre	Curve-billed thrasher	SC
	Toxostoma longirostre	Long-billed thrasher	SC
	Tringa flavipes	Lesser yellowlegs	SC
	Tringa solitaria	Solitary sandpiper	SC
	Tyrannus forficatus	Scissor-tailed flycatcher	SC
	Tyrannus vociferans	Cassin's kingbird	SC
	Tyto alba	Barn owl	SC
	Vermivora crissalis	Colima warbler	SC
	Vermivora luciae	Lucy's warbler	SC
	Vermivora virginiae	Virginia's warbler	SC
	Vireo atricapillus	**Black-capped vireo	FE/SE
	Vireo bellii	Bell's vireo	SC
	Vireo gilvus	Warbling vireo	SC
	Vireo vicinior	Gray vireo	SC
Mammals	*Ammospermophilus interpres*	Texas antelope squirrel	SC
	Antilocapra americana	Pronghorn	SC
	Antrozous pallidus	Pallid bat	SC
	Chaetodipus eremicus	Chihuahuan Desert pocket mouse	SC
	Conepatus leuconotus	Hog-nosed skunk	SC
	Corynorhinus townsendii	**Townsend's big-eared bat	SC
	Cratogeomys castanops	Yellow-faced pocket gopher	SC
	Cynomys ludovicianus	Black-tailed prairie dog	SC
	Dipodomys spectabilis	Banner-tailed kangaroo rat	SC
	Erethizon dorsatum	Porcupine	SC
	Euderma maculatum	Spotted bat	ST
	Eumops perotis californicus	Greater western bonneted bat	SC
	Geomys aurenarius	Desert pocket gopher	SC

Lasiurus xanthinus	Western yellow bat	SC
Leopardus pardalis	**Ocelot	FE/SE
Leptonycteris nivalis	**Mexican/greater longnosed bat	FE/SE
Mephitis macroura	Hooded skunk	SC
Microtus mogollonensis	Mogollon vole	SC
Mormoops megalophylla	Ghost-faced bat	SC
Mustela frenata	Long-tailed weasel	SC
Mustela nigripes	Black-footed ferret	FE/SE
Myotis velifer	Cave myotis	SC
Myotis yumanensis	Yuma myotis	SC
Mytois thysanodes	Fringed myotis	SC
Nasua narica	White-nosed coati	ST
Notisorex crawfordii	Desert shrew	SC
Nyctinomops femorosaccus	Pocketed free-tailed bat	SC
Nyctinomops macrotis	Big free-tailed bat	SC
Onychomys arenicola	Mearn's grasshopper mouse	SC
Peromyscus nasutus	Northern rock mouse	SC
Puma concolor	Mountain lion	SC
Scalopus aquaticus texanus	Presidio mole	SC
Sigmodon fulviventer	Tawny-bellied cotton rat	SC
Spilogale gracilis	Western spotted skunk	SC
Sylvilagus robustus	Davis Mountain cottontail	SC
Tadarida brasiliensis	Brazilian free-tailed bat	SC
Tamias canipes	Gray-footed chipmunk	SC
Taxidea taxus	American badger	SC
Thomomys bottae guadalupensis	Southern pocket gopher	SC
Thomomys bottae limpia	Limpia southern pocket gopher	SC
Thomomys bottae texensis	Limpia Creek pocket gopher	SC
Ursus americanus	Black bear	ST

	Vulpes velox	Swift fox (Kit fox)	SC
Reptiles	*Agkistrodon contortrix pictigaster*	Trans-Pecos copperhead	SC
	Aspidocelis dixoni	Gray-checkered whiptail	SC
	Coleonyx reticulatus	Reticulate banded gecko	ST
	Crotalus viridis	Prairie rattlesnake	SC
	Gambelia wislizeni	Long-nosed leopard lizard	SC
	Heterodon nasicus gloydi	Dusty hog-nosed snake	SC
	Kinosternon hirtipes	Chihuahuan mud turtle	ST
	Phrynosoma cornutum	Texas horned lizard	ST
	Phrynosoma hernandesi	Mountain short-horned lizard	ST
	Phrynosoma modestum	Round-tailed horned lizard	SC
	Sceloporus arenicolus	Dunes sagebrush lizard	SC
	Sistrurus catenatus	Massasauga	SC
	Terrapene spp.	Box turtles	SC
	Trachemys gaigeae	Big Bend slider	SC
	Trimorphodon vilkinsonii	Chihuahuan Desert lyre snake	ST

Group	Family	Species Name	Federal Status
Invertebrates			
	Stylommatophora (Gastropoda)		
	Helminthoglyptidae	*Sonorella metcalfi*	SC
	Humboldtianidae	*Humboldtiana cheatumi*	SC
	Humboldtianidae	*Humboldtiana chisosensis*	SC
	Humboldtianidae	*Humboldtiana ferrissiana*	SC
	Humboldtianidae	*Humboldtiana palmeri*	SC
	Humboldtianidae	*Humboldtiana texana*	SC
	Humboldtianidae	*Humboldtiana ultima*	SC
	Polygyridae	*Daedalochila hippocrepis*	SC

Araneae (Arachnida)		
Dictynidae	*Cicurina delrio*	SC
Dictynidae	*Cicurina holsingeri*	SC
Dictynidae	*Cicurina mirifica*	SC
Nesticidae	*Eidmannella bullata (Gertsch)*	SC
Nesticidae	*Eidmannella tuckeri*	SC
Opiliones (Arachnida)		
Phalangodidae	*Texella longistyla*	SC
Pseudoscorpiones (Arachnida)		
Garypidae	*Archeolarca guadalupensis (Muchmore)*	SC
Lepidoptera (Insecta)		
Hesperiidae	*Agathymus neumoegeni chisosensis*	SC
Hesperiidae	*Agathymus neumoegeni mcalpinei*	SC
Hesperiidae	*Piruna haferniki*	SC
Lycaenidae	*Fixsenia polingi*	SC
Riodinidae	*Apodemia chisosensis*	SC
Sphingidae	*Adhemarius blanchardorum*	SC
Hymenoptera (Insecta)		
Apoidea	*Perdita (Hexaperdita) albipes (Timberlake)*	SC
Apoidea	*Perdita (Perdita) cara (Timberlake)*	SC
Apoidea	*Perdita (Perdita) congrua (Timberlake)*	SC

Element 2

Location and Condition of the Trans-Pecos Ecoregion

The Trans-Pecos is perhaps the most remarkable ecoregions in Texas, offering at once breathtakingly spectacular vistas and incredible biological diversity. Located west of the Pecos River are 19 million ac. featuring an impressive array of habitats from desert grasslands, desert scrub, salt basins, sand hills and rugged plateaus to wooded mountain slopes whose summits support mixed hardwood and coniferous forests (Correll and Johnston 1979). The Trans-Pecos combines Chihuahuan Desert flats with more humid mountain ranges of diverse geological origin to create a living museum of biological wonders. More rare and endemic species are found among its desert valleys, grassy plateaus, wooded mountains and protected canyons than in any other part of Texas. One out of five Texas endemic plants occurs nowhere else.

The Trans-Pecos cannot really be considered a single unit. For what occurs on the summit of the south rim of the Chisos Mountains, alligator juniper, Texas madrone and ponderosa pine for example, bears no resemblance to the vegetation of the surrounding desert, creosote, tarbush, ocotillo and lechuguilla. Parts of this region are the hottest and driest in Texas with the western-most reaches receiving eight inches of annual rainfall and sometimes less. With elevations ranging from 2,500 ft. to over 8,500 ft. above MSL, precipitation levels increase with increasing elevation which gives rise to more moisture-loving communities in the mountainous areas. Soils are complex ranging from very alkaline limestone-derived soils to highly acidic volcanically derived soils. The average annual temperature of 64°F over the entire area does not reflect temperature extremes with heat being an important feature of the area.

Indeed, the Trans-Pecos region as a whole represents the largest U.S. portion of true Chihuahuan Desert. Dominated by creosote-tarbush desert scrub grasslands, there are scattered inclusions of montane ponderosa pine forest, pinyon pine and oak forests; yucca and juniper savannahs, grama grasslands and saltbush and alkali sacaton dominated salt basins. Much of the landscape is dominated by desert grassland, but many of the desirable grasses have been replaced by lower quality plants under continuous overgrazing. Stream courses or riparian areas are the oases of the desert, yet few remain relatively undisturbed. These areas support stands of willows, cottonwoods, sycamores, ash and little walnuts. In these spring canyons, plants that cannot tolerate the rigors of dry desert conditions find refuge in the cool, moist surroundings. A total of 54 species of birds are primarily confined to this region, among them the crissal thrasher, the black-tailed gnatcatcher, Gambel's quail and Lucy's warbler (Fisher 1984). In fact, the Chisos Mountains are the only place in Texas where the Lucifer hummingbird, gray-breasted jay, Hutton's vireo and painted redstart can be reliably found. Reptiles abound, notable among them the eastern collared lizard, southwestern blackneck garter snake and the Trans-Pecos rat snake. Mammals are equally diverse with Mexican long-tongued bat, spotted bat, Texas antelope squirrel, Kit fox and bighorn sheep occurring mainly in this region. Long gone are the native populations of wapiti and grizzly bear. Black bear and mountain lions can still be found. And finally, unique species of desert-adapted and relict pupfish, mosquito fish and shiners inhabit the few remaining undisturbed desert watercourses and cienegas.

This ecoregion can be broken down into five main habitat classes consisting of brushland, grassland, parkland woodland mosaic, shrubland, and urban.

Trans-Pecos Brushland

The Trans-Pecos brushlands consist of woody plants mostly less than nine feet tall which are dominant and growing as closely spaced individuals, clusters or closed canopied stands (greater than 10% canopy cover). Typically there are continuous, impenetrable shrubs covering over 75% of the ground (McMahan et al. 1984, Bridges et al. 2002). A total of six plant associations dominate this habitat class.

The *mesquite-lotebush* association is most commonly found in the northeastern part of the Trans-Pecos and is typically deciduous. Commonly associated plants include yucca species, skunkbush sumac, agarito, elbowbush, juniper, tasajillo, cane bluestem, silver bluestem, little bluestem, sand dropseed, Texas grama, sideoats grama, hairy grama, red grama, tobosa, buffalograss, Texas wintergrass, purple three-awn, Roemer three-awn, Engelmann daisy, broom snakeweed and bitterweed (McMahan et al. 1984). Cross-referenced communities: 1) mesquite-midgrass series (Diamond 1993), 2) upland mesquite-midgrass savannahs (Bezanson 2000), and 3) honey mesquite woodland alliance (Weakley et al. 2000). The *mesquite-lotebush*, community is considered secure globally and throughout the state with more than 100 occurrences documented. Occurrences may be rare in part of its range with associations becoming infrequent at the periphery (Diamond 1993).

The *mesquite-salt cedar* association is typically found in ephemeral drainages of the Pecos and Rio Grande drainages where saline, sandy soils occur. It can also be found around ephemeral drainages, springs, cienegas and washes throughout the Trans-Pecos depending on the amount and more importantly consistency of water in those areas (Diamond 1993). Commonly associated plants include creosote, cottonwood, desert willow, giant reed, seepwillow, common buttonbush, burrobush, whitethorn acacia, Australian saltbush, fourwing saltbush, lotebush, wolfberry, tasajillo, guayacan, alkali sacaton, Johnsongrass, saltgrass, cattail, bushy bluestem, chino grama and Mexican devil-weed (McMahan et al. 1984). Cross-referenced communities: 1) floodplain forest and savannah (Kuchler 1974), 2) cottonwood-tallgrass series (Diamond 1993), 3) cottonwood-willow riparian woodlands (Bezanson 2000), and 4) eastern cottonwood temporarily flooded alliance woodland (Weakley et al. 2000). This community is considered imperiled, or very rare, globally and statewide. It is endangered throughout its range globally and it is considered vulnerable to extirpation within the state. It is determined that 6-20 occurrences are documented (Diamond 1993).

The *Harvard shin oak-mesquite* association occurs primarily on sandy soils and includes plants such as sandsage, catclaw acacia, yucca species, giant dropseed, sand dropseed, Indiangrass, silver bluestem, sand bluestem, little bluestem, feather plume, Illinois bundleflower, foxglove and yellow evening primrose (McMahan et al. 1984). This association is widespread and deciduous occurring primarily on limestone or caliche soils (Diamond 1993). It typically occurs in the northeastern portion of the Trans-Pecos and is indicative of the High and Rolling Plains ecoregions (McMahan et al. 1984). Cross-referenced communities: 1) Harvard shin oak-tallgrass series (Diamond 1993), 2) Harvard shin oak brush (Bezanson 2000), and 3) Harvard shin oak shrubland alliance (Weakley et al. 2000). The *Harvard shin oak-mesquite* community is considered secure globally and throughout the state with more than 100 occurrences documented. Occurrences may be rare in part of its range with associations becoming infrequent at the periphery (Diamond 1993).

The *Harvard shin oak* association is found chiefly on sandy soils and degraded sand sheet in the far northeastern Trans-Pecos ecoregion, which is typically associated with the counties of Andrews, Crane, Ward and Winkler (McMahan et al. 1984, Diamond 1993, Bezanson 2000). This is a broadly-defined, evergreen vegetation association typically isolated to stabilized sand dunes. Composition is dependent on precipitation and factors relating to the disturbance of the sand dunes such as depth and degree of stabilization (Diamond 1993). Plants found in this association are catclaw acacia, bush morning glory, southwest rabbitbrush, sandsage, mesquite, hooded windmillgrass, sand bluestem, big sandreed, false buffalograss, spike dropseed, giant dropseed, mesa dropseed, narrowleaf sand verbena, sweet sand verbena, bull nettle, sand dune spurge, prairie spurge, firewheel and plains sunflower (McMahan et al. 1984). Cross-referenced communities: 1) Harvard shin oak low shrublands (Bezanson 2000), and 2) Harvard oak shrubland alliance (Weakley et al. 2000). *Harvard shin oak* communities are considered rare or uncommon. They are typically only found locally in restricted areas throughout its range with less than 100 occurrences within the state (Diamond 1993). The best protected location of this community occurs at the Monahans Sandhills State Park (Bezanson 2000). On a global scale it is considered very rare and local within its range or found locally within a restricted range. Sometimes they are found in a single physiographic region. There are fewer than 100 occurrences documented and due to various threats these communities are vulnerable to extinction throughout their global range (Diamond 1993).

The *cottonwood-hackberry-salt cedar* association is the most prominent in the Guadalupe Mountains of Culberson county in the Trans-Pecos. It is a deciduous forest community that was occupied by floodplains of perennial streams which has since subsided due to disturbances (Diamond 1993). Commonly associated plants include Lindheimer's black willow, buttonbush, groundsel-tree, rough-leaf dogwood, Panhandle grape, heartleaf ampelopsis, false climbing buckwheat, cattail, switchgrass, prairie cordgrass, saltgrass, alkali sacaton, spikesedge, horsetail, bulrush, coarse sumpweed and Maximilian sunflower (McMahan et al. 1984). Cross-referenced communities: 1) floodplain forest and savannah (Kuchler 1974), 2) cottonwood-tallgrass series (Diamond 1993), 3) cottonwood-willow riparian woodlands (Bezanson 2000), and 4) eastern cottonwood temporarily flooded alliance woodland (Weakley et al. 2000). The c*ottonwood-hackberry-salt cedar* community is considered imperiled, or very rare, globally. It is endangered throughout its range. It is determined that 6-20 occurrences are documented (Diamond 1993). This association is also considered imperiled, or very rare, throughout the state therefore this association is considered vulnerable to extirpation within the state (Diamond 1993).

The final association consists of *mesquite-juniper* which is naturally found on mesas and hillsides of the western portion of the Edwards Plateau and northeastern portions of the Trans-Pecos. This association is commonly found on rocky slopes and follows disturbed areas with plant types varying depending on soil, slope and past history (Diamond 1993). Plants found in this group include lotebush, shin oak, sumac species, Texas prickly pear cactus, guajillo, tasajillo, kidneywood, agarito, redbud, yucca species, Lindheimer silktassel, sotol, catclaw acacia, Mexican persimmon, sideoats grama, three-awn, Texas grama, hairy grama, curly mesquite, buffalograss and hairy tridens (McMahan et al. 1984). Cross-referenced communities: 1) upland juniper-mesquite savannahs (Bezanson 2000), and 2) redberry juniper woodland alliance, one-seed juniper woodland alliance (Weakley et al. 2000). The *mesquite-juniper* community is considered secure globally and throughout the state with more than 100 occurrences documented. Occurrences may be rare in part of its range with associations becoming infrequent at the periphery (Diamond 1993).

Trans-Pecos Grassland

Grasslands consist of herbs (grasses, forbs and grass-like plants) which are dominant. Woody vegetation is lacking or nearly so (generally 10% or less woody canopy cover) (McMahan et. at 1984). There are two dominant plant associations found in the Trans-Pecos grasslands.

The first is the shortgrass *Tobosa-black grama* association which is found principally in low elevation plains of Jeff Davis, Presidio, Brewster, Culberson and Hudspeth counties (McMahan et al. 1984). It typically occurs in heavy igneous soils and also on flat limestone areas that sometimes receive excessive runoff from the surrounding areas. This explains why these grasslands are represented within small, internally drained basin bottoms (Diamond 1993). Commonly associated plants found in this subclass consist of blue grama, sideoats grama, chino grama, hairy grama, burrograss, bush muhly, Arizona cottontop, javelina bush, creosote, butterfly bush, palmella, whitethorn acacia, cholla cactus, broom snakeweed and rough menodora (McMahan et al. 1984). Cross-referenced communities: 1) desert grassland (Burgess and Northington 1979, Dick-Peddle 1993, Powell 1994), 2) lechuguilla-grass (Plumb 1988), 3)lower-elevation desert grassland

(Bezanson 2000), and 4) chino grama herbaceous alliance, black grama herbaceous alliance, hairy grama-blue grama-black grama shrub herbaceous alliance, smooth sotol (lechuguilla, skeletonleaf goldeneye) shrubland alliance (Weakley et al. 2000). The *Tobosa-black grama* community is secure statewide and globally. However, they have been invaded by desert shrubs and are now compacted because of over-use. For this reason it is a community that is considered of medium priority for further protection (Bezanson 2000).

The second plant association is the *blue grama-buffalograss* association. This shortgrass grassland is most commonly found in the central and northwestern High Plains although there are patches in the Trans-Pecos and Rolling Plains ecoregions. It is recognized by dominant upland soils (McMahan et al. 1984, Diamond 1993). Common plants associated with this subclass include sideoats grama, hairy grama, sand dropseed, cholla cactus, grassland prickly pear cactus, narrowleaf yucca, western ragweed, broom snakeweed, zinnia, rushpea, scurfpea, catclaw sensitive briar, wild buckwheat and woollywhite (McMahan et al. 1984). Cross-referenced communities: 1) mixed prairie climax (Rowell 1967), 2) blue grama-buffalograss (Diamond 1993), 3) blue grama-buffalograss short grasslands (Bezanson 2000), and 4) blue grama herbaceous alliance (Weakley et al. 2000). The *blue grama-buffalograss* community is considered secure globally. Statewide, this community is considered rare or uncommon. Non-native grasses, such as kleingrass, have been seeded on millions of acres throughout this community. Mesquite, narrowleaf yucca, juniper species and other brushy species have invaded these once treeless prairies. Broomweed species and other weedy forbs now dominate grazed pastures (Bezanson 2000). Approximately 21-100 occurrences are documented within the state (Diamond 1993). Due to these concerns, this community is considered of medium priority for further protection.

Trans-Pecos Shrubland

Shrublands consist of individual woody plants generally less than nine feet tall scattered throughout arid or semi-arid regions where the vegetation is evenly spaced covering over 75% of the ground (Bridges et al. 2002). Typically there is less than 30% woody canopy cover overhead (McMahan et al. 1984). The Trans-Pecos shrubland includes six different plant associations, some being very unique and limited in range within Texas.

The *yucca-ocotillo* association is found principally in the Chinati Mountains, surrounding the Solitario, and throughout the rest of Presidio and Brewster counties. Commonly associated plants include catclaw acacia, whitethorn acacia, sotol, cholla cactus, Torrey yucca, palmella, brickellbush, mesquite, javelina bush, beargrass, black grama, chino grama, fluffgrass, broom snakeweed and jimmyweed (McMahan et al. 1984). This association prefers soils which are shallow and rocky, occurring at elevations below 4,500 ft. Cross-referenced communities: 1) creosote-ocotillo-mesquite association, creosote-lechuguilla association, sotol-lechuguilla association (Denyes 1956), 2) chino grama-lechuguilla, chino grama-candelilla (Warnock and Kittams 1970), 3) shrub desert (Wauer 1971), 4) limestone Chihuahuan Desert (Burgess and Northington 1979), 5) mixed desert scrub, lechuguilla scrub (Henrickson and Johnston 1986), 6) lechuguilla-grass-prickly pear, creosote-lechuguilla, lechuguilla-grass-candelilla, lechuguilla-grass-hechtia assemblages (Plumb 1988), 7) lechuguilla-sotol series (Diamond 1993), 8) Chihuahuan Desert scrub (Bezanson 2000), and 9) ocotillo shrubland alliance, creosote shrubland alliance, smooth sotol (lechuguilla, skeletonleaf goldeneye) shrubland (Weakley et al. 2000). The *yucca-ocotillo* community is apparently secure across the globe and also within the state (Diamond 1993).

The *creosote-tarbush* association consists of range ratany, cholla, fourwing saltbush, sotol, mesquite, whitethorn acacia, catclaw acacia, lechuguilla, chino grama, gyp grama, alkali sacaton, false nightshade, false broomweed and jimmyweed (McMahan et al. 1984). This association is typically found in Pecos and Reeves counties in fairly level, arid, non-saline alluvial plains (bajadas) below 3,800 ft. (Bezanson 2000). Cross-referenced communities: 1) mesquite-creosote bush association (Webster 1950), 2) creosote-tarbush association, creosote-tasajillo association (Denyes 1956), 3) shrub desert (Whitson 1970), 4) creosote, creosote-tarbush (Warnock and Kittams 1970), 5) creosote flats (Burgess and Northington 1979), 6) *Larrea* scrub (Henrickson and Johnston 1986), 7) creosote series (Diamond 1993), 8) creosote flats, creosote-grass, lechuguilla-tarbush assemblages (Plumb 1988), 9) creosote open shrub deserts, and 10) creosote shrubland alliance, tarbush shrubland alliance (Weakley et al. 2000). The *creosote-tarbush* community is apparently secure across the globe and also within the state (Diamond 1993).

The *creosote-lechuguilla* association includes mesquite, yucca species, lotebush, ocotillo, javelina bush, catclaw acacia, whitethorn acacia, whitebrush, ceniza, allthorn, guayacan, prickly pear cactus, pitaya, tasajillo, chino grama, black grama, fluffgrass, range ratany, skeletonleaf goldeneye, tarbush and mariola (McMahan et al. 1984). These associated plants are often found in the lower slopes (3,500 ft.) and intermountain valleys of the Trans-Pecos ecoregion, especially in Jeff Davis, Presidio and Brewster counties (Diamond 1993). Cross-referenced communities: 1) creosote-ocotillo-mesquite association, creosote-lechuguilla association, sotol-lechuguilla association (Denyes 1956), 2) chino grama-lechuguilla, chino grama-candelilla (Warnock and Kittams 1970), 3) shrub desert (Wauer 1971), 4) limestone Chihuahuan Desert (Burgess and Northington 1979), 5) mixed desert scrub, lechuguilla scrub (Henrickson and Johnston 1986), 6) lechuguilla-grass-prickly pear, creosote-lechuguilla, lechuguilla-grass-candelilla, lechuguilla-grass-hechtia assemblages (Plumb 1988), 7) lechuguilla-sotol series (Diamond 1993), 8) Chihuahuan Desert scrub (Bezanson 2000), and 9) ocotillo shrubland alliance, creosote shrubland alliance, smooth sotol (lechuguilla, skeletonleaf goldeneye) shrubland (Weakley et al. 2000). The *creosote-lechuguilla* and *creosote-mesquite* communities are demonstratably secure globally and statewide. These five communities are considered the most extensively protected community types in Texas and are considered a low to fairly low priority for further protection (Bezanson 2000).

The *creosote-mesquite* association is found principally in the east of the Delaware Mountains in Culberson County (McMahan et al. 1984). It is a xeromorphic shrubland inhabiting lower elevation flats (below 3,500 ft.) of the Trans-Pecos ecoregion. The creosote is highly associated with disturbed soil types, dominating shallow, rocky soils (Diamond 1993). The associated plants include sotol, lechuguilla, catclaw acacia, cholla, plains prickly pear cactus, Mormon tea, range ratany, desert sumac, plains bristlegrass, bush muhly, black grama, chino grama, fluffgrass, burrograss, mesa dropseed, purple three-awn, rough menodora, coldenia, mariola, grassland croton and sickle-pod rushpea

(McMahan et al. 1984). Cross-referenced communities: 1) mesquite-sumac-condalia association (Webster 1950), mesquite association (Denyes 1956), 2) mesquite-giant reed (Warnock and Kittams 1970), 3) mesquite thicket (Plumb 1988), 4) mesquite thickets (Bezanson 2000), and 5) honey mesquite temporarily flooded woodland alliance (Weakley et al. 2000).

The *fourwing saltbush-creosote* association is found principally in washes and alluvium of the Pecos River in Reeves, Ward and Crane counties (McMahan et al. 1984). The soil they prefer is typically saline and plant composition can vary depending on the magnitude of salinity, water availability and amount of disturbance (Diamond 1993). The associated plants include mesquite, salt cedar, tarbush, grassland prickly pear cactus, tasajillo, alkali sacaton, Wright's sacaton, tobosa, black grama, mesa dropseed, purple three-awn, two-flowered trichloris, jimmyweed, broom snakeweed and James rushpea (McMahan et al. 1984). Cross-referenced communities: 1) saline bolson (Burgess and Northington 1979), 2) *Prosopis-Atriplex* scrub (Henrickson and Johnston 1986), 3) mesquite-saltbush series (Diamond 1993), 4) mesquite-saltbush saline brush (Bezanson 2000), and 5) fourwing saltbush shrubland alliance (Weakley et al. 2000). The *fourwing saltbush-creosote* community is apparently secure globally; however, they were once fairly rare or uncommon throughout the state with less than 100 known occurrences (Diamond 1993). According to Bezanson (2000), they are no longer considered rare or uncommon but now widespread. They are currently unthreatened and occur in Guadalupe Mountains National Park and other locations throughout the Trans-Pecos. Therefore, he ranks them as fairly low priority for suggested protection.

The *mesquite-sandsage* association is a deciduous shrubland found in sandy soils of the western Trans-Pecos, principally in El Paso and Hudspeth counties (Diamond 1993, McMahan et al. 1984). The common plant associations include fourwing saltbush, palmella, Mormon tea, sotol, sand dropseed, mesa dropseed, spike dropseed, blue grama, black grama, chino grama, broom snakeweed and devil's claw (McMahan et al. 1984). It is secure statewide and globally. Cross-referenced communities: 1) sandsage prairie (Kuchler 1974), 2) sandsage shrub grassland (Bezanson 2000), and 3) sandsage shrubland alliance (Weakley et al. 2000). The *mesquite-sandsage* community is apparently secure across the globe and also within the state (Diamond 1993).

Trans-Pecos Parkland Woodland Mosaic

The parkland woodland mosaic can be best described by pastures or fields with widely scattered vegetation (trees and/or shrubs) covering 10-25% of the ground (Bridges et al. 2002). There are two plant associations in this habitat class.

The first dominant plant association found in this habitat class within the Trans-Pecos ecoregion is the *Ponderosa pine-Douglas fir* association. It is found on north facing canyons and slopes above 6,000 ft. in elevation. The main locations for this association occur in the mountains of the Trans-Pecos which are principally the Guadalupe Mountains in Guadalupe Mountain National Park, the Chisos Mountains in Big Bend National Park and the Davis Mountains located on private lands owned by The Nature Conservancy (McMahan et al. 1984, Diamond 1993, Bezanson 2000). The commonly associated plants are southwestern pine, bigtooth maple, alligator juniper, Gambel's oak, chinkapin oak, Emory oak, Texas madrone, Apache plum, mountain mahogany, Wright's silktassel, mountain snowberry, southwestern chokecherry, Pringle needlegrass, finestem needlegrass, pinyon ricegrass, cliff muhly, pine dropseed, largeleaf oxalis, rock betony and trumpet currant (McMahan et al. 1984). Cross-referenced communities: 1) moist woodland/forest (Wauer 1971), 2) pine woodland (Henrickson and Johnston 1986), 3) Ponderosa pine series (Diamond 1993), 4) montane conifer forest (Bezanson 2000), and 5) Douglas-fir forest alliance, Ponderosa pine forest alliance, Ponderosa pine woodland alliance (Weakley et al. 2000). All three occurrences of the *ponderosa pine-Douglas fir* community are located on conservation lands and are currently protected. However, this community it considered critically imperiled within the state meaning it is very vulnerable to extirpation. Globally it maintains a current status of "apparently secure" (Diamond 1993). Because it is so rare, fewer than six occurrences are documented within Texas. The *Ponderosa pine-Douglas fir* community is geographically isolated and highly dependent upon unique climatic conditions, therefore it is considered a vulnerable community type (Bezanson 2000).

The second plant association is the *gray oak-pinyon pine-alligator juniper* association typically found in sheltered canyons, at cliff bases and north-facing slopes occurring from 4,500 to 7,500 ft. in elevation. Typically this community is found in the major mountain ranges such as the Davis, Guadalupe and Chisos Mountain ranges (McMahan et al. 1984, Plumb 1988, Diamond 1993, Bezanson 2000). This association is mostly evergreen and typically found in alluvial soils in mountain valleys. Deciduous gray oak-oak series also occur in these areas but are restricted to the bottomlands of mesic mountain canyons. Many of the associated plants are very distinctive and restricted to this plant association alone (Diamond 1993). These plants include Emory oak, silverleaf oak, Gambel's oak, mountain mahogany, evergreen sumac, mountain snowberry, Texas madrone, southwestern chokecherry, bullgrass, Pringle needlegrass, finestem needlegrass, pine dropseed, sideoats grama, blue grama, pine muhly, pinyon ricegrass, largeleaf oxalis, heartleaf groundcherry and Torrey antherium (McMahan et al. 1984). Cross-referenced communities: 1) pinyon-juniper-oak savannah/woodland (Wauer 1971), 2) oak woodlands (Henrickson and Johnston 1986), 3) mixed oak, pinyon-oak-juniper assemblages (Plumb 1988), 4) gray oak-oak series (Diamond 1993), 5) montane oak-juniper-pinyon woodlands (Bezanson 2000), and 6) Mexican pinyon-Chisos red oak forest alliance, gray oak woodland alliance, Emory oak woodland alliance (Weakley et al. 2000). The *gray oak-pinyon pine-alligator juniper* is fairly common throughout the southwestern United States. However, in Texas this community only occurs in a few isolated mountain ranges within the Trans-Pecos making it fairly rare throughout the state. This community is considered apparently secure statewide and globally (Diamond 1993). A medium priority for further protection is suggested by Bezanson (2000). The *gray oak-pinyon pine-alligator juniper* community is fairly rare within the state, therefore, existing habitats should be monitored.

Urban Trans-Pecos Community

Urban habitats are cities or towns which are areas dominated by human dwellings including the fences, shrub rows, windbreaks and roads associated with their presence (Bridges at al. 2002). The biggest city in the Trans-Pecos is El Paso which is in northwestern most corner. Fort Stockton is the next biggest city in this ecoregion.

Smaller communities include Wink, Kermit, Monahans, Marathon, Terlingua, Wickett, Crane, Toyah and Marfa.

The City of El Paso's Public Service Board (PSB) owns thousands of acres of lands located within the foothills, bajadas, canyons, arroyos and mountainous regions of El Paso. These ecologically sensitive areas were originally purchased to serve as watershed protection lands. These areas contain the highest diversity of native plant and wildlife habitats, mainly within and near the Franklin Mountains and the Military's Castner Range.

Most of the land purchased by the PSB to protect watershed habitat is now being sold for development. The City of El Paso has addressed the water shortage by planning to build the largest de-salinization plant in the country. Well-water injection will be used to re-charge the bolsoms as the ecologically sensitive habitats are no longer thought valuable enough to protect.

Development of Castner Range is currently a hot issue in El Paso. Other important habitats to protect or restore is the riparian corridor along the Rio Grande, wetland habitats, and all other grassland, mountain and foothill areas, such as the Hueco Mountains and Keystone Heritage Park.

High Priority Communities: A Further Emphasis

Springs, streams, creeks, and other desert *water sources* such as *cienegas* are scattered throughout the Trans-Pecos ecoregion. These water sources are necessary to sustain flora and fauna in these microhabitats especially during the hottest times of the year. Common plants found in this community include spikesedges, sawgrass, caric sedges, Torrey rush, brookweed, western umbrella-sedge and water bentgrass. Prairie wedgegrass and other grasses can be found on the stream banks (Butterwick and Strong 1976, Johnston et al. 1976, Burgess and Northington 1979, Bezanson 2000). Many species of invertebrates and fish are found in or near these springs which occur nowhere else in the world. For example, within Pecos and Reeves counties there are springs which have created saline wetlands and contain endemic species such as the Leon Springs pupfish (Bezanson and

Wolfe 2001). Cross-referenced communities: 1) aquatic (Burgess and Northington 1979), and 2) spring-fed steams and cienegas (Bezanson 2000). *Desert springs, streams, and other water sources* in this ecoregion are now rare and those that remain are in danger of extirpation. Because there are not many springs that remain, they are more susceptible to overuse and pollution. Presently, even streams are rare. Most of these streams and springs have dried up within the last century. Specifically, 63 springs have failed out of 281 total springs in the state of Texas (Gunnar 1975) and many streams and creeks that once flowed are now dry. The desert water sources that remain are highly affected by drought years especially when large quantities of water are pumped for irrigation purposes (Bezanson and Wolfe 2001). Protected springs and streams are found at McKittrick Canyon in Guadalupe Mountains National Park, Big Bend Ranch State Park and Balmorhea State Park (Bezanson 2000). The Natural Area Preservation Association along with Environmental Defense, conserve approximately 250 ac. of desert spring wetland habitats in the Trans-Pecos ecoregion (Bezanson and Wolfe 2001).

Sand dunes are home to many rare plants which prefer the saline and gypsum-rich soils or the clay soils found in select locations of this ecoregion. These localities are considered "barrens". Around cities such as Monahans and Kermit, sheets of quartz sand dunes can grow up to 60 ft. tall. In the swales created from strong winds moving the dunes, water can accumulate and remain for long periods creating semi-permanent water sources for many wildlife species (Bezanson and Wolfe 2001). *Sand dunes* are protected within the Monahans Sandhills State Park, however, these unique communities deserve further protection (Bezanson and Wolfe 2001).

Canyons and riparian woodlands are found in mesic canyons and valleys sheltered from the heat and wind of the desert (Bezanson 2000). Typically these areas act as isolated microhabitats for many species especially during the summer months (Bezanson and Wolfe 2001). In areas where water flows occasionally, such as at the base of an intermittent waterfall, standing pools of water are typically found creating miniature oases with lush vegetation and great amounts of wildlife activity. Associated species include bigtooth maple, chinkapin oak, western hophornbeam, netleaf hackberry, velvet ash, little walnut, Mexican buckeye, acacia species, Emory oak, alligator juniper, evergreen sumac, Texas madrone, beargrass, Arizona grape, different grasses, sedges and forbs (Bezanson 2000). Cross-referenced communities: 1) riparian woodland (Burgess and Northington 1979), 2) deciduous woodland (Wauer 1971), 3) bigtooth maple-oak series and velvet ash series (Diamond 1993), 4) bigtooth maple montane forest alliance, Xalapa madrone-bigtooth maple-oak forest (Weakley et al. 2000), 5) canyon scrub (Henrickson and Johnston 1986), 6) deciduous canyon forests, and 7) canyon riparian woodlands (Bezanson 2000). *Canyons and riparian woodlands* are fairly protected from settlement and even public management. These habitats are isolated, very small and uncommon. There are scattered, tiny patches in the Chisos Mountains within Big Bend National Park as well as about 300 ac. in McKittrick Canyon that are presently conserved. It is suggested that these habitats are of high priority for protection due to the relative rareness and high importance of these habitats for desert wildlife species (Bezanson 2000).

Rock outcrops, made of limestone or igneous rock, are exposed throughout the Trans-Pecos. Locations such as talus slopes and cliffs typically contain one of these types of outcrops, sometimes both. Examples of these communities are found in mountain ranges located within Guadalupe Mountains National Park and Black Gap Wildlife Management Area and throughout the Davis, Chinati and Chisos Mountain ranges (Bezanson 2000). Endemic plants found in this community include true mountain-mahogany, rock-daisies, tufted rockmat, esperanza, yellow rock-nettle, cliff fendlerbush, mock-oranges, namas, false pennyroyal species, salvia species, needleleaf bluet, lip ferns and other lithophilic shrubs and forbs that are unique to these areas. In seeps, maidenhair fern, columbines and other species can be found as well (Correll and Johnston 1970, Johnston et al. 1976, Burgess and Northington 1979, Powell and Whitefield 1994, Bezanson 2000). Cross-referenced communities: 1) mountain outcrops (Burgess and Northington 1979), 2) limestone cliffs/outcrops (Bezanson 2000), and 3) pericome sparsely vegetated alliance (Weakley et al. 2000). Igneous and limestone *rock outcrops* are home to many endemic shrub and forb species that only grow in rock crevices found in the Trans-Pecos and are found no where else (local). Because they are very inaccessible to the general public they are not greatly threatened presently, however, most are not protected. Bezanson suggests that this community has a medium priority for protection at present (Bezanson 2000). More research and possible monitoring is needed for this community.

Problems Affecting the Trans-Pecos

See the Texas Priority Species List……………………733

Element 3

The *Tobosa-black grama* community is widespread but has been over-used and under-managed. The once pristine grassland areas have been invaded by species such as lechuguilla, creosote and other desert shrub species. Due to inappropriate grazing regimes, soil compaction has decreased the health of this community. Intact stands are still found and protected in Big Bend National Park, Sierra Diablo Wildlife Management Area and Franklin Mountains State Park (Yancey 1997, Bezanson 2000). The *blue grama-buffalograss* community has also been over-used and under-managed. The prevention of wildland fires and seeding this area with non-native grass species for grazing purposes has caused the invasion of non-native and brushy species. Areas of this community are protected in Lake Meredith National Recreation Area, Buffalo Lake and Muleshoe National Wildlife Refuge (Bezanson 2000).

Many *aquifer water tables* have been lowered due to increased populations and, in return, water usage. This has caused many springs in the Trans-Pecos to run dry preventing water from reaching streams that once flowed. Endangered fish species, many times endemic to specific springs, must compete with non-native fish species. Due to an increase in the human population, habitat loss is also a factor. Other issues such as contamination of water sources from nearby pollution and overuse of riparian areas are also affecting the desert oases negatively (Bezanson and Wolfe 2001).

Sand dunes are a very popular attraction. Most of this habitat has become rare due to development and habitat encroachment and some areas are degraded from erosion, compaction and degradation from off-roading vehicle use. The remaining *sand dune* habitat is in poor condition. About one hundred years ago, the loss of the original grass cover in these areas permitted the rapid entry of mesquite, which can sprout when covered by sand. Under these conditions, it assumes a prostrate form that stabilizes the areas of soil beneath its canopy. Wind erosion between the shrubs creates the mound-depression aspect of the landscape. It is theorized that the changes in vegetation that occurred in native grasslands resulted from overgrazing, perhaps in concert with a subtle change in climate and by changes in the animal population.

Canyons and riparian woodlands, especially in the lower elevations, have been detrimentally affected by water diversion, overgrazing and persistence of the invasive salt cedar. Potential increases in the change of land ownership and the building of subdivisions on large ranches could create further degradation of these canyons and riparian woodlands (Bezanson and Wolfe 2001). There are also issues of limited habitat due to urban encroachment and habitat development.

A majority of communities in the Trans-Pecos ecoregion are degraded from compaction, erosion, cacti poaching and pollution. In some areas there are also issues of over-grazing, and the invasion of woody species and non-native grasses. This ecoregion is also being rapidly developed, therefore, limited habitat remains due to urban encroachment and habitat development. This fact also creates problems with habitat that is degraded by pollution, trash, erosion and native plant destruction.

Element 5

High Priority Research and Monitoring Efforts for the Trans-Pecos

See Monitoring and Adaptive Management………… 559

See the Texas Priority Species List……………………733

- More research on the species richness and density of bats located in the ecologically sensitive areas
- Research on local bird species (e.g. Swainson's and red-tailed hawk, golden eagle, American kestrel and loggerhead shrike) that roost in many areas located within the ecologically sensitive PSB and other development Master Plans
- Study reptile species of concern in the area (e.g. short-horned mountain horned lizard, lyre snake and rock rattlesnakes)

- Study the endangered cacti species that are found in these habitats (e.g. Sneed's pincushion and desert night-blooming cactus)
- Continuance of the Rio Bosque Wetlands Park (UTEP and City of El Paso) and Featherlake Bird Sanctuary (Trans-Pecos Chapter of Audubon Society) monitoring and habitat restoration plans
- Continuance of the Keystone Heritage Park's (KHP) habitat and wetland restoration. Current habitat work is monitored by the local Urban Wildlife Biologist

High Priority Conservation Actions for the Trans-Pecos

See High Priority Conservation Strategies…………..517
See the Texas Priority Species List…………………... 733

Element 4

- An Arroyo Protection and a Natural Open Space Ordinance in El Paso. Work has begun on arroyo protection and open space plans that include recreational areas, like City Parks and golf courses. Open Space Preservation methods need to focus on natural undisturbed native habitats. The City of El Paso's development Master Plan's need to include a protocol of looking at the entire habitat before making development plans. This will include surveying the entire area to protect arroyos, canyons and other areas of high ecological importance prior to drafting a master plan
- The PSB is currently using an accelerated gradation of development density from higher to lower elevations that does not provide enough open space or low-density development. High cluster density needs to increase at lower elevations to allow more open space and low-density development closer to the mountains and to the border of the Franklin Mountain State Park
- Construction methods need to be revised to preserve remaining native habitat in these areas. Currently, the most popular way to build is to completely scrape the entire area prior to building

- A new non-profit land trust, Frontera Land Alliance, has formed and is working on acquiring ecologically sensitive habitat. The organization needs support and funding
- Encourage cities to modify mowing regimes and start prairie restoration projects.
- Emphasize the importance of proper grazing. Work with state, federal and private agencies to continue to develop cost-effective means to balance grazing and wildlife. Patch grazing appears to be very promising
- Work with federal, state and private organizations to promote (incentives) leaving some cover for wildlife. The economic benefits of wildlife can sometimes equal or surpass the agricultural value of land

Inland Aquatic Resources Conservation Priorities for Texas Waters based on the *Land and Water Resources Conservation and Recreation Plan* (Land and Water Conservation Plan)

Associated Maps

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Introduction

Texas has nearly 200,000 mi. of streams and rivers and approximately 1.7 million ac. of reservoirs and public water impoundments which provide habitat for the state's diverse fish and wildlife species. Scientists recognize 247 fish species that inhabit fresh water for at least a part of their lives. Texas Parks and Wildlife Department estimates that 25% of native freshwater fish species are threatened, endangered, or already extirpated.

In the 15 major river basins, watercourses range from wide, shallow and sandy prairie rivers, clear, spring-fed streams, to slow-moving bayous with extensive hardwood bottomlands. Many of the state's rivers and streams originate from Texas freshwater springs. Many of these spring systems support unique habitats with species found nowhere else in the world. Both the river and stream systems provide water for reservoirs, which range in size from less than one acre to the 185,000 acre Toledo Bend Reservoir. In addition, aquifers underlie much of the state and provide water for various functions including meeting the needs of wildlife.

Springs and Aquifers

Groundwater systems in Texas are very diverse. Rainfall can be taken up by plants, evaporate over time, form runoff into streams, rivers and estuaries, or it can become groundwater by seeping into soil, sand and other land features. Water that moves into groundwater can begin the process of aquifer recharge. Aquifers are ground formations that store and transport water and are often tapped for human use.

Major aquifers in the state are often vast, extending under dozens of counties and reaching from one border of the state to another. There are nine major aquifer outcrops in the state with some having associated downdrips which are “water bearing rock layers which ‘dip’ below other rock layers”. In addition, there are 21 minor or smaller aquifers in the state. The associated maps from the TWDB indicate the locations of these aquifers and give an indication of how large they are and where their associated downdrips are located. In addition, the TWDB has produced the “Aquifers of Texas” by John Ashworth and Janie Hopkins, which describes these aquifers in detail and gives information on their importance to Texas water quality and quantity issues (1995).

Springs are the natural outlets of aquifers. Springs that have run dry have had profound effects on surface water because they often form the base flows that sustain rivers and streams during drought. It is difficult, if not impossible, to restore aquifers that have been drawn down and continue to have withdrawals that greatly exceed the available recharge, but it is possible to conserve springs that depend on aquifers that recharge quickly. Gunnar Brune’s *Springs of Texas* does an excellent job of outlining the characteristics of the springs of Texas as well as offering insight into geology, flora and fauna associated with these springs (1995). In addition, Mr. Brune discussed the decline of springs as well as Texas water law. While this book was originally published in 1981, the bulk of the information is still relevant today and offers insight into Texas water issues.

Wetlands in Texas (information adapted from the Texas Wetlands Conservation Plan)

Wetlands are among the most important habitats in Texas. These interfaces between water and land are integral in supporting a vast array of plants, fish and wildlife. They also perform numerous valuable functions: they trap water, sediments and nutrients and therefore play a major role in improving water quality and decreasing pollution. They are invaluable for their ability to prevent and minimize flooding, protect shorelines and replenish groundwater sources.

Texas has lost thousands of acres of historic wetlands, while human activities, including landscape alteration for agricultural, industrial or urban uses, significantly threaten remaining wetland habitats. Subsurface mineral and water extraction can also destroy wetlands, especially along the coast. Over harvest of timber threatens wooded wetlands as is evidenced in the state's bottomland hardwoods, pine flatwoods and swamps. Reservoir construction can submerge wetland areas upon filling, or they may be destroyed by diverting or capturing their source of water. Along the coast, reduced flow in rivers and streams can cause loss of freshwater wetlands due to increased saltwater intrusion. In the Panhandle, increased siltation from natural and agricultural erosion threatens playa lakes, which are important habitat for waterfowl and many other wildlife species.

Aquatic Conservation Threats

Element 3

The most significant conservation challenges to both freshwater and saltwater systems in Texas are reduced water quality and decreased water quantity. Factors such as increasing population, increasing demands for water and increasing shoreline development directly affect water quality and quantity.

Reduced Water Quality

Point source and nonpoint source pollution, which contribute to nutrient loading, directly threaten native fish and wildlife species that rely on clean water. Water that will not support fish and wildlife will not support human needs either. As the population grows and water demands and waste runoff increases, water flow in rivers and streams, or instream flow, decreases. In the next decade, pollutant concentrations in rivers and streams may increase to a point where they have a detrimental effect on aquatic life including low oxygen, harmful algal growth and fish kills.

Reduced Water Quantity

Decreased or altered water quantity will affect the ecosystems, habitats and wildlife that depend on the natural flow regime of the stream or river. For example, groundwater withdrawals, inflow rerouting, reservoir operations and increased use of water make rivers, streams and springs and the fish and wildlife resource they support exceptionally vulnerable to the effects of drought.

Reservoir Construction

Texas Parks and Wildlife Department recognizes that reservoirs are necessary to store water for human water consumption, flood control and hydropower generation and to provide much of the freshwater recreational opportunities available to the public. However, reservoir development significantly alters the stream and river systems that supply water for storage as well as the bay and estuary systems downstream. Direct impacts of reservoir construction are caused by inundation of the land which displaces wildlife and causes the loss of terrestrial, wetland, riverine, riparian and bottomland hardwood habitat types. Indirect impacts include reduction and/or alteration of downstream riverine, estuarine riparian, wetland and bottomland hardwood habitat types which harm species that depend on them.

Introduced Species to Aquatic Environments

Exotic plant and animal species that are introduced either by design or by accident can cause unintended harmful consequences. Exotic species may become invasive, spreading rapidly, displacing native species and threatening community relationships that are necessary to sustain the aquatic environment. Eighteen non-native fish species have been documented in Texas as well as a number of snail and bi-valve species. Some have had an extremely negative impact on native fish communities. Further, great effort and resources have been expended to control invasive aquatic plants such as water hyacinth, hydrilla and giant salvinia, which have negatively affected native freshwater communities.

Conservation of Texas' Freshwater Systems

Conserving freshwater begins when it rains and where the raindrops make first contact with the soil. Sufficient, quality freshwater runoff from land into rivers, streams, springs and reservoirs is critical to conserve and maintain the health of aquatic and terrestrial systems. In addition to the habitat that these systems support, they can also provide drinking water, food, power, irrigation, transportation and wastewater treatment. With the responsibility for maintaining these habitats and as the state trustee for aquatic resources, TPWD has developed numerous programs to promote the conservation of rivers, streams, springs and reservoirs in order to provide quality recreational opportunities.

Instream Flow Study Needs for Texas River Basin Conservation

Over the past 12 years, TPWD has studied and determined the quantity of freshwater inflows to Texas' seven major bay and estuary systems necessary to maintain healthy habitats along the coast. Today, a similar effort is needed for rivers. Instream flow studies are evaluations of river and stream systems that are conducted to determine the appropriate flow regimes necessary to conserve fish and wildlife resources. Texas Parks and Wildlife Department conducts these studies to better understand river systems and to minimize impacts from existing and future water development. Given that instream flow studies can involve years of research and data analysis, TPWD developed a tiered system to make decisions on allocating resources to study the state's 15 major river basins. Each river basin was categorized by the type of instream flow study needed based on water availability, water rights permits, proposed water development projects and biological factors. The main resource studied was the instream flow as it pertains to water development projects, therefore the tiered system is less appropriate for the CWCS; and as a result was not used to delineate priority in this strategy. While the tiered system is not as applicable to the CWCS, it is important in terms of instream flow and should be reviewed for the sake of its importance to Texas water conservation. In addition, the 15 river basins chosen are also the focus of the CWCS.

Major Conservation Goals Associated with Texas Fresh Water

Maintain or Improve Water Quality

Element 4

- Work to assure water quality needs are met in all streams, rivers, reservoirs and coastal systems
- Collaborate with the TCEQ and other regulatory agencies to promote the conservation of water quality in streams and rivers

- Support efforts to integrate biological and physical habitat data into water quality standards
- Conduct research and evaluate water quality concerns in Texas' freshwater and coastal water resources

Maintain Adequate Water Quantity

- Implement and update tiered instream flow study priorities
- Complete instream flow studies at the basin and subbasin level in coordination with TCEQ and TWDB. Site-specific assessments will also be required to address specific water development projects
- Design studies to assist in regional water planning and water rights decision making

Strategies for Meeting the Conservation Needs on Water

- Implement freshwater inflow and instream flow studies' recommendations
- Support amending the Texas Water Code to better recognize instream uses (instream flows, freshwater inflows to bays and estuaries, water quality, fish and wildlife resources, aesthetics and recreation) as beneficial uses when appropriating state water to ensure water is available for the health of fish and wildlife
- Work with regulators, regional water planning groups and stakeholders to develop state and regional water plans that protect the needs of fish and wildlife by incorporating flow regimes that adequately protect aquatic systems
- Work with regulators, permit holders and stakeholders on water rights permits to protect the needs of fish and wildlife by incorporating special conditions that adequately protect aquatic systems. Texas Parks and Wildlife Department will encourage the conversion or transfer of existing unused water rights to the Texas Water Trust to protect instream uses
- When a water right is converted to a different use, sold or transferred out of basin, it is recommended that those actions should include permit conditions to mitigate

detrimental impacts and ensure flows necessary to maintain the health of fish and wildlife

- Encourage private landowners to use a watershed management approach to increase water quantity and quality in rivers and streams to increase freshwater inflows to the bays and estuaries
- Incorporate the goal of watershed management and improving water quality and quantity into all Wildlife Management Plans (WMP)
- Texas Parks and Wildlife Department, Texas Department of Agriculture, Texas Agricultural Extension Service, River Authorities and other organizations shall work to fund projects that increase water yields while protecting or improving wildlife habitat

Protect Texas Springs and Wetlands

- Fully implement the *Wetlands Conservation Plan.*
- Ensure that future legislation affecting groundwater also protects springs and other beneficial uses for wildlife
- Texas Parks and Wildlife Department shall participate in the Groundwater Availability Models effort being directed by TWDB and advocate that these models be used to manage groundwater dumping to minimize impacts to springs and other associated surface water features
- Encourage groundwater districts to implement management practices that protect springs and spring habitats in their plans

Improve Outreach and Education

- To increase support for conserving Texas freshwater and coastal water resources, conservation partners must increase outreach and education efforts
- Increase efforts to produce public education materials that discuss the importance of river, spring, reservoir, wetland, bay and estuary conservation
- Encourage anglers and boaters to increase their role as conservationists
- Assist local communities in planning and education programs that promote water conservation for fish and wildlife

- Work with schools to integrate water resource and recreation information into their curriculum

Reduce User Conflicts

- Provide education and communication with all user groups concerning recreation impacts on water resources

Increase Knowledge and Understanding of Aquatic Ecosystems

- Base conservation decisions that impact fish and wildlife resources using the best science available
- Prioritize waterways that are important for conservation
- Develop and refine tools for analyzing aquatic systems and develop new conservation strategies like the CWCS
- Identify river and stream segments most at risk from over appropriation
- Increase our understanding of biological resources present in Texas rivers, streams, springs and reservoir systems
- Make historical reports and associated data available for research to document long term changes to flora and fauna of rivers and streams
- Improve monitoring and research on aquatic species or groups suspected to be declining or whose status is unknown. Texas Parks and Wildlife Department will research and monitor bay and estuary systems
- Determine freshwater inflows and nutrient and sediment loading regimes to tidal streams

Exotic Species

- Prevent the introduction of potentially harmful, nonindigenous fishes, shellfish and aquatic plants into freshwater and marine environments through education and regulations
- Implement the State Aquatic Vegetation Management Plan (Durocher and Chilton)

- The following goals and objectives are provided as a method of measuring the success of the Land and Water Plan. They also provide guidelines by which state planners may evaluate the success of future conservation efforts

Major Goals and Objectives for the Next Ten Years

Goal: Increase Support for Conservation on Private Land

Objectives:

- Incorporate recommendations for watershed management in all Wildlife Management Plans (WMP)

Element 5

Goal: Improve Science and Data Collection

Objectives:

Undertake a complete review of all scientific and conservation programs.

- Review assessment and monitoring functions for fish and wildlife populations
- Complete an independent programmatic peer review
- Establish a systematic review process

Develop an integrated GIS database of fish, wildlife and water data to assure that decisions are based on sound science and the best available data.

- Annually develop Internet accessible data and analytical capability. Develop provisions for continuous updating and coordination with other state agencies to access pertinent data
- Complete formal agreements with state and federal resource agencies where necessary

Goal: Maintain Sufficient Water Quality and Quantity to Support the Needs of Fish and Wildlife

Objectives:

In conjunction with TCEQ and TWDB, complete instream flow studies to determine the quantity and timing of water and flow regime necessary to support a sound ecological environment in rivers and streams.

- Work with TCEQ and TWDB and with each of the 16 water planning regions over the next two state water planning cycles in 2006 and 2011 to incorporate fish, wildlife and recreation needs into each regional plan and the state water plan

Encourage the conversion or transfer of existing unused water rights to the Texas Water Trust to protect instream uses.

Work with landowners, river authorities and regulatory entities on a watershed management approach, including range and habitat management practices, to improving water quality and quantity.

Work with appropriate agencies to develop and implement nutrient, habitat and biological criteria for state waters (rivers and estuaries) to protect the health and productivity of those waters.

- During each of the subsequent triennial reviews (2003, 2006 and 2009) TPWD will work with affected stakeholders to assure the water quality standards increasingly incorporate biological information conducive to the management of fish and wildlife resources and implementation of this Plan

The Land and Water Plan assists in providing guidance for future conservation of Texas inland waters over the next 10 years. Goals for TPWD have been set and these goals are useful in moving conservation forward in Texas. When coupled with the CWCS effort, these goals can be used independently or they can be sharpened and made more specific to meet the needs of Texas native species and the habitats associated with these species. The following chapters supply facts on the major river basins of Texas and provide more specific information concerning the issues associated with each basin. The 15 river basins are highlighted with information concerning the location and condition of each basin and its tributaries as well as the problems associated with these waterways. In order to address the goals of the Land and Water Plan as well as the problems associated with these basins, actions are also provided that supply guidance for future conservation efforts within the basins.

Brazos River Basin

Associated Maps

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Associated Section IV Documents

The Texas Priority Species List…………….733

Element 1

Priority Species

Group	Scientific Name	Common Name	State/Federal Status
Amphipods	*Stygobromus bifurcatus*	Bifurcated cave amphipod	SC
Crayfish	*Fallicamberus macneesei*	MacNeeses crayfish	SC
	Procambarus brazoriensis	Brazoria crayfish	SC
Shrimp	*Macrobrachium carcinus*	Bigclaw river shrimp	SC
	Macrobrachium ohione	Ohio shrimp	SC
Mussels	*Arcidens confragosus*	Rock pocketbook	SC
	Lampsilis bracteata	Texas fatmucke	SC
	Quadrula houstonensis	Smooth pimpleback	SC
	Quincuncina mitchelli	False spike	SC
	Strophitus undulatus	Creeper	SC

	Truncilla macrodon	Texas fawnsfoot	SC
Snails	*Orygocerus* sp.	Straight-shell hybrobia	SC
Fish	*Anguilla rostrata*	American eel	SC
	Cycleptus elongatus	Blue sucker	ST
	Cyprinodon rubrofluviatilis	Red River pupfish	SC
	Macryhbopsis storeriana	Silver chub	SC
	Micropterus treculii	Guadalupe bass	SC
	Notropis atrocaudalis	Blackspot shiner	SC
	Notropis buccula	Smalleye shiner	FC
	Notropis oxyrhynchus	Sharpnose shiner	FC
	Notropis potteri	Chub shiner	SC
	Notropis shumardi	Silverband shiner	SC

Location and Condition of Brazos River Basin

Element 2

Within Texas, the Brazos River has a total basin drainage area of 42,800 sq. mi., and its total length equals 840 mi. The Brazos River begins in eastern New Mexico and northwest Texas and flows in a southeastern direction to its mouth at the Gulf of Mexico. Normal yearly rainfall in the basin ranges from about 19 in. per year in Lubbock to more than 56 in. per year in Angleton (BRA 2005). The Brazos flows through most of the major physiographic ecoregions of Texas beginning with the High Plains in the uppermost part of the basin, followed by the Rolling Plains, Cross Timbers, Edwards Plateau, Blackland Prairies, Post Oak Savannah and ending in the Gulf Coast Prairies and Marshes (BEG 1996a). Nearly 3.3 million people live within the Brazos basin (BRA 2005).

Three main tributaries make up the headwaters of the Brazos River: the Double Mountain, the Salt Fork and the Clear Fork. The main stem of the Brazos River begins at the junction of the Double Mountain and Salt Forks in Stonewall County. There are 19 major reservoirs in the basin with a total conservation storage of 3,322,880 ac. ft. (BEG 1996b), including three major reservoirs on the main stem.

The Double Mountain Fork forms near Tahoka in Lynn County, flowing east for approximately 150 mi. to its confluence with the Salt Fork. Presently, the river continues to flow through ranching and farming country, with little development surrounding it. During periods of normal flow the river is extremely shallow and meanders within its stream bed.

The Salt Fork forms in southeastern Crosby County, flowing southeast for about 175 mi. to join the Double Mountain Fork in Stonewall County. The Salt Fork is intermittent and very shallow a majority of the time, meandering across a wide stream bed containing many large sand bars. During heavy rains flash floods are common. Flood waters are typically muddy and contain high concentrations of salty minerals.

The Clear Fork is characterized by muddy water, steep banks and low overhanging willow, pecan and elm trees. The flood plain is generally utilized for farming and ranching. Except during periods of heavy rainfall, the river flows slowly. Between US 180 and US 380, a lake of about four miles in length is formed by a small dam. Below the dam the river is scenic, passing through rolling hills and ranch country of west Central Texas.

There are 52 water body segments listed as impaired on the 2004 draft 303(d) list (TCEQ). These include 41 segments listed for bacteria, seven segments listed for depressed dissolved oxygen, two for toxicity to aquatic organisms, two for chlorides, two for total dissolved solids, one for sulfate and one for both high and low pH (several segments are listed for more than one parameter). Segments listed for depressed DO include Gibbons Creek in Grimes County, Lake Mexia in Limestone County, Rocky Creek in Burnet County, Proctor Lake in Comanche County, Salado Creek in Bell and

Williamson counties, Upper Oyster Creek in Fort Bend County and Aquilla Reservoir in the Hill County. The Brazos G Regional Water Quality Planning Group (one of 16 such groups in Texas contributing to the 2002 State Water Plan) describes natural salt pollution as the most serious and widespread water quality problem in the region, which includes the entire middle basin and some of the upper basin (HDR 2001). Mean total dissolved solids concentrations range from 40,399 mg/L in the Salt Fork of the Brazos River in the upper reaches of the basin, to 433.6 mg/L in main stem Brazos River upstream of the intertidal area near the Gulf of Mexico (TCEQ 2002, based on the 1996 through 2001 assessment period). The regional water planning group also projects water shortages for 30 counties in the region primarily due to increases in municipal and steam-electric uses during the first half of the 21st century. The proposed Little River Reservoir is among the water management strategies recommended by the regional water planning group to address future water needs (TWDB 2002). Five minor reservoirs were also recommended: New Throckmorton, Brushy Creek, Meridian Off-Channel, Somervell Off-Channel and Groesbeck Off-Channel. In addition, there are several major water rights requests in the Brazos Basin pending at TCEQ. Combined, these requests total 489,083 ac. ft. per year for new diversions, including the Brazos River Authority's request to operate its reservoirs as a system. The cities of Lubbock and Cleburne have also requested permission to divert and use all of their historic and future treated effluent.

Associated Water Bodies

Main tributaries further downstream of the Double Mountain, the Salt Fork and the Clear Forks include Yegua Creek, Bosque River, Little River (fed by the Leon, Lampasas and San Gabriel rivers) and the Navasota River.

Bosque River

The Bosque River rises in northern Erath County and flows approximately 115 mi. southeast through Hamilton, Bosque and McLennan counties to join the Brazos River at Waco. One reservoir, Lake Waco, is located on the river in McLennan County. The Bosque flows through rolling hills with post oak and juniper dominating the vegetation. The river is a perennially flowing stream, but its suitability for recreational use is restricted during dry periods. Since the 1980's, the North Bosque has been heavily impacted by nutrient runoff from intensive dairy farm development in Erath County.

The North Bosque River in its upper reaches in Erath, Hamilton and Bosque counties is a relatively narrow, free-flowing stream. From Iredell to Clifton the North Bosque River is lined with scenic vegetated banks of pecan, sycamore, elm and cottonwood. At Lake Waco the North Bosque joins the other Bosque tributaries, Hog Creek, Middle Bosque and South Bosque. Below Lake Waco, the Bosque River flows into the Brazos River in the city of Waco.

Paluxy River

Rising in northeastern Erath County, the Paluxy River flows southeast for 38 mi. through Wood and Somervell counties to join the Brazos River. The river is formed by the junction of the North and South Forks, both small streams with limited flow. The stretch between Paluxy and Glen Rose contains the famous Dinosaur Valley where well-exposed dinosaur tracks have been found in the riverbed (Dinosaur Valley State Park is located within this area). The river at the Park is a small, narrow waterway but has numerous rapids during periods of heavy rainfall. Scenic hardwood bottomlands consisting of oak, elm and Ashe juniper are common along the entire section. Limestone outcroppings are common and in some places the riverbed is composed entirely of limestone with sandy banks.

San Gabriel

The San Gabriel River is formed at Georgetown by the union of its North and the South Forks. After the forks unite, the river flows northeast about 50 mi. through Williamson and Milam counties where it joins the Little River. The scenery along the main stem of the San Gabriel is varied, with heavy vegetation on the banks and periodic bluffs. Water levels fluctuate for the entire length of the river; however, except during the dry summer periods, there is normally sufficient water for recreational use.

The North Fork San Gabriel River originates in Burnet County and flows southeastward through Burnet and Williamson counties to Lake Georgetown before joining the South

Fork in the city of Georgetown. The river flows through limestone formations typical of the Edwards Plateau. Also formed in Burnet County, the South San Gabriel River flows generally eastward through Williamson County to eventually join the North Fork in Georgetown. The topography and vegetation along this fork is similar to its Northern counterpart. Further downstream, in eastern Williamson County, the San Gabriel is impounded at Lake Granger.

Lampasas River

The Lampasas River rises in western Hamilton County and flows approximately 100 mi. southeast through Lampasas, Burnet and Bell counties. The river unites with the Leon River to form the Little River just south of Belton. Flowing through rugged hill country, the Lampasas contains heavily vegetated banks. The River is characterized by low flows most of the time.

The upper reaches of the Lampasas River flow through a region of Central Texas that is typical of the Edwards Plateau. Here, limestone bluffs are prominent and vegetation is abundant along both banks of the river. The banks of the Lampasas are made up of elm, willow and sycamore, and become fairly steep. From the Stillhouse Hollow Reservoir to the Leon River Water turbidity is clear below Stillhouse Hollow Dam, but becomes increasingly muddy as the river moves downstream. By the time the Lampasas reaches the confluence with the Leon River, the water flows very slowly between steep, muddy banks.

Little River

Formed in Bell County by the union of the Leon and Lampasas rivers, the Little River flows southeast for 75 mi. to join the Brazos River in Milam County. This waterway has sufficient water for recreational use at all times due to major inputs from these two tributaries. A third major tributary, the San Gabriel River, joins the Little River in Milam County. The Little River flows very slowly, winding between heavily vegetated banks for its entire distance.

The first section of the Little River flows through relatively flat farming and pasture country. A number of high earthen bluffs are prevalent, particularly in the vicinity of the town of Little River. Vegetation consists predominantly of willow, elm and sycamore. The Little River continues to flow through relatively flat farm land along its central expanse. The river is slow-moving and the banks are steep and muddy. Because of this, the water has a murky appearance.

There are 19 major reservoirs in the basin with a total conservation storage of 3,322,880 ac. ft. (BEG 1996b). Three major reservoirs are located on the main stem, and the best sections for recreation are found below Possum Kingdom Dam. Few major hazards are found on the entire river.

Reservoirs

Associated Reservoir	Location	Size (ac.)	Max Depth (Ft.)	Date Impounded	Water Level Fluctuation	Water Clarity	Aquatic Vegetation
Alan Henry	45 mi. south of Lubbock and 4 mi. east of Justiceburg on the Double Mountain of the Brazos River	2880	100	1993	2-4 ft. annually	Murky to clear, visibility 1-4 ft.	Vegetation in the lake is primarily flooded trees.
B.A. Steinhagen Lake	On the Neches River 14 mi. west of Jasper on US 190	16830	35	1951	3 ft. annually	High turbidity	Primarily water hyacinth, hydrilla and American lotus
Bryan Utility Lake	In Brazos County 5 mi. west of Bryan, Texas	828	45		Limited	Moderately stained	Native emergent
Gibbons Creek Reservoir	On Gibbons Creek in the Navasota River drainage in Grimes County, just off Texas Highway 30 at Carlos, 20 mi. east of	2500	34	1981	1-2 ft. annually	Slightly to moderately stained	Hydrilla and American lotus dominate, with traces of other native emergent aquatic plants.

	Bryan/College Station						
Granger Lake	Located Northeast of Austin in Williamson County, on the San Gabriel River near the towns of Granger and Taylor	4040	50	1980	Moderate	Turbid to moderately turbid	None
Hubbard Creek Reservoir	On Sandy Creek, Hubbard Creek and Brushy Creek in Stephens County, 51 mi. northeast of Abilene and about five mi. west of Breckenridge	15250	60	1962	Moderate, sometimes prone to long periods with dropping water levels	Slightly stained to clear with visibility up to 6 ft.	Hydrilla, bulrush and floating-leaf pondweed
Lake Cisco	On Sandy Creek 55 mi. east of Abilene and 5 mi. north of Cisco	1050	70	1923	Moderate, sometimes prone to long periods with dropping water levels	Clear to slightly stained, visibility up to 6 ft.	None

Lake Clyde	On the headwaters of the Pecan Bayou 25 mi. east of Abilene and 5 mi. south of Clyde	500	30	1970	Moderate, sometimes prone to long periods with dropping water levels	Slightly stained to stained, visibility up to 3 ft.	None
Lake Creek Lake	Reisal, TX	590	35	1952			American lotus, American pondweed, common buttonbush, common cattail, cutgrass, narrow leaf cattail, round rush, spikerush, spiny naid, willow
Lake Daniel	On Gonzales Creek in Stephens County, 65 mi. northeast of Abilene and about 10 mi. south of Breckenridge	950	42	1948	Moderate, sometimes prone to long periods of dropping water levels	Stained	Floating-leaf pondweed when lake is full
Lake Fort Phantom Hill	On Elm Creek in Taylor County, 15 mi. north of Abilene	4246	66	1938	Moderate to severe, sometimes prone to long periods with dropping water levels	Stained to muddy and red-colored in upper end	Stargrass, bulrush, pondweed, smartweed
Lake Georgetown	Williamson County, just west of Georgetown, 20 mi. north of Austin	1310	85	1980	5-30 ft. annually	Clear to slightly stained	None

Lake Graham/Lake Eddleman	On the Salt Creek in Young County, five mi. north of Graham on US 380	300	45	1929	Minimal, sometimes prone to long periods with dropping water levels	Slightly stained to stained	Bulrushes, lily pads, smartweed
Lake Granbury	On the Brazos River in downtown Granbury, off US 377 33 mi. southwest of Forth Worth	8700	75	1969	1 ft. or less annually	Clear to stained	Limited amounts of bulrush, cattails and water stargrass
Lake Kirby	On the south side of Abilene, just east of US 83	740	16	1928	Variable	Red colored with visibility less than 12 in.	Bulrushes
Lake Leon	On the Leon River in Eastland County, 68 mi. east of Abilene and 10 mi. south of Eastland	1590	55	1954	Minimal, sometimes prone to long periods of dropping water levels	Slightly stained to clear with visibility up to 4 ft.	Floating-leaf pondweed, bulrush, water willow
Lake Limestone	On the Navasota River 15 mi. southeast of Groesbeck on FM 3371 in Leon, Robertson and Limestone counties	13680	43	1978	Low, 1-3 ft. annually	Stained	Cattails, hydrilla, lily pads, pondweed, water hyacinth, willows

Lake Mexia	On the Navasota River, 7 mi. west of the City of Mexia off US 84	1200	20	1961	1-2 ft. annually	Murky to turbid	Waterwillow, lotus, cattail, cutgrass, pondweed
Lake Mineral Wells	Immediately east of Mineral Wells off US 180	440	30	1920	Limited	Stained	Mostly water willow, bulrush, cattail and some floating pondweed. Approximately 70% of the shoreline is ringed with a band of water willow 10-25 ft. wide.
Lake Olney/Lake Cooper	City of Olney	112	18	1936			American pondweed, bulrush, cattail willow
Lake Palo Pinto	In Palo Pinto County, 79 mi. southwest of Fort Worth	2399	47	1964	5 ft. annually	1-2 ft. visibility	Some standing bulrushes
Lake Pat Cleburne	On the Nolan River just southwest of the City of Cleburne off US 67	1545	64	1961	1-2 ft. annually	Stained to murky	Water willow, lotus, cattail, bulrush and buttonbush
Lake Stamford	10 mi. east of Stamford on Paint Creek, a tributary of the Clear Fork of the Brazos River	5200	36	1953	Severe, 4-10 ft. annually	Turbid, visibility 1-2 ft.	Limited stands of cattail

Lake Sweetwater	On Bitter Creek and Cottonwood Creek in Nolan County, 45 mi. west of Abilene and about 5 mi. east of Sweetwater	630	45	1930	Moderate, sometimes prone to long periods with dropping water levels	Clear to stained with visibility up to 4 ft.	Bulrush and pondweed when lake is full
Lake Waco	Bulrush, cattails, lotus, hydrilla	7270	85	1965	2-6 ft. annually	Stained to murky most of the year	Mostly water willow, although lotus, cattails, pondweed and buttonbush are present
Lake Whitney	On the Brazos and Nolan rivers off Texas Highway 22, about 30 mi. northwest of Waco	23560	108	1951	Moderate, 3-4 ft. annually	Clear to stained	Willow, bushy pondweed, buttonbush, bulrush, coontail, pondweed, water willow
Millers Creek	77 mi. southwest of Wichita Falls	1794	46	1974	5 ft. annually	1 to 2 ft. visibility	Pondweed near boat ramp
Possum Kingdom Lake	On the Brazos River in Palo Pinto and Young counties, 75 mi. west of Fort Worth off Texas Highway 16	15588	145	1941	Moderately high	Clear	Emergent rushes can be found in the mid- to upper part of the reservoir at 2-3 ft. depths. Submerged vegetation is found throughout the lake in late summer and fall.

Proctor Lake	On the Sabanna and Leon rivers in Comanche County, off US 67 between the towns of Comanche and Proctor	4610	34	1963	Moderate, sometimes prone to long periods with dropping water levels	Slightly stained to stained with visibility up to 3 ft.	None
Somerville Lake	On Yegua Creek in Somerville, Washington County, 30 mi. from Bryan/College Station	11400	38	1967	Low to moderate, 1-6 ft.	Slightly stained	American lotus, hydrilla
Squaw Creek Reservoir	Glen Rose, TX	3272	135	1979			Common cattail, hydrilla, water milfoil, water stargrass, willow
Stillhouse Hollow Lake	Five miles west of Belton off US 190	6430	107	1968	3-4 ft. annually	Very clear	Hydrilla
Tradinghouse Creek Reservoir	On FM 2957 east of Waco	2012	42	1968	1-3 ft. annually	Stained	Bulrush, cattails, lotus, hydrilla
White River Lake	25 mi. south of Crosbyton on the White River, a tributary of the Salt Fork of the Brazos River	2020	65	1963	Severe, 4-10 ft. annually	Turbid, visibility 1-2 ft.	Primarily cattails and pondweed, with some areas of milfoil and coontail

Aquifers

The Brazos River Basin cuts across several major aquifers on its way to the Gulf of Mexico. Major aquifers include the Ogallala, Seymour alluvium, Trinity, Carrizo-Wilcox and Gulf Coast (BEG 2001). The basin begins on the edge of the Ogallala Aquifer in West Texas and moves through the Seymour Aquifer in North Texas. The Seymour Aquifer exists in patches with part of the aquifer existing on the northern border of Texas along the Red River Basin and occurring south as far as Jones County. Farther south and east, the Brazos flows over the Trinity Basin and cuts across the northern edge of the Edwards Aquifer. The Trinity Aquifer exists from the northern border of Texas in Montague and Cooke counties down to the Edwards Plateau as far south as Medina and Uvalde counties.

East of the Trinity Aquifer, the Carrizo Aquifer is a long narrow strip that runs from the northeast corner of Texas to the Rio Grande in Webb and Maverick counties. The Brazos flows over the Carrizo in Bastrop, Lee, Milam and Robertson counties, and continues on to the Gulf Coast Aquifer. The Gulf Coast Aquifer is a large aquifer that lines the majority of the Texas Coast.

Problems Affecting the Brazos River Basin

See the Texas Priority Species List………… ………733

Projected increases in water demand for human uses, combined with the problems of high salt concentrations from the upper portions of the basin have been the impetus for placing the Brazos system on a Tier 1 (highest priority) status for completion of instream flow studies to determine optimal flow regimes for protection of aquatic life which may otherwise be heavily impacted by water withdrawals.

Element 3

Golden algae blooms and fish kills have occurred in the river and reservoirs from Lubbock to downstream from Lake Whitney. The golden alga (*Prymnesium parvum*) produces toxins that kill all fish species, mussel/clam species and gill breathing amphibians/salamanders. It is a threat to all the aquatic ecosystems. Research is needed on its distribution; bloom and toxin production dynamics; water quality effects on the alga and its toxin; possible management/treatment options for ponds and large waterbodies; interactions, population control and effects within the plankton community (bacteria, phytoplankton and zooplankton); and genetics of the organism and its possible strains. The need for coordination and cooperation between the various regulatory and resource agencies (local, state and federal) is a very important need for developing research efforts and any future management plans or actions dealing with this toxic alga.

Texas Parks and Wildlife Department has identified several reaches of the main stem Brazos and 14 tributaries as ecologically significant stream segments (TPWD 2003). These stream segments exhibit exceptional ecological characteristics including high water quality, exceptional aquatic life, high aesthetic value, presence of threatened or endangered species, or valuable riparian habitats. Further study of such stream reaches would provide much needed data enabling more effective conservation of those resources.

Element 5

High Priority Research and Monitoring Efforts for the Brazos River Basin

See Monitoring and Adaptive Management………… 559

See the Texas Priority Species List……………………733

- Monitor species of concern — Special studies and routine monitoring should be targeted at specific species of concern. Species-specific monitoring will provide population trend data and may be particularly important for species that are federally or state listed as endangered or threatened as well as those being considered for listing or delisting
- Monitor taxonomic groups suspected to be in decline or for which little is known. Monitoring and special studies should also target particular groups of organisms that are suspected to be on the decline or for which little is known. Research across North America and Europe has documented the overall decline of mussels and amphibians

- Monitoring of exotic plants and animals should be an integral part of any biological monitoring program or special study, with the goal of controlling the spread of invasive species, and where possible preventing their introduction
- Ensure adequate instream flows and water quality through evaluation of proposed reuse projects and water diversions in the Brazos River basin
- Monitor golden alga problems to determine extent of impacts on aquatic communities, aid in developing management plans for affected ecosystems and determine potential control mechanisms
- Facilitate the availability of historical reports and associated data—Departmental and other publications containing biological data are not readily available and that situation inhibits the ability to document faunal changes through time in the state's rivers and streams
- Conduct studies, monitoring programs and activities to develop the scientific basis for assuring adequate instream flows for rivers, freshwater inflows to estuaries and water quality with the goal of conserving the health and productivity of public waters in Texas. The Texas Instream Flow Program, directed by Senate Bill 2 (2001), identified the Brazos River basin as a priority study area. Research needs as identified by TIFP study designs should be considered as high priority for the basin

High Priority Conservation Actions for the Brazos River Basin

See High Priority Conservation Strategies…………..517
See the Texas Priority Species List……………………733

- Work with river authorities to develop water management plans to address instream and freshwater inflow needs as practical
- Participate in development of the State Water Plan through the 16 planning regions to assure consideration of fish and wildlife resources
- Facilitate coordination of all TPW divisions with other state and federal resource agencies to assure that water quantity and water quality needs of fish and wildlife

Element 4

resources are incorporated in those agencies' activities and decision-making processes

- Review water rights and water quality permits to provide recommendations to the TCEQ and participate as warranted in regulatory processes to assure that fish and wildlife conservation needs are adequately considered in those regulatory processes
- Investigate fish kills and other pollution events that adversely affect fish and wildlife resources, make use of civil restitution and role as a natural resource trustee to restore those resources, water quality and habitat
- Research golden alga problems to determine extent of impacts on aquatic communities, aid in developing management plans for affected ecosystems and determine potential control mechanisms
- Continue to increase the information available to the public about conserving Texas rivers, streams and springs with the goal of developing greater public support and involvement when important water resource decisions are made. Development of integrated GIS products for analyzing and sharing information should be a focus of this effort
- Continue to provide technical support and advice to entities developing Habitat Conservation Plans to address instream flow, habitat and water quality issues and needs
- Conduct habitat restoration projects where possible to return aquatic and riparian habitats to a more natural condition

Canadian River Basin

Associated Maps

Texas Rivers and River Basins……............. 12

Canadian River Basin……………………… 14

Minor Aquifers of Texas………….…...........26

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Texas Rivers and Reservoirs……………......28

Associated Section IV Documents

The Texas Priority Species List…………….733

Element 1

Priority Species

Group	Scientific Name	Common Name	State/Federal Status
Fish	*Anguilla rostrata*	American eel	SC
	Cycleptus elongatus	Blue sucker	ST
	Macrhybopsis tetranema	Peppered chub	SC
	Notropis girardi	Arkansas River shiner	FT/ST

Location and Condition of Canadian River Basin

Element 2

The Canadian River headwaters begin in northeastern New Mexico and bisect the northern portion of the panhandle from Oldham County along the western border moving across Porter, Hutchison and Roberts, exiting along the eastern border of Hemphill County. The Canadian River is a tributary of the Arkansas River and has a length of a little over 900 mi. The Texas portion of the Canadian River basin is 200 mi. long and covers 12,700 sq. mi. (BEG 1996a). The river crosses a relatively flat prairie and traverses two physiographic ecoregions: the High Plains and the Rolling Plains (Gould 1960, BEG 1996b). The Canadian River is wide, shallow and sandy-bottomed with seasonal fluctuations in streamflow and harsh water quality conditions especially in hot summer months. High levels of chloride in the Canadian River basin originate from dissolution of Permian salt deposits and emanate from brine springs in New Mexico. Average annual precipitation varies from 25 in. in the mountainous upper reaches in New Mexico, 15 in. in west Texas and 22 in. near the Texas-Oklahoma border (RRA 1998).

From the Texas-New Mexico state line eastward, the Canadian River enters an area known as the Canadian River Breaks, a narrow strip of rough and broken land extensively dissected by tributaries of the Canadian River. Elevations in the northwestern portion of the basin extend to 4,400 ft. above MSL in Dallam County. Elevations in the eastern portion of the basin range from 2,175 ft. above MSL in the river bed at the Texas-Oklahoma border to 2,400 ft. above MSL in Lipscomb County. Land use in the Texas portion of the Canadian River watershed is predominantly irrigated, dryland farming and cattle ranching. Average annual precipitation of the Texas portion of the basin varies from 15 in. near the New Mexico border to 22 in. near the eastern state boundary with Oklahoma. Streamflow measured near Canadian, Texas, approximately 22 mi. upstream of the Texas-Oklahoma state line, averages 89 cubic ft. per second (CFS), or 64,700 ac. ft. per annum (RRA, 1999).

The largest urban area is Amarillo (which partially lies in the Red River basin as well). Other relatively large cities include Pampa, Borger and Dumas. The Panhandle region is the largest water-consuming region in the state (TWDB 1997) with agriculture accounting for 94% of the total water use in the basin. Groundwater sources account for 99% of the supply. In fact, the Ogallala Aquifer is the primary source of water for the region and is being over-drafted to meet irrigation and municipal demands leading to long-term regional declines in water levels. Plans to export significant amounts of groundwater out of the basin have been recently proposed. The Canadian River Municipal Water Authority owns and operates Lake Meredith, which supplies water to 11 member cities in four river basins (Canadian, Red, Brazos and Colorado). Inflows into Lake Meredith are highly regulated by two upstream reservoirs in New Mexico, Conchas and Ute Reservoirs. The Canadian River Compact apportions water among New Mexico, Texas and Oklahoma. Instream flows downstream of Meredith Reservoir are largely dependent on watershed contributions and groundwater sources since no water is released from Lake Meredith. Two smaller reservoirs are Palo Duro Reservoir on Palo Duro Creek and Lake Rita Blanca on Punta de Aqua Creek. In addition to the Ogallala, the Dockum and Rita Blanca underlie parts of the basin (TWDB 1997).

In 1996, total water use in the Canadian River Basin consisted largely of groundwater sources, with less than three percent contributed by surface water sources. The greatest surface water contribution to total water use by county were Potter and Oldham (42% from surface water, each), Hemphill (29% surface water), and Gray (23% surface water). The remaining counties in the Panhandle Water Planning Area (PWPA) utilize surface waters for less than 10% of their total water use (TWDB, 1998).

Due to the scarcity of locally-developable surface water supplies, any additional water needed for the basin will likely come from reuse of present supplies, development of additional well fields in the Ogallala aquifer and possible new development in minor aquifers present in the basin.

Four water body segments are listed as impaired on the 2004 draft 303(d) list (TCEQ 2005). Dixon Creek is listed for not meeting the state water quality standard for bacteria and depressed dissolved oxygen. Lake Meredith is listed for mercury in walleye. Rita Blanca Lake is listed for total dissolved solids and Palo Duro Reservoir is listed for depressed dissolved oxygen.

Associated Water Bodies

Tributaries of the Canadian River in Texas include Big Blue, Tallahone, Red Deer, Pedarosa, Punta Agua, Amarillo, Tascosa and White Deer creeks; Wolf Creek, a perennial stream in the western Panhandle joins the Canadian in Oklahoma.

There are three major reservoirs in the Texas portion of the Basin: Lake Meredith, Palo Duro Reservoir and Rita Blanca Lake which are used for municipal and recreation purposes. Smaller reservoirs in the basin include Lake Marvin near the city of Canadian in Hemphill County and Lake Fryer near Perryton in Ochiltree County.

Lake Meredith is owned by the National Park Service and the Bureau of Reclamation (BuRec) and is operated by the Canadian River Municipal Water Authority (CRMWA). It was built by the Bureau of Reclamation with conservation storage of 500,000 ac. ft., limited by the Canadian River Compact (CRC). Impoundment of Lake Meredith began in January 1965 (TWDB 1974), but hydrological and climatic conditions have prevented the reservoir from ever filling completely. Most of the inflow to Lake Meredith originates below the Ute Reservoir in New Mexico.

The Palo Duro River Authority owns and operates the Palo Duro Reservoir as a water supply for its six member cities of Cactus, Dumas, Sunray, Spearman, Gruver and Stinnett. The reservoir is located on Palo Duro Creek in Hansford County, 12 mi. north of Spearman. The dam began impounding water in January 1991 and was over 80% full (by depth) in July 1999. The original conservation storage capacity of the reservoir was estimated to be 60,897 ac. ft.

Rita Blanca Lake is on Rita Blanca Creek, a tributary of the Canadian River, located three miles south of Dalhart in Hartley County. The Rita Blanca Lake project was started in 1938 by the WPA in association with the Panhandle Water Conservation Authority (Breeding 1999). The lake is currently owned by the TPWD and is operated and managed jointly by Hartley and Dallam county commissioners for recreational purposes (TNRCC 1999). The lake has a capacity of 12,100 ac. ft.

Reservoirs

Associated Reservoir	Location	Size (ac.)	Max Depth (Ft.)	Date Impounded	Water Level Fluctuation	Water Clarity	Aquatic Vegetation
Lake Rita Blanca		524	5	1939, renovated in 1973			
Lake Meredith	45 mi. northeast of Amarillo on the Canadian River	Maximum 16,000 ac., current size 12,000 ac.	127	1965	Moderate to severe, 4-10 ft. per year	Upper reservoir turbid red water (3-6 in. visibility), lower reservoir clear (4-8 ft. visibility)	Limited; primarily milfoil and cattails in arms off the main lake
Palo Duro Reservoir	10 mi. north of Spearman on Palo Duro Creek, a tributary of the North Canadian River	2413	77	1991	Severe, 4-10 ft. annually	Turbid, visibility 1-2 ft.	Scattered stands of native emergent vegetation and stands of flooded timber

Aquifers

Ogallala Aquifer

The Ogallala aquifer consists of Tertiary-age alluvial fan, fluvial, lacustrine and eolian deposits derived from the erosion of the Rocky Mountains. The Ogallala overlies Permian, Triassic and other Mesozoic formations and in turn may be covered by Quaternary fluvial, lacustrine and eolian deposits (Dutton et. al. 2000a).

The Ogallala is a major aquifer that contains approximately 417 million ac. ft. of fresh groundwater within the State of Texas. It supports the major irrigated agricultural production base, as well as municipal water needs in much of the panhandle. Water-table elevations approximately parallel the land surface and dip from the northwest to the southeast. The aquifer is recharged by precipitation and runoff that drains into lakes, rivers and streams (Mullican et al. 1994).

The quality of Ogallala water is controlled by the composition of the recharge water and the geologic features and deposits above and within the aquifer. According to the results of a study of the Ogallala aquifer (Nativ 1988) the total dissolved salt concentration of the Ogallala is in the vicinity of the PWPA averaged 429 mg/L. The major constituent, bicarbonate, averaged 278 mg/L, while minor constituents such as sulfate, calcium, sodium, chloride and potassium averaged from eight mg/L to 66 mg/L (Nativ, 1988).

Dockum Aquifer

The Dockum is a minor aquifer which underlies the Ogallala aquifer and extends laterally into parts of west Texas and New Mexico. The primary water-bearing zone in the Dockum Group, commonly called the “Santa Rosa”, consists of up to 700 ft. of sand and conglomerate interbedded with layers of silt and shale. Aquifer permeability is typically low and well yields normally do not exceed 300 gal/min (Ashworth and Hopkins 1995). According to Bradley (1997), the base of the Dockum Group aquifer is mudstones at elevations ranging from 1,200 ft. above MSL in the south (Crockett County) to 3,200 ft.

above MSL in Oldham County, and to 3,400 ft. above MSL in Dallam County. Saturated thicknesses range from 100 ft. to 2,000 ft. The water table ranges from approximately 3,800-4,000 ft. above MSL in Oldham, Hartley and Dallam counties to 3,200 ft. above MSL or less in Potter, Carson, Armstrong, Moore and Sherman counties. Recharge to the Dockum aquifer is negligible except in the outcrop areas, where approximately 23,500 ac. ft. is estimated to occur annually (Bradley 1997). Concentrations of TDS in the Dockum aquifer range from less than 1,000 mg/L in the eastern outcrop of the aquifer to more than 20,000 mg/L in the deeper parts of the formation to the west. The highest water quality in the Dockum occurs in the shallowest portions of the aquifer and along outcrops at the perimeter. The Dockum underlying Potter, Moore, Carson, Armstrong and Randall counties has a TDS content of around 1,000 mg/L (Bradley 1997). The lowest water quality (highest salinity) occurs outside of the PWPA. Dockum water, used for municipal supply by several cities, often contains chloride, sulfate and dissolved solids that are near or exceed EPA/State secondary drinking-water standards (Ashworth and Hopkins 1995).

Rita Blanca Aquifer

The Rita Blanca is a minor aquifer which underlies the Ogallala Formation in western Dallam and Hartley counties in the northwest corner of the Texas Panhandle. The portion of the aquifer located in the PWPA makes up a small part of a large aquifer system that extends into Oklahoma, Colorado and New Mexico. Recharge to the aquifer in Texas occurs by leakage from the Ogallala and by lateral flow from portions of the aquifer system in New Mexico and Oklahoma. Effective recharge and recoverable storage for the Rita Blanca have not been quantified but historically have been included with regional recharge and storage estimates for the Ogallala aquifer. Aquifer water level declines in excess of 50 ft. have occurred in some irrigated areas from the early 1970's to the middle 1980's. These declines were the result of pumpage which exceeded effective recharge. Evidence of aquifer declines included the disappearance of many springs in the northern part of Dallam County that once contributed to the constant flow of creeks that are now ephemeral. Since the middle 1980's, the rate of decline has generally slowed and, in some areas, water-level rises have occurred (Ashworth and Hopkins 1995).

Problems Affecting the Canadian River Basin

See the Texas Priority Species List……………………733

Element 3

Threats and constraints to water supply in the Canadian Basin are related to surface water and groundwater sources. The actual and potential threats may be similar or unrelated for surface or groundwater. Because water use in the Basin is primarily for agriculture, some of the constraints to use are not as severe as those for water used for human consumption. However, in most cases the same water sources are used for both agricultural and potable water supply.

Groundwater development in the Canadian basin has been extensive and is projected to continue given the increasing demand for irrigation and municipal water. Springs emanate from aquifers and supply water to perennial streams in this arid region; alluvial water from shallow aquifers also supports surface water flow. Major reservoirs on the Canadian in Texas and New Mexico have significantly altered flow regimes. For example, Lake Meredith releases no water downstream; the stream channel has constricted due to encroaching vegetation and the lack of channel-forming flows (e.g. high flow pulses). Upstream of Meredith, in New Mexico, Ute Reservoir has altered flow regimes (reduced annual flows, reduced peak flows) in the Canadian. These reservoirs have also contributed to fragmenting once contiguous riverine habitat. Riverine habitat fragmentation coupled with changes in flow regimes affect the migration and colonization dynamics of prairie stream fishes. Habitat suitability is affected by the resultant channel adjustments. These factors have contributed to the decline of prairie stream fishes in the Arkansas drainage system. In 1998, the USFWS listed the Arkansas River shiner as threatened. This species of prairie stream minnow has been extirpated from more than 80% of its historical range and is mostly restricted to about 500 mi. of the Canadian River in Oklahoma, Texas and New Mexico (Larson et al. 1991). Other species such as the peppered speckled chub have reduced distributions in the Canadian basin.

Most water used in the Basin is supplied from aquifers such as the Ogallala, making aquifer depletion a potentially major constraint on water sources in the region. Depletions lower the water levels, making pumping more expensive and reducing the potential available supply. Another potential constraint to both groundwater pumping and maintenance of streamflows relates to restrictions that could be implemented due to the presence of endangered or threatened species. The Federal listing of the species like the Arkansas River shiner as threatened species has the potential to affect water resource projects as well as other activities in Hemphill, Hutchinson, Oldham, Potter and Roberts counties.

Potential contamination of groundwater may be associated with oil-field practices, including seepage of brines from pits into the groundwater; brine contamination from abandoned wells; and broken or poorly constructed well casings. Agricultural and other practices may have contributed to elevated nitrates in groundwater and surface water. Surface waters in the area may also experience elevated salinity due to brines from oil-field operations, nutrients from municipal discharges and other contaminants from industrial discharges. Other potential sources of contaminants include industrial facilities near Amarillo; an abandoned smelter site at Dumas; and concentrated animal feeding operations in various locations throughout the basin. However, most of these potential sources of contamination are regulated and monitored by the TCEQ or other state agencies. Naturally occurring brine seeps also restrict the suitability of surface waters, such as Lake Meredith, for certain uses.

Chloride control projects may lead to changes in flow regime and water quality. The high salinity of much of the area's water resources is largely due to natural salt deposits and brine disposal in oil production. In order to reduce chlorides in water supplied to municipal, agricultural and industrial water users, saline water is intercepted and disposed of by deep-well injection. One existing project is the U.S. Bureau of Reclamations's Lake Meredith Salinity Control Project located near Logan, New Mexico; it has been operational since 1998. These highly saline flows are natural in the region. Native prairie stream fishes have evolved under these conditions and are uniquely adapted for life in these harsh aquatic ecosystems. Changes in salinity levels can promote colonization (invasion) by generalist species, which may compete with the specialist prairie stream fishes for limited resources. The interception of brine flows can also significantly reduce the base flows of the Canadian River.

Fish kills have occurred in the stilling basin downstream of Lake Meredith as a result of golden algae blooms. The golden alga produces toxins that kill all fish species, mussel/clam species and gill breathing amphibians/salamanders. It is a threat to all the aquatic ecosystems. Research is needed on its distribution; bloom and toxin production dynamics; water quality affects on the alga and its toxin; possible management/treatment options for ponds and large waterbodies; interactions, population control and affects within the plankton community (bacteria, phytoplankton and zooplankton); and genetics of the organism and its possible strains. The need for coordination and cooperation between the various regulatory and resource agencies (local, state and federal) is a very important need for developing research efforts and any future management plans or actions dealing with this toxic alga.

The Canadian River Basin in Texas has experienced drought conditions since the mid 1990's. Regional water planning efforts (Region A) recommend improvements in irrigated agriculture (e.g. low-energy precision application), enhanced precipitation and additional well-fields for meeting future supplies (TWDB 2002). No new reservoirs were recommended but feasibility studies were recommended for a potential reservoir site on Sweetwater Creek. Brush control has also been studied and proposed for the watershed upstream of Lake Meredith. Brush control, theoretically, could increase base flows but may lead to changes in stream bank vegetation and erosion processes. Increased silt loads from erosion could affect the suitability of riverine habitat, invertebrate production and fish survival especially in egg and larval stages.

High Priority Research and Monitoring Efforts for the Canadian River Basin

See Monitoring and Adaptive Management………. 559

See the Texas Priority Species List……………………733

Element 5

- Monitor species of concern—Special studies and routine monitoring should be targeted at specific species of concern. Species-specific monitoring will provide population trend data and may be particularly important for species that are federally or state listed as endangered or threatened as well as those being considered for listing or delisting. In 1998, the USFWS listed the Arkansas River shiner as threatened; this species has been extirpated from more than 80% of its historical range and is mostly restricted to about 500 mi. of the Canadian River in Oklahoma, Texas and New Mexico (Larson et al. 1991)
- Monitor taxonomic groups suspected to be in decline or for which little is known. Monitoring and special studies should also target particular groups of organisms that are suspected to be on the decline or for which little is known. Research across North America and Europe has documented the overall decline of mussels and amphibians. Previous synopses of fish collections indicate that prairie stream fishes have declined in abundance and distribution over time
- Ensure adequate instream flows and water quality through evaluation of proposed reservoir(s), groundwater usage and exports, brush control and chloride control projects in the Canadian basin
- Monitor golden alga problems to determine extent of impacts on aquatic communities, aid in developing management plans for affected ecosystems and determine potential control mechanisms
- Facilitate the availability of historical reports and associated data — Departmental and other publications containing biological data are not readily available and that situation inhibits the ability to document faunal changes through time in the state's rivers and streams
- Conduct studies, monitoring programs and activities to develop the scientific basis for assuring adequate instream flows for rivers, freshwater inflows to

estuaries and water quality with the goal of conserving the health and productivity of public waters in Texas

Element 4

High Priority Conservation Actions for the Canadian River Basin

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- Participate in development of the State Water Plan through the 16 planning regions to assure consideration of fish and wildlife resources
- Facilitate coordination of all TPW divisions with other state and federal resource agencies to assure that water quantity and water quality needs of fish and wildlife resources are incorporated in those agencies' activities and decision-making processes
- Review water rights and water quality permits to provide recommendation to the TCEQ and participate as warranted in regulatory processes to assure that fish and wildlife conservation needs are adequately considered in those regulatory processes
- Investigate fish kills and other pollution events that adversely affect fish and wildlife resources, make use of civil restitution and role as a natural resource trustee to restore those resources, water quality and habitat
- Research golden alga problems to determine extent of impacts on aquatic communities, aid in developing management plans for affected ecosystems and determine potential control mechanisms
- Continue to increase the information available to the public about conserving Texas rivers, streams and springs with the goal of developing greater public support and involvement when important water resource decisions are made

Colorado River Basin

Associated Maps

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Associated Section IV Documents

The Texas Priority Species List…………….733

Element 1

Priority Species

Group	Scientific Name	Common Name	State/Federal Status
Amphipods	*Hyalella texana*	Clear Creek amphipod	SC
	Stygobromus balconis	Balcones Cave amphipod	SC
	Stygobromus bifurcatus	Bifurcated cave amphipod	SC
	Stygobromus flagellatus	Ezell's Cave amphipod	SC
	Stygobromus n. sp. 2	Neel's Cave amphipod	SC
	Stygobromus reddelli	Reddell's Cave amphipod	SC
Crayfish	*Procambarus texanus*	Smithville crayfish	SC
Shrimp	*Macrobrachium carcinus*	Bigclaw river shrimp	SC
	Macrobrachium ohione	Ohio shrimp	SC
	Macrobrachium olfersii	Bristled river shrimp	SC

Other Crustaceans	*Iberobathynella bowmani*	Bathynellid (primitive crustacean)	SC
Mussels	*Arcidens confragosus*	Rock pocketbook	SC
	Lampsilis bracteata	Texas fatmucket	SC
	Popenaias popeii	Texas hornshell	FC
	Quadrula aurea	Golden orb	SC
	Quadrula houstonensis	Smooth pimpleback	SC
	Quadrula petrina	Texas pimpleback	SC
	Quincuncina mitchelli	False spike	SC
	Strophitus undulatus	Creeper	SC
	Truncilla macrodon	Texas fawnsfoot	SC
Insects	*Comaldessus stygius*	Comal Springs diving beetle	SC
	Haideoporus texanus	Texas diving beetle	SC
	Heterelmis comalensis	Comal Springs riffle beetle	SC
	Protoptila arca	San Marcos saddle-case caddisfly	SC
	Stygoparnus comalensis	Comal Springs dryopid beetle	FE
	Erpetogomphus eutainia	Blue-faced ringtail (dragonfly)	SC
	Erythrodiplax fusca	Red-faced dragonlet (dragonfly)	SC
Fish	*Anguilla rostrata*	American eel	SC
	Cycleptus elongatus	Blue sucker	ST
	Cyprinodon rubrofluviatilis	Red River pupfish	SC
	Gambusia heterochir	Clear Creek gambusia	FE/SE

Ictalurus lupus	Headwater catfish	SC
Micropterus treculii	Guadalupe bass	SC
Notropis oxyrhynchus	Sharpnose shiner	FC
Notropis shumardi	Silverband shiner	SC

Location and Condition of Colorado River Basin

Element 2

The Colorado River basin originates in eastern New Mexico and runs in a southeastern direction to the Gulf of Mexico. The basin is bordered on the north by the Brazos River basin, the south by the Guadalupe River basin and to the south and west by the Pecos River basin. The total area of the watershed is 42,318 sq. mi., of which the upper 11,000 sq. mi. is considered non-contributing (Tovar and Maldonado 1981). The westernmost part of the basin is best characterized as a series of poorly defined drainages with sandy soils, gently rolling plains and numerous playa lakes. This area contributes little direct runoff to the Colorado River (USACE 1987). The Colorado River becomes a defined channel in Dawson County, Texas and flows approximately 900 mi. into Matagorda Bay in Matagorda County. There are six major tributaries (contributing drainage area greater than 1,000 sq. mi.): Bealls Creek, the Concho, San Saba, Llano and Pedernales rivers, and Pecan Bayou. Rainfall varies substantially; average annual precipitation near the headwaters of the river is about 15 in. while the average annual precipitation near the Gulf Coast is more than 45 in. The Colorado River bisects several physiographic ecoregions; the High Plains, Rolling Plains and Edwards Plateau. The lower 300 mi. of the Colorado River basin bisects the Cross Timbers, Blackland Prairie, Post Oak Savannah and the Gulf Coast Prairies and Marshes (Gould 1960, BEG 1996a).

From San Saba County through Burnet counties the Colorado River is very unique and scenic. Among its scenic attributes are high limestone bluffs, vistas of rugged Ashe juniper-covered hills and the existence of Gorman Falls; formed at the point where Gorman Creek tumbles into the Colorado over a 75 ft. tall limestone bluff. The river is wide and relatively shallow, flowing over a bed of limestone and gravel. Extensive irrigation upstream depletes the water supply during dry months. A few small rapids exist on the upper part of this section down to the point where the backwaters of Lake Buchanan deepen the river and slow its flow.

From Buchanan Dam in Austin to Bastrop County the Colorado River contains a water flow controlled exclusively by the entire series of Highland Lakes located upstream. The river is extremely wide and slow-moving with no rapids or hazardous places, only slow-moving water with a few ripples and areas of swift water. Vegetation along the banks consists of elm, willow and sycamore; while the riverbed contains various aquatic plants which provide cover for many fishes. The flood plain is flat and limestone outcroppings are not as abundant as they are above the Highland Lakes. Several earthen cut-banks are exposed throughout this section. The river bottom is composed of sand and gravel, with sand and gravel bars and islands cropping up along this stretch.

The river through Bastrop County is similar to the section immediately upstream. That is, vegetative types are basically the same, consisting of elm, willow, sycamore and various aquatic plants which are found in the riverbed. However, the Lost Pines, a section of pines that have become isolated from the East Texas Pineywoods, are found along the river in several places between Bastrop and Smithville. Sand and gravel compose the river bottom and sand and gravel bars appear frequently. The river, along this section, is extremely wide and water flow is consistent, but slow. There exist no difficult rapids or other hazardous places on this entire section, although a few minor rapids are found. The banks of the Colorado River gradually grow steep as the river moves downstream. The riverbed exhibits steep banks made up of high sandstone bluffs and cliffs along with several islands and sand bars.

Through Fayette County the Colorado contains a number of unique points of interest. Several large cliffs exist along this section and many springs lined with ferns issue from these formations. The presence of petrified logs in some of the limestone cliffs has been reported and fossils have been discovered in some of the cut banks along the river. The river itself is a slow, meandering stream that is quite scenic with heavy vegetation lining the banks.

From Fayette County to Matagorda Bay in the Gulf of Mexico this river continues to be slow-moving and scenic. The river is wide, deep and plenty of water for recreational use is available at all times. There are no hazards but occasional strong headwinds from the south often hinder recreational use of this stretch. Numerous hardwood trees line steep banks and large sand bars.

Associated Water Bodies

Concho River

The Concho River, formed in San Angelo by the confluence of its North and South Forks, flows through Tom Green County, then through Concho County where it joins the Colorado River 12 mi. northeast of Paint Rock. The river flows predominantly through rolling hills and semi-arid ranch and farm land. The Concho contains many small limestone outcroppings and vegetation consists of mesquite, willow, elm, pecan, yucca, cacti and different grass species. Three major reservoirs are located on the three upper forks of the Concho. These reservoirs regulate the flow of the main stem. There are also two low water dams which pose some problems to use of the river.

The North Fork of the Concho River from San Angelo Dam to Bell Street City Park in San Angelo is an eight mile stretch which is suitable for recreational use when the dam is releasing water. Above the San Angelo Reservoir, the North Fork is intermittent. The South Concho River is a perennially flowing, spring-fed stream; however, Twin Buttes Reservoir and Lake Nasworthy restrict the natural flow. When Lake Nasworthy Dam is releasing water, the South Concho is sometimes suitable for recreational use from the dam to Bell Street City Park in San Angelo, where it joins the North Fork.

Llano River

The Llano River is formed in Kimble County by the union of the North and South Llano rivers. The main stem flows east through Kimble, Mason and Llano counties to where it joins the Colorado River and aids in forming Lake Lyndon B. Johnson. The Llano is a spring-fed river of the Edwards Plateau and is widely known for its scenic beauty. Minor rapids, areas of swift water and cliffs composed of layers of reddish-brown sandstone rock rise 200-300 ft. upward in places. Also present in some locations are large boulders and slabs of granite and gneiss which cause the river to split, sometimes in several directions. Sections of the Llano are widely known for the one-billion year old igneous and metamorphic rocks which form certain spots of the riverbed. These areas are part of the Llano Uplift which is one of the most unique geologic features in Texas.

Vegetation consists of plants such as yucca, cacti, mesquite, Ashe juniper and live oak. These plants are especially noticeable whenever the flood plain widens; however, hardwood bottomlands containing elm, pecan willow, sycamore and salt cedar are also present. In places where there is little current, hydrophytic plants such as water lilies and oleander are found. The river from Junction to Lake LBJ best accommodates recreational use when the river is on a slight rise.

The North Llano River rises in central Sutton County and flows eastward to join the South Llano River in Junction. The North Llano flows through an area of scenic limestone bluffs and hills. The North Fork contains a limited water flow during normal conditions averaging approximately 40 cfs. In Sutton County the river is 20-50 ft. wide, and is interspersed with shallower areas. The section in Kimble County consists of quiet pools and some small rapids. The South Llano River, formed in Edwards County, flows northeast into Kimble County. Because of springs, the South Llano River has a healthy flow of water at all times, averaging in the vicinity of 75 cfs. However, some shallow places are generally found at normal water levels. One of the most scenic and popular sections of the South Llano is located near Telegraph, Texas. This area is widely known for the "700 springs" which pour out of high limestone bluffs. The river in this vicinity contains short riffles, chutes, small rapids and still pools of water.

Pedernales River

The Pedernales River rises in Kimble County and flows southeast through Gillespie, Blanco, Hays and Travis counties where it meets the Colorado River. The backwaters of Lake Travis are formed on the last few miles of the Pedernales. The river is spring-fed and free-flowing; traveling through rocky, rugged country. Large limestone outcroppings, juniper-covered hills and bluffs and bald cypress trees are present along with abundant wildlife. The river generally has a wide flood plain and the land opens out for a distance before the hill and bluffs begin. Water levels are usually insufficient for normal recreational use of the upper reaches during most of the year.

San Saba River

The San Saba River is a scenic waterway located on the northern boundary of the Edwards Plateau. From its beginnings in springs near the Schleicher-Menard county line, the San Saba flows approximately 100 mi. east into Menard, Mason, McCulloch and San Saba counties to join the Colorado River. The San Saba is a typical Hill Country river consisting of sparkling, clear water which flows through limestone bluffs and hills. The river bottom is composed of limestone and in several places large boulders protrude. Many limestone outcroppings are evident along the river and vegetation is thick. The local flora includes pecan, oak, sycamore, elm, Ashe juniper, yucca and cacti. The river flows through predominantly ranch country although some farming activities are apparent near the flood plain. The San Saba remains relatively undeveloped and natural, since little residential development has appeared and no impoundments other than low water crossings exist. A few areas of swift water and some small rapids exist.

The 59 mi. section of the San Saba River in McCulloch and San Saba counties provides the best conditions for recreational use of the river at normal water levels. The segment from the Voca Crossing to just above US Highway 190 contains clear waters and limestone outcroppings. However, when the river reaches US 190, the banks begin to steepen and the river becomes muddy. The water deepens considerably as the river moves slowly between steep banks with the lower segment containing thick vegetation along its boundary.

The TCEQ has divided the Colorado River and it's tributaries into 34 classified water quality segments (1,583 stream miles). Nine of these segments are listed as impaired in the 2004 draft 303(d) list (TCEQ); O. C. Fisher Lake and the Colorado River downstream of E.V. Spence Reservoir are listed due to high dissolved solids and several streams in the urbanized Austin area are listed due to elevated bacterial levels or low dissolved oxygen levels.

There are 15 major reservoirs on the Colorado River and its tributaries. The Lower Colorado River Authority (LCRA) operates several mainstem reservoirs known collectively as the Highland Lakes (Lake Buchanan, Inks Lake, Lake Lyndon B. Johnson, Lake Marble Falls and Lake Travis). The City of Austin have two mainstem reservoirs; Lake Austin and Town Lake. The Colorado River Municipal Water District operate Lake J. B. Thomas, Lake E. V. Spence and Lake O. H. Ivy. Other major reservoirs in the basin are lakes O. C. Fisher, Twin Buttes and Nasworthy in the Concho River watershed and lakes Coleman and Brownwood in the Pecan Bayou watershed.

Reservoirs

Associated Reservoir	Location	Size (ac.)	Max Depth (Ft.)	Date Impounded	Water Level Fluctuation	Water Clarity	Aquatic Vegetation
Brady Creek Reservoir	Outside Brady, Texas, in McCulloch County	2020	48	1963	2- to 4-ft. visibility	3-5 ft.	Limited
Champion Creek Reservoir	On Champion Creek in Mitchell County, 7 mi. south of Colorado City on Texas 208	1560	62	1969	Extreme, up to 10 ft. annually	Clear to very turbid	None
E.V. Spence Reservoir	On the Colorado River in Coke County, 2 mi. west of Robert Lee	14950	108	1969	6-10 ft. annually	Clear at the dam, more turbid upstream	None
Hords Creek Lake	On Hords Creek in Coleman County, 63 mi. south of Abilene and about 10 mi. west of Coleman	510	39	1948	Moderate, sometimes prone to long periods with dropping water levels	Slightly stained to clear with visibility up to 4 ft.	Floating-leaf pondweed and water willow
Inks Lake	On the Colorado River in Burnet County, west of the town of Burnet	803	60	1968	1 ft. annually	Clear to slightly stained	No significant aquatic vegetation present

Lake Austin	On the Colorado River in the City of Austin	1830	75	1939	Constant-level lake; however, level may fluctuate slightly with releases from Lake Travis upstream	Clear to slightly stained	Water milfoil, hydrilla and pondweed
Lake Brownwood	On Pecan Bayou and Jim Ned Creek, 70 mi. southeast of Abilene and about 10 mi. north of Brownwood	7500	95	1933	Moderate, sometimes prone to long periods with dropping water levels	Clear to stained	Water willow when lake is full
Lake Buchanan	On the Colorado River in Burnet County and Llano counties, west of the town of Burnet	23200	132	1937	Considerable	Clear to heavily stained	No significant aquatic vegetation present
Lake Coleman	On Jim Ned Creek in Coleman County, 45 mi. southeast of Abilene and about 13 mi. north of Coleman	200	48	1966	Average 3 ft. annually, but lake may have prolonged periods with dropping water levels	Clear to stained, with visibility up to 4 ft.	Water willow and star grass when the lake is full
Lake Colorado City	On Morgan Creek in Mitchell County, south of I-20 and 5 mi. west of Colorado City	1618	51	1949	3-6 ft. seasonally	Clear at the dam and mid-lake, turbid at the upper end	Large areas of shore lined with bulrushes

Lake J.B. Thomas	on the Colorado River, 12 mi. southwest of Snyder	7820	61	1952	4-10 ft. annually	Turbid, visibility 1 ft. or less	Limited to scattered areas of cattail and bulrush
Lake Lyndon B. Johnson	On the Colorado River in Burnet County, near the towns of Marble Falls, Kingsland and Granite Shoals	6375	90	1951	0-2 ft. annually	Clear to slightly stained	Water willow, bulrush and spatterdock (a variety of water lily). Efforts to establish several native aquatic plants were initiated in 2000.
Lake Marble Falls	On the Colorado River in Burnet and Llano counties, near the town of Marble Falls. Lake LBJ is just upstream; Lake Travis is just downstream	780	60	1951	Constant Level	Clear to slightly stained	None
Lake Travis	On the Colorado River northwest of Austin in Travis and Burnet counties	18930	190	1942	High, 10-20 ft.	Clear to slightly off-color in upper sections	None
Lake Walter E. Long	Travis County, just east of the City of Austin. Also known as Decker Lake	1210	60	1967	Nearly constant	Slightly stained	Hydrilla, pondweed species, bulrush, water-star grass, American lotus, coontail and southern naiad

O.C. Fisher Lake	West side of San Angelo on the North Concho River in Tom Green County	5440	58	1958	6-8 ft. annually	Clear near the dam, stained in the upper end	None
O.H. Ivie Reservoir	On the Colorado and Concho rivers in Concho, Coleman and Runnels counties, 55 mi. east of San Angelo	19200	119	1990	6-10 ft. annually	Clear in the main lake and Concho arm, turbid in the Colorado arm	Sago and American pondweed, marine naiad and hydrilla
Oak Creek Reservoir	On Oak Creek in Coke County, 8 mi. north of Bronte on Texas Highway 70	2375	51	1952	6-8 ft. annually	Clear in the lower end, stained in the upper end	A few cattails along the shore in the main part of the lake
Lake Nasworthy	On the southwest side of San Angelo in Tom Green County	1598	29	1930	Nearly constant water level maintained by discharge from Twin Buttes	Slightly stained	Large areas of shoreline are lined with bulrushes and alligator weed. Star grass, sago pondweed and coontail are also found in the reservoir.
Belton Lake	On the Leon River in Bell and Coryell counties, 5 mi. northwest of the City of Belton off FM 317	12300	120	1954	3-5 ft. annually	4-6 ft. visibility	Very sparse buttonbush and cattail
Twin Buttes Reservoir	West of San Angelo in Tom Green County on the Middle and South Concho rivers	9080	46	1963	6-8 ft. annually	Fairly clear	None

Aquifers

The Colorado River Basin cuts across several major aquifers on its way to the Gulf of Mexico. These include the Ogallala, the Edwards, the Trinity Group, the Carrizo-Wilcox and Gulf Coast. Additionally, there are several minor aquifers (BEG). The basin begins on the southern edge of the Ogallala Aquifer in West Texas and moves through the Edwards-Trinity basin in west and central Texas. The Edwards-Trinity Aquifer is large and exists below much of the Edwards Plateau and eastern portions of the Trans Pecos. Farther south and east, the Colorado flows over the Trinity Basin along its southern expanse and cuts across the central portion of the Edwards Aquifer. The Trinity Aquifer exists from the northern border of Texas in Montague and Cooke counties down to the Edwards Plateau as far south as Medina and Uvalde counties.

East of the Trinity Aquifer, the Carrizo-Wilcox Aquifer is a long, narrow strip that runs from the northeast corner of Texas to the Rio Grande in Webb and Maverick counties. The Colorado flows over the Carrizo-Wilcox in Bastrop County and continues on to the Gulf Coast Aquifer. The Gulf Coast Aquifer is a large aquifer that lines the majority of the Texas Coast.

Problems Affecting the Colorado River Basin

See the Texas Priority Species List……………………733

Riverine habitat on the Colorado River has been substantially modified as a result of the construction and operation of reservoirs. All of the major reservoirs within the basin are operated as water supplies; the Highland Lakes and Lake Austin also include hydropower operations. ***Element 3***

E. V. Spence and O. H. Ivy Reservoirs (CRMWD) have substantially modified flow regimes in the upper Colorado River; both are required to release water to maintain instream habitat for the Concho River water snake, a federally threatened species. The Highland Lakes regulate flow in the lower 300 mi. of the Colorado River, from Austin to

Matagorda Bay. The LCRA has identified appropriate instream flows for the Colorado River (Mosier and Ray 1992) and those flows have been integrated into the LCRA's management plan for the Highland Lakes and the lower Colorado River.

The Colorado River and its tributaries support several threatened and endangered aquatic species. In addition to the Concho River water snake, the endangered Clear Creek gambusia and Barton Springs salamander are endemic to Clear Creek Springs in the San Saba watershed and the Barton Springs complex in Austin, respectively. The blue sucker which is found in the Colorado River downstream of Austin, is listed as threatened by the state of Texas.

Hydropower operations are a significant issue in the Colorado River mainstem immediately downstream of Austin. All of the LCRA's reservoirs (Buchanan, Inks, L.B.J., Marble Falls and Travis) and Lake Austin are operated for hydropower generation conjunctively with water supply operations. Since the Highland Lakes chain and Lake Austin form a continuous chain of impoundments with no intervening freeflowing reaches, the impact of hydropower operations on aquatic habitat is largely confined to the riverine reaches immediately downstream of Austin. The LCRA operates the reservoirs to meet peak electrical demand; consequently there are substantial daily fluctuations in water levels immediately downstream of Austin.

Kills have occurred in and near this river from the area near Colorado City downstream to the area of the city of Bend as a result of toxic golden alga blooms. The golden alga produces toxins that kill all fish species, mussel/clam species and gill breathing amphibians/salamanders. It is a threat to all aquatic ecosystems. Research is needed on its distribution; bloom and toxin production dynamic; water quality affects on the alga and its toxin; possible management/treatment options for ponds and large waterbodies; interactions, population control and affects within the plankton community (bacteria, phytoplankton and zooplankton); and genetics of the organism and its possible stains. The need for coordination and cooperation between the various regulatory and resource agencies (local, state and federal) is a very important need for developing research efforts and any future management plans or actions dealing with this toxic alga.

High Priority Research and Monitoring Efforts for the Colorado River Basin

See Monitoring and Adaptive Management………. 559
See the Texas Priority Species List……………………733

Element 5

- Monitor species of concern — Special studies and routine monitoring should be targeted at specific species of concern. Species-specific monitoring will provide population trend data and may be particularly important for species that are federally or state listed as endangered or threatened as well as those being considered for listing or delisting
- Monitor taxonomic groups suspected to be in decline or for which little is known. Monitoring and special studies should also target particular groups of organisms that are suspected to be on the decline or for which little is known. Research across North America and Europe has documented the overall decline of mussels and amphibians
- Facilitate the availability of historical reports and associated data — Departmental and other publications containing biological data are not readily available and that situation inhibits the ability to document faunal changes through time in the state's rivers and streams
- Monitor golden alga problems to determine extent of impacts on aquatic communities, aid in developing management plans for affected ecosystems and determine potential control mechanisms
- Conduct studies, monitoring programs and activities to develop the scientific basis for assuring adequate instream flows for rivers, freshwater inflows to estuaries and water quality with the goal of conserving the health and productivity of public waters in Texas

Element 4

High Priority Conservation Actions for the Colorado River Basin

See High Priority Conservation Strategies…………..517

See the Texas Priority Species List……………………733

- Participate in development of the State Water Plan through the 16 planning regions to assure consideration of fish and wildlife resources
- Facilitate coordination of all TPWD divisions with other state and federal resource agencies to assure that water quantity and water quality needs of fish and wildlife resources are incorporated in those agencies' activities and decision-making processes
- Review water rights and water quality permits to provide recommendation to the TCEQ and participate as warranted in regulatory processes to assure that fish and wildlife conservation needs are adequately considered in those regulatory processes
- Investigate fish kills and other pollution events that adversely affect fish and wildlife resources, make use of civil restitution and role as a natural resource trustee to restore those resources, water quality and habitat
- Research golden alga problems to determine extent of impacts on aquatic communities, aid in developing management plans for affected ecosystems and determine potential control mechanisms
- Continue to increase the information available to the public about conserving Texas rivers, streams and springs with the goal of developing greater public support and involvement when important water resource decisions are made

Cypress Creek Basin

Associated Maps

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Texas Rivers and Reservoirs……………......28

Associated Section IV Documents

The Texas Priority Species List……………..733

Element 1

Priority Species

Group	Scientific Name	Common Name	State/Federal Status
Mussels	*Arcidens confragosus*	Rock pocketbook	SC
	Arkansia wheeleri	Ouachita rock-pocketbook	FE/SE
	Fusconaia askewi	Texas pigtoe	SC
	Lampsilis satura	Sandbank pocketbook	SC
	Obovaria jacksoniana	Southern hickorynut	SC
	Pleurobema riddellii	Louisiana pigtoe	SC
	Quadrula nodulata	Wartyback	SC
	Strophitus undulatus	Creeper	SC
Insects	*Somatochlora margarita*	Texas emerald (dragonfly)	SC
Fish	*Ammocrypta clara*	Western sand darter	SC
	Anguilla rostrata	American eel	SC

Cycleptus elongatus	Blue sucker	ST
Erimyzon oblongus	Creek chubsucker	ST
Notropis atrocaudalis	Blackspot shiner	SC
Notropis chalybaeus	Ironcolor shiner	SC
Notropis maculatus	Taillight shiner	SC
Notropis shumardi	Silverband shiner	SC
Polyodon spathula	Paddlefish	ST

Location and Condition of Cypress Creek Basin

Element 2

The Cypress Creek basin has its origins in northeast Texas and drains an area of 2,812 sq. mi. (TWDB 1997). It is contained within the Post Oak Savannah and Pineywoods ecoregions (Gould 1960, BEG 1996). The landscape consists of rolling wooded hills and broad, frequently flooded and densely vegetated stream bottoms. Big Cypress Creek's extensive floodplain is marked by numerous sloughs, oxbows and other wetlands that trap water and sediment following flood events, forming important wetland habitat. Typical floodplains are heavily wooded with semi-aquatic species (e.g. bald cypress) and are undisturbed relative to uplands, which are extensively used for ranching. Land uses in the Cypress Creek basin include: woodlands (66%), agriculture (28%), urban (5.5%) and water (4.3%) (NETMWD 2000). Rainfall is abundant ranging from 35 in. per year at the western extreme of the basin to over 55 in. annually at the Louisiana border. Total storage capacity in the basin exceeds 790,000 ac. ft. (TWDB, unpublished data). Black Cypress Bayou and Little Cypress Creek are the only major tributaries that are unimpounded.

Caddo Lake was once one of the largest natural lakes in the South. Originally, it was impounded by a large log jam on the Red River, which was removed by the U.S. government in 1874 to facilitate navigation. In 1914 a dam was constructed near Mooringsport, Louisiana. The USACE completed a replacement dam in 1971. In 1993 Caddo Lake was recognized as an international wetlands site.

The economy of the basin is comprised of manufacturing, retail and wholesale trade, mineral production and agriculture (TWDB 1997). Intensive poultry operations are located in the upper watersheds of the major watercourses. Major cities include Marshall, Mount Pleasant, Atlanta and Gilbert. In 1990, the population of the basin was 124,177 (TWDB 1997). Water management in the basin is controlled by several districts, which own and operate the large reservoirs. The Red River Compact apportions waters of the Red River basin among Oklahoma, Arkansas, Louisiana and Texas. Surface water sources supply about 89% of the water demand.

Three water body segments are listed as impaired on the 2004 draft 303(d) list (TCEQ 2005). Various areas of Caddo Lake are listed for different reasons, including depressed dissolved oxygen concentrations, mercury in largemouth bass and freshwater drum and low pH. Big Cypress Creek below Lake O' the Pines is listed for mercury in fish tissue, lead (chronic) in water, low pH and depressed dissolved oxygen. Harrison Bayou is listed for depressed dissolved oxygen.

Associated Water Bodies

Cypress Creek contains two major tributaries, Black Cypress Bayou and Little Cypress Creek, which join Big Cypress Creek near the town of Jefferson before entering Caddo Lake. In Louisiana Black Bayou and James Bayou feed into Big Cypress Creek which joins the Red River near Shreveport, Louisiana.

Large multi-purpose (flood control and water supply) reservoirs constructed on Big Cypress include Lake O' the Pines and Bob Sandlin. The largest reservoir is Lake O' the Pines. It was constructed by USACE to control flooding in Jefferson, Texas, which is located upstream of Caddo Lake. Northeast Texas Municipal Water District (NETMWD) controls releases when reservoir stage is below flood pool. There are nine smaller reservoirs in the watershed (excluding Caddo Lake); several of these provide cooling water for steam-electric power plants.

Reservoirs

Associated Reservoir	Location	Size (ac.)	Max Depth (Ft.)	Date Impounded	Water Level Fluctuation	Water Clarity	Aquatic Vegetation
Caddo Lake	On Big Cypress Bayou on the Texas-Louisiana state line, northeast of Marshall in Harrison and Marion counties	26810	20	First dam built in 1914, replaced in 1971	4-8 ft. annually	Moderately clear to stained	Approximately 60% coverage dominated by native submerged and emergent aquatic vegetation
Lake Bob Sandlin	On Big Cypress Creek 5 mi. southwest of Mount Pleasant in Titus, Camp and Franklin counties	9460	66	1977	2-3 ft. annually	Moderate, 2-4 ft. visibility	Coverage less than 3% of the lake's total surface area. The dominant species is hydrilla.
Lake Cypress Springs	On Cypress Creek in the Cypress River Basin 15 mi. northwest of Pittsburg in Franklin County	3450	56	1970	2-3 ft. annually	Clear	Covers less than 10% of the lake's total surface area

Lake Gilmer	On Kelsey Creek in the Cypress River Basin, 15 mi. north of Longview and 4 mi. west of Gilmer	1010	28	2001	< 3 ft. annually	Moderately clear	Low densities of native aquatic plants
Lake O' the Pines	On Big Cypress Creek in the Cypress River Basin, approximately 25 mi. northeast of Longview in Marion, Morris, Upshur and Camp counties	18700	49.5	1959	4-5 ft. annually	Moderately clear	Coverage ranges from 15% to 20% of the lake's surface area. Dominant species include hydrilla, buttonbush, water primrose and American lotus.
Welsh Reservoir	On Swuanano Creek in Titus County, 10 mi. southeast of Mount Pleasant	1465	50	1976	< 3 ft. annually	Clear	Covers less than 5% of lake's surface area. Dominant species include coontail and southern naiad.

Aquifers

Cypress Creek and its reservoirs are all found over the Carrizo-Wilcox Aquifer in northeast Texas. Therefore, groundwater supplies are largely obtained from the Carrizo-Wilcox Aquifer.

Element 3

Problems Affecting the Cypress Creek Basin

See the Texas Priority Species List……………………733

Major reservoirs have altered the flow regime in the Cypress basin. Operations of Lake O' the Pines have dramatically altered flow regimes downstream in Big Cypress Creek. Most notable is that pre-dam flows included peak flows exceeding 57,000 cfs while post-dam peak flows rarely exceed 3,000 cfs; variation in peak flows has been dramatically reduced. Low flows during the historically dry periods have noticeably increased following dam construction. Significant physical effects on riverine and floodplain habitat include: reduced floodplain connectivity, altered channel and habitat-forming processes and altered sediment transport and delivery. Influences on biological processes, include reduced seed dispersal, encroachment of upland species into floodplains, alterations to spawning and foraging habitat and potential elimination of spawning cues for fishes.

The paddlefish has been greatly reduced in abundance and distribution throughout its range including the Cypress basin. Paddlefish spawn in the spring when water levels rise rapidly. After the larvae develop within deep pools the juveniles move into backwater habitats. Spring floods have been greatly curtailed in Big Cypress Creek, and this may have eliminated cues and conditions needed for spawning. In addition, the lack of floods has likely resulted in the degradation of shoal habitats that are critical spawning habitat for this species. In the past, paddlefish were stocked in Caddo Lake in hopes to recover populations in the Cypress basin which were extirpated in the 1960's. The bluehead shiner is a state-threatened species that schools in backwaters and spawns from early May to July. It appears that late spring and early summer low flow conditions may be most conducive to successful spawning and recruitment, but its presence in oxbow lakes reveals a necessity for periodic overbank flows allowing dispersal between channel and oxbow habitats. Oil drilling and chicken farming are presumed to have negatively impacted mussel populations.

Hydrologic modifications have not been the only negative impact to this system. Other perturbations, such as nutrient and contaminant loading, logging and drainage and conversion of the watershed to agriculture or residential development, have altered the system. Growth of macrophytes in the upper reaches of Caddo Lake are problematic in that decay of this accumulated biomass leads to conditions of low dissolved oxygen. Exotic species such as hydrilla and water hyacinth are abundant. Caddo Lake also suffers from pollution of heavy metals and organic chemicals from multiple sources. In the past, this has even led to warnings to limit the consumption of large fish.

No major water development projects that affect the Cypress basin were identified in the state water plan (TWDB 2002). Black Cypress and Little Cypress reservoirs have been proposed in past water plans; Little Cypress, on Little Cypress Creek, was recommended as a unique reservoir site (TWDB 2002). Potential hydropower issues could develop for Lake O' the Pines.

High Priority Research and Monitoring Efforts for the Cypress Creek Basin

See Monitoring and Adaptive Management………… 559

See the Texas Priority Species List……………………733

Element 5

- Monitor species of concern — Special studies and routine monitoring should be targeted at specific species of concern. Species-specific monitoring will provide population trend data and may be particularly important for species that are federally or state listed as endangered or threatened as well as those being considered for listing or delisting
- Monitor taxonomic groups suspected to be in decline or for which little is known. Monitoring and special studies should also target particular groups of organisms

that are suspected to be on the decline or for which little is known. Research across North America and Europe has documented the overall decline of mussels and amphibians. Distribution and abundance of paddlefish has been greatly reduced throughout its range due primarily to the construction and operation of dams. Little is known of the bluehead shiner, a state-listed species

- Ensure adequate instream flows and water quality through evaluation of proposed projects and water diversions in the Cypress Creek basin. Continue participation in the collaborative process (hosted by the Nature Conservancy and the Caddo Lake Institute) to identify flow conditions necessary to restore ecosystem functions in Caddo Lake and the Cypress basin and develop a research agenda to address critical information needs
- Facilitate the availability of historical reports and associated data — Departmental and other publications containing biological data are not readily available and that situation inhibits the ability to document faunal changes through time in the state's rivers and streams
- Conduct studies, monitoring programs and activities to develop the scientific basis for assuring adequate instream flows for rivers, freshwater inflows to estuaries and water quality with the goal of conserving the health and productivity of public waters in Texas

Element 4

High Priority Conservation Actions for the Cypress Creek Basin

See High Priority Conservation Strategies…………..517

See the Texas Priority Species List……………………733

- Participate in development of the State Water Plan through the 16 planning regions to assure consideration of fish and wildlife resources
- Facilitate coordination of all TPWD divisions with other state and federal resource agencies to assure that water quantity and water quality needs of fish and wildlife resources are incorporated in those agencies' activities and decision-making processes

- Review water rights and water quality permits to provide recommendation to the TCEQ and participate as warranted in regulatory processes to assure that fish and wildlife conservation needs are adequately considered in those regulatory processes
- Investigate fish kills and other pollution events that adversely affect fish and wildlife resources, make use of civil restitution and role as a natural resource trustee to restore those resources, water quality and habitat
- Continue to increase the information available to the public about conserving Texas rivers, streams and springs with the goal of developing greater public support and involvement when important water resource decisions are made

Guadalupe River Basin

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Element 1

Associated Section IV Documents

The Texas Priority Species List……………..733

Priority Species

Group	Scientific Name	Common Name	State/Federal Status
Amphipods	*Artesia subterranea*	Hadziid amphipod	SC
	Holsingerius samacos	Hadziid amphipod	SC
	Ingolfiella n. sp.	Comal Springs ingolfiellid amphipod	SC
	Stygobromus bifurcatus	Bifurcated cave amphipod	SC
	Stygobromus dejectus	Cascade Cave amphipod	SC
	Stygobromus flagellatus	Ezell's Cave amphipod	SC
	Stygobromus longipes	Long-legged cave amphipod	SC
	Stygobromus pecki	Peck's Cave amphipod	FE/SE/ST
	Texiweckelia texensis	Hadziid amphipod	SC
Isopods	*Lirceolus smithii*	San Marcos well isopod	SC
Crayfish	*Cambarellus ninae*	Texas coastal crayfish	SC

Shrimp	*Calathaemon holthuisi*	Ezell's Cave shrimp	SC
	Macrobrachium carcinus	Bigclaw river shrimp	SC
	Macrobrachium ohione	Ohio shrimp	SC
Mussels	*Arcidens confragosus*	Rock pocketbook	SC
	Lasmigona complanata	White heelsplitter	SC
	Quadrula aurea	Golden orb	SC
	Quincuncina mitchelli	False spike	SC
	Strophitus undulatus	Creeper	SC
Snails	*Phreatodrobia imitata*	Mimic cavesnail	SC
Plants	*Zizania texana*	Texas wild-rice	FE/SE
Fish	*Anguilla rostrata*	American eel	SC
	Cycleptus elongatus	Blue sucker	ST
	Dionda nigrotaeniata	Guadalupe roundnose minnow	SC
	Erimyzon oblongus	Creek chubsucker	ST
	Etheostoma fonticola	Fountain darter	FE/SE
	Ictalurus lupus	Headwater catfish	SC
	Macrhybopsis marconis	Burrhead chub	SC
	Micropterus treculii	Guadalupe bass	SC
	Notropis chalybaeus	Ironcolor shiner	SC

Location and Condition of Guadalupe River Basin

Element 2

Rising from its North and South forks in Kerr County, the spring-fed river flows eastward into Kendall and Comal counties where it then turns and flows south to the Gulf of Mexico, crossing Guadalupe, Gonzales, DeWitt, Victoria, Calhoun and Refugio counties along the way. Its total length is approximately 250 mi. (BEG 1996a, Texas Natural Resource Conservation Commission 2000). Over its course, the river traverses the Edwards Plateau, Blackland Prairie, Post Oak Savannah and Gulf Coast Prairies and Marshes physiographic ecoregions (Gould 1960, BEG 1996). Total basin drainage area is 6,070 sq. mi. and rainfall varies from 30-40 in. per year (BEG 1996). One major reservoir, Canyon Reservoir and several smaller ones, Lake McQueeney, Lake Dunlap, Lake Placid, Lake Gonzales, Wood Lake and Meadow Lake, are located on the river (USFWS 1976).

The upper reaches of the Guadalupe River meander through limestone bluffs and banks lined with a wide diversity of trees. Numerous rapids and falls exist which attract great numbers of water enthusiasts. The aquatic and riparian habitats support an exceptionally diverse assemblage of invertebrates, fish, birds, mammals and plants characteristic of the Edwards Plateau (Kutac and Caran 1994). From Kendall County to Comal County the Guadalupe River is one of the most scenic stretches of river in Texas. Except during periods of extreme drought there is always sufficient water in this section of the river for recreational use. From Canyon Dam to Interstate Highway 35 the Guadalupe River in Comal County is considered one of the finest white-water stretches in the State. The river is scenic, with limestone bluffs, bald cypress, pecan, elm and other vegetation lining the banks. The river along this stretch is being subjected to development, with many subdivisions becoming evident; however, many natural areas can still be found. The flow of the river here is largely controlled by water releases from Canyon Dam.

Gradient decreases in the middle reach as the river leaves the Edwards Plateau and runs toward the Gulf Coast Prairies and Marshes. As a result the river becomes slower moving. Water clarity also declines as substrates shift from limestone to much more erodable soil types (Belisle and Josselet 1974). The lower reach contains extensive freshwater and estuarine wetlands, including the Guadalupe Delta Wildlife Management Area, which is one of the largest wetland reserve projects in the United States at almost 6,000 ac. (B. Ortega 1999, pers. comm.).

Overall, the Guadalupe River Basin is characterized by generally high water quality throughout; however, seven water body segments are listed as impaired on the 2004 draft 303(d) list (TCEQ 2004). All the listings are due to depressed dissolved oxygen and/or high bacteria counts. Low dissolved oxygen concentrations were found to be generally restricted to the tidal segment and to smaller tributaries. Elevated fecal coliform bacteria levels were found in four tributaries and in the mainstem reach upstream of Canyon Reservoir.

Associated Water Bodies

Blanco River

The Blanco River rises in northeast Kendall County, then flows approximately 87 mi. southeast through Blanco and Hays counties, where it joins the San Marcos River just downstream of the City of San Marcos. The upper reach consists of long, shallow stretches flowing over a limestone substrate. It is noted for historic Indian mounds, unusual geologic formations and dinosaur tracks. Limestone bluffs and bald cypress line the banks.

The middle and lower reaches of the Blanco River flow through some of the most interesting scenery in Central Texas. The river continues to flow over a bed of limestone and the banks are lined with bald cypress, pecan, black willow and sycamore trees, while the hills away from the river are covered with oaks and Ashe juniper. Numerous outcroppings of rocks and bluffs are present. Two noteworthy landmarks are "the narrows" and "Devil's Backbone". The narrows is an area where the river is constricted between steep bluffs while the Devil's Backbone is an extensive area of rugged, hilly country located adjacent to the river. The river is extremely shallow for several miles downstream of Blanco, until sufficient spring and creek inflows increase the water level in the vicinity of the Devil's Backbone near Wimberley.

Comal River

The Comal River is one of two major tributaries to the Guadalupe River, the other being the San Marcos River. It rises from Comal Springs, within the City of New Braunfels, and has the distinction of being the shortest river in the state (only two and one-half miles long); however, its flow contribution is significant. Average discharge is 330 cfs and when combined with the San Marcos River contributes around 30% of the total annual flow recorded in the Guadalupe River (Espey 1988). During the record drought of 1948-1956 spring flow from these two rivers contributed on average 48% of the total annual flow at that same location (Espey 1988).

San Marcos River

The San Marcos River originates from Aquarena Springs (second largest spring in Texas, with Comal Springs being the largest) within the city limits of San Marcos. The springs have historically exhibited the greatest flow dependability and environmental stability of any spring system in the southwestern United States and as a consequence have a greater known diversity of aquatic organisms than any other ecosystem within that area (USFWS 1984). The river flows about 75 mi. through heavily wooded banks to join the Guadalupe River near Gonzales.

Reservoirs

Associated Reservoir	Location	Size (ac.)	Max Depth (Ft.)	Date Impounded	Water Level Fluctuation	Water Clarity	Aquatic Vegetation
Canyon Lake	On the Guadalupe River, 16 mi. Northwest of New Braunfels in Comal County	8240	125	1964	Moderate		None
Coleto Creek Reservoir	Guadalupe River Basin, 15 mi. west-southwest of Victoria off US 59. Access road marked with sign.	3100	46	1980	1-3 ft. annually	Clear to slightly stained	Isolated beds of coontail, American pondweed, American lotus, cattail, rushes and moderate densities of hydrilla

Aquifers

The Guadalupe River Basin cuts across five major aquifers on its way to the Gulf of Mexico. These include the Edwards-Trinity, Trinity, Edwards, Carrizo-Wilcox and Gulf Coast (BEG 2001). The river begins in the Edwards-Trinity Aquifer in Kerr County and flows southeast over the Trinity and Edwards Aquifers. Once across the Edwards Aquifer, the river moves through Guadalupe County over to the Carrizo-Wilcox Aquifer. Southeast of the Carrizo-Wilcox Aquifer, the Guadalupe River flows over the Gulf Coast Aquifer, a large aquifer lining the majority of the Texas coast.

Element 3

Problems Affecting the Guadalupe River Basin

See the Texas Priority Species List……………………733

The population in the South Central Texas regional water planning area (Region L), which includes all but the uppermost reach of the Guadalupe River in Kerr County, is projected to double between 2000 and 2060, reaching more than four million people (TWDB 2005). The Lower Guadalupe Water Supply Project has been approved for inclusion in the state water plan by Region L to provide an additional source of water to meet future needs in the region. Components of the project include diversion of water at a point on the Lower Guadalupe River downstream of the confluence of the San Antonio River as well as additional groundwater pumping primarily from the Gulf Cost Aquifer System (Lower Guadalupe Water Supply Project 2004). A number of technical and environmental studies have been initiated regarding the project. Major water rights applications pending at TCEQ include a request for 289,600 ac. ft. per year.

Element 5

High Priority Research and Monitoring Efforts for the Guadalupe River Basin

See Monitoring and Adaptive Management………… 559

See the Texas Priority Species List……………………733

- Monitor species of concern — Special studies and routine monitoring should be targeted at specific species of concern. Species-specific monitoring will provide population trend data and may be particularly important for species that are federally or state listed as endangered or threatened as well as those being considered for listing or delisting

- Monitor taxonomic groups suspected to be in decline or for which little is known. Monitoring and special studies should also target particular groups of organisms that are suspected to be on the decline or for which little is known. Research across North America and Europe has documented the overall decline of mussels and amphibians
- Exotic species monitoring — A number of exotic (non-native) species have been introduced (some intentionally) into the river basin. Monitoring specifically designed to target these species is important as a number of exotic species have proven capable of hybridizing or competing with native species (Miller et al. 1989, Williams et al. 1989, Garrett 1991)
- Ensure adequate instream flows and water quality through evaluation of proposed reuse projects and water diversions in the basin
- Facilitate the availability of historical reports and associated data — Departmental and other publications containing biological data are not readily available and that situation inhibits the ability to document faunal changes through time in the state's rivers and streams
- Conduct studies, monitoring programs and activities to develop the scientific basis for assuring adequate instream flows for rivers, freshwater inflows to estuaries and water quality with the goal of conserving the health and productivity of public waters in Texas. The Texas Instream Flow Program (TIFP), directed by Senate Bill 2, identified the Guadalupe River Basin as a priority study area (TPWD, TCEQ and TWDB 2002). Research needs as identified by TIFP study designs should be considered as high priority for the basin

Element 4

High Priority Conservation Actions for the Guadalupe River Basin

See High Priority Conservation Strategies…………..517

See the Texas Priority Species List……………………733

- Work with river authorities to develop water management plans to address instream and freshwater inflow needs as practical
- Participate in development of the State Water Plan through the 16 planning regions to assure consideration of fish and wildlife resources
- Facilitate coordination of all TPWD divisions with other state and federal resource agencies to assure that water quantity and water quality needs of fish and wildlife resources are incorporated in those agencies' activities and decision-making processes
- Review water rights and water quality permits to provide recommendations to the TCEQ and participate as warranted in regulatory processes to assure that fish and wildlife conservation needs are adequately considered in those regulatory processes
- Investigate fish kills and other pollution events that adversely affect fish and wildlife resources, make use of civil restitution and role as a natural resource trustee to restore those resources, water quality and habitat
- Continue to increase the information available to the public about conserving Texas rivers, streams and springs with the goal of developing greater public support and involvement when important water resource decisions are made. Development of integrated GIS products for analyzing and sharing information should be a focus of this effort
- Continue to provide technical support and advice to entities developing Habitat Conservation Plans to address instream flow, habitat and water quality issues and needs

Lavaca River Basin

Associated Maps

Texas Rivers and River Basins…................. 12

Lavaca River Basin………………………… 24

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Associated Section IV Documents

The Texas Priority Species List……………..733

Element 1

Priority Species

Group	Scientific Name	Common Name	State/Federal Status
Crayfish	*Cambarellus ninae*	Texas coastal crayfish	SC
Shrimp	*Macrobrachium carcinus*	Bigclaw river shrimp	SC
	Macrobrachium ohione	Ohio shrimp	SC
	Macrobrachium olfersii	Bristled river shrimp	SC
Fish	*Anguilla rostrata*	American eel	SC
	Cycleptus elongatus	Blue sucker	ST

Location and Condition of the Lavaca Basin

Element 2

The Lavaca River is located on the coastal prairie lying north of the San Antonio-Matagorda bay area. Headwaters originate in southern Fayette County and flow through Lavaca and Jackson counties into Lavaca Bay.

The Navidad River and its tributaries drain approximately 60% of the basin. The basin drainage area is 2,309 sq. mi. (TCEQ 2004b). The stream is classified as intermittent due to its dependence on rainfall rather than permanent spring flows (UT 2005); however, average annual rainfall varies between 36 and 42 in., (BEG 1996a) and the average annual flow is about 600,000 ac. ft. (UT 2005). Heavy rains bring frequent flooding as far upstream as Hallettsville. During the 19th century the river was normally navigable to Texana, 30 mi. above its mouth (UT 2005).

Major towns in the basin include Moulton, Hallettsville, Edna and Vanderbilt. Land use is primarily for ranching and the production of oil and gas from the numerous oilfields along its banks (UT 2005).

Associated Water Bodies

Its primary tributary is the Navidad River, which enters from the east two miles northeast of Vanderbilt. The North Fork of the Lavaca River rises on the Lavaca-Fayette county line and flows south through Lavaca County for 7½ mi. to its mouth on the main Lavaca River, three miles southwest of Komensky. The loamy clay erodable upland soils of the area are used primarily for rangeland, pastureland and the production of corn and grain sorghum. Until the second half of the twentieth century this area produced good yields of cotton, but soil erosion and depletion encouraged many farmers to convert their lands to pasture for beef and dairy cattle. The course of the stream is marked with scattered oak, willow and sycamore, and unimproved pasture reverts to scattered cedar and mesquite (UT 2005).

The West Prong of the Lavaca River rises three miles southwest of Moulton in western Lavaca County and flows east for 7½ mi. to its mouth on the Lavaca River, 1½ mi. southeast of Moulton. It borders the south and west sides of Moulton and flows through rolling hills surfaced by well-drained loamy and clay soils of generally open upland prairie. Occasional outcroppings of sandstone occur and on steeper slopes erosion can be severe. Vegetation consists of scattered oak, willow and hackberry mottes that provide cover for small game and upland birds. The stream is used for recreation in Moulton (UT

2005). The Lavaca River is found within the Post Oak Savannah, Blackland Prairie and Gulf Coast Prairies and Marshes physiographic ecoregions (Gould 1960, BEG 1996b).

One of five major water body segments is listed as impaired on the 2004 draft 303 (d) list (TCEQ 2004a). Depressed dissolved oxygen was the parameter listed for this segment.

Lake Texana Reservoir is the only major impoundment in the basin (TCEQ 2004b).

Reservoirs

Associated Reservoir	Location	Size (ac.)	Max Depth (Ft.)	Date Impounded	Water Level Fluctuation	Water Clarity	Aquatic Vegetation
Lake Texana	Jackson County, 8 mi. east of Edna, Texas on US 59	10134	58	1980	High, 10-15 ft. annually	Stained to muddy	Lake Texana contains most native species of aquatic vegetation and many exotic species. Large stands of water hyacinth are present throughout the reservoir while moderate densities of hydrilla, coontail, spikerush, cattail, pondweed, bull's tongue, pickerel weed and duckweed are also present. The discovery of giant salvinia, an extremely invasive exotic species, in the Sandy Creek arm has prompted extensive management efforts to contain and control its spread to the main reservoir.

Aquifers

The Gulf Coast is the only major aquifer found in the Basin (BEG 2001). The Lavaca Basin is almost entirely encompassed by the Gulf Coast Aquifer.

Problems Affecting the Lavaca River Basin

See the Texas Priority Species List……………………733

In addition to the impaired water body segment, potential water development and transfer from Lake Texana to meet urban water needs poses a risk to bay and estuary inflows, which are critical to coastal fisheries resources. Population growth in the Lavaca Region (Region P) regional water planning area is not expected to be significant with a 3% increase forecast for 2060 (total population forecast 49,663) (TWDB 2005). No major reservoir construction is proposed within the current planning horizon but the Palmetto Bend II proposed reservoir site was recommended for designation as a unique reservoir site.

Element 3

High Priority Research and Monitoring Efforts for the Lavaca River Basin

See Monitoring and Adaptive Management………… 559
See the Texas Priority Species List……………………733

Element 5

- Monitor species of concern — Special studies and routine monitoring should be targeted at specific species of concern. Species-specific monitoring will provide population trend data and may be particularly important for species that are federally or state listed as endangered or threatened as well as those being considered for listing or delisting
- Monitor taxonomic groups suspected to be in decline or for which little is known. Monitoring and special studies should also target particular groups of organisms that are suspected to be on the decline or for which little is known. Research

across North America and Europe has documented the overall decline of mussels and amphibians

- Exotic species monitoring
- Ensure adequate instream flows and water quality through evaluation of proposed projects and water diversions in the Lavaca River basin
- Facilitate the availability of historical reports and associated data — Departmental and other publications containing biological data are not readily available and that situation inhibits the ability to document faunal changes through time in the state's rivers and streams
- Conduct studies, monitoring programs and activities to develop the scientific basis for assuring adequate instream flows for rivers, freshwater inflows to estuaries and water quality with the goal of conserving the health and productivity of public waters in Texas. Work with river authorities to develop water management plans to address instream and freshwater inflow needs as practical

Element 4

High Priority Conservation Actions for the Lavaca River Basin

See High Priority Conservation Strategies…………..517

See the Texas Priority Species List……………………733

- Participate in development of the State Water Plan through the 16 planning regions to assure consideration of fish and wildlife resources
- Facilitate coordination of all TPWD divisions with other state and federal resource agencies to assure that water quantity and water quality needs of fish and wildlife resources are incorporated in those agencies' activities and decision-making processes
- Review water rights and water quality permits to provide recommendations to the TCEQ and participate as warranted in regulatory processes to assure that fish and wildlife conservation needs are adequately considered in those regulatory processes

- Investigate fish kills and other pollution events that adversely affect fish and wildlife resources, make use of civil restitution and role as a natural resource trustee to restore those resources, water quality and habitat
- Continue to increase the information available to the public about conserving Texas rivers, streams and springs with the goal of developing greater public support and involvement when important water resource decisions are made. Development of integrated GIS products for analyzing and sharing information should be a focus of this effort
- Continue to provide technical support and advice to entities developing Habitat Conservation Plans to address instream flow, habitat and water quality issues and needs

Neches River Basin

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Element 1

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The Texas Priority Species List……………..733

Priority Species

Group	Scientific Name	Common Name	State/Federal Status
Isopods	*Caecidotea n. sp*	Big Thicket blind isopod	SC
	Caecidotea n. sp	Cave Springs isopod	SC
Crayfish	*Fallicamberus devastator*	Texas prairie crayfish	SC
	Orconectes maletae	Upshur crayfish	SC
	Procambarus kensleyi	Kensleys crayfish	SC
	Procambarus nechesae	Neches crayfish	SC
	Procambarus nigrocinctus	Black-girdled crayfish	SC
Shrimp	*Macrobrachium carcinus*	Bigclaw river shrimp	SC
	Macrobrachium ohione	Ohio shrimp	SC
Mussels	*Arcidens confragosus*	Rock pocketbook	SC

	Fusconaia askewi	Texas pigtoe	SC
	Lampsilis satura	Sandbank pocketbook	SC
	Obovaria jacksoniana	Southern hickorynut	SC
	Pleurobema riddellii	Louisiana pigtoe	SC
	Potamilus amphichaenus	Texas heelsplitter	SC
	Quadrula nodulata	Wartyback	SC
	Strophitus undulatus	Creeper	SC
	Truncilla donaciformis	Fawnsfoot	SC
Insects	*Somatochlora margarita*	Texas emerald (dragonfly)	SC
Fish	*Ammocrypta clara*	Western sand darter	SC
	Anguilla rostrata	American eel	SC
	Cycleptus elongatus	Blue sucker	ST
	Erimyzon oblongus	Creek chubsucker	ST
	Notropis atrocaudalis	Blackspot shiner	SC
	Notropis chalybaeus	Ironcolor shiner	SC
	Notropis sabinae	Sabine shiner	SC
	Notropis shumardi	Silverband shiner	SC
	Polyodon spathula	Paddlefish	ST

Location and Condition of Neches River Basin

Element 2

The Neches River originates in Van Zandt County, flowing southeastward through parts of east Texas to Sabine Lake. Here, it joins the Sabine River before flowing into the Gulf of Mexico. The Neches River basin is located entirely within Texas and has an approximate total area of 10,011 sq. mi., and a total length of 416 mi. Mean annual rainfall ranges from around 44 in. in the upper basin to about 55 in. where it reaches Sabine Lake. The abundant rainfall over the entire Neches Basin results in a flow near the Gulf of approximately 6,000,000 ac. ft. per year. The river runs most of its course through the Post Oak Savannah, Pineywoods and the northern tip of the Gulf Coast Prairies and Marshes ecoregions (Gould 1960, BEG 1996a).

The upper reaches of the Neches River in Van Zandt, Smith, Henderson, Cherokee, Anderson, Houston, Angelina, Trinity and Polk counties, flow through typical East Texas pine and hardwood bottomlands. Here, the river is scenic and an abundance of wildlife can be sighted on the banks. The only prevailing obstacles found along this section are occasional log jams. From Rhine Lake to Lake Palestine the Neches is extremely narrow and shallow. The Neches River is typically wide, free-flowing and has maintained much of its natural character. Here again, the only potential obstacles to be found are occasional log jams.

Certain portions of the Neches River are adjacent to areas managed by the U. S. Forest Service such as the Davy Crockett National Forest and the Angelina National Forest. Many areas on this river contain a wide variety of vegetative types, including oak, hickory, bald cypress, sweetgum and pine. This river has considerable merit for recreational activities due to the existence of the Big Slough Wilderness Area which contains a small channel in the floodplain which diverges from the Neches then returns to the river about four miles downstream. Many portions along the Neches River are very remote, due largely to the scarcity of road crossings. The water along this river is often murky in appearance.

There are 32 water body segments listed as impaired on the 2004 draft 303(d) list (TCEQ 2004). These include 15 segments listed for bacteria, 12 segments listed for depressed dissolved oxygen (DO), four for mercury in fish tissue, two for low pH, two for lead in water, one for zinc in water, one for aluminum in water and one for impaired fish community (several segments are listed for more than one parameter). Segments listed for depressed DO include Star Lake Canal in Jefferson County, Booger Branch in Hardin

County, Piney Creek in Houston, Trinity and Polk counties, Neches River along the western border of Smith County, Pine Island Bayou in Hardin and Jefferson counties, Boggy Creek in Hardin County, Little Pine Island Bayou in Hardin County, Willow Creek in Jefferson and Liberty counties, Beech Creek in Hardin and Tyler counties, Cypress Creek in Hardin County, Sam Rayburn Reservoir in Angelina, Nacogdoches and San Augustine counties and the Angelina River upstream from Sam Rayburn Reservoir on the northern border of Angelina County.

Associated Water Bodies

Major tributaries include the Angelina River, Attoyac Bayou (a tributary of the Angelina River), Pine Island Bayou and Village Creek.

Angelina River

Formed by the junction of Barnhardt, Scober and Shawnee Creeks in Rusk County, the Angelina River flows through Cherokee, Nacogdoches, Angelina, San Augustine and Jasper counties, joining the Neches River at B. A. Steinhagen Reservoir 12 mi. west of Jasper. The Angelina is a meandering stream flowing through forested bottomlands, many owned by lumber companies. In Rusk and Cherokee counties, it flows through heavily forested East Texas. From Cherokee, Nacogdoches and Angelina counties water flow often fluctuates; however, due to the many feeder streams, the river generally maintains consistent water levels in all but dry periods. Very little current is evident at normal water levels. The Angelina National Forest borders the river along portions. Two reservoirs are located on the Angelina River: Sam Rayburn Reservoir and B. A. Steinhagen Lake.

Pine Island Bayou

Pine Island Bayou rises in eastern Liberty County and flows southeast through Hardin County where it empties into the Neches River. Flowing through the Big Thicket country for approximately 25 mi., Pine Island Bayou is remote and retains a wilderness character. The almost impenetrable thicket holds a wide variety of plant life, which, in turn, provides excellent cover for many wildlife species. Much of this plant and animal life is rare or endangered, thus nature is in delicate balance throughout this area. The bayou itself is scenic with clear waters flowing over white sand and gravel, with periodic sand and gravel bars coming out of the water. The bayou is very narrow with a well developed riparian canopy. The lower part forms the northern boundary of the Beaumont City Limit and some development exists.

Village Creek

Village Creek, formed in northwestern Hardin County, joins with Big Sandy Creek then flows southeast where it meets the Neches River near Silsbee. This is free-flowing and passes through the heart of the Big Thicket. The streamflows through cypress swamps, pine and hardwood forests. Because of its remoteness, outstanding scenic qualities and lack of impoundments, Village Creek retains its wild and pristine characteristics. The upper section of Village Creek consists of still or slow-moving water, which is 20-30 ft. wide and characterized by overhanging brush, limbs and an occasional log jam. Large bald cypress trees and fresh water swamps exist just yards back from the creek. Clear waters of the creek flow over white sand and gravel, with almost impenetrable thicket bordering the creek and maintaining a remarkably wide variety of plant life, some of which is rare or endangered. These valuable habitats are very delicate and deserve protection.

There are four major reservoirs in the basin with a total conservation storage of 3,455,500 ac. ft. (BEG 1996b). Two of the major reservoirs are located on the Neches River. Lake Palestine is located near the headwaters of the river in Henderson, Smith, Cherokee and Anderson counties; and B. A. Steinhagen Lake is located on the lower section in Tyler and Jasper counties. A small reservoir, Rhine Lake, is located above Lake Palestine. The river between Rhine Lake, Lake Palestine and immediately below Lake Palestine has a limited flow and recreational usage is restricted to periods of heavy rainfall.

Reservoirs

Associated Reservoir	Location	Size (ac.)	Max Depth (Ft.)	Date Impounded	Water Level Fluctuation	Water Clarity	Aquatic Vegetation
Lake Athens	Approximately 5 mi. east of Athens, south of FM 317 in Henderson County	1500	50	1962	2 ft. annually	Moderately clear	Shoreline beds of hydrilla, watermilfoil and alligator weed
Lake Jacksonville	3 mi. southwest of Jacksonville off US 79	1352	62	1957	3 ft. annually	Clear to fairly clear	Moderate stands of hydrilla and native vegetation in upper end and coves
Lake Nacogdoches	On Loco Bayou, 10 mi. west of Nacogdoches off FM 225	2200	40	1976	1-3 ft. annually	Moderately clear	Primarily hydrilla
Lake Palastine	On the Neches River, 15 mi. southwest of Tyler on Texas 155	25500	58	1962	2 ft. annually	Moderately clear	Native submergent, emergent and floating, moderate in upper end and creek arms
Lake Striker	On Striker Creek, 20 mi. east of Jacksonville	2400	35	1957	1-2 ft. annually	Moderately turbid	Primarily emergent and floating native vegetation
Lake Tyler	On Mud and Prairie creeks, southeast of Tyler off Texas 64	2450	40	1949	2 ft. annually	Moderately Clear	Moderate native vegetation, floating, submergent and emergent.

Lake Tyler East	On Mud and Prairie creeks, southeast of Tyler off Texas 65	2530	40	1966	2 ft. annually	Moderately Clear	Moderate native vegetation, floating, submergent and emergent. Some hydrilla in east lake.
Pinkston Reservoir	On Sandy Creek, 10 mi. west of Center on State Highway 7	560	45	1976	1-5 ft. annually	Clear	Primarily non-native submersed (hydrilla and milfoil), but a variety of native aquatic plants are also established
Sam Rayburn Reservoir	On the Angelina River; the dam is located in Jasper County approximately 15 mi. north of Jasper.	114500	80	1965	10 ft. annually	Clear to off-color	Primarily non-native submersed (hydrilla); a variety of native aquatic plants are also established.
Choke Canyon Lake	Frio River watershed in Live Oak and McMullen counties, 4 mi. west of Three rivers	25989	95.5	1982	High, 10-15 ft. annually	Clear to slightly stained	Isolated beds of water stargrass, American pondweed, coontail, cattail, rushes and moderate densities of hydrilla
Lake Corpus Christi	Neches River watershed in San Patricio, Live Oak and Jim Wells counties, 20 mi. northeast of Corpus Christi	21900	60	1958	High, 10-15 ft. annually	Stained to partly clear	Isolated beds of water stargrass, American pondweed, coontail, cattail, rushes, water lettuce and high densities of water hyacinth

Aquifers

Major aquifers include the Carrizo-Wilcox and the Gulf Coast (BEG 2001). The Neches River Basin begins in the Carrizo-Wilcox Basin in Van Zandt, Henderson and Smith counties and journeys southeast to the Gulf Coast Aquifer where it continues to the Gulf of Mexico.

Problems Affecting the Neches River Basin

See the Texas Priority Species List……………………733

Element 3

The East Texas Regional Water Quality Planning Group (one of 16 such groups created in Texas contributing to the 2002 State Water Plan) encompasses the Neches basin as well as small portions of adjacent basins (ETRWPG 2001). Human population in the planning region is expected to increase from 1,011,317 in the year 2000 to 1,482,448 in 2060 (TWDB 2005a). Water demand is predicted to increase during the same period from 704,320 ac. ft. to 1,261,320 ac. ft. (TWDB 2005b). A proposed water supply reservoir, Lake Columbia, is planned for helping meet water needs for the region and is in the permitting phase. If constructed, it will inundate 10,000 ac. on Mud Creek, a tributary of the Neches near the city of Jacksonville. Storage capacity of Lake Columbia would be 187,839 ac. ft. (ANRA 2005). Another proposed reservoir discussed during the current round of regional water planning is the Fastrill Reservoir site on the upper Neches River. Though not facing potential critical water supply shortages, sufficient concern exists that the Neches basin has been placed on a Tier 2 (second highest priority) status for conducting instream flow studies to determine optimal flow regimes for protection of aquatic life which may otherwise be heavily impacted by water withdrawals.

In addition to basin wide concerns about water supplies for human uses and instream flow needs for aquatic life, the TPWD has identified several reaches of the main Neches stem and 24 tributary segments as ecologically significant stream segments (TPWD 2003). These stream segments exhibit exceptional ecological characteristics including high water quality, exceptional aquatic life, high aesthetic value, presence of threatened or endangered species, or valuable riparian habitats. Further study of such stream reaches would provide much needed data enabling more effective conservation of those resources. Issues of particular concern for conservation in East Texas include loss of wetlands and bottomland hardwood forest, mercury accumulation in aquatic food chains and better understanding and protection of the Big Thicket, an area with unusually rich species diversity.

Element 5

High Priority Research and Monitoring Efforts for the Neches River Basin

See Monitoring and Adaptive Management………… 559

See the Texas Priority Species List……………………733

- Monitor species of concern — Special studies and routine monitoring should be targeted at specific species of concern. Species-specific monitoring will provide population trend data and may be particularly important for species that are federally or state listed as endangered or threatened as well as those being considered for listing or delisting
- Monitor taxonomic groups suspected to be in decline or for which little is known. Monitoring and special studies should also target particular groups of organisms that are suspected to be on the decline or for which little is known. Research across North America and Europe has documented the overall decline of mussels and amphibians
- Monitoring of exotic plants and animals should be an integral part of any biological monitoring program or special study, with the goal of controlling the spread of invasive species and where possible preventing their introduction.
- Ensure adequate instream flows and water quality through evaluation of proposed reuse projects and water diversions in the Neches River basin
- Facilitate the availability of historical reports and associated data — Departmental and other publications containing biological data are not readily available and that situation inhibits the ability to document faunal changes through time in the state's rivers and streams
- Conduct studies, monitoring programs and activities to develop the scientific basis for assuring adequate instream flows for rivers, freshwater inflows to

estuaries and water quality with the goal of conserving the health and productivity of public waters in Texas. The Texas Instream Flow Program, directed by Senate Bill 2 (2001), identified the Neches River basin as a Tier 2 study area. Research needs as identified by TIFP study designs should be considered as moderately high priority for the basin

High Priority Conservation Actions for the Neches River Basin

See High Priority Conservation Strategies…………..517
See the Texas Priority Species List……………………733

Element 4

- Work with river authorities to develop water management plans to address instream and freshwater inflow needs as practical
- Participate in development of the State Water Plan through the 16 planning regions to assure consideration of fish and wildlife resources
- Facilitate coordination of all TPWD divisions with other state and federal resource agencies to assure that water quantity and water quality needs of fish and wildlife resources are incorporated in those agencies' activities and decision-making processes
- Review water rights and water quality permits to provide recommendations to the TCEQ and participate as warranted in regulatory processes to assure that fish and wildlife conservation needs are adequately considered in those regulatory processes
- Investigate fish kills and other pollution events that adversely affect fish and wildlife resources, make use of civil restitution and role as a natural resource trustee to restore those resources, water quality and habitat
- Continue to increase the information available to the public about conserving Texas rivers, streams and springs with the goal of developing greater public support and involvement when important water resource decisions are made. Development of integrated GIS products for analyzing and sharing information should be a focus of this effort

- Continue to provide technical support and advice to entities developing Habitat Conservation Plans to address instream flow, habitat and water quality issues and needs
- Conduct habitat restoration projects where possible to return aquatic and riparian habitats to a more natural condition

Nueces River Basin

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Associated Section IV Documents

The Texas Priority Species List……………..733

Element 1

Priority Species

Group	Scientific Name	Common Name	State/Federal Status
Amphipods	*Stygobromus hadenoecus*	Devil's Sinkhole amphipod	SC
	Stygobromus n. sp. 1	Lost Maples cave amphipod	SC
Crayfish	*Cambarellus ninae*	Texas coastal crayfish	SC
	Procambarus nueces	Nueces crayfish	SC
Shrimp	*Macrobrachium carcinus*	Bigclaw river shrimp	SC
	Macrobrachium ohione	Ohio shrimp	SC
Mussels	*Quadrula aurea*	Golden orb	SC
Snails	*Orygocerus* sp.	Straight-shell hybrobia	SC
Insects	*Leptobasis melinogaster*	Cream-tipped swampdamsel	SC

Fish	*Anguilla rostrata*	American eel	SC
	Cycleptus elongatus	Blue sucker	ST
	Cyprinella lepida	Plateau shiner	SC
	Cyprinella sp.	Nueces River shiner	SC
	Dionda serena	Nueces roundnose minnow	SC
	Ictalurus lupus	Headwater catfish	SC
	Menidia clarkhubbsi	Unisexual silverside	SC
	Micropterus salmoides. nuecensis		SC
	Micropterus treculii	Guadalupe bass	SC

Location and Condition of Nueces River Basin

Element 2

The Nueces River basin has its origins north and west of the urban areas of Uvalde and Hondo and enters Nueces Bay after traversing in a generally southeast direction. The basin is approximately 315 mi. long and the major fork of the river is the Frio, which joins the Nueces River in Live Oak County. The drainage area of the basin is 16,950 sq. mi. and occurs entirely in Texas (TCEQ 2004b). Rainfall averages from 20-32 in. per year (BEG 1996a). The Nueces River is contained within three physiographic ecoregions beginning with the Edwards Plateau in the upper basin, flowing through the South Texas Plains and ending in the Gulf Coast Prairies and Marshes (Gould 1960, BEG 1996b).

Land in the upper basin, north of U.S. Highway 90, which passes through the City of Uvalde, covers 3,100 sq. mi. of terrain known as the “Hill Country”. Approximately 90% of the land is used for grazing. Water-oriented recreation and hunting are also important to local economies. Upper basin streamflow is sustained by numerous springs in the Nueces, West Nueces, Leona, Frio and Sabinal rivers. Approximately 60% of the recharge water in the Edwards Aquifer comes from this portion of the basin as it crosses the Balcones Fault Zone (NRA 2003).

The middle portion of the basin, which extends to within 60 mi. of the Gulf Coast is characterized by a low, rolling, chaparral thicketed plain known as "Brush County". Here the Nueces River and its tributaries depend on runoff events and local precipitation for flows. Zero flow periods are frequent during which only perennial pools remain. Less than 20% of flood flows passing U.S. Highway 90 at Uvalde reach the lower end of the Nueces River Basin near Three rivers. Greater than 80% of this portion of the basin is used for cattle ranching and hunting, with some areas also farmed. Farming relies heavily on withdrawals from the Nueces River and Carrizo-Wilcox Aquifer (NRA 2003).

The lower portion of the basin, within a 60 mi. corridor adjacent to the Gulf Coast was historically covered with grasses and prickly pear; however a significant portion has been converted for cultivation leaving only a narrow belt of marsh adjacent to the coast. Oil production, chemical plants, refineries, shipping, military bases, seafood production and coastal recreation characterize the Coastal Bend. Flows of the Nueces River have profound impacts on the environmental and social well-being of this region (NRA 2003).

Six of 17 major water body segments are listed as impaired on the 2004 draft 303 (d) list (TCEQ 2004a). Depressed dissolved oxygen is problematic in four segments; bacterial levels in three segments including the Atascosa and Frio River above Choke Canyon Reservoir segments. Nitrate levels are listed as problematic in the lower Sabinal River segment. Total solids and bacteria levels are listed as problematic in the Choke Canyon Reservoir.

Associated Water Bodies

Major tributaries include the Frio, Leona, Sabinal and Atascosa rivers, as well as Seco, Hondo and San Miguel Creeks (TCEQ 2004b).

Frio River

The Frio River rises in northeast Real County and flows southeast through Uvalde, Medina, Frio, La Salle and Live Oak counties. Totaling in length approximately 250 mi., the Frio is spring-fed in its upper section and flows through picturesque canyons. Garner

State Park is located on the banks of this upper section. The waterway is a free-flowing river, since there are no major impoundments or reservoirs located along its entire course.

A 31 mi. section of the Frio River, located in Real and Uvalde counties, is considered by some as one of the most scenic sections of river in the State. The width of the stream is generally very narrow and water flow at normal levels is approximately 100 cfs. Many shallow rapids and an occasional low water dam are found along this expanse. The banks of the waterway are lined with bald cypress, pecans and oaks, while juniper and live oak-covered hills rise above the river. Canyons dissect many limestone outcroppings and bluffs.

Flowing through semi-arid ranching country, the Frio River below the town of Concan at times, is completely dry. During periods of heavy rainfall, the river consists of deep pools interspersed between very shallow areas. The normal average waterflow below the confluence with the Dry Frio is only 20.5 cfs, while the river is usually dry east of Uvalde. Semi-arid conditions exist throughout most of the river's entire course until it reaches the vicinity of Three rivers, where the Frio joins the Atascosa and Nueces River.

Choke Canyon and Lake Corpus Christi Reservoirs are the only major impoundments in the basin (TCEQ 2004b). Flood control projects are currently under investigation within the basin (USACOE 2002).

Reservoirs

Associated Reservoir	Location	Size (ac.)	Max Depth (Ft.)	Date Impounded	Water Level Fluctuation	Water Clarity	Aquatic Vegetation
Choke Canyon Lake	Frio River watershed in Live Oak and McMullen counties, 4 mi. west of Three rivers	25989	95.5	1982	High, 10-15 ft. annually	Clear to slightly stained	Isolated beds of water stargrass, American pondweed, coontail, cattail, rushes and moderate densities of hydrilla
Lake Corpus Christi	Nueces River watershed in San Patricio, Live Oak and Jim Wells counties, 20 mi. northeast of Corpus Christi	21900	60	1958	High, 10-15 ft. annually	Stained to partly clear	Isolated beds of water stargrass, American pondweed, coontail, cattail, rushes, water lettuce and high densities of water hyacinth

Aquifers

Four major aquifers are found in the Nueces River Basin, the Edwards-Trinity, Edwards, Carrizo-Wilcox and Gulf Coast, as well as three minor aquifers including the Queen City, Sparta and Yegua-Jackson. Local aquifers of varying quantity and quality also occur (BEG 2001). The Nueces River Basin begins in the downdrip of the Trinity Basin and flows through the Carrizo-Wilcox Aquifer before exiting Texas to Louisiana in the northeast corner of Texas.

Element 3

Problems Affecting Habitat and Species for the Nueces River Basin

See the Texas Priority Species List……………………733

In addition to impaired water body segments, population in the Nueces River Basin is projected to increase. Population in the South Central Texas planning region is projected to double over the planning period, rising from two million (2000) to four million by 2050 (TWDB 2005). Population in the Coastal Bend planning region is also expected to increase, rising from about 0.5 million to about 0.9 million by 2050. No major reservoir construction is proposed within the current planning horizon. The USACE is conducting a basin feasibility study that includes proposed recharge dams, a proposed reservoir on the Nueces River near Cotulla and a proposed off-channel reservoir near the existing Choke Canyon Reservoir (USACOE 2002). The intended purpose of these projects, if built, would be to increase water supply and flood control while enhancing natural resources such as springflows at Comal and San Marcos Springs and freshwater inflows to the Nueces Estuary. Various stream segments within the upper basin are considered ecologically significant (TPWD 2004).

Element 5

High Priority Research and Monitoring Efforts for the Nueces River Basin

See Monitoring and Adaptive Management………… 559
See the Texas Priority Species List……………………733

- Monitor species of concern — Special studies and routine monitoring should be targeted at specific species of concern. Species-specific monitoring will provide population trend data and may be particularly important for species that are federally or state listed as endangered or threatened as well as those being considered for listing or delisting

- Monitor taxonomic groups suspected to be in decline or for which little is known. Monitoring and special studies should also target particular groups of organisms that are suspected to be on the decline or for which little is known. Research across North America and Europe has documented the overall decline of mussels and amphibians
- Ensure adequate instream flows and water quality through evaluation of proposed reuse projects and water diversions in the Nueces River basin. The Department has reviewed proposed flood control projects within the basin and should continue its involvement to ensure fish and wildlife resources are protected
- Facilitate the availability of historical reports and associated data — Departmental and other publications containing biological data are not readily available and that situation inhibits the ability to document faunal changes through time in the state's rivers and streams
- Ecologically significant stream designation in conjunction with the seasonal nature of the river in the lower segment points to the need to investigate thoroughly prior to development of flood control structures
- Conduct studies, monitoring programs and activities to develop the scientific basis for assuring adequate instream flows for rivers, freshwater inflows to estuaries and water quality with the goal of conserving the health and productivity of public waters in Texas. Work with river authorities to develop water management plans to address instream and freshwater inflow needs as practical

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- Participate in development of the State Water Plan through the 16 planning regions to assure consideration of fish and wildlife resources

- Facilitate coordination of all TPWD divisions with other state and federal resource agencies to assure that water quantity and water quality needs of fish and wildlife resources are incorporated in those agencies' activities and decision-making processes
- Review water rights and water quality permits to provide recommendations to the TCEQ and participate as warranted in regulatory processes to assure that fish and wildlife conservation needs are adequately considered in those regulatory processes
- Investigate fish kills and other pollution events that adversely affect fish and wildlife resources, make use of civil restitution and role as a natural resource trustee to restore those resources, water quality and habitat
- Continue to increase the information available to the public about conserving Texas rivers, streams and springs with the goal of developing greater public support and involvement when important water resource decisions are made. Development of integrated GIS products for analyzing and sharing information should be a focus of this effort
- Continue to provide technical support and advice to entities developing Habitat Conservation Plans to address instream flow, habitat and water quality issues and needs

Red River Basin

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Element 1

Priority Species

Group	Scientific Name	Common Name	State/Federal Status
Crayfish	*Orconectes maletae*	Upshur crayfish	SC
	Procambarus kensleyi	Kensleys crayfish	SC
Mussels	*Arcidens confragosus*	Rock pocketbook	SC
	Arkansia wheeleri	Ouachita rock-pocketbook	FE/SE
	Fusconaia askewi	Texas pigtoe	SC
	Lampsilis satura	Sandbank pocketbook	SC
	Obovaria jacksoniana	Southern hickorynut	SC
	Pleurobema riddellii	Louisiana pigtoe	SC
	Quadrula nodulata	Wartyback	SC
	Strophitus undulatus	Creeper	SC
	Truncilla donaciformis	Fawnsfoot	SC

Insects	*Somatochlora margarita*	Texas emerald (dragonfly)	SC
Fish	*Ammocrypta clara*	Western sand darter	SC
	Anguilla rostrata	American eel	SC
	Cycleptus elongatus	Blue sucker	ST
	Cyprinodon rubrofluviatilis	Red River pupfish	SC
	Erimyzon oblongus	Creek chubsucker	ST
	Etheostoma radiosum	Orangebelly darter	SC
	Hiodon alosoides	Goldeye	SC
	Macrhybopsis australis	Prairie chub	SC
	Notropis atrocaudalis	Blackspot shiner	SC
	Notropis bairdi	Red River shiner	SC
	Notropis chalybaeus	Ironcolor shiner	SC
	Notropis potteri	Chub shiner	SC
	Notropis shumardi	Silverband shiner	SC
	Percina maculata	Blackside darter	ST
	Polyodon spathula	Paddlefish	ST
	Scaphirhynchus platorynchus	Shovelnose sturgeon	ST

Element 2

Location and Condition of Red River Basin

The Red River, which borders Hardeman, Wilbarger, Wichita, Clay, Montague, Cooke, Fannin, Lamar, Red River and Bowie counties, is the second largest river associated with Texas at 1,290 mi. total length and a drainage area of 48,030 sq. mi. Even though the river forms a major Texas boundary, it is considered to belong wholly to Oklahoma. For this reason, the Red River has not been investigated in-depth by the TPWD.

The Red River begins in New Mexico, extends across the Texas Panhandle and follows the Oklahoma-Texas border to Arkansas. The Texas portion of this river basin is 680 mi. long (BEG 1996a) and its drainage area is 24,463 sq. mi. (TWDB 1997). Average flow of the Red River near the Texas-Arkansas state line averages 11,490 cfs. The major forks include the North, Salt and Prairie Dog Town Forks in the Panhandle and major tributaries include the Pease, Wichita and Little Wichita rivers in north-central Texas. The watershed in Texas receives an average annual precipitation varying from 15 in. near the New Mexico border to 55 in. near the Arkansas border (RRA 1999).

The upper basin is largely comprised of prairie streams and rivers, with sandy bottoms; and contains substantial amounts of natural chlorides leading to unique fish assemblages. Low rolling hills and prairies and nearly level valleys characterize the lower basin. The Red River basin is contained within several physiographic ecoregions beginning with the High Plains in the upper basin, the Rolling Plains (including the Grand Prairie) in the central portion and the Blackland Prairies in the lower basin (Gould 1960, BEG 1996b).

Eleven water body segments are listed as impaired on the 2004 draft 303(d) list (TCEQ 2005). Seven are listed for not meeting the state water quality standard for bacteria. Little Wichita River, Beaver Creek and the Upper Prairie Dog Town Fork Red River are listed for depressed dissolved oxygen concentrations. The North Fork Wichita River and Middle Fork Wichita River are listed for selenium (chronic) in water.

According to the TWDB estimates of water use during 1996, 273,289 ac. ft. of water were used in the portion of the Panhandle Water Planning Area (PWPA) located in the Red River Basin. Water used for irrigated agriculture accounted for about 76% of the total water use, with municipal use accounting for approximately 15%, and industrial uses accounting for less than 10% (TWDB 1998).

Although surface water supplies account for a larger percent of the total water use in the Red River portion of the PWPA than in the Canadian River portion of the PWPA, less than 15% of the total water use in the Red River portion was provided by surface water sources.

Associated Water Bodies

Rivers and reservoirs within the planning area are recognized as important ecological resources. These are sources of diverse aquatic flora and fauna. Important river systems in the planning area are the Canadian River and the Red River. Reservoirs in the PWPA include Lake Meredith, Palo Duro Reservoir, Rita Blanca Lake, Marvin Lake and Fryer Lake in the Canadian River Basin and the Greenbelt Reservoir, Bivens Reservoir, McClellan Lake, Lake Tanglewood, Baylor Lake, Lake Childress and Buffalo Lake in the Red River Basin. The high salinity of much of the area's surface and groundwater resources, largely due to natural salt deposits, presents a challenge to natural resource planners and managers. Municipal, agricultural and industrial water users strive to lower the salinity of certain surface-water supplies for higher uses. One method for this is by intercepting and disposing of the naturally saline flows of certain streams, usually originating from natural salt springs and seeps, in order to improve the quality of downstream surface-water supplies. There are several such chloride control projects, both existing and proposed, in the study area.

One of the largest reservoirs, the Greenbelt Reservoir, is owned and operated by the Greenbelt Municipal and Industrial Water Authority (GM&WA), and is located on the Salt Fork of the Red River near the city of Clarendon. Construction of the Greenbelt Reservoir was completed in March 1968 and impoundment of water began on December 1966 (Freese and Nichols 1978). The original storage capacity of Greenbelt was 59,100 ac. ft. at the spillway elevation of 2,663.65 ft. (TWDB 1974).

Two yield studies have been completed for the Greenbelt Reservoir since its original permit application in 1965 (Freese and Nichols 1978 & 1997). The most recent of the studies estimated the firm yield of the Greenbelt Reservoir to be 7,699 ac. ft. per yr. The reservoir's critical period occurred from August 1961 to December 1996, with a minimum content occurring in June 1996. The safe yield of the reservoir is estimated to be 6,350 ac. ft. per yr (5.67 MGD). Inflow estimates prior to September 1967 were based on USGS gages near Mangum, Wellington and Clarendon. Inflows after September 1967 were based on a volumetric balance of the reservoir with USGS surface elevation measurements taken at the dam. Net reservoir evaporation rates were derived from one degree quadrangle data published by the TWDB (1967). Reservoir operation studies also included an estimate of historical low-flow releases. Sedimentation rates characteristic of the area were used to estimate a reservoir capacity reduction of 5,770 ac. ft. by 1996 (Freese and Nichols 1997). Based on analysis of existing studies and historical data, estimates of capacity, firm yield and available supply of the Greenbelt Reservoir were projected by decade for the planning period. The yield is expected to decrease from 7,699 ac. ft. in 2000 to 6,942 ac. ft. by 2050.

Significant water development has occurred within the basin, with five major storage reservoirs (> 100,000 ac. ft.) and storage capacity of over 3.7 million ac. ft. Lake Texoma, which impounds the Red River, is the fifth largest reservoir in the state. There are two primary water authorities (Red River Authority and Greater Texoma Water Authority) and one interstate compact. The Red River Compact was entered by the states of Arkansas, Louisiana, Oklahoma and Texas for the purpose of allocating basin waters among the states.

Reservoirs

Associated Reservoir	Location	Size (ac.)	Max Depth (Ft.)	Date Impounded	Water Level Fluctuation	Water Clarity	Aquatic Vegetation
Baylor Lake	12 mi. west of Childress on the Prairie Dog Fork of the Red River	600	50	1950	2-4 ft. annually	Clear with 2-4 ft. visibility in lower reservoir; 1-2 ft in upper	Limited; some areas of pondweed
Buffalo Lake	20 mi. from Wichita Falls MSA	1577	28	1964	8 ft. annually	1-2 ft. visibility	None
Greenbelt Lake	60 mi. east of Amarillo and 4 mi. north of Clarendon on the Salt Fork of the Red River	1,990 ac. possible, currently about 1,500 ac.	84	1967	2-4 ft. annually	4-6 ft. visibility	Vegetation in Greenbelt includes potamogeton, coontail, milfoil and cattails. Vegetation can be dense around shoreline areas and coves. In Kelly Creek and the Salt Fork, there are stands of flooded timber.

Lake Arrowhead	15 mi. southeast of Wichita Falls off US Highway 281	14390	45	1965	4-6 ft. annually	1-2 ft. visibility	Limited primarily to floating mats of American pondweed located around the state park and nearby coves and some reeds when lake is at normal elevations. Due to fluctuating water levels and periodic high turbidity, there are periods with no vegetation.
Lake Bonham	Three miles northeast of Bonham off FM 898	1020	30	1969	Moderate	Moderate	Native emergent vegetation includes cattail, pondweed and American lotus. Native submerged vegetation includes bushy pondweed and coontail.
Lake Crook	On Pine Creek, a tributary of the Red River, 5 mi. north of Paris in Lamar County	1226	24	1923	Moderate, 2-4 ft. annually	Turbid	Emergent varieties

Lake Diversion	30 mi. from Wichita Falls on the Archer/Baylor county line	3491	35	1924	3 ft. annually	2 to 4 ft. visibility	About one-third of the shore is lined with emergent vegetation. Submerged plants occupy about 420 ac., mainly on the northside coves west of the boat ramp.
Lake Kemp	On the Wichita River north of Seymour, off US 183	15104	53	1923	6-8 ft., average 7.6 ft. annually	Visibility 4-6 ft.	Limited
Lake Kickapoo	29 mi. from Wichita Falls in southern Archer County	6028	48	1947	6 ft. annually	1-2 ft. visibility	Extremely limited in this turbid lake
Lake Nocona	Eight miles northeast of Nocona off FM 2634	1470	80	1961	Moderate	Moderately clear to stained	Milfoil and floating pondweed
Lake Texoma	A Red River impoundment on the Texas-Oklahoma border northwest of Sherman-Denison, west of US 75	89000	100	1944	5-8 ft. annually	Moderate to clear	Not abundant, but there are some stands of water willow, American lotus, floating heart and bushy pondweed

Mackenzie Reservoir	10 mi. northwest of Silverton on Tule Creek, a tributary of the Prairie Dog Fork of the Red River	900 ac. possible, currently about 320 ac.	150	1974	Severe, 4-10 ft. per year	Clear with visibility 4-6 ft	The reservoir has very little aquatic vegetation. Most of the structure is flooded timber and terrestrial vegetation.
Pat Mayse Lake	In Lamar County 12 mi. north of Paris on Sanders Creek, a tributary of the Red River	5993	55	1967	Moderate, 2-4 ft. annually	Moderately stained	Moderate amounts of submerged aquatics and hydrilla

Aquifers

Several major aquifers are found in the Red River Basin including Ogallala, Trinity Group and Carrizo-Wilcox, as well as a few minor aquifers including the Blaine, Seymour alluvium, Blossom and Nacatoch (BEG 1996b).

The Seymour is a major aquifer located in north central Texas and some Panhandle counties. The aquifer consists of isolated areas of alluvium that are erosional remnants of a larger area or areas. Thick accumulations overlie buried stream channels or sinkholes in underlying formations. This aquifer is under water-table conditions in most of its extent, but artesian conditions may occur where the water-bearing zone is overlain by clay. Fresh to slightly saline groundwater recoverable from storage from these scattered alluvial aquifers is estimated to be 3.18 million ac. ft. based on 75% of the total storage. Annual effective recharge to the aquifer is approximately 215,200 ac. ft., or 5% of the average annual precipitation that falls on the aquifer outcrop. No significant long-term water-level declines have occurred in areas supplied by groundwater from the Seymour aquifer. The lower, more permeable part of the aquifer produces the greatest amount of groundwater. Yields of wells average about 300 gal/min and range from less than 100 gal/min to as much as 1,300 gal/min (Ashworth and Hopkins 1995).

Water quality in these alluvial remnants generally ranges from fresh to slightly saline, although a few higher salinity problems may occur. The salinity has increased in many heavily-pumped areas to the point where the water has become unsuitable for domestic uses. Brine pollution from oil-field activities has resulted in localized contamination of former fresh groundwater supplies. Nitrate concentrations in excess of primary drinking-water standards are widespread in the Seymour groundwater (Ashworth and Hopkins 1995).

The Blaine is a minor aquifer located in portions of Wheeler, Collingsworth and Childress counties and extends into western Oklahoma. Saturated thickness of the formation in its northern region varies from approximately 10 to 300 ft. Recharge to the aquifer travels along solution channels which contribute to its overall poor water quality.

Dissolved solids concentrations increase with depth and in natural discharge areas at the surface, but TDS concentrations in the aquifer are less than 10,000 mg/L. The primary use is for irrigation of highly salt-tolerant crops, with well yields varying from a few gallons per minute (gpm) to more than 1,500 gpm (Ashworth and Hopkins 1995).

Problems Affecting the Red River Basin

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Element 3

Issues that are of concern for water supplies include aquifer depletions due to pumping exceeding recharge; contamination of surface water and groundwater; and drought related shortages for both surface water and groundwater. Potential groundwater contamination may supersede water quantity as a consideration in evaluating the amount of water available for a use (see Wheeler section 5.4.15).

Water development in the Red River basin has been significant. Major and minor reservoirs are present on forks and tributaries throughout the basin, altering the flow regime and water quality of riverine systems. The proposed Lower Bois d'Arc Reservoir was recommended for construction in the State Water Plan (TWDB 2002) by the Region C planning group to supply water to the North Texas Municipal Water District. The proposed reservoir site is on Bois d'Arc Creek, a tributary of the Red River entering downstream of Lake Texoma. Reallocation of hydropower storage at Lake Texoma to municipal storage and diversion may lead to modified streamflows downstream. The North Texas Municipal Water District has a major water rights permit request to divert 113,000 ac. ft. per year and to store 100,000 ac. ft. pending at TCEQ. Export of water out of the basin may further modify streamflows.

Most water used in the PWPA is supplied from aquifers such as the Ogallala, making aquifer depletion a potentially major constraint on water sources in the region. Depletions lower the water levels, making pumping more expensive and reducing the potential available supply. Another possible constraint to both groundwater pumping and maintenance of streamflows relates to restrictions that could be implemented due to the presence of endangered or threatened species. The Federal listing of species like the

Arkansas River shiner as threatened has the potential to affect water resource projects as well as other activities in Hemphill, Hutchinson, Oldham, Potter and Roberts counties.

Threats and constraints to water supply in the PWPA are related to surface water and groundwater sources. The actual and potential threats may be similar or unrelated for surface or groundwater. Because water use in the PWPA is primarily for agriculture, some of the constraints for use are not as severe as those of water used for human consumption. However, in most cases the same water sources are used for both agricultural and potable water supply.

Potential contamination of groundwater may be associated with oil-field practices, including seepage of brines from pits into the groundwater; brine contamination from abandoned wells; and broken or poorly constructed well casings. Agricultural and other practices may have contributed to elevated nitrates in groundwater and surface water. Surface waters in the area may also experience elevated salinity due to brines from oil-field operations, nutrients from municipal discharges and other contaminants from industrial discharges. Other potential sources of contaminants include industrial facilities such as the Pantex plant near Amarillo; the Celanese plant at Pampa; an abandoned smelter site at Dumas; and concentrated animal feeding operations in various locations throughout the PWPA. However, most of these potential sources of contamination are regulated and monitored by the TCEQ or other state agencies. Naturally occurring brine seeps also restrict the suitability of surface waters, such as Lake Meredith, for certain uses.

A federal chloride control project in the Wichita River watershed is currently being planned for completion by the USACE in order to reduce the chloride load entering Lake Kemp and Diversion Lake; a Record of Decision for the project has been signed. Potential impacts from this project involve changes in low flow hydrology and water quality. Resource agencies identified several concerns related to the chloride control project including: impacts to prairie stream ecosystems, impaired reservoir sport fisheries, elevated selenium concentrations and associated contaminant-based impacts, increased chance of golden algae fish kills and impaired operations at the Dundee State

Fish Hatchery. Future brush control is also an element of the chloride control project which could lead to impacts to stream habitat. Parts of the project (e.g. Truscott Brine Lake) have been in operation for two decades but other parts of the project are only partially constructed or have not been constructed. If completed and proven effective the scope of chloride control could be significantly expanded in the future to include other portions of the Red River basin; the range of impacts of a larger project could include the Pease River, Salt Fork of the Red River, Red River and Lake Texoma.

Golden algae blooms and fish kills have occurred from Lake Pauline to the upper portion of Lake Texoma. The golden alga produces toxins that kill all fish species, mussel/clam species and gill breathing amphibians/salamanders. It is a threat to all aquatic ecosystems. Research is needed on its distribution; bloom and toxin production dynamics; water quality affects on the alga and its toxin; possible management and treatment options for ponds and large waterbodies; interactions, population control and affects within the plankton community (bacteria, phytoplankton and zooplankton); and genetics of the organism and its possible strains. The need for coordination and cooperation between the various regulatory and resource agencies (local, state and federal) is a very important need for developing research efforts and any future management plans or actions dealing with this toxic alga.

The City of Wichita Falls obtained a permit to discharge brine reject into the Wichita River from a reverse osmosis plant (desalinization). The plant is expected to be operational in the Fall of 2005.

High Priority Research and Monitoring Efforts for the Red River Basin

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- Monitor species of concern — Special studies and routine monitoring should be targeted at specific species of concern. Species-specific monitoring will provide

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population trend data and may be particularly important for species that are federally or state listed as endangered or threatened as well as those being considered for listing or delisting

- Monitor taxonomic groups suspected to be in decline or for which little is known. Monitoring and special studies should also target particular groups of organisms that are suspected to be on the decline or for which little is known. Research across North America and Europe has documented the overall decline of mussels and amphibians. Previous synopses of fish collections indicate that prairie stream fishes have declined in abundance and distribution over time
- Ensure adequate instream flows and water quality through evaluation of chloride control projects, desalinization projects and proposed reservoirs. Texas Parks and Wildlife Department actively participated in the review of the environmental impact statement for the Wichita River Chloride Control Project developed by the USCOE; participation in workgroups and studies contained in the environmental operational plan will be required. Texas Parks and Wildlife Department studies have been planned and implemented to document changes in aquatic life and water quality due to desalinization project operations in the Wichita River. The Texas Instream Flow Program identified the proposed Lower Bois d'Arc Creek reservoir as a second tier priority study
- Facilitate the availability of historical reports and associated data — Departmental and other publications containing biological data are not readily available and that situation inhibits the ability to document faunal changes through time in the state's rivers and streams
- Monitor golden alga problems to determine extent of impacts on aquatic communities, aid in developing management plans for affected ecosystems and determine potential control mechanisms
- Conduct studies, monitoring programs and activities to develop the scientific basis for assuring adequate instream flows for rivers, freshwater inflows to estuaries and water quality with the goal of conserving the health and productivity of public waters in Texas

High Priority Conservation Actions for the Red River Basin

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Element 4

- Participate in development of the State Water Plan through the 16 planning regions to assure consideration of fish and wildlife resources
- Facilitate coordination of all TPWD divisions with other state and federal resource agencies to assure that water quantity and water quality needs of fish and wildlife resources are incorporated in those agencies' activities and decision-making processes
- Review water rights and water quality permits to provide recommendation to the TCEQ and participate as warranted in regulatory processes to assure that fish and wildlife conservation needs are adequately considered in those regulatory processes
- Investigate fish kills and other pollution events that adversely affect fish and wildlife resources, make use of civil restitution and role as a natural resource trustee to restore those resources, water quality and habitat.
- Research golden alga problems to determine extent of impacts on aquatic communities, aid in developing management plans for affected ecosystems and determine potential control mechanisms
- Continue to increase the information available to the public about conserving Texas rivers, streams and springs with the goal of developing greater public support and involvement when important water resource decisions are made

Rio Grande Basin

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Priority Species

Group	Scientific Name	Common Name	State/Federal Status
Amphipods	*Gammarus hyalelloides*	Diminutive amphipod	FC
	Gammarus pecos	Diamond Y amphipod	SC
	Gammarus sp. 1 (Lang et al. 23)	Giffin Spring amphipod	SC
	Gammarus sp. 2 (Lang et al. 23)	East Sandia Spring amphipod	SC
	Gammarus sp. C (Cole 1985)	Phantom Lake amphipod	SC
	Gammarus sp. M (Cole 1985)	Toyahvale amphipod	SC
	Gammarus sp. S (Cole 1985)	San Solomon Spring amphipod	SC
	Stygobromus limbus	Border Cave amphipod	SC
Isopods	*Lirceolus n. sp.*	Dandrige Springs isopod	SC
Shrimp	*Macrobrachium acanthurus*	Cinnamon river shrimp	SC
	Macrobrachium carcinus	Bigclaw river shrimp	SC

Mussels	*Popenaias popeii*	Texas hornshell	FC
	Potamilus metnecktayi	Salina mucket	SC
	Quadrula couchiana	Rio Grande monkeyface	SC
	Quincuncina mitchelli	False spike	SC
	Truncilla cognata	Mexican fawnsfoot	SC
Snails	*Assiminea pecos*	Pecos assiminea snail	FC
	Cochliopa texana	Phantom Cave Snail	FC
	Pseudotryonia adamantina	Diamond Y Spring	FC
	Pygulopsis metcalfi	Naegele springsnail	SC
	Pyrgulopsis davisi	Limpia Creek springsnail	SC
	Tryonia brunei	Brunes tryonia	SC
	Tryonia cheatumi	Phantom tryonia	FC
	Tryonia circumstriata	Gonzales springsnail	SC
Insects	*Homoleptohyphes mirus*	Desert stream mayfly	SC
	Limnebius texanus	Texas minute moss beetle	SC
	Stictotarsus neomexicanus	Bonita diving beetle	SC
	Gomphus gonzalezi	Tamaulipan clubtail (dragonfly)	SC
Plants	*Potamogeton clystocarpus*	Little aguja pondweed	FE/ SE
Fish	*Anguilla rostrata*	American eel	SC
	Awaous banana	River goby	ST
	Campostoma ornatum	Mexican stoneroller	ST

Cycleptus elongatus	Blue sucker	ST
Cyprinella proserpina	Proserpine shiner	ST
Cyprinodon bovinus	Leon Springs pupfish	FE/ SE
Cyprinodon elegans	Comanche Springs pupfish	FE/ SE
Cyprinodon eximius	Conchos pupfish	ST
Cyprinodon eximius ssp	Devils River pupfish	ST
Cyprinodon pecosensis	Pecos pupfish	ST
Dionda argentosa	Manantial roundnose minnow	SC
Dionda diaboli	Devils River minnow	FT/ST
Dionda episcopa	Roundnose minnow	SC
Etheostoma grahami	Rio Grande darter	ST
Gambusia clarkhubbsi	San Felipe gambusia	SC
Gambusia gaigei	Big Bend gambusia	FE/ SE
Gambusia nobilis	Pecos gambusia	FE/ SE
Gambusia senilis	Blotched gambusia	SE/ST
Gila pandora	Rio Grande chub	ST
Gobionellus atripinnis	Blackfin goby	ST
Hybognathus amarus	Rio Grande silvery minnow	FE/ SE/ST
Ictalurus lupus	Headwater catfish	SC
Ictalurus sp.	Chihuahua catfish	SC
Macrhybopsis aestivalis	Speckled chub	SC
Microphis brachyurus	Opossum pipefish	ST
Micropterus salmoides nuecensis	-	SC
Scartomyzon austrinus	Mexican redhorse	SC
Notropis braytoni	Tamaulipas shiner	SC

Notropis chihuahua	Chihuahua shiner	ST
Notropis jemezanus	Rio Grande shiner	SC
Notropis simus pecosensis	Pecos bluntnose shiner	SE/ST
Oncorhynchus clarki virginalis	Rio Grande cutthroat trout	FE/SE
Rhinichthys cataractae	Longnose dace	SC
Scaphirhynchus platorynchus	Shovelnose sturgeon	ST

Location and Condition of Rio Grande Basin

Element 2

The Rio Grande originates in the San Juan Mountains of southern Colorado and flows southward through New Mexico to the Gulf of Mexico. Its total length is approximately 1,896 mi., with approximately 1,248 mi. being located along the southern border of Texas.

The drainage area of the entire basin is 335,500 sq. mi. and covers three U.S. (Colorado, New Mexico and Texas) and five Mexican (Chihuahua, Coahuila, Durango, Nuevo Leon and Tamaulipas) states. Texas portions of the basin account for 48,259 sq. mi. of catchment (TCEQ 2004b). Rainfall averages from 8-32 in. per year in the Texas portion of the basin (BEG 1996a). The Rio Grande crosses four physiographic ecoregions in Texas beginning with the Trans-Pecos, then the Edwards Plateau, flowing into the South Texas Plains and finally the tip of the Gulf Coast Prairies and Marshes (Gould 1960, BEG 1996b).

The Rio Grande borders the Texas counties of El Paso, Hudspeth, Presidio, Brewster, Terrell, Val Verde, Kinney, Maverick, Webb, Zapata, Starr, Hidalgo and Cameron. The river dwindles to nearly zero flow at Presidio and does not flow again in earnest until water from the Río Conchos of Mexico joins the Rio Grande near Presidio.

Major cities and towns include Santa Fe, Albuquerque, Socorro, Truth or Consequences, Mesilla and Las Cruces in New Mexico; El Paso, Presidio, Del Rio, Eagle Pass, Laredo, Rio Grande City, McAllen and Brownsville in Texas; and Ciudad Juárez, Ojinaga, Ciudad Acuña, Piedras Negras, Nuevo Laredo, Camargo, Reynosa and Matamoros in Mexico.

Downstream of Presidio the Rio Grande flows into the canyon lands of Big Bend National Park. A 191.2 mi. strip of the American bank called Rio Grande Wild and Scenic River begins in Big Bend National Park and runs downstream to the Terrell-Val Verde county line. South of Redford (formerly Polvo), the Bofecillos and the Chihuahua Mountains converge to form Colorado Canyon after which follow Santa Elena, Mariscal and Boquillas canyons. Further downstream are smaller, white-water canyons such as Horse, Big and Reagan canyons (UT 2005).

Cattle ranches and farms with broad open valleys typify the Rio Grande downstream of Del Rio, Eagle Pass and Laredo. The river at this point becomes more meandering and tropical evidenced by fertile citrus groves. The river terminates in a delta at the Gulf of Mexico (UT 2005).

The Rio Grande flows through several types of habitat, which include deserts, wetlands, mountains and subtropical coastal regions. The importance of the Rio Grande as a water supply and as an international boundary poses an environmental challenge in protecting its water quantity and quality.

The Rio Grande from below Falcon Dam, in Starr County downstream to the Rio Grande Wier, in Cameron County (TNRCC stream segment 2302) has an ecologically significant designation (El-Hage and Moulton 2000). One reason for the ecological significance of this segment is the presence of priority riparian habitat, extensive freshwater wetlands, subtropical resaca woodlands and brushland of thicket forming, thorny shrubs and small trees (Bauer et al. 1991). The resaca banks support a luxuriant growth of cedar elm, anacua, ebony, hackberry, Mexican ash and tepequaje, a very large Mexican lead tree. Further support of this designation is the presence of the Lower Rio Grande Valley National Wildlife Refuge (LRGVNWR). From Falcon Dam downstream to the mouth of the Rio Grande, the LRGVNWR is one of the most biologically diverse national wildlife refuges in the continental United States. Some of the unusual birds observed in the area include: paraque, groove-billed ani, green kingfisher, blue bunting, black-bellied whistling duck, clay-colored robin, rose-throated becard, tropical parula and masked tityra. The area is also one of the last natural refuges in Texas for cats such as the ocelot and jaguarundi.

Elephant Butte and Caballo dams impound the Rio Grande near Truth or Consequences, New Mexico and the river downstream is used for irrigation in the Mesilla Valley of New Mexico and the 90 mi. long El Paso-Juárez valley, the oldest irrigated area in the state. The annual water allowance for Mexican farmers near Juarez is by treaty 60 thousand ac. ft., although during periods of low snow melt runoff in Colorado, this figure is reduced proportionately (UT 2005).

Texas-New Mexico Border to Presidio

From El Paso downstream to Presidio the Rio Grande is approximately 258 mi. of virtually dry riverbed because of extensive irrigation in New Mexico and Texas. The river once again flows in earnest when the Rio Concho enters the streambed from Mexico, just upstream from Presidio-Ojinaga. The river bordering Hudspeth and Presidio counties, particularly in the vicinity of the Quitman Mountains, is very scenic. From Presidio downstream for approximately 300 mi., the river flows through a series of some of the most rugged canyons in the United States.

In the vicinity of and below Redford, the Rio Grande flows through rugged terrain and a series of large rapids exist. In addition, Colorado Canyon is a short, but scenic canyon which is also noted for its rapids. Below Colorado Canyon, the river flows through relatively flat desert terrain enroute to its rendezvous with the Mesa de Anguila and Santa Elena Canyon.

The 26 mi. section of the Rio Grande from Lajitas to Castolon contains Santa Elena Canyon and is one of the most famous segments of the river. The entire section is scenic with the main feature being Santa Elena Canyon, which rises as much as 1,500 ft above the riverbed.

Bancos (wide, usually brushy curves shaped like horseshoes or oxbows) have generated significant problems in defining the international boundary, especially in the lower Rio

Grande valley; as they frequently overflow and form new channels. This became a serious issue not resolved until the Banco Treaty of 1905. Elephant Butte Dam in New Mexico opened in 1916 was to provide a steady supply of irrigation water on demand. In 1933 the United States and Mexico approved the Rio Grande Rectification Treaty, which straightened the channel east of El Paso reducing the river's length from 155.2 mi. to 85.6 mi. The subsequent Rio Grande Channelization Project straightened the Rio Grande in New Mexico from Caballo Dam south to the Texas line, roughly 100 mi. In 1932, the United States and Mexico ratified the Lower Rio Grande Valley Flood Control Project, which strengthened and raised levees and dredged the channel and floodways.

Five of 14 major water body segments are listed as impaired in the 2004 draft 303 (d) list (TCEQ 2004a). All sites were listed for high bacteria levels, two for chronic toxicity in water to aquatic organisms and total dissolved solids along with elevated chloride levels were listed in the Rio Grande below Riverside Diversion Dam. In addition to the five impaired water bodies, water development throughout the basin has altered natural flow regimes drastically. It is not uncommon for the Rio Grande to cease flowing near Fort Quitman and within the last decade the river has ceased to flow at its mouth on various occasions for prolonged periods. Water development in the upper basin both by Mexico and the U.S. along with flood control structures has altered the natural hydrograph dramatically. Concomitant with these efforts has been the loss of channel maintenance flows. In many areas this has caused the encroachment of invasive riparian species such as salt cedar and giant cane, which in turn have reduced flows through uptake and evapotranspiration.

Associated Water Bodies

Major tributaries are the Pecos, Devils, Chama and Puerco rivers in the United States and the Conchos, Salado and San Juan in Mexico (UT 2005). Lesser tributaries include perennial streams such as San Felipe and Sycamore Creeks. Many seasonal creeks such as Terlingua Creek contribute during runoff events, but otherwise do not contribute significant flow.

Pecos River

The Pecos River rises on the eastern slope of the Santa Fe Mountain Range in Mora County New Mexico. It enters the State of Texas in Loving County at Red Bluff Lake; meanders in a general southeasterly course approximately 170 mi. through a narrow alluvial valley to Sheffield. From this point it continues in a southeasterly course 90 mi. through a deep box canyon to its junction with the Rio Grande 10 mi. west of Comstock, in Val Verde County. Its principal tributaries are Toyah and Comanche creeks in Texas and Delaware Creek just north of the New Mexico-Texas state line. These creeks are intermittent. The Pecos River is the principal tributary of the lower Rio Grande. There are no power developments along the stream in Texas, but considerable water is diverted near Pecos and Grandfalls for irrigation. The lower reach of the Pecos River from the Val Verde/Crockett county line downstream to a point just downstream of Painted Canyon (Val Verde County) is considered by the TPWD to have significant ecological value (El-Hage and Moulton 2001). The aquatic and riparian habitats associated with the river in this reach support a diverse assemblage of invertebrates, reptiles, fish, birds and plants. The river here flows through a region that represents three ecological zones; the Trans Pecos to the west, the Edwards Plateau to the east and the South Texas Plains to the south. Riparian gallery forests include salt cedar, oaks, willows, huisache, baccharis and many other brush species.

Devil's River

The Devil's River rises in northwestern Sutton County. The river flows south through Val Verde County to International Amistad Reservoir. The Devil's River is one of two major tributaries to the Rio Grande in Texas, along with the Pecos River. Perennial flows start about 50 mi. upstream from the mouth at Pecan Springs seven miles southwest of Juno. Downstream, a series of springs (including Dolan Springs) provide up to 80% of the river's baseflow. These springs issue from the Georgetown limestone of the Edwards-Trinity (Plateau). There are no impoundments on the river and little local use for irrigation because the river flows through a deeply eroded canyon. The Devil's River is within the Edwards Plateau ecoregion. The segment of this river between the Val Verde/Sutton county line downstream to just past the confluence of Little Satan Creek (Val Verde County) is considered by the TPWD as having special ecological significance

(El-Hage and Moulton 2001). The riparian and aquatic habitats associated with the river support a diverse assemblage of invertebrates, reptiles, fish, birds and plants. The river is considered by many to be the cleanest and clearest naturally flowing river in Texas, supports exceptional aquatic life uses, has exceptional aesthetic value and is rich in prehistoric archeological sites with pictographs and burned rock middens (National Park Service 1995, Texas Natural Resource Conservation Commission 1995). It has been proposed for inclusion in the National Wild and Scenic Rivers System.

Mexico

In Mexico, the Rio Conchos, Rio Salado and the Rio San Juan are the largest tributaries of the Rio Grande. The Rio Conchos drains over 26,000 sq. mi. and flows into the Rio Grande near the town of Presidio, Texas, about 350 river miles upstream of Amistad Reservoir. The Rio Salado has a drainage area of about 23,000 sq. mi. and discharges directly into Falcon Reservoir on the Rio Grande. Falcon Reservoir is located between the cities of Laredo, Texas and Rio Grande City, Texas, about 275 river miles upstream from the Gulf of Mexico. The Rio San Juan has a drainage area of approximately 13,000 sq. mi. and enters the Rio Grande about 36 river miles below Falcon Dam near Rio Grande City, Texas.

Reservoirs

The Mexican-United States Treaty of February 3, 1944, committed both countries to the construction of two Rio Grande dams: Falcon and Amistad, each designed to store five million or more af. Falcon Dam 50 mi. downstream from Laredo, Texas was dedicated in October 1953. Not far downstream is Mission Reservoir, at Mission, Texas. Amistad (Friendship) Dam was finished in 1969 and is 12 mi. northwest of Del Rio (UT 2005).

Reservoirs

Associated Reservoir	Location	Size (ac.)	Max Depth (Ft.)	Date Impounded	Water Level Fluctuation	Water Clarity	Aquatic Vegetation
International Amistad Reservoir	On the Rio Grande, 12 mi. northwest of Del Rio in Val Verde County	67000	217	1969	Dependent on rainfall and downstream irrigation demands. Annual fluctuations can be 5-10 ft. Historical fluctuations have dropped lake as much as 50 ft. below conservation pool.	Clear to slightly stained	1999 surveys indicated approximately 1,000 ac. of aquatic vegetation, primarily hydrilla.
International Falcon Reservoir	Falcon is a mainstream reservoir on the Rio Grande River, located 40 mi. east of Laredo on Highway 83 in Zapata and Starr counties.	78300	110	1954	Severe, 40 to 50 ft. or more	Turbid (upper) to stained (lower)	Sparse hydrilla

Aquifers

Five major aquifers are found in the Texas portion of the basin, the Bolson, Edwards-Trinity, Edwards, Carrizo-Wilcox and Gulf Coast. Minor aquifers in the basin include Igneous, Yegua-Jackson and various local aquifers of varying quantity and quality (BEG 2001).

The Rio Grande Basin cuts across every major aquifer in the state except for the Ogallala and the Seymour. The Rio Grande proper enters the state near El Paso where it flows across the Hueco Aquifer, which is a relatively small aquifer (in Texas) that exists in El Paso and Hudspeth counties. As the Rio Grande reaches Brewster County and begins to go north, it begins to flow over the Edwards-Trinity Aquifer. As the Rio Grande begins to flow southeast again, it comes in contact with the Carrizo –Wilcox Aquifer which extends as a narrow band from Maverick, Dimmit and Webb counties along the Mexican border, up to the northeast corner of Texas. As the Rio Grande makes its way to the coast it crosses over the Gulf Coast Aquifer in Starr and Hidalgo counties.

The Cenozoic Pecos Alluvium Aquifer (Cenozoic) is located in the northern regions of the Rio Grande Basin where the Pecos River crosses the state line from New Mexico. The river flows southeast across the Cenozoic, which is entirely located inside the Rio Grande Basin.

Element 3

Problems Affecting the Rio Grande Basin

See the Texas Priority Species List……………………733

The water quality of the Rio Grande Basin has been studied extensively in recent years to assess concentrations of salts, conventional pollutants, and toxins. Data indicate increasing levels of fecal coliform as an indicator of declining water quality. However, through the construction of new wastewater treatment facilities in Nuevo Laredo, as well as active programs for wastewater treatment improvements administered by the Border Environmental Cooperation Commission, these influences are not considered to be of long-term significance (STDC 1998). Wastewater treatment plant expansions should be encouraged in the colonias to improve the quality of water that is discharged into the river.

Surface and sub-surface discharges that arise from both natural processes and the activities of man affect the quality of these water resources. In general, the presence of minerals, which contribute to the total dissolved solids concentration in surface water, arise from natural sources, but can be concentrated as flows travel downstream. Return flows from both irrigation and municipal uses can concentrate dissolved solids, but can also add other elements such as nutrients, sediments, chemicals and pathogenic organisms.

Water in the Rio Grande normally is of suitable quality for irrigation, treated municipal supplies, livestock and industrial uses; however, salinity, nutrients and fecal coliform bacteria are of concerns throughout the basin. Salinity concentrations in the Rio Grande are the result of both human activities and natural conditions: the naturally salty waters of the Pecos River are a major source of the salts that flow into Amistad Reservoir and continue downstream. Untreated or poorly treated discharges from inadequate wastewater treatment facilities primarily in Mexico, is the principal source for fecal coliform bacteria contamination. A secondary source is from nonpoint source pollution on both sides of the river, including poorly constructed or malfunctioning septic and sewage collection systems and improperly managed animal wastes. Although frequently identified as a concern, nutrient levels do not commonly represent a threat to human health, nor have they supported excessive aquatic plant growth or caused widespread depressed dissolved oxygen levels, commonly. In the Rio Grande, downstream of Amistad Reservoir, contact recreation use is not supported due to the elevated levels of fecal coliform bacteria that have been observed.

The entire length of the Pecos River has been subject to kills from toxic golden alga blooms. The golden alga produces toxins that kill all fish species, mussel/clam species and gill breathing amphibians/salamanders. It is a threat to all the aquatic ecosystems. The organisms killed on the Pecos River have included the state threatened fish species

Rio Grande darter and blue sucker. Research is needed on its distribution; bloom and toxin production dynamic; water quality affects on the alga and its toxin; possible management/treatment options for ponds and large waterbodies; interactions, population control and affects within the plankton community (bacteria, phytoplankton and zooplankton); and genetics of the organism and its possible stains. The need for coordination and cooperation between the various regulatory and resource agencies (local, state and federal) is a very important need for developing research efforts and any future management plans or actions dealing with this toxic alga. Research is needed on its distribution

The Arroyo Colorado traverses Willacy, Cameron and Hidalgo counties and is the major drainage way for approximately two dozen cities in this area, with the notable exception of Brownsville. Almost 500,000 ac. in these three counties are irrigated for cotton, citrus, vegetables, grain sorghum, corn and sugar cane production, and much of the runoff and return flows from these areas are discharged into the Arroyo Colorado. The Arroyo Colorado and the Brownsville Ship Channel both discharge into the Laguna Madre near the northern border of Willacy County. Use of the water in the Arroyo Colorado for municipal, industrial and/or irrigation purposes is severely limited because of the poor water quality conditions that exist there.

In general, groundwater from the various aquifers in the region have total dissolved solids concentrations exceeding 1,000 mg/L (slightly saline) and often exceeds 3,000 mg/L (moderately saline). The salinity hazard for groundwater ranges from high to very high and localized areas of high boron content are shown to occur. Salinity hazard is a measure of the potential for salts to be concentrated in the soil from high salinity groundwater. Accumulation or buildup of salts in the soil can affect the ability of plants to take in water and nutrients from the soil.

While population in the Rio Grande Region has increased rapidly since 1980, total reported water use over this period has actually decreased. Reported water use in 1996 is approximately 25% less than was reported in 1980. Although water use in any given year can be quite variable, there has been a steady trend towards decreasing irrigation water use since 1980 and a more pronounced increase in municipal water use over this same period. The decrease in irrigation water use is at least partly attributable to improved irrigation efficiency and reductions in irrigated land as a result of urbanization. The pronounced increase in municipal water demand (up 45% since 1980) is directly related to the large population increases over this period.

The majority of the water used in the region is in the Lower Rio Grande Valley, where approximately three quarters of a million people live and where irrigated farming is practiced extensively. In 1980, water use in Hidalgo and Cameron counties alone accounted for 86% of the total water use in the Rio Grande Region. However, by 1996 water use in Cameron and Hidalgo counties accounted for only 72% of the regional total. This shift in the relative share of total regional water demand is primarily the result of decreasing irrigation demand in Cameron and Hidalgo counties.

In addition to the impaired stream segments, water development has been extensive and is projected to continue given increasing urbanization especially in the lower Rio Grande. The combined 2,060 populations of the Far West (E), Plateau (J) and Rio Grande (M) water planning regions are projected to rise by 822,314 (54% increase), 29,492 (40% increase), and 2,589,755 (68% increase) respectively (TWDB 2005). Not only is water supply an issue within these planning regions but so also is sewage discharge. In many areas untreated or poorly treated effluent is discharged into the river. Concerns exist that remaining springs will be negatively impacted by increased groundwater pumping. Reservoir construction is not proposed for the Texas portion of the basin. No new water rights applications are pending as the basin is fully appropriated.

Various stream segments are considered ecologically significant (TPWD 2004). These stream segments exhibit exceptional ecological characteristics including high water quality, exceptional aquatic life, high aesthetic value, presence of threatened or endangered species, or valuable riparian habitats. Further study of such stream reaches would provide much needed data enabling more effective conservation of those resources.

Element 5

High Priority Research and Monitoring Efforts for the Rio Grande Basin

See Monitoring and Adaptive Management………… 559

See the Texas Priority Species List……………………733

- Monitor species of concern — Special studies and routine monitoring should be targeted at specific species of concern. Species-specific monitoring will provide population trend data and may be particularly important for species that are federally or state listed as endangered or threatened as well as those being considered for listing or delisting
- Monitor taxonomic groups suspected to be in decline or for which little is known. Monitoring and special studies should also target particular groups of organisms that are suspected to be on the decline or for which little is known. Research across North America and Europe has documented the overall decline of mussels and amphibians
- Exotic species monitoring - A number of exotic (non-native) species have been introduced (some intentionally) into the river basin. Monitoring specifically designed to target these species is important as a number of exotic species have proven capable of hybridizing or competing with native species (Miller et al. 1989, Williams et al. 1989, Garrett 1991)
- Ensure adequate instream flows and water quality through evaluation of proposed projects and water diversions in the Rio Grande-Rio Bravo basin. The Department completed a bi-national interagency study of water quality and fish assemblages in the Rio Grande in the early 1990's. That study, coupled with more recent data should allow detailed analysis of the effects of potential shifts in flow regimes from proposed projects
- Research golden alga problems to determine extent of impacts on aquatic communities, aid in developing management plans for affected ecosystems, and determine potential control mechanisms

- Monitor golden alga problems to determine extent of impacts on aquatic communities, aid in developing management plans for affected ecosystems, and determine potential control mechanisms
- Facilitate the availability of historical reports and associated data — Departmental and other publications containing biological data are not readily available and that situation inhibits the ability to document faunal changes through time in the state's rivers and streams
- Conduct studies, monitoring programs, and activities to develop the scientific basis for assuring adequate instream flows for rivers, freshwater inflows to estuaries, and water quality with the goal of conserving the health and productivity of public waters in Texas. Work with the IBWC to develop water management plans to address instream and freshwater inflow needs as practical

High Priority Conservation Actions for the Rio Grande Basin

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- Participate in development of the State Water Plan through the 16 planning regions to assure consideration of fish and wildlife resources

Element 4

- Facilitate coordination of all TPWD divisions with other state and federal resource agencies to assure that water quantity and water quality needs of fish and wildlife resources are incorporated in those agencies' activities and decision-making processes
- Review water rights and water quality permits to provide recommendations to the TCEQ and participate as warranted in regulatory processes to assure that fish and wildlife conservation needs are adequately considered in those regulatory processes
- Investigate fish kills and other pollution events that adversely affect fish and wildlife resources, make use of civil restitution and role as a natural resource trustee to restore those resources, water quality, and habitat.

- Research golden alga problems to determine extent of impacts on aquatic communities, aid in developing management plans for affected ecosystems, and determine potential control mechanisms
- Continue to increase the information available to the public about conserving Texas rivers, streams and springs with the goal of developing greater public support and involvement when important water resource decisions are made. Development of integrated GIS products for analyzing and sharing information should be a focus of this effort
- Continue to provide technical support and advice to entities developing Habitat Conservation Plans to address instream flow, habitat, and water quality issues and needs

Sabine River Basin

Associated Maps

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Associated Section IV Documents

The Texas Priority Species List……………..733

Element 1

Priority Species

Group	Scientific Name	Common Name	State/Federal Status
Isopods	*Caecidotea n. sp*	Big Thicket blind isopod	SC
	Caecidotea n. sp	Cave Springs isopod	SC
Crayfish	*Fallicamberus devastator*	Texas prairie crayfish	SC
	Orconectes maletae	Upshur crayfish	SC
	Procambarus kensleyi	Kensleys crayfish	SC
	Procambarus nechesae	Neches crayfish	SC
	Procambarus nigrocinctus	Black-girdled crayfish	SC
Shrimp	*Macrobrachium carcinus*	Bigclaw river shrimp	SC
	Macrobrachium ohione	Ohio shrimp	SC
Mussels	*Arcidens confragosus*	Rock pocketbook	SC

	Fusconaia askewi	Texas pigtoe	SC
	Fusconaia lananensis	Triangle pigtoe	SC
	Lampsilis satura	Sandbank pocketbook	SC
	Obovaria jacksoniana	Southern hickorynut	SC
	Pleurobema riddellii	Louisiana pigtoe	SC
	Potamilus amphichaenus	Texas heelsplitter	SC
	Quadrula nodulata	Wartyback	SC
	Strophitus undulatus	Creeper	SC
	Truncilla donaciformis	Fawnsfoot	SC
Insects	*Somatochlora margarita*	Texas emerald (dragonfly)	SC
Fish	*Ammocrypta clara*	Western sand darter	SC
	Anguilla rostrata	American eel	SC
	Cycleptus elongatus	Blue sucker	ST
	Erimyzon oblongus	Creek chubsucker	ST
	Notropis atrocaudalis	Blackspot shiner	SC
	Notropis chalybaeus	Ironcolor shiner	ST
	Notropis sabinae	Sabine shiner	SC
	Notropis shumardi	Silverband shiner	SC
	Polyodon spathula	Paddlefish	ST
	Pteronotropis hubbsi	Bluehead shiner	ST

Element 2

Location and Condition of Sabine River Basin

The Sabine River begins in northeast Texas near Greenville and flows south making up the Texas-Louisiana border before flowing into the Gulf of Mexico. The Sabine River rises in three main forks: the Cowleech Fork, the Caddo Fork, and the South Fork. The two upper forks of the Sabine River, the South and Cowleech Forks, are formed in eastern Collin County and northwestern Hunt County respectively. These two forks meet in Hunt County forming the main stem. Lake Fork Creek joins the mainstem Sabine 40 mi. downstream of the confluence of the other three forks. The river then empties into the Gulf of Mexico at Sabine Lake. The Sabine River is 360 mi. long (BEG 1996a) and has the largest volume of water discharged (approximately 6,800,000 af) at its mouth of any river in Texas (TCEQ 2004). The word "Sabine" comes from the Spanish word for "cypress", referring to the bald cypress trees which line the banks of the river.

Total drainage of the Sabine River basin is 9,756 sq. mi.; the Texas portion drains 7,426 sq. mi. (BEG 1996a). Rainfall varies from 41 in. near the headwaters to 59 in. at the Gulf of Mexico (SRA 2004). It is characterized by low rolling, forested hills and wide, timbered floodplains. The watershed upstream of Lake Tawakoni lies within the Blackland Prairies (BEG 1996b) and consists of predominately agricultural lands, oak forests and wetlands. However, the majority (88%) of the basin lies within the Gulf Coast Prairies and Marshes ecoregion and consists of mostly forested lands, agricultural lands and wetlands. The lower 10 mi. of the basin lies within the Gulf Coast Prairies and Marshes ecoregion where soils are derived from deltaic and lagunal deposits laid down in fresh water as the Gulf receded; freshwater wetlands are abundant. Underlying the Sabine basin are two major aquifers: the Carrizo-Wilcox and the Queen City-Sparta as well as the Gulf Coast aquifers: Jasper, Evangeline and Chicot (SRA 2004).

Principal cities include Longview, Greenville, Kilgore, Marshall, Orange, Bridge City and Gladewater. The population in 1990 was 442,358 (TWDB 1997). Regional economies include petroleum and mineral production, timber, agriculture, manufacturing, shipping, recreation and tourism (SRA 2004). During the late 19th and early twentieth centuries the middle Sabine River basin was the site of intensive logging operations. The growth of the oil industry, in the last century, led to the development of the Beaumont-Port Arthur-Orange metropolitan area as a major site for oil refining, processing and shipping (Handbook of Texas Online, sv. Sabine River).

Total flow of wastewater discharge exceeds 1.6 MGD (SRA 1996). Twenty-three water body segments are listed as impaired on the 2004 draft 303(d) list (TCEQ 2005). Several are listed for not meeting the state water quality standard for bacteria. Nichol, Grace, Wards, Cole and Harris Creeks, Lake Tawakoni, Cowleech Fork Sabine River, Adams Bayou segments, Gum Gully, Hudson Gully, Cow Bayou segments and Coon Bayou are all listed for depressed dissolved oxygen concentrations. Several segments are listed for chronic toxicity in water to aquatic organisms including: Little Cypress Bayou, Nichols Creek, Palo Gaucho Bayou and Little White Oak Creek. Toledo Bend Reservoir is listed for mercury in largemouth bass and freshwater drum.

Associated Water Bodies

Wide and slow-moving, the Sabine is characterized by occasional log jams and a large variety of plant and animal life. Many locations along this river are scenic with limited development along its banks. Vegetation is widely varied, ranging from giant bald cypress to pines and various hardwoods. The Sabine is fed by several creeks and bayous at certain points and an abundance of wildlife exists. Once the Sabine reaches Shelby County it begins to take on a swampy appearance, with enormous bald cypress trees lining each bank and trees covered with Spanish moss. Reportedly, Toledo Bend Reservoir maintains an almost continuous release of water. Many fine white sand bars which are often utilized as camping and day use areas are present. Downstream from Shelby County the river becomes very isolated. Even though it is isolated, water quality continues to be affected by pollution from upstream metro areas.

In Panola County, the Sabine becomes the state boundary between Texas and Louisiana. The Sabine has four major tributaries. The Cowleech Fork is located northeast of Lake Tawakani in Hunt County and essentially establishes the northern fork of the upper Sabine. Lake Fork Creek flows from the Lake Fork Reservoir into the Sabine in central Wood County. The creek flows east to west approximately 10 mi. before entering the Sabine. Big Sandy Creek also flows east along the northern corner of Wood County and enters the Sabine in the southern corner of Upshur County. Big Cow Creek is south of Toledo Bend Reservoir in Newton County where it flows southeast to enter the Sabine in east central Newton County along the Texas Louisiana border. Bayou Anacoco enters from the Louisiana side into the Big Sandy and the Big Cow Creeks.

The South and Cowleech Forks of the Sabine River above Lake Tawakoni do not have sufficient water for recreation use. Both forks are extremely narrow containing many log jams and overhanging branches, which may be hazardous to navigation. The Lake is a water storage reservoir and water is released only when the lake level exceeds conservation pool. A few shoal areas, among which are Watson Shals and Massive Rock Crossing, are present. In addition, a small 2-3 ft. waterfall is located below State Highway 42. Numerous oil derricks, remnants of the past, are standing in the riverbed in isolated areas of this river. Here, the river is presently receiving a large amount of pollution from the surrounding metro areas.

Three large reservoirs (> 100,000 af) have been constructed in the basin. The first, Toledo Bend Reservoir on the Sabine River is the largest reservoir in the State. It is located along the Texas and Louisiana border and controls the lower Sabine River. The second, Lake Tawakoni in Hunt, Rains and Van Zandt counties, is a water storage reservoir which largely controls the upper portion of the river. This reservoir has been constructed at the confluence of the South, Caddo and Cowleech Forks. The third, Lake Fork Reservoir, possesses a renowned trophy bass fishery. Smaller reservoirs include: Greenville, Quitman, Holbrook, Hawkins, Winnsboro, Gladewater, Cherokee, Martin, Murvaul and Brandy Branch lakes. Storage capacity in the Sabine basin reservoirs exceeds 6.0 million af (BEG 1996a). The Sabine River Authority of Texas manages water quality in the basin and owns and operates the three large reservoirs. Toledo Bend Reservoir is managed by both the Sabine River Authority of Texas and the Sabine River Authority of Louisiana under the Sabine River Compact. Toledo Bend's hydroelectric production and distribution is also shared between the states.

Reservoirs

Associated Reservoir	Location	Size (ac.)	Max Depth (Ft.)	Date Impounded	Water Level Fluctuation	Water Clarity	Aquatic Vegetation
Lake Gladewater	On Glade Creek in the City of Gladewater, 20 mi. west of Longview off FM 2685 and north of US 80	800	30	1953	2-3 ft. annually	Moderately clear	Less than 10% of the lake's surface area is covered, mostly with native species. American lotus dominates.
Lake Hawkins	On Little Sandy Creek, a tributary of the Sabine River, in Wood County 4 mi. northwest of Hawkins	800	30	1962	Moderate, 2-4 ft. annually	Clear	Native floating plants (American lotus, spatterdock, waterlily, watershield), native submergent plants (Chara, Cabomba) and Eurasian watermilfoil
Lake Holbrook	On Lankford Creek, a tributary of the Sabine River, in Wood County 3 mi. northwest of Mineola	1050	30	1962	Moderate, 2-4 ft. annually	Moderately clear	Limited
Lake Murvaul	On Murvaul Bayou in Panola County, 15 mi. west of Carthage	3890	36	1958	2-3 ft. annually	Moderately clear	Native and non-native aquatic plants are present, with total coverage ranging from 10% to 30% of the lake's surface

Lake Quitman	On Dry Creek, a tributary of the Sabine River, in Wood County 5 mi. north of Quitman	814	25	1962	Moderate, 2-4 ft. annually	Lightly stained	Limited
Lake Tawakoni	In Van Zandt, Rains and Hunt counties, 15 mi. southeast of Greenville on Caddo Creek and the South Fork and Cowleech Fork of the Sabine River	36700	70	1960	Moderate, 2-4 ft. annually	Moderately stained	Limited
Lake Winnsboro	On Big Sandy Creek, a tributary of the Sabine River, in Wood County 5 mi. southwest of Winnsboro	1100	23	1962	Moderate, 2-4 ft. annually	Lightly stained	Shoreline is fringed with native emergent vegetation. Submerged and floating types are scarce.
Lake Fork Reservoir	On the Sabine River in Hopkins, Rains and Wood counties, 5 mi. northwest of Quitman	27680	70	1980	Moderate, 2-4 ft. annually	Moderately clear	Hydrilla, Eurasian milfoil, coontail, American lotus, water primrose, water hyacinth and pennywort
Toledo Bend Reservoir	On the Sabine River in Shelby, Sabine and Newton counties, straddling the Texas-	185000	110	1967	1-5 ft. annually	Clear in middle and lower lake to slightly turbid in upper region	Primarily non-native submersed plants such as hydrilla; a variety of native aquatic plants are also

	Louisiana state line. The dam is in Newton County approximately 24 mi. northeast of Jasper.						established

Aquifers

The Sabine River Basin cuts across two major aquifers on its way to the Gulf of Mexico. The river begins in the Carrizo-Wilcox Aquifer in Van Zandt County and flows southeast before reaching the Louisiana border and flowing mostly south. South of the Carrizo-Wilcox Aquifer, the Sabine enters the Gulf Coast Aquifer. The Gulf Coast Aquifer is a large aquifer that lines the majority of the Texas Coast.

Problems Affecting the Sabine River Basin

See the Texas Priority Species List……………………733

Element 3

Water development in the Sabine River basin has been extensive including construction of the largest reservoir in Texas. Three large reservoirs and numerous smaller reservoirs on tributary streams coupled with the hydropower operations at Toledo Bend Reservoir highly alter the flow regime within the basin. Over 115,000 af of water was exported from the basin in 1990 (TWDB 1997). Demands to export more water from the basin are expected to increase given the surrounding population growth (e.g. DFW and Houston) and the abundant water resources and storage capacity in the Sabine basin. Population in the East Texas (Region I) water planning region is expected to increase from about one million to 1.5 million by 2060 (TWDB 2005). Population in the Northeast Texas (Region D) water planning region is expected to increase from about 0.7 million to 1.2 million by 2060 (TWDB 2005). In addition to potential exports, Prairie Creek reservoir was recommended for construction in the State Water Plan (TWDB 2002). Hydropower re-licensing will be an issue in the near future because of the drastic changes in hydrology caused by hydropower operations at Toledo Bend; the Federal Energy Regulatory Commission hydropower license for Toledo Bend Reservoir expires in 2013. The Sabine River Authority has a water rights permit application pending at TCEQ for an additional 293,000 af diversion from Toledo Bend Reservoir.

Element 5

High Priority Research and Monitoring Efforts for the Sabine River Basin

See Monitoring and Adaptive Management………… 559

See the Texas Priority Species List…………………….733

- Monitor species of concern — Special studies and routine monitoring should be targeted at specific species of concern. Species-specific monitoring will provide population trend data and may be particularly important for species that are federally or state listed as endangered or threatened as well as those being considered for listing or delisting
- Monitor taxonomic groups suspected to be in decline or for which little is known. Monitoring and special studies should also target particular groups of organisms that are suspected to be on the decline or for which little is known. Research across North America and Europe has documented the overall decline of mussels and amphibians
- Ensure adequate instream flows and water quality through evaluation of proposed water supply projects, exports, water diversions and hydropower operations in the Sabine River basin. The Texas Instream Flow Program identified the lower Sabine River basin (i.e. downstream of Toledo Bend) as a first priority study in response to water development and export potential, pending water rights application(s) and hydropower licensing issues; the upper Sabine River basin is included in the second tier of priorities
- Facilitate the availability of historical reports and associated data — Departmental and other publications containing biological data are not readily available and that situation inhibits the ability to document faunal changes through time in the state's rivers and streams
- Conduct studies, monitoring programs and activities to develop the scientific basis for assuring adequate instream flows for rivers, freshwater inflows to estuaries and water quality with the goal of conserving the health and productivity of public waters in Texas

High Priority Conservation Actions for the Sabine River Basin

See High Priority Conservation Strategies…………..517

See the Texas Priority Species List……………………733

Element 4

- Participate in development of the State Water Plan through the 16 planning regions to assure consideration of fish and wildlife resources
- Facilitate coordination of all TPWD divisions with other state and federal resource agencies to assure that water quantity and water quality needs of fish and wildlife resources are incorporated in those agencies' activities and decision-making processes
- Review water rights and water quality permits to provide recommendation to the TCEQ and participate as warranted in regulatory processes to assure that fish and wildlife conservation needs are adequately considered in those regulatory processes
- Investigate fish kills and other pollution events that adversely affect fish and wildlife resources, make use of civil restitution and role as a natural resource trustee to restore those resources, water quality and habitat
- Continue to increase the information available to the public about conserving Texas rivers, streams and springs with the goal of developing greater public support and involvement when important water resource decisions are made

San Antonio River Basin

Associated Maps

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Element 1

Associated Section IV Documents

The Texas Priority Species List……………..733

Priority Species

Group	Scientific Name	Common Name	State/Federal Status
Amphipods	*Artesia subterranea*	Hadziid amphipod	SC
	Holsingerius samacos	Hadziid amphipod	SC
	Ingolfiella n. sp.	Comal Springs ingolfiellid amphipod	SC
	Stygobromus bifurcatus	Bifurcated cave amphipod	SC
	Stygobromus dejectus	Cascade Cave amphipod	SC
	Stygobromus flagellatus	Ezell's Cave amphipod	SC
	Stygobromus longipes	Long-legged cave amphipod	SC
	Stygobromus pecki	Peck's Cave amphipod	FE/SE/ST
	Texiweckelia texensis	Hadziid amphipod	SC
Isopods	*Lirceolus smithii*	San Marcos well isopod	SC
Crayfish	*Cambarellus ninae*	Texas coastal crayfish	SC

Shrimp	*Calathaemon holthuisi*	Ezell's Cave shrimp	SC
	Macrobrachium carcinus	Bigclaw river shrimp	SC
	Macrobrachium ohione	Ohio shrimp	SC
Mussels	*Arcidens confragosus*	Rock pocketbook	SC
	Lasmigona complanata	White heelsplitter	SC
	Quadrula aurea	Golden orb	SC
	Quadrula petrina	Texas pimpleback	SC
	Quincuncina mitchelli	False spike	SC
	Strophitus undulatus	Creeper	SC
Snails	*Phreatodrobia imitata*	Mimic cavesnail	SC
Insects	*Comaldessus stygius*	Comal Springs diving beetle	SC
	Haideoporus texanus	Texas diving beetle	SC
	Heterelmis comalensis	Comal Springs riffle beetle	FE
	Protoptila arca	San Marcos saddle-case caddisfly	SC
	Erpetogomphus eutainia	Blue-faced ringtail (dragonfly)	SC
Fish	*Anguilla rostrata*	American eel	SC
	Cycleptus elongatus	Blue sucker	ST
	Ictalurus lupus	Headwater catfish	SC
	Micropterus treculii	Guadalupe bass	SC

Satan eurystomus	Widemouth blindcat	ST
Trogloglanis pattersoni	Toothless blindcat	ST

Element 2

Location and Condition of San Antonio Basin

The San Antonio River originates in Brackenridge Park and flows southeastward for approximately 180 mi. across five physiographic ecoregions before a confluence with the Guadalupe River near San Antonio Bay (BEG 1996b, Huser 2000, Texas Natural Resource Conservation Commission 2000). These ecoregions include the Edwards Plateau, Blackland Prairie, Post Oak Savannah, South Texas Plains and Gulf Coast Prairies and Marshes. Total basin drainage area is 4,180 sq. mi. and rainfall varies from about 25 in. per year in the upper basin to 36 in. near the coast (Texas Water Commission 1992). Principal tributaries to the San Antonio River include the Medina River, Leon Creek, Cibolo Creek and Salado Creek (Texas Natural Resource Conservation Commission 2000).

The upper San Antonio River Basin is mainly comprised of intermittent hill country streams and flood control channels (Texas Water Commission 1992). The main stem has its beginning in large springs within the corporate limits of San Antonio. Within the downtown area of the city, the river has been developed into a river walk area which attracts many tourists each year (USFWS 1976). South of San Antonio, the watershed undergoes a dramatic transformation as the river leaves its concrete lined channels and regains a more natural condition. From this point on, the river meanders slowly between steep, earthen banks (USFWS 1976).

Historically, water quality in the basin has been relatively poor, particularly during periods of low flow. In recent years, advanced waste treatment has been instituted at the three major City of San Antonio wastewater treatment plants (Dos Rios, Leon Creek and Salado Creek) and a former facility, the Rilling Road plant, has been eliminated (Texas Natural Resource Conservation Commission 2000). As a result, dissolved oxygen levels in the river have increased substantially and aquatic life has been enhanced; however, a few water quality problems remain. Seven water body segments are listed as impaired on the 2004 draft 303(d) list (TCEQ 2004). The upper and middle reaches of Cibolo Creek are listed for depressed dissolved oxygen levels. The upper reach of the San Antonio River as well as the lower reaches of Cibolo Creek and the San Antonio River are listed for elevated fecal coliform bacteria concentrations. An impaired fish community and elevated fecal coliform bacteria concentrations were documented in Salado Creek. PCB's were detected in fish tissue collected from the lower reach of Leon Creek. This segment was also listed for elevated fecal coliform bacteria levels and depressed dissolved oxygen concentrations.

Associated Water Bodies

Cibolo Creek

Cibolo Creek originates west of Bracken (Comal County) and flows a distance of 91 mi. to its confluence with the San Antonio River near Karnes City (Karnes County). The upper reach traverses the Edwards Aquifer recharge zone and therefore is normally dry. Headwater flow originates southwest of the City of Schertz in Bexar County (Buzan 1982). This creek is considered to have a high aquatic life use by the TCEQ (2004).

Leon Creek

Leon Creek flows about 40 mi. from its origin in Northwest Bexar County to its confluence with the Medina River. It begins as an intermittent hill country stream becoming perennial as it meanders through the western edge of San Antonio. There are no major impoundments on the creek; however, some channel and bank modifications have been made in the vicinity of Kelly Air Force Base (De La Cruz 1994). Leon Creek is considered to have a high aquatic life use (TCEQ 2004).

Medina River

The Medina River rises in Northwest Bandera County and flows southeast for about 116 mi. to the San Antonio River near Elmendorf (Bexar County). One major reservoir, Lake Medina, is present on the river in Bandera and Medina counties. The Medina River is spring-fed and is a typical hill country river, containing crystal clear waters, bald cypress lined banks and limestone outcroppings. The reach downstream of Medina Lake has been rated as having a high aquatic life use by the TCEQ (2004). The reach upstream of the lake has been rated as exceptional (TCEQ 2004).

The TPWD (El-Hage and Moulton 2001) reported on the ecological significance of the upper reach indicating the aquatic and riparian habitats associated with the river there support an exceptionally diverse assemblage of invertebrates, fish, reptiles and birds characteristic of the Edwards Plateau ecoregion. Some of the species include the golden-cheeked warbler, black-capped vireo, zone-tailed hawk, Guadalupe bass and Tobusch fishhook cactus (TPWD 2000). Willows, sycamore, bald cypress and pecan dominate the riparian gallery forests. The surrounding slopes are dominated by plateau live oak and Ashe juniper. This segment has been nominated for inclusion in the proposed Texas Natural Rivers System and is the fourth most popular for recreational river floating in Texas (National Park Service 1995).

Salado Creek

Salado Creek traverses the Edwards Aquifer recharge zone and extends for about 40 mi. through the City of San Antonio to its confluence with the San Antonio River. Although the upper half of the creek is normally dry, it is a major source of aquifer recharge during heavy storm events (Texas Clean Rivers Program 1996). Documented water quality and fish community problems have resulted in the creek being placed on the impaired water bodies list resulting in the initiation of a special study to determine the causes for the creek not attaining its designated high aquatic life use (TCEQ 2004).

Reservoirs

Associated Reservoir	Location	Size (ac.)	Max Depth (Ft.)	Date Impounded	Water Level Fluctuation	Water Clarity	Aquatic Vegetation
Medina Lake	40 mi. northwest of San Antonio in Bandera and Medina counties	4246	152	1913	Large fluctuations, up to 40 ft., based on area rainfall	Clear	Sparse

Aquifers

The San Antonio River Basin cuts across five major aquifers on its way to the Gulf of Mexico. These include the Edwards-Trinity, Trinity, Edwards, Carrizo-Wilcox and Gulf Coast (BEG 2001).

Element 3

Problems Affecting the San Antonio River Basin

See the Texas Priority Species List……………………733

The population in regional water planning area L, which includes all but the uppermost reach of the San Antonio River Basin (the upper reach of the Medina River upstream of Medina Lake in Bandera County), is projected to double between 2000 and 2060, reaching more than four million people (TWDB 2005). The Lower Guadalupe Water Supply Project has been approved for inclusion in the state water plan by Region L to provide an additional source of water to meet future needs in the region. Components of the project include diversion of water at a point on the Lower Guadalupe River downstream of the confluence of the San Antonio River as well as additional groundwater pumping primarily from the Gulf Coast Aquifer System (Lower Guadalupe Water Supply Project 2004). A number of technical and environmental studies have been initiated regarding the project.

Element 5

High Priority Research and Monitoring Efforts for the San Antonio River Basin

See Monitoring and Adaptive Management………… 559

See the Texas Priority Species List……………………733

- Monitor species of concern — Special studies and routine monitoring should be targeted at specific species of concern. Species-specific monitoring will provide population trend data and may be particularly important for species that are federally or state listed as endangered or threatened as well as those being considered for listing or delisting
- Monitor taxonomic groups suspected to be in decline or for which little is known. Monitoring and special studies should also target particular groups of organisms

that are suspected to be on the decline or for which little is known. Research across North America and Europe has documented the overall decline of mussels and amphibians

- Exotic species monitoring — A number of exotic (non-native) species have been introduced (some intentionally) into the river basin. Monitoring specifically designed to target these species is important as a number of exotic species have proven capable of hybridizing or competing with native species (Miller et al. 1989, Williams et al. 1989, Garrett 1991)
- Ensure adequate instream flows and water quality through evaluation of proposed reuse projects and water diversions in the basin
- Facilitate the availability of historical reports and associated data — Departmental and other publications containing biological data are not readily available and that situation inhibits the ability to document faunal changes through time in the state's rivers and streams
- Conduct studies, monitoring programs and activities to develop the scientific basis for assuring adequate instream flows for rivers, freshwater inflows to estuaries and water quality with the goal of conserving the health and productivity of public waters in Texas. The Texas Instream Flow Program (TIFP), directed by Senate Bill 2, identified the San Antonio River Basin as a priority study area (TPWD, TCEQ and TWDB 2002). Research needs as identified by TIFP study designs should be considered as high priority for the basin

High Priority Conservation Actions for the San Antonio River Basin

See High Priority Conservation Strategies…………..517

See the Texas Priority Species List……………………733

- Work with river authorities to develop water management plans to address instream and freshwater inflow needs as practical

Element 4

- Participate in development of the State Water Plan through the 16 planning regions to assure consideration of fish and wildlife resources

- Facilitate coordination of all TPWD divisions with other state and federal resource agencies to assure that water quantity and water quality needs of fish and wildlife resources are incorporated in those agencies' activities and decision-making processes
- Review water rights and water quality permits to provide recommendations to the TCEQ and participate as warranted in regulatory processes to assure that fish and wildlife conservation needs are adequately considered in those regulatory processes
- Investigate fish kills and other pollution events that adversely affect fish and wildlife resources, make use of civil restitution and role as a natural resource trustee to restore those resources, water quality and habitat
- Continue to increase the information available to the public about conserving Texas rivers, streams and springs with the goal of developing greater public support and involvement when important water resource decisions are made. Development of integrated GIS products for analyzing and sharing information should be a focus of this effort
- Continue to provide technical support and advice to entities developing Habitat Conservation Plans to address instream flow, habitat and water quality issues and needs

San Jacinto River Basin

Associated Maps

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Texas Rivers and Reservoirs……………......28

Associated Section IV Documents

The Texas Priority Species List……………..733

Element 1

Priority Species

Group	Scientific Name	Common Name	State/Federal Status
Crayfish	*Fallicamberus macneesei*	MacNeeses crayfish	SC
	Procambarus steigmani	Steigmans crayfish	SC
Shrimp	*Macrobrachium carcinus*	Bigclaw river shrimp	SC
Mussels	*Arcidens confragosus*	Rock pocketbook	SC
	Fusconaia askewi	Texas pigtoe	SC
	Lampsilis satura	Sandbank pocketbook	SC
	Lasmigona complanata	White heelsplitter	SC
	Pleurobema riddellii	Louisiana pigtoe	SC
	Potamilus amphichaenus	Texas heelsplitter	SC
	Strophitus undulatus	Creeper	SC
	Truncilla donaciformis	Fawnsfoot	SC

Insects	*Comaldessus stygius*	Comal Springs diving beetle	SC
	Somatochlora margarita	Texas emerald (dragonfly)	SC
Fish	*Anguilla rostrata*	American eel	SC
	Cycleptus elongatus	Blue sucker	ST
	Erimyzon oblongus	Creek chubsucker	ST
	Notropis atrocaudalis	Blackspot shiner	SC
	Notropis potteri	Chub shiner	SC
	Notropis sabinae	Sabine shiner	SC
	Notropis shumardi	Silverband shiner	SC
	Polyodon spathula	Paddlefish	ST

Element 2

Location and Condition of San Jacinto River Basin

The San Jacinto River has its beginnings in its East and West Forks in San Jacinto and Walker counties, respectively, and traverses an easterly direction. The two forks then flow into northeastern Harris County where they merge to form the main stem. The basin is 70 mi. long and drains 5,600 sq. mi. (TCEQ 2004). The East and West forks merge in the upper end of Lake Houston, with the river flowing to its confluence with the Houston Ship Channel and then emptying into Galveston Bay (*op cit*). The West Fork is dammed in Montgomery County, creating Lake Conroe. Both forks of the San Jacinto have limited flows of water and recreational use depends upon sufficient rainfall to increase the volume of water. The main stem is infeasible as a recreational waterway.

Rainfall for the San Jacinto River basin varies from 50-60 in. (BEG 1996a). The basin is contained within the Gulf Coast Prairies and Marshes physiographic ecoregion (Gould 1960, BEG 1996b). The terrain represents gently rolling topography with forests to the north, sloping toward the southeast into the flat coastal plains. It flows through pine and hardwood bottomlands, as it makes its way toward the Gulf of Mexico. Parts of this river are located in the vicinity of Sam Houston National Forest.

The West Fork of the San Jacinto River, above Lake Conroe, is extremely narrow. This stretch is located immediately below Lake Conroe Dam. The dam does not have a set generating schedule or a minimum daily release; therefore, times exist when the river has only a small volume of water. Even during periods of heavy rainfall when water levels are up, the narrow width of the river and presence of overhanging branches result in navigational difficulties.

Associated Water Bodies

Tributaries include Spring Creek, Lake Creek, Cypress Creek, Caney Creek, Peach Creek, Buffalo Bayou, Greens Bayou and Whiteoak Bayou. More than 40 water body segments are listed as impaired on the 2004 draft 303(d) list (TCEQ 2005), mostly for bacteria, though several are listed for contaminants in shellfish and fish tissue. Among the contaminants identified are PCB's, chlordane, dieldrin, dioxin and heptachlor epoxide.

Two major reservoirs are found in the basin, Lake Conroe and Lake Houston, with conservation storage of 570,400 af (TWDB). More than 1.5 million persons are estimated to reside in the basin, primarily in Harris County.

Reservoirs

Associated Reservoir	Location	Size (ac.)	Max Depth (Ft.)	Date Impounded	Water Level Fluctuation	Water Clarity	Aquatic Vegetation
Lake Conroe	West Fork of San Jacinto River in Montgomery and Walker counties, Conroe, Texas	21,000 ac. at conservation pool level		1973	1-3 ft. annually	Slight to moderate algal staining	Low Density
Lake Houston	West Fork of San Jacinto River, 15 mi. northeast of Houston in Harris County, Texas	12240	45	1954	Low	Moderately turbid	Various flooded terrestrial and native emergent plants along with exotic species water hyacinth, alligatorweed and water lettuce

Aquifers

The San Jacinto River Basin flows over only one principal aquifer which is the Gulf Coast Aquifer (BEG 2001). This Aquifer is large and lines the majority of the Texas Coast.

Problems Affecting the San Jacinto River Basin

See the Texas Priority Species List……………………733

Aside from water quality problems mentioned previously, a major conveyance of water has been proposed that would run from the Trinity River to Luce Bayou, a tributary to Lake Houston. That project will require site-specific evaluations. Luce Bayou is identified as an ecologically significant stream. Rectification of eight miles of stream would be a very significant impact. Significant bottomland forest is present along the creek. Luce Bayou is one of the few streams that remain relatively unimpacted by urban development. Increased streamflow may impact the stream detrimentally as well as cause erosion.

Element 3

High Priority Research and Monitoring Efforts for the San Jacinto River Basin

See Monitoring and Adaptive Management………… 559
See the Texas Priority Species List……………………733

- Monitor species of concern — Special studies and routine monitoring should be targeted at specific species of concern. Species-specific monitoring will provide population trend data and may be particularly important for species that are federally or state listed as endangered or threatened as well as those being considered for listing or delisting
- Monitor taxonomic groups suspected to be in decline or for which little is known. Monitoring and special studies should also target particular groups of organisms that are suspected to be on the decline or for which little is known. Research across North America and Europe has documented the overall decline of mussels and amphibians

Element 5

- Ensure adequate instream flows and water quality through evaluation of proposed projects and water diversions in the Sulphur River basin. Facilitate the availability of historical reports and associated data — Departmental and other publications containing biological data are not readily available and that situation inhibits the ability to document faunal changes through time in the state's rivers and streams
- Conduct studies, monitoring programs and activities to develop the scientific basis for assuring adequate instream flows for rivers, freshwater inflows to estuaries and water quality with the goal of conserving the health and productivity of public waters in Texas

Element 4

High Priority Conservation Actions for the San Jacinto River Basin

See High Priority Conservation Strategies…………..517

See the Texas Priority Species List…………………….733

- Participate in development of the State Water Plan through the 16 planning regions to assure consideration of fish and wildlife resources
- Facilitate coordination of all TPWD divisions with other state and federal resource agencies to assure that water quantity and water quality needs of fish and wildlife resources are incorporated in those agencies' activities and decision-making processes
- Review water rights and water quality permits to provide recommendation to the TCEQ and participate as warranted in regulatory processes to assure that fish and wildlife conservation needs are adequately considered in those regulatory processes
- Investigate fish kills and other pollution events that adversely affect fish and wildlife resources, make use of civil restitution and role as a natural resource trustee to restore those resources, water quality and habitat
- Continue to increase the information available to the public about conserving Texas rivers, streams and springs with the goal of developing greater public support and involvement when important water resource decisions are made

Sulphur River Basin

Associated Maps

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Sulphur River and Cypress Creek Basins….. 16

Minor Aquifers of Texas…………………....26

Major Aquifers of Texas……………………27

Texas Rivers and Reservoirs………………..28

Associated Section IV Documents

The Texas Priority Species List……………..733

Element 1

Priority Species

Group	Scientific Name	Common Name	State/Federal Status
Isopods	*Caecidotea n. sp*	Big Thicket blind isopod	SC
	Caecidotea n. sp	Cave Springs isopod	SC
Crayfish	*Fallicamberus devastator*	Texas prairie crayfish	SC
	Orconectes maletae	Upshur crayfish	SC
	Procambarus kensleyi	Kensleys crayfish	SC
	Procambarus nechesae	Neches crayfish	SC
	Procambarus nigrocinctus	Black-girdled crayfish	SC
Shrimp	*Macrobrachium ohione*	Ohio shrimp	SC
Mussels	*Arcidens confragosus*	Rock pocketbook	SC
	Fusconaia askewi	Texas pigtoe	SC

	Fusconaia lananensis	Triangle pigtoe	SC
	Lampsilis satura	Sandbank pocketbook	SC
	Obovaria jacksoniana	Southern hickorynut	SC
	Pleurobema riddellii	Louisiana pigtoe	SC
	Potamilus amphichaenus	Texas heelsplitter	SC
	Quadrula nodulata	Wartyback	SC
	Strophitus undulatus	Creeper	SC
	Truncilla donaciformis	Fawnsfoot	SC
Insects	*Somatochlora margarita*	Texas emerald (dragonfly)	SC
Fish	*Ammocrypta clara*	Western sand darter	SC
	Anguilla rostrata	American eel	SC
	Cycleptus elongatus	Blue sucker	SC
	Erimyzon oblongus	Creek chubsucker	SC
	Notropis atrocaudalis	Blackspot shiner	SC
	Notropis chalybaeus	Ironcolor shiner	SC
	Notropis maculatus	Taillight shiner	SC
	Polyodon spathula	Paddlefish	SC

Element 2

Location and Condition of Sulphur River Basin

The Sulphur River is formed in east Delta County by the union of its North and South Forks and flows through Bowie, Morris and Cass counties into the Red River in Arkansas. Approximately 75 mi. of the main stem are located in Texas. Flowing through heavily timbered woods where little or no current is present, the water is generally muddy due to channelization upstream. No rapids are present. Lake Texarkana is located on the

Sulphur River and recreational use of the section below the dam depends upon water releases from the dam. The portion above the reservoir contains sufficient water for recreational activities almost any time.

The Sulphur River basin has its origins northwest of Commerce and traverses a generally eastern direction. The basin is 150 mi. long (straight-line distance) and within Texas drains 3,558 sq. mi. before entering Arkansas where it ultimately joins with the Red River (TCEQ 2004). The South Sulphur River originates in southeastern Fannin County and flows eastward, joining the Middle Sulphur and North Sulphur rivers (*op cit*). Rainfall averages between 40-50 in. per year (BEG 1996a). The Sulphur River basin is contained within the Blackland Prairies, Post Oak Savannah and Pineywoods physiographic ecoregions and is characterized by low rolling terrain with chalks and marls weathering into deep, black, fertile clay soils (BEG 1996b). Land use in the Sulphur River Basin is 17.6% cropland, 23.9% timber and 54.3% pasture (Osting et al. 2004). Urban areas include Texarkana, Commerce and Sulphur Springs.

Conditional information of the Sulphur River is scarce. As of 2000, it was requested that the definition of ecologically unique stream segment designation be further clarified by the legislature. A five year update will be examined by the North East Texas Regional Water Planning Group (RWPG).

Associated Water Bodies

Major tributaries include Days Creek and White Oak Bayou. Four water body segments are listed as impaired on the 2004 draft 303(d) list (TCEQ). They include both major reservoirs and the Upper South Sulphur River for high pH and depressed dissolved oxygen and White Oak Creek for depressed dissolved oxygen. The two major reservoirs are Wright Patman and Jim Chapman, with conservation storage of more than 421,000 af (Osting et al. 2004).

Reservoirs

Associated Reservoir	Location	Size (ac.)	Max Depth (Ft.)	Date Impounded	Water Level Fluctuation	Water Clarity	Aquatic Vegetation
Wright Patman Lake	On the Sulphur River in Bowie and Cass counties, 10 mi. southwest of Texarkana	20300	40	1956	4-5 ft. annually	Moderate	Covers less than 10% of the lake's total surface area. Dominant species include chara, American lotus, black willow and buttonbush.
Cooper Lake	On the Middle and South Forks of the Sulphur River, northwest of Sulphur Springs in Delta and Hopkins counties	19280	55	1991	Moderate, 2-4 ft. annually	Stained	Limited
Lake Sulphur Springs	On White Oak Creek, a tributary of the Sulphur River, 2 mi. northwest of Sulphur Springs in Hopkins County	1340	28	1973	Moderate, 2-4 ft.	Turbid	Sparse

Aquifers

Two major aquifers are included in the Sulphur River Basin, the Trinity Group and Carrizo-Wilcox, as well as a minor aquifer, the Woodbine (BEG 2001). The Sulphur River Basin begins in the downdrip of the Trinity Basin and flows over the Carrizo-Wilcox Aquifer before exiting Texas to Louisiana in the northeast corner of Texas.

Problems Affecting the Sulphur River Basin

Element 3

See the Texas Priority Species List……………………733

Major reservoir projects in the Sulphur River basin have been limited to Wright Patman and Jim Chapman Reservoirs, though several additional reservoirs have been proposed. The Region C water planning group, which includes the Dallas-Fort Worth Metroplex, has recommended Marvin Nichols I Reservoir be constructed to help meet the region's water demand. Alternative projects that have been suggested are Marvin Nichols II and George Parkhouse I and II. As proposed, Marvin Nichols I would inundate or otherwise impact downstream portions of a 94,252 ac. tract identified by USFWS as a Priority 1 preservation site that contains habitat of high value to waterfowl and other wildlife. This proposed project is estimated to inundate more than 45,000 ac. of forested habitat, including more than 30,000 ac. of bottomland hardwoods. A reach of the Sulphur River downstream of the proposed site has previously been identified by TPWD as a "Significant Stream Segment" based on a wetland habitat mitigation area administered by TPWD as the White Oak Creek Wildlife Management Area (WMA) (Bauer *et al*. 1991). That area could be negatively impacted by altered flow regimes as a result of reservoir operations. Construction of the proposed reservoir would eliminate or reduce habitat for six state-threatened, flow-dependant fish species: the creek chubsucker, western sand darter, blue sucker, blackside darter, paddlefish and shovelnose sturgeon as well as several other species of aquatic and terrestrial animals.

An alternate project, Marvin Nichols II, would inundate or otherwise impact downstream portions of a 27,990 ac. tract identified by USFWS as a Priority 1 preservation site and the White Oak Creek WMA, which was placed in a federal conservation easement as a result of mitigation for habitat lost to construction of Jim Chapman Reservoir. Construction of the proposed reservoir would eliminate or reduce habitat for two state-threatened, flow-dependant fish species: creek chubsucker and paddlefish.

George Parkhouse I and II could also negatively affect bottomland hardwood habitat, since Frye and Curtis (1990) estimated that 38% (10,690 ac.) of the former site contains this class of vegetation compared to 17% (1,865 ac.) of the latter site. Reservoir construction could eliminate or reduce habitat for three state-threatened, flow-dependant fish species: creek chubsucker, blackside darter and paddlefish.

The Upper Trinity Regional Water District has a major water rights permit request to divert and transfer out-of-basin 180,000 afy pending at TCEQ.

Element 5

High Priority Research and Monitoring Efforts for the Sulphur River Basin

See Monitoring and Adaptive Management………… 559

See the Texas Priority Species List……………………733

- Monitor species of concern — Special studies and routine monitoring should be targeted at specific species of concern. Species-specific monitoring will provide population trend data and may be particularly important for species that are federally or state listed as endangered or threatened as well as those being considered for listing or delisting
- Monitor taxonomic groups suspected to be in decline or for which little is known. Monitoring and special studies should also target particular groups of organisms that are suspected to be on the decline or for which little is known. Research across North America and Europe has documented the overall decline of mussels and amphibians
- Ensure adequate instream flows and water quality through evaluation of proposed projects and water diversions in the Sulphur River basin. Facilitate the

availability of historical reports and associated data — Departmental and other publications containing biological data are not readily available and that situation inhibits the ability to document faunal changes through time in the state's rivers and streams

- Conduct studies, monitoring programs and activities to develop the scientific basis for assuring adequate instream flows for rivers, freshwater inflows to estuaries and water quality with the goal of conserving the health and productivity of public waters in Texas

High Priority Conservation Actions for the Sulphur River Basin

See High Priority Conservation Strategies…………..517
See the Texas Priority Species List……………………733

Element 4

- Participate in development of the State Water Plan through the 16 planning regions to assure consideration of fish and wildlife resources
- Facilitate coordination of all TPWD divisions with other state and federal resource agencies to assure that water quantity and water quality needs of fish and wildlife resources are incorporated in those agencies' activities and decision-making processes
- Review water rights and water quality permits to provide recommendation to the TCEQ and participate as warranted in regulatory processes to assure that fish and wildlife conservation needs are adequately considered in those regulatory processes
- Investigate fish kills and other pollution events that adversely affect fish and wildlife resources, make use of civil restitution and role as a natural resource trustee to restore those resources, water quality and habitat
- Continue to increase the information available to the public about conserving Texas rivers, streams and springs with the goal of developing greater public support and involvement when important water resource decisions are made

Trinity River Basin

Associated Maps

Texas Rivers and River Basins…..………… 12

Trinity River Basin…………………………25

Minor Aquifers of Texas…………………....26

Major Aquifers of Texas……………………27

Texas Rivers and Reservoirs……………......28

Element 1

Associated Section IV Documents

The Texas Priority Species List……………..733

Priority Species

Group	Scientific Name	Common Name	State/Federal Status
Crayfish	*Fallicamberus macneesei*	MacNeeses crayfish	SC
	Procambarus steigmani	Steigmans crayfish	SC
Shrimp	*Macrobrachium carcinus*	Bigclaw river shrimp	SC
Mussels	*Arcidens confragosus*	Rock pocketbook	SC
	Fusconaia askewi	Texas pigtoe	SC
	Lampsilis satura	Sandbank pocketbook	SC
	Lasmigona complanata	White heelsplitter	SC
	Pleurobema riddellii	Louisiana pigtoe	SC
	Potamilus amphichaenus	Texas heelsplitter	SC
	Strophitus undulatus	Creeper	SC

	Truncilla donaciformis	Fawnsfoot	SC
Insects	*Somatochlora margarita*	Texas emerald (dragonfly)	SC
Fish	*Anguilla rostrata*	American eel	SC
	Cycleptus elongatus	Blue sucker	ST
	Erimyzon oblongus	Creek chubsucker	ST
	Notropis atrocaudalis	Blackspot shiner	SC
	Notropis sabinae	Sabine shiner	SC
	Notropis shumardi	Silverband shiner	SC
	Polyodon spathula	Paddlefish	ST

Location and Condition of Trinity River Basin

Element 2

The Trinity River has its beginnings in four forks, the East Fork in Grayson County, the Elm Fork in Montague County, the West Fork in Archer County and the Clear Fork in Parker County. The main stem begins at the junction of the Elm and West Forks in Dallas. The entire length of the Trinity totals 550 mi., most of which can be utilized for recreational purposes. The drainage area of the basin is 17,969 sq. mi. and occurs entirely in Texas. Rainfall varies from 36-52 in. per year (Ulery et al. 1993). Characteristic of the Trinity is its large number of meanders, resulting in hazardous log jams at numerous bends, particularly between Dallas and Lake Livingston. The river banks above Lake Livingston are usually steep and muddy, but become gently sloping and composed of sand below Livingston Dam.

Land use in the Trinity basin is 57% agricultural, 25% forest and wetlands, 10% rangeland and 5% urban (Ulrey et al. 1993). Significant water development has occurred within the basin, with 14 major reservoirs and conservation storage of 6.9 million af

(TWDB 2002). Approximately 3.5 million people are served by eight major wastewater treatment plants operated by the Trinity River Authority which include Dallas, Fort Worth, Garland and the North Texas Municipal Water District with discharges of more than 500 million gallons per day of treated effluent.

Sixteen water body segments are listed as impaired on the 2004 draft 303(d) list (TCEQ). Several are listed for not meeting the state water quality standard for bacteria. Lake Livingston, the West Fork Trinity River above Bridgeport Reservoir, Chambers Creek above Richland-Chambers Reservoir and the Clear Fork Trinity River above and below Lake Weatherford are all listed for depressed dissolved oxygen concentrations. The Upper Trinity River, West Fork Trinity River below Lake Worth, Lake Worth, Clear Fork Trinity River below Benbrook Lake and Lower West Fork Trinity River are all segments listed for PCB's in fish tissue.

Associated Water Bodies

The Clear Fork of the Trinity River in Parker and Tarrant counties is feasible for recreational use both above and below Benbrook Reservoir. The stream along this section is predominantly narrow and shallow. Here, steep banks are present and the river has a sand and gravel bottom. The West Fork of the Trinity River flows southeast to join with the Clear Fork in Fort Worth. Three reservoirs-Lake Bridgeport, Eagle Mountain Lake and Lake Worth, are located at various intervals along the West Fork. During periods when water is being released from the dams, the West Fork maintains a good flow. The river along this stretch is relatively narrow with steep muddy banks and occasional log jams which could be hazardous. The East Fork of the Trinity River flows through Grayson, Collin, Rockwall, Dallas and Kaufman counties. Here, the river rambles through typical wooded bottomlands of post oak, elm, ash and pecan. Two reservoirs are located on the East Fork, Lavon Lake and Lake Ray Hubbard. Lavon Lake is located in Collin County and Lake Ray Hubbard is located in Dallas, Kaufman and Rockwall counties.

The Elm Fork of the Trinity River flows southeast meeting the West Fork to create the main stem of the Trinity. Garza-Little Elm Reservoir (Lake Dallas) is located on the Elm Fork where sufficient water releases from the Little Elm occur at all times. Even though points along this river are comparatively remote, it flows through a heavily timbered strip of elm, oak and willow within the densely populated Dallas Metropolitan District. It meanders by several public areas allowing for easy accessibility because of the many road crossings and parks. Potential hazardous log jams are present, although the Dallas municipal water authorities attempt to keep the river unobstructed. Along the fork, two small dams have been constructed downstream from Interstate Highway 35. Here, the flood plain, which is flat and over 0.5 mi. wide in some places, has been stripped of most of its native vegetation.

The Trinity River has three additional tributaries including a myriad of smaller creeks. The main three include Denton Creek in Denton County, Richland Creek and Cedar Creek. Richland Creek is located west of Richland-Chambers Reservoir and flows from Navarro Mills Lake in western Navarro County. The creek is less then 20 mi. long and enters the Richland-Chambers Reservoir at the western end of the southern fork. Cedar Creek Reservoir flows into the Trinity in western Henderson County along the upper Trinity. The reservoir extends north into southern Kaufman County.

Reservoirs

Associated Reservoir	Location	Size (ac.)	Max Depth (Ft.)	Date Impounded	Water Level Fluctuation	Water Clarity	Aquatic Vegetation
Bardwell Lake	4 mi. southwest of Ennis, Texas in Ellis County	3570	43	1965	4 ft. annually	Moderately clear to milky	Sparse to light vegetation in upper end
Benbrook Lake	On the Clear Fork of the Trinity River, off US 377 in Tarrant County, 10 mi. southwest of downtown Fort Worth	3770	70	1952	4 ft. annually	Murky	Sparse
Cedar Creek Reservoir	15 mi. west of Athens in the area between US 175 and Texas 274	34300	53	1965	4 ft. annually	Moderately clear at lower end to muddy in the upper end	Native emergent, submergent and floating, light in coves and creek arms in lower end of the lake
Eagle Mountain Lake	On the West Fork Trinity River, just north of Fort Worth and Lake Worth in Tarrant County	9200	47	1932	2-9 ft. annually	Clear in the lower end near the dam, murky uplake	Very little present. Controlling authority has initiated attempts to establish native aquatic vegetation in the reservoir.

Fairfield Lake	5 mi. northeast of Fairfield off FM 488	2353	49	1969	4 ft. annually	Moderately clear	Hydrilla heavy along shoreline; with American lotus, common cattail, common reed and marine naiad moderate to heavy in shallow areas
Grapevine Lake	On Denton Creek, a tributary of the Elm Fork of the Trinity River in Tarrant and Denton counties, just north of the City of Grapevine	7280	65	1952	5-10 ft.	Murky	American lotus, Pondweed, water primrose
Houston County Lake	On Little Elkhart Creek (Trinity River drainage), in Houston County 10 mi. northwest of Crockett, Texas	1523	40	1966	1-2 ft. annually	Clear to slightly stained	Native emergent, native submergent and water hyacinth
Joe Pool Lake	In Tarrant, Ellis and Dallas counties 4 mi. south of Grand Prairie on Mountain Creek, a tributary of the Trinity River	7470	75	1986	2-4 ft. annually	Murky	Small stands of American pondweed are found, but the lake generally lacks vegetation

Lake Amon G. Carter		2126	50	1956, renovated in 1985			Black willow, buttonbush, narrow leaf cattail, pondweed, water primrose
Lake Anahuac		5300	8	1954			Bald cypress
Lake Arlington		2275	51	1957			Hydrilla, pondweed species
Lake Bridgeport	On the West Fork Trinity River in Jack and Wise counties, off US Highway 380	13000	85	1932, renovated in 1972 with a new spillway	12 ft. annually	Moderately clear	Sparse colonies of floating pondweed, chara and water willow (less than 100 ac.). Stands of cattail and bulrush are also present.
Lake Halbert	East of US Highway 287, 3/4 mi. southeast of Corsicana	650	18	1921	2-3 ft. annually	Cloudy to muddy	Button bush, cattail, giant bulrush, giant reed, hydrolea, smartweed, spikerush. Shoreline vegetation light to sparse.
Lake Livingston	On the Trinity River in Polk, San Jacinto, Trinity and Walker counties. Dam is in Polk and San Jacinto counties, west of Livingston and 50 mi. north of Houston.	90000	77	1969	1-2 ft. annually	Moderately to highly turbid	Native emergent plants are limited to the upper areas of the reservoir and in the backs of coves and embayments. The floating exotic water hyacinth is found throughout the reservoir.

Lake Ray Hubbard	In Collin, Dallas, Rockwall and Kaufman counties, 1 mi. east of Rockwall on the East Fork of the Trinity River	22745	40	1968	1-3 ft. annually	Murky	There are stands of emergent vegetation in shallow flats and several areas of the lake have been infested with hydrilla.
Lake Ray Roberts	On the Elm Fork of the Trinity River, 10 mi. north of Denton off FM 455. The dam is in Denton County but pushes water into Cook and Grayson counties.	29350	106	1987	3-5 ft. annually	Clear	More than half the shoreline has native floating, native submersed, or non-native submersed aquatic vegetation (about 2,212 surface ac. in all). Floating species include floating pondweed, American lotus and water primrose. Native submersed species are American milfoil, bushy pondweed and Chara. Non-native hydrilla is also present.
Lake Waxahachie	On Prong Creek 2 mi. south of Waxahachie off FM 877	690	48	1956	2 ft. annually	Moderate	Sparse

Lake Weatherford	East of Weatherford off US 80/180, 19 mi. from downtown Fort Worth	1144	39	1957	Limited	Moderately clear to stained	Many cattails grow on the shoreline and water milfoil can be found occasionally in a 15-20 ft. band around the perimeter of the lake, especially along the beach and dam on the south side. There is some floating pondweed in the upper reaches of the lake.
Lake Worth	On the West Fork of the Trinity River, entirely within the Fort Worth city limits	3560	22	1914	Moderate	Murky	Submerged vegetation is sparse. There are shallow flats covered with cattails.
Lavon Lake	Four miles northeast of Wylie, Texas, off Texas Highway 78 in Collin County, northeast of Dallas	21400	59	1953, reservoir size doubled 1974	Moderate	Moderate, greenish color	Not much, but there is some coontail, bushy pondweed and floating pondweed around the shoreline. Most structure in this lake is in the form of standing timber.

Lewisville Lake	On the Elm Fork of the Trinity River in Denton County near Lewisville	29592	67	1954	4-8 ft. annually	Murky	Sparse at present; a native plant restoration project is currently being conducted by the USACE Lewisville Aquatic Ecosystem Research Facility and Texas Parks and Wildlife
Lost Creek Reservoir	58 mi. southeast of Wichita Falls, near Jacksboro	385	60	1990	6 ft. annually	2 to 4 ft. visibility	Very little, but plenty of standing timber
Mountain Creek Lake	In Dallas County 4 mi. southeast of Grand Prairie on Mountain Creek, a tributary of the Trinity River	2710	26	1937	1-3 ft. annually	Murky	A stand of lotus occurs near the northwest corner of the dam, but in general, vegetation is sparse.
Navarro Mills Lake	North of Texas 31 between Waco and Corsicana	5070	49	1963	4 ft. annually	Muddy	Sparse, with some floating pondweed
Richland-Chambers Reservoir	On Richland and Chambers creeks, east-southeast of Corsicana on US 287	4400	75	1987	3 ft. annually	Cloudy to moderately clear	Moderate to light vegetation in coves and creek arms; some beds of floating pondweed

Aquifers

The Trinity River flows over three major aquifers on its way to the Gulf of Mexico. The river begins in the Trinity Aquifer in Wise County and flows southeast toward the Carrizo-Wilcox Aquifer. The Trinity meets the Carrizo-Wilcox Aquifer in Navarro and Henderson County and continues to travel southeast. Once across the Carrizo-Wilcox, the river moves through Walker County where it begins its final leg to the Gulf of Mexico, crossing the Gulf Coast Aquifer. The Gulf Coast Aquifer is a large aquifer that lines the majority of the Texas Coast.

Element 3

Problems Affecting the Trinity River Basin

See the Texas Priority Species List……………………733

In addition to the 16 impaired water body segments, water development in the Trinity basin has been extensive and is projected to continue given the increasing urbanization within the upper basin. Population in water planning region C, which includes the upper Trinity basin, is projected to double between 2000 and 2050, reaching more than nine million people. Major reservoirs are present on forks and tributaries throughout the upper basin, altering the flow regime within the river. As diversions for municipal supply have increased, so has the quantity of wastewater being discharged. Given the large volume of wastewater currently discharged into the river and its tributaries, there are existing and probable permit applications for substantial water reuse within and downstream of Dallas/Fort Worth. Available water in this reach and instream flows are to a large extent dependent on wastewater return flows in the Dallas/Fort Worth and north central Texas area. Capturing return flows may prove to be a more economical short-term alternative for Dallas and other entities than tapping water supplies that will incur significant transmission costs or building new storage reservoirs. However, Bedias and Tehuacana are recommended as unique reservoir sites in the State Water Plan.

Hydropower may be an issue in the future. The Trinity River Authority was issued a preliminary permit to study a hydropower project on Lake Livingston Dam. These preliminary permits do not entitle applicants the right to new construction. Applications for hydropower licenses would still need to be made that would trigger Federal Energy and Regulatory Commission proceedings. Consequently, such a study may or may not mature into an actual FERC license with associated dam and operation modifications. FERC permits on two projects in the Elm Fork Trinity River expire in 2034 and 2035, respectively.

High Priority Research and Monitoring Efforts for the Trinity River Basin

See Monitoring and Adaptive Management………… 559

See the Texas Priority Species List……………………733

Element 5

- Monitor species of concern — Special studies and routine monitoring should be targeted at specific species of concern. Species-specific monitoring will provide population trend data and may be particularly important for species that are federally or state listed as endangered or threatened as well as those being considered for listing or delisting
- Monitor taxonomic groups suspected to be in decline or for which little is known. Monitoring and special studies should also target particular groups of organisms that are suspected to be on the decline or for which little is known. Research across North America and Europe has documented the overall decline of mussels and amphibians
- Ensure adequate instream flows and water quality through evaluation of proposed reuse projects and water diversions in the Trinity River basin. The Department completed a multi-year study of water quality and fish assemblages in the upper Trinity River in the late 1980's. That study, coupled with more recent data should allow detailed analysis of potential shifts in flow regimes from proposed projects
- Facilitate the availability of historical reports and associated data — Departmental and other publications containing biological data are not readily available and that situation inhibits the ability to document faunal changes through time in the state's rivers and streams
- Conduct studies, monitoring programs and activities to develop the scientific basis for assuring adequate instream flows for rivers, freshwater inflows to estuaries and water quality with the goal of conserving the health and productivity

of public waters in Texas. The Texas Instream Flow Program, directed by Senate Bill 2 (2001), identified the middle Trinity River basin as a priority study area. Research needs as identified by TIFP study designs should be considered as high priority for the basin

Element 4

High Priority Conservation Actions for the Trinity River Basin

See High Priority Conservation Strategies…………..517

See the Texas Priority Species List…………………….733

- Work with river authorities to develop water management plans to address instream and freshwater inflow needs as practical
- Participate in development of the State Water Plan through the 16 planning regions to assure consideration of fish and wildlife resources
- Facilitate coordination of all TPWD divisions with other state and federal resource agencies to assure that water quantity and water quality needs of fish and wildlife resources are incorporated in those agencies' activities and decision-making processes
- Review water rights and water quality permits to provide recommendations to the TCEQ and participate as warranted in regulatory processes to assure that fish and wildlife conservation needs are adequately considered in those regulatory processes
- Investigate fish kills and other pollution events that adversely affect fish and wildlife resources, make use of civil restitution and role as a natural resource trustee to restore those resources, water quality and habitat
- Continue to increase the information available to the public about conserving Texas rivers, streams and springs with the goal of developing greater public support and involvement when important water resource decisions are made. Development of integrated GIS products for analyzing and sharing information should be a focus of this effort
- Continue to provide technical support and advice to entities developing Habitat Conservation Plans to address instream flow, habitat and water quality issues and needs

Coastal Conservation Priorities for Texas Waters based on the *Land and Water Resources Conservation and Recreation Plan* (Land and Water Plan)

Associated Maps

Texas Bays and Estuaries…………………..29

Introduction

The Texas coast is one of the most ecologically complex and biologically diverse regions of the state. It is comprised of nine major bays from Sabine Lake in the north to the upper and lower Laguna Madre in the south as well as the Texas Territorial Sea, covering an area that extends from the Gulf of Mexico beach seaward nine nautical miles. More than one-third of Texas' population and about 70% of its industrial base, commerce and jobs are located within 100 mi. of the coastline. More than half of the nation's chemical and petroleum production are located on the coast and the coastal waters support major commercial and recreational fishing industries. Texas leads the nation in marine commerce and the beaches, bays, marshes, coastal prairies and other fish and wildlife habitats of the coast provide numerous recreational opportunities.

Coastal Aquatic Conservation Threats

Element 3

The most significant conservation challenges to both freshwater and saltwater systems in Texas are reduced freshwater quality and quantity. Factors such as the increasing population, increasing demands for water and increasing shoreline development directly affect water quality and quantity.

Navigational Dredging and Disposal

Altered circulation in the deep waters of the coast that result from channel-dredging facilitates movement of high-saline water into the upper estuarine areas as well as artificial closing of traditional migratory passes for numerous saltwater species. In addition, disposing of dredged material in open water increases turbidity and covers bottom habitat including seagrasses.

Bycatch and Commercial Trawling

Some commercial fishing techniques can have negative impacts on fish species. For example, excessive bottom trawling can alter or damage important habitats, which can lead to a decline in overall fish catch size and abundance, increase turbidity and put pressure on all marine species. Bycatch, or the catch of non-targeted species, from commercial trawling is detrimental to many other ecologically, commercially and recreationally important species.

Conservation of Texas Bays and Estuaries

Fishing, hunting, birding and boating activities all depend on the successful conservation of our coastal waters. The health of the coastal economy is also directly related to the health of the coastal zone. Adequate supplies of clean and fresh water that carries nutrients and sediments to many different coastal wetland habitats, such as saltmarshes and seagrass beds, are essential for economically and ecologically important species of fish, birds and wildlife.

Element 1

Priority Bay and Estuary Systems

The bay and estuary systems along the Texas coast have great commercial, recreational and conservation value. Each bay has numerous conservation threats that are specific to that system. All systems face conservation challenges to varying degrees and a specific issue can quickly change priorities, increasing the importance of conservation action. The greatest long-term threat to the health and productivity of these systems is diminished freshwater inflows. For many, the more immediate challenges include habitat loss, poor water quality, fisheries management conflicts and related issues. Texas Parks and Wildlife Department evaluated bay systems using information compiled from the Shrimp Habitat chapter of the *Draft Texas Shrimp Fishery: A Report to the Governor and 77th Legislature* (2002). Each bay system was evaluated using the following categories: development, petrochemical production, substrate alterations, exotic species, fishing, water quality, point-source pollution, non-point source pollution and numerous sub-categories (a total of 22 elements). The bay systems were prioritized as High Priority Systems or Priority Systems. It is difficult not to include most bay and estuary systems as a high priority. However, it is important to identify those systems where immediate attention can be most beneficial for fish and wildlife management.

High Priority Systems

Galveston Bay System

Galveston Bay is the largest estuary on the Texas coast. It is part of the National Estuary Program and faces the greatest conservation challenges of any system. This complex is adjacent to the most populated and industrialized area of the state. Suburban and industrial development are reducing critical wetland habitat at a faster rate than anywhere else along the coast. The majority of Texas' hazardous chemical spills and the largest oil spills occur in this system. Both domestic and industrial wastewaters also flow into the bay. Periodic dredging of the channel and bycatch associated with commercial harvest are significant conservation threats to this bay. Exotic species like Chinese tallow, giant salvinia, water hyacinth and grass carp also threaten native habitats throughout the bay. The regional water plan recognizes the importance of freshwater inflows to the bay, but strategies to legally preserve inflows have not been identified.

Matagorda Bay System

The Matagorda Bay system includes the Matagorda Peninsula and the Colorado River Delta. It is home to one of the largest shrimp fleets on the coast. The bay is very popular with recreational anglers and commercial fishing fleets, resulting in excess harvest of targeted species and bycatch. Mercury contamination from large smelting operations in the 1970's and 1980's in Lavaca Bay is often exacerbated by frequent dredging activity. Currently, management of inflows is inadequate to protect the bay during water shortages, but further inflow studies are needed to improve management strategies.

Corpus Christi Bay System

The Corpus Christi Bay is also in the National Estuary Program. The primary sources of freshwater inflow are Oso Creek and the Nueces River. However, reservoir construction, increased population and industrial growth in the area have greatly reduced freshwater inflows in this already arid region. Reduced inflows have contributed to salinization of the delta and shoreline erosion. Extensive recreational and commercial fishing cause over-harvest and excess bycatch of non-targeted species. Intense industrial, commercial and shoreline development has affected Corpus Christi Bay. Dredging the Intercoastal Waterway and spoil disposition also harm water quality of the system.

San Antonio Bay System

The San Antonio Bay system consists of the primary bays San Antonio and Espiritu Santo and the secondary bays Hynes, Guadalupe and Shoalwater. Several large natural saltwater lakes occur along Matagorda Island and connect with the primary bays via sloughs and small passes. Threats to San Antonio Bay system come from the commercial harvest, trawling and inadvertent bycatch of non-target species, dredge and fill operations along the Intercoastal Waterway and the lack of adequate freshwater inflows.

Sabine Lake System

Sabine Lake makes up the southern border between Texas and Louisiana. It is adjacent to one of the largest petrochemical producing complexes in Texas and both industrial and domestic waste water are discharged into the Sabine Lake system. Water quality and aquatic health in Sabine Lake has improved since the introduction of the Clean Water Act in 1972 and subsequent regulations. Threats to the system include industrial and commercial development along the shoreline, operation of petroleum and chemical plants and general non-point source pollution primarily from agricultural lands. Gulf waters and tidal streams experience low oxygen levels following tropical storms. Other threats include the proposed dredging of the Sabine-Neches Waterway, increasing salinities that damage wetland habitats and the exotic plants that clog tidal streams and channels.

Priority Systems

Lower Laguna Madre Bay System

The lower Laguna Madre is a long shallow bay extending from Port Isabel to the Kennedy Land Cut. The Arroyo Colorado and North Floodway are the main freshwater inflow sources for the bay, which is also hypersaline. Rapid population growth in the Lower Rio Grande Valley is affecting the bay system. As with the upper Laguna Madre, dredging, spoil removal and the presence of excess nutrients are primary threats to extensive seagrass meadows. High nutrient concentrations come from municipal and industrial discharges, agricultural runoff and discharged wastewaters from the largest shrimp farms in the United States. Another serious concern is that there is currently no connection between the Rio Grande and the Gulf because there is not sufficient freshwater inflow while exotic plants are constricting the river.

Texas Territorial Sea

The Texas Territorial Sea is that portion of the Gulf of Mexico extending seaward from Texas' Gulf shoreline out to nine nautical miles. Extensive oil, gas and petrochemical production, marine commerce and transportation are major industries that utilize the Texas Territorial Sea. It is widely used for commercial shrimp trawling, menhaden trawling, longlining, recreational fishing, oil and gas production and recreational scuba diving. Threats to this nearshore gulf area and its associated marine organisms include potential oil and chemical spills, over-harvest of shrimp, finfish and other marine species, bycatch of fish, invertebrates and sea turtles and damages from the hypoxia, or reduced oxygen zone and harmful algal blooms.

Aransas Bay System

The Aransas Bay complex extends from Aransas Pass to Bayside. Aransas Bay supports an extensive commercial fishery comprised of shrimp, crab, oyster and finfish species. The intense fishing pressure, both recreationally and commercially, threaten the health of the bay. Freshwater inflows are often inadequate to support the rich species diversity in the estuaries and bay area. In addition, the Texas Department of Health (TDH) has closed several shoreline areas of the bay to all shellfishing because of inadequate sewage treatment.

Upper Laguna Madre System

Located on the lower Texas coast, the upper Laguna Madre system consists of upper Laguna Madre and Baffin Bay systems. The system is a long, narrow and shallow lagoon, bordered on the east by Padre Island and on the west by Corpus Christi. The surrounding areas have very little development and industrialization. The upper Laguna Madre, with no constant openings into the Gulf of Mexico and limited freshwater inflow, is characterized as a hypersaline estuary. The substantial source of freshwater is runoff from various watersheds into Baffin Bay. In the 1990's, the bay regularly experienced brown tide that increased turbidity and reduced seagrass beds and also negatively impacted tourism and recreational fishing. Dredging, moving the spoils and excess nutrient runoff threaten extensive seagrass beds and may be responsible for harmful algal blooms.

Important Aquatic Habitat Types for TPWD Efforts

As with prairies and riparian habitats on land, there are important, natural water-based resources that cross all ecoregion, river basin and bay system boundaries. These resources are important for wildlife, water quality and quantity and other conservation values and warrant priority effort.

Element 4

Major Conservation Goals Associated with Texas Coastal Habitat

Maintain or Improve Water Quality

- Continue research studies to evaluate water quality concerns in tidal streams, bays and estuaries

Coastal Navigational Dredging and Spoil Disposal

- Remain involved in the approval of dredging plans and be actively involved in finding alternative spoil sites
- Continue to support methods of channel and port expansion that minimize impacts to marine resources

Improve Outreach and Education

- Increase efforts to produce public education materials that discuss the importance of river, spring, reservoir, wetland, bay and estuary conservation

Increase TPWD's Knowledge and Understanding of Aquatic Ecosystems

- Work with the TWDB to establish freshwater inflow needs, nutrient and sediment loading regimes to Texas' minor estuaries, specifically East Matagorda Bay, South Bay, Christmas Bay Coastal Preserve, Cedar Lakes and the San Bernard River estuary and the Brazos River estuary
- Maintain water quality monitoring programs to identify threats, guide management and avoid or minimize impacts to bay and estuary systems
- Develop indices of biotic integrity to measure the health of marine ecosystems
- Increase support of research on Texas algal blooms and develop routine monitoring and rapid response to algal bloom events

Reduce Excess Commercial Fishing Impacts

- Reduce excess fishing effort in the commercial fishing industries
- Continue license buyback programs for commercial shrimp, crab and finfish fisheries
- Evaluate the need for a license management program, including license buyback, in the Gulf shrimp fishery
- Research and support methods that reduce the quantity and mortality of bycatch
- Continue the Texas Gulf Shrimp seasonal closure for the benefits it has produced for shrimp and sea turtles

Major Goals and Objectives for the Next 10 Years

<u>Goal: Improve Science and Data Collection</u>

Objectives:

Undertake a complete review of all scientific and conservation programs.

Element 5

- Review assessment and monitoring functions for fish and wildlife populations
- Complete an independent programmatic peer review
- Establish a systematic review process

Goal: Maintain Sufficient Water Quality and Quantity to Support the Needs of Fish and Wildlife

Objectives:

- In conjunction with TCEQ and the TWDB, set incremental deadlines to complete all major and minor bay and estuarine system evaluations
- Incorporate freshwater inflow recommendations of Texas' major bay sand estuaries into water planning, development and management processes

The Texas Coast and the associated bays and estuaries are critical to the Texas economy but they are also critical habitat areas that need to be protected and maintained for native Texas wildlife. The following chapter contains detailed information on the coast and specific information on the major bays and estuaries. The majority of this information was obtained with permission from *Draft Texas Shrimp Fishery: A Report to the Governor and 77th Legislature* – Appendix A, which contains a detailed report that focuses on shrimp in the Gulf of Mexico but details marine habitats within the appendix (2002). This document was developed by TPWD and investigates several habitat threats that apply to coastal areas. The TPWD's Coastal Fisheries program takes a holistic approach to managing the bays and estuaries and has developed a monitoring program that allows the program to detect fisheries-related habitat fluctuations and deal with them quickly when necessary. Overall, Texas coastal resource managers have an effective program that incorporates holistic management practices into the maintenance of a large fisheries as well as the protection of nongame species and habitats.

Coastal Aquatic Resources Conservation Priorities for Texas Waters

Element 1

Associated Maps

Texas Bays and Estuaries…………………...29

Associated Section IV Documents

The Texas Priority Species List……………. 733
Supplemental Mammal Information………. 897
Supplemental Herptile Information………... 988

Priority Species

Group	Species Name	Common Name	State/Federal Status
	Octocorals		SC
	Stony corals		SC
	Black corals		SC
	Fire corals		SC
Shrimp	*Farfantopenaeus aztecus*	Brown shrimp	SC
	Penaeus aztecus	Brown Shrimp	SC
	Farfantopenaeus duorarum	Pink shrimp	SC
	Penaeus duorarum	Pink Shrimp	SC
	Pleoticus robustus	Royal red shrimp	SC
	Litopenaeus setiferus	White shrimp	SC
	Penaeus setiferus	White Shrimp	SC
Crabs	*Callinectes sapidus*	Blue crab	SC

Fish	*Centropomus parallelus*	Fat Snook	SC
	Centropomus undecimalis	Common Snook	SC
	Microphis brachyurus	Opossum Pipefish	ST
	Pristis pectinata	Smalltooth Sawfish	FE
	Pristis perotteti	Largetooth Sawfish	IUCN RED LIST
	Rhinobatos lentiginosus	Atlantic Guitarfish	SC
Drums	*Cynoscion nebulosus*	Spotted Seatrout	SC
	Micopogonias undulatus	Atlantic croaker	SC
	Pogonias cromis	Black Drum	SC
	Sciaenops ocellatus	Red Drum	SC
Flounders	*Paralichthys leghostigma*	Southern Flounder	SC
Jacks	*Seriola dumerili*	Greater Amberjack	SC
Mackerels	*Scomeromorus cavalla*	King Mackerel	SC
	Scomeromorus maculatus	Spanish Mackerel	SC
Mullets	*Mugil cephalis*	Striped Mullet	SC
	Mugil curema	White Mullet	SC
Sea Basses	*Epinephalus drummondhayi*	Yellowedge Grouper	SC
	Epinephalus itajara	Goliath Grouper (Jewfish)	SC
	Epinephalus morio	Red Grouper	SC
	Mycteroperca bonaci	Black grouper	SC
	Mycteroperca microlepis	Gag Grouper	SC
	Mycteropterca phenax	Scamp	SC

Snappers	*Lutjanus campechanus*	Red Snapper	SC
	Rhomboplites aurorubens	Vermilion Snapper	SC
Sharks	*Alopias superciliosus*	Bigeye Thresher	SC
	Alopias vulpinus	Thresher	SC
	Carcharhinus acronotus	Blacknose	SC
	Carcharhinus altimus	Bignose	SC
	Carcharhinus brachyurus	Narrowtooth	SC
	Carcharhinus brevipinna	Spinner	SC
	Carcharhinus falciformis	Silky	SC
	Carcharhinus galapagensis	Galapagos	SC
	Carcharhinus isodon	Finetooth	SC
	Carcharhinus leucas	Bull	SC
	Carcharhinus limbatus	Blacktip	SC
	Carcharhinus longimanus	Oceanic Whitetip	SC
	Carcharhinus obscurus	Dusky	SC
	Carcharhinus perezi	Caribbean Reef	SC
	Carcharhinus plumbeus	Sandbar	SC
	Carcharhinus porosus	Smalltail	SC
	Carcharhinus signatus	Night	SC
	Carcharodon carcharias	White	SC
	Cetorhinus maximus	Basking	SC
	Galeorhinus cuvier	Tiger	SC

	Ginglymostoma cirratum	Nurse	SC
	Hexanchus griseus	Sixgill	SC
	Hexanchus nakamurai	Bigeye Sixgill	SC
	Isurus oxyrinchus	Shortfin Mako	SC
	Isurus paucus	Longfin Mako	SC
	Lamna nasus	Porbeagle	SC
	Negaprion brevirostris	Lemon	SC
	Notorynchus cepedianus	Sevengill	SC
	Odontaspis noronhai	Bigeye Sand Tiger	SC
	Odontaspis taurus	Sand Tiger	SC
	Prionace glauca	Blue	SC
	Rhincodon typus	Whale	SC
	Rhizoprinodon porosus	Caribbean Sharpnose	SC
	Rhizoprinodon terranovae	Atlantic Sharpnose	SC
	Sphyrna lewini	Scalloped Hammerhead	SC
	Sphyrna mokorran	Great Hammerhead	SC
	Sphyrna tiburo	Bonnethead	SC
	Sphyrna zygaena	Smooth Hammerhead	SC
	Squatina dumeril	Atlantic Angel	SC
Billfish	*Istiophorus platypterus*	Sailfish	SC
	Makaira nigrican	Blue Marlin	SC
	Tetrapturus albidus	White Marlin	SC

	Tetrapturus pfluegeri	Longbill Spearfish	SC
	Magalops atlanticus	Atlantic Tarpon	SC
	Rachycentron canadum	Cobia	SC
	Xiphias gladius	Swordfish	SC
Mammals	*Balaenoptera musculus*	Blue Whale	FE/SE
	Balaenoptera physalus	Finback Whale	FE/SE
	Eubalaena glacialis	Black Right Whale	FE/SE
	Feresa attenuata	Pygmy Killer Whale	ST
	Globicephala macrorhynchus	Short-finned Pilot Whale	ST
	Kogia breviceps	Pygmy Sperm Whale	ST
	Kogia simus	Dwarf Sperm Whale	ST
	Mesoplodon europaeus	Gervais Beaked Whale	ST
	Orcinus orca	Killer Whale	ST
	Physeter macrocephalus	Sperm Whale	FE/SE
	Pseudorca crassidens	False Killer Whale	ST
	Stenella frontalis	Atlantic Spotted Dolphin	ST
	Steno bredanensis	Rough-toothed Dolphin	ST
	Ziphius cavirostris	Goose-beaked Whale	ST
	Trichechus manatus	West Indian Manatee	FE/SE
	Tursiops truncatus	Atlantic bottlenose dolphin	SC
Reptiles	****Chelonia mydas**	**Green Sea Turtle	FT/ST
	***Dermochelys coriacea*	**Leatherback Sea Turtle	FE/SE

***Lepidochelys kempii*	**Kemp's Ridley Sea Turtle	FE/SE
Caretta caretta	Loggerhead Sea Turtle	FT/ST
Eretmochelys imbricate	Hawksbill Sea Turtle	FE/SE

Material derived from *The Texas Shrimp Fishery – A report to the Governor and the 77th Legislature of Texas* (2002). Materials used with permission from the Coastal Division of TPWD.

Element 2

Location and Condition of the Bays, Estuaries, and Other Marine Systems

Estuaries in Texas waters of the Gulf of Mexico differ in several respects from a classical estuary as defined by Pritchard (1967). First, their connection with the open sea is more restricted, being confined to a few tidal channels that breach the offshore barrier islands. Secondly, Gulf shore estuaries are often divided into at least primary and secondary basins. Tidal waters from the Gulf flow into these basins first. Primary bays rarely receive land runoff directly from major river channels, although a number of minor tributaries flow into them (Britton and Morton 1989).

Major rivers in Texas (e.g. the Brazos, Colorado and Rio Grande) flow directly into the Gulf, or more commonly, into the secondary or lower salinity bays and associated marshlands, which are typically connected to the primary bays by a second restricted inlet maintained by runoff or tidal currents. Due to this separation of primary and secondary bays, distinctly different salinity regimes normally characterize the two basins. Primary bays vary in salinity from 30-40 ppt at tidal inlets, to 12-30 ppt near their connections with secondary bays. Brackish to freshwater transition is completed within the secondary basins. Tidal range in the Gulf at maximum declination is about three ft (0.8 m), and at minimum about eight in (0.2 m) and is relatively small in the northwestern Gulf compared to the Atlantic or Pacific coasts (Armstrong 1987). The presence of a second restricted inlet at the entrance of secondary bays further inhibits tidal distribution of saline water (Britton and Morton 1989).

Some of the best examples of primary-secondary bay systems on the Texas coast occur from Corpus Christi northwards, including the Corpus Christi-Nueces, Aransas-Copano and Galveston-Trinity bay systems. The main basins of Texas secondary bays are relatively shallow at 1-7 ft (0.3-2 m). Bay bottoms consist of various clays and silt. Secondary bay shores are often bounded by extensive low-lying marshlands bisected by numerous narrow drainage channels. Discharge currents in these bays are weak except near the river and drainage channels. Tidal influence is also minimal here, since tidal energy has been dissipated by the tidal inlet bottleneck between the barrier islands and broad expanse of the primary bays behind.

Normally, the influence of seawater is similarly reduced with secondary estuaries, inhibited by the shallow bottoms, minimal tidal force and restricted inlets. Surface waters may be significantly fresher, but density gradients help to maintain at least mesohaline salinities near the bottom. Periods of increased precipitation in the spring and fall often flush all brackish waters out of secondary bays, killing many benthic invertebrates. Silts suspended in river waters settle out as the relative turbulence of river flow is dissipated in the broader expanse of the secondary bay. Nutrient loadings increase at this time and oxygen levels become depleted. Although creating a short-term negative effect; these increased inflow periods are long-term positive events for the estuaries and are necessities for wetland maintenance, overall productivity and health of the ecosystem. See Britton and Morton (1989) for a more detailed description of various bay systems in Texas and the influence of tides, seawater wedges and salinity gradients.

Emergent vegetation provides essential habitat for many managed species. Marshes are an integral part of the estuarine system, serving as nursery grounds for larvae, postlarvae, juveniles and adults of several species. The role of nursery, however, is but one important function of marshes and mangroves. They also: 1) export nutrients that are vital to adjacent waters; 2) provide an important water quality function in the form of secondary and tertiary waste treatment through removal and recycling of inorganic nutrients; 3) serve as an important buffer against storms by absorbing energy of storm waves and acting as a water reservoir to reduce damage farther inland; and 4) serve an important role in global cycles of nitrogen and sulfur (Gosselink, Odum and Pope 1974, Turner 1977, Thayer and Ustach 1981, Zimmerman et al.1984).

Submerged vegetation is found along most of the Gulf coast. Lindall and Saloman (1977) reported 796,805 ac (322,593 ha) of submerged vegetation in estuaries along the Gulf, of which 63% were found in Florida and 31% were found in the Laguna Madre and Copano-Aransas Bays in Texas (see submerged and emergent vegetation sections for additional information).

As with emergent vegetation, submerged vegetation is extremely important to fisheries production. Seagrass meadows are often populated by diverse and abundant fish faunas (Zieman and Zieman 1989). The seagrasses and their attendant epiphytic and benthic fauna and flora provide shelter and food to the fishes in several ways and are used by many species as nursery grounds for juveniles. The grass canopy provides shelter for juvenile fish and for small permanent residents. These also can feed on the abundant invertebrate fauna of the seagrass meadows, on the microalgae, on the living seagrasses themselves or on seagrass detritus. In addition, because of the abundance of smaller fish and large invertebrate predators, such as blue crabs and penaeid shrimp, larger fish in pursuit of prey organisms use the meadows as feeding grounds.

Bays and Estuaries

Texas has approximately 365 mi (586 km) of open Gulf shoreline and contains 2,361 mi (3,798 km) of bay-estuary-lagoon shoreline. This is the most biologically rich and ecologically diverse region in the state and supports more than 601,000 ac (243,000 ha) of fresh, brackish and salt marshes (Matlock and Ferguson-Osborn 1982).

Henderson (1997) describes the Gulf coast as containing a diversity of salt, brackish, intermediate and fresh wetlands. Of the marshes described, saline and brackish marshes are most widely distributed south of Galveston Bay, while intermediate marshes are the most extensive marsh type east of Galveston Bay. The lower coast has only a narrow band of emergent marsh, but has a system of extensive bays and lagoons.

From the Louisiana border to Galveston, the coastline is comprised of marshy plains and low, narrow beach ridges. From Galveston Bay to the Mexican border, the coastline is characterized by long barrier islands and large shallow lagoons. Within this estuarine environment are found the profuse seagrass beds of the Laguna Madre, a rare hypersaline lagoon, and Padre Island, the longest undeveloped barrier island in the world (TGLO 1996). The Gulf Intracoastal Waterway (GIWW), a maintenance dredged channel, extends from the lower Laguna Madre to Sabine Lake. Dredging of the channel has created numerous spoil banks and islands adjacent to the channel.

The major bay systems from the lower-to-upper coast are lower and upper Laguna Madre, Corpus Christi and Aransas Bays, San Antonio, Matagorda and Galveston Bays and Sabine Lake. It was estimated that in 1992, these estuaries encompassed 1,550,073 ac (627,780 ha) of open water (estuarine subtidal areas) and 3,894,753 ac (1,577,375 ha) of wetlands. About 85.3% of the total wetlands were palustrine, 14.5% were estuarine and 0.1% marine (Moulton, Dahl and Dall 1997). Climate ranges from semi-arid on the lower coast, where rainfall averages 25 in (635 mm), to humid on the upper coast where average annual rainfall is 55 in (1,397 mm) (Diener 1975).

Submerged Vegetation

Seagrasses are submerged, grass-like plants that occur mostly in shallow marine and estuarine waters. Submerged aquatic vegetation (SAV) occurs in relatively shallow [6 ft (2 m)] subtidal areas. They may form small patchy or large continuous beds, known as seagrass meadows, which serve as valuable Essential Shrimp Habitat (ESH). Seagrass meadows may require decades to form. In shallower waters of good quality, seagrass meadows may be lush and have a high leaf density, but in deeper waters, they may be sparse or species composition may shift to a less robust species (Sargent, Leary, Crewz and Kruer 1995).

Seagrasses are recognized as a dominant, unique habitat in many Texas bays and estuaries. They provide nursery habitat for estuarine-dependent species, are a major source of organic biomass for coastal food webs, are effective natural agents for stabilizing coastal erosion and sedimentation and are major biological agents in nutrient cycling and water quality processes. They form some of the most productive communities in the world (Zieman and Zieman 1989) and are aesthetically and economically valuable to humans. Because seagrasses are sensitive to nutrient enrichment, water quality problems and physical disturbance, distribution of seagrasses is used as an indicator of the health of an environment.

There are five marine spermatophytes that occur in Texas: shoalgrass, widgeongrass, turtlegrass, clovergrass and manateegrass. Only turtle grass, widgeon grass, shoal grass and clovergrass have been reported on the central and upper coast. The most abundant species, coastwide, is shoal grass. Seagrasses are dominant on the central to lower coast where rainfall and freshwater inflows are low and salinities are higher (TPWD 1986). Species of SAV that occur in river deltas and lack long-term tolerance for salinities above six ppt include *Najas* sp. and *Vallisneria* sp. (Zimmerman, Minello, Castiglione and Smith 1990). Turtlegrass, manateegrass, shoalgrass and clovergrass spp. are seagrasses and widgeongrass is a euryhaline aquatic plant. Widgeongrass is found in freshwater and is not considered a seagrass (Kaldy and Dunton 1994).

The Texas Seagrass Plan (TPWD 1999) estimated that in 1994, the total seagrass habitat was approximately 235,000 ac (94,000 ha) coastwide. This applied to permanently established beds of the four perennial seagrass species: shoalgrass, turtlegrass, manateegrass, clover grass and annual widgeon grass beds.

Seagrass distribution parallels precipitation and inflow gradients along the Texas coast. Seagrasses are dominant on the middle to lower coast where rainfall and inflows to the bays are low, evaporation is high and salinities are >20 ppt. The majority, about 79%, of seagrass habitat occurs in the upper and lower Laguna Madre, about 19% is found in San Antonio, Aransas and Corpus Christi Bays and less than 2% occurs north of Pass Cavallo in Matagorda Bay.

It is difficult to generalize impacts on seagrasses in all bays, since conditions vary geographically between and even within individual bays. Availability of reliable photographic and good historical field data limits trend analysis of seagrass beds to Galveston Bay, Corpus Christi – Redfish bays and the upper and lower Laguna Madre systems. However, trend data and anecdotal information over the last 40-50 years indicate that considerable change has occurred coastwide, with seagrass beds becoming scarce in some areas and more abundant in others. Change has occurred from both natural and anthropogenic causes. Natural causes include hurricanes, sea level change and climatic cycles. Anthropogenic causes include direct and indirect destruction and/or degradation from over 770 mi (1,239 km) of federally maintained navigation channels and over 500 disposal sites, shoreline developments, commercial and recreational boating, nutrient loading, etc. The cumulative effects of anthropogenic threats are increasing in their complexity and severity.

Scarring of seagrass beds by boat propellers was commented on in the scientific literature as early as the late 1950's (Woodburn, Eldred, Clark, Hutton and Ingle 1957, Phillips 1960). Concerns have increasingly been voiced since then (US Dept. of the Interior 1973, Chmura and Ross 1978). Eleuterius (1987) noted that scarring in Louisiana seagrasses was common. In deeper water, scarring was caused by shrimp boats, which also ripped up the margins of the beds with their trawls. Shrimp fishery related scarring and seagrass bed damage was also recognized by Woodburn, Eldred, Clark, Hutton and Ingle (1957), as cited in Sargent et al. 1995.

Recently, severe scarring and fragmentation of seagrass beds as a result of boat propellers was found in several areas of Redfish Bay, inside of Corpus Christi Bay. In one effort to rejuvenate seagrass beds damaged from boat prop scarring, TPWD, along with citizens, the Coastal Bend Bays and Estuaries Program and other entities designated several areas of Redfish Bay in Corpus Christi as a State Scientific Area on June 1, 2000 (McEachron, Pulich, Hardegree and Dunton 2001).

Within the Scientific Area three voluntary "No-Motor" zones covering 1,385 ac (561 ha) were established. These zones were intended to facilitate seagrass recovery and provide enhanced fishing opportunities in areas free of high speed motor boat traffic. From July 1999 through August 2001, a variety of seagrass prop scar restoration techniques were evaluated. Shoalgrass appeared to recover extensively by natural re-colonization, whereas *T. testudinum* showed poor recovery, even with active manipulation. This led investigators to conclude that the best recommendation for *T. testudinum* would be protective management of these beds (McEachron et al. 2001).

Emergent Vegetation

The following emergent vegetation discussion was taken largely from the TPWD Coastal Wetlands Conservation Plan (TPWD unpublished manuscript).

Coastal wetlands are an integral part of Texas estuarine ecosystems and have tremendous biological and economic values. Coastal wetlands serve as nursery grounds for shrimp species and many recreational and commercially important fish species found in the Gulf; provide breeding, nesting and feeding grounds for more than a third of all threatened and endangered animal species and support many endangered plant species (Kusler 1983); and provide permanent and seasonal habitat for a great variety of wildlife (Nelson 1992, Patillo et al. 1997).

Coastal wetlands also perform many chemical and physical functions. They can filter nitrates and phosphates from rivers and streams that receive wastewater effluents. Wetlands also can temporarily retain pollutants in the form of suspended material, excess nutrients, toxic chemicals and disease-causing microorganisms. Pollutants associated with the trapped material in wetlands may be converted biochemically to less harmful forms, or may remain buried and be absorbed by the wetland plants themselves. Robinson (1995) reported that studies show restoring just 1% of a watershed's area to appropriately located wetlands can reduce runoff of nitrates and herbicides by up to 50%.

Wetlands can also reduce erosion by absorbing and dissipating wave energy, binding and stabilizing sediments and increasing sediment deposition. Wetlands decrease the hazards of hurricanes and other coastal storms by protecting coastal and inland properties from wind damage and flooding (Whittington et al. 1994). Due to their topography, wetlands can reduce and retain surface-water runoff, providing storage capacity and overall protection of surrounding areas during periods of flooding. Wetlands located in the mid- or lower reaches of a watershed contribute the most to flood control. These values provide economic benefits to downstream property owners. Wetlands also promote groundwater recharge by diverting, slowing and storing surface water.

Functions of wetlands have been defined as all processes and manifestations of processes that occur in wetlands while value is associated with goods and services that society recognizes (NRC 1995). Alteration of wetland functions can weaken the capacity of a wetland to supply these goods and services. A list of the relationships between wetland broad functional categories and related effects of functions and societal values is given below in Table 1. Emergent vegetation underlying or adjacent to tidal waters within Texas coastal areas is discussed below.

Table 1. Functions, related effects of functions and corresponding societal values (unpublished TPWD Coastal Wetlands Conservation Plan).

Function	Effects	Societal Value
Hydrologic		
Short-term surface water storage	➢ Reduced downstream flood peaks	➢ Reduced damage from floodwaters
Long-term surface water storage	➢ Maintenance of base flows, seasonal flow distribution	➢ Maintenance of fish habitat during dry periods
Maintenance of high water table	➢ Maintenance of hydrophytic community	➢ Maintenance of biodiversity
Biogeochemical		
Transformation, cycling of elements	➢ Maintenance of nutrient stocks within wetland	➢ Wood production
Retention, removal of dissolved substances	➢ Reduced transport of nutrients downstream	➢ Maintenance of water quality

Accumulation of peat	➢ Retention of nutrients, metals, other substances	➢ Maintenance of water quality
Accumulation of inorganic sediments	➢ Retention of sediments, some nutrients	➢ Maintenance of water quality
<u>*Habitat and Food Support*</u>		
Maintenance of characteristic plant communities	➢ Food, nesting, cover for animals	➢ Support for furbearers, waterfowl; ecotourism
Maintenance of characteristic energy flow	➢ Support for populations of vertebrates	➢ Maintenance of biodiversity; ecotourism

Salt Marsh

Coastal marshes in Texas can be divided into two major ecosystems; the Chenier Plain Ecosystem from the Texas-Louisiana border to East Bay (Texas) and the Texas Barrier Island Ecosystem from Galveston East Bay to the Texas-Mexico border (Webb 1982).

Salt marshes near Texas estuaries are typically dominated by cordgrass, although black mangrove (*Avicennia germinans*) predominate in certain areas. They are subject to intermittent inundation due to tidal action and high levels of freshwater inflow. Fluctuations in temperature, salinity, water depth and sediment composition can have a limiting effect on the number of plant species found (Armstrong 1987). Typical species in the salt marsh community include smooth cordgrass, saltwort, glasswort (*Salicornia virginica* and *S. bigelovii*), saltgrass, saltflat grass (*Monanthochloe littoralis*), sea-lavender (*Limonium nashii*), Carolina wolfberry (*Lycium carolinianum*), seashore dropseed (*Sporobolus virginicus*), sea ox-eye (*Borrichia frutescens*) and salt-marsh bulrush (*Scirpus maritimus*).

The intertidal zone is dominated by *S. alterniflora*. Black needlerush (*Juncus roemerianus*) is a common salt to brackish marsh species occurring on the upper coast, especially in the

Galveston-Houston area, at slightly higher elevations than *S. alterniflora*. In areas south of the Corpus Christi/Nueces Bay system, *S. alterniflora* is found only in small areas of South Bay and Laguna Madre. Black mangroves (*A. germinans*) are significant components of salt marsh systems in some areas along the central and south Texas coast. Black mangroves occur on Galveston Island but distribution is limited by extended periods of subfreezing temperatures (McMillan and Sherrod 1986, Everitt, Judd, Escobar and Davis 1996).

The broadest distribution of salt marshes is found south of the Galveston Bay area, where they are common on the bayward side of barrier islands and peninsulas and along the mainland shores of narrow bays, such as West Galveston Bay. Although salt marshes occur on bay-head deltas, their biological plant communities change rapidly from brackish to intermediate and fresh marshes.

Brackish Marsh

The brackish-marsh community is a transitional area between salt marshes and fresh marshes. Dominant species include marshhay cordgrass (*Spartina patens*), Gulf cordgrass (*Spartina spartinae*), saltgrass, salt-marsh bulrush (*Scirpus maritimus*) and sea ox-eye. Brackish marshes are the dominant wetland communities in the Galveston Bay system (White and Paine 1992). They are widely distributed along the lower reaches of the Trinity River delta (inland from West Galveston Bay), in the inland system west of the Brazos River and along the lower reaches of the Lavaca and Guadalupe river valleys.

Intermediate Marsh

Intermediate marsh assemblages occur on the upper coast above Galveston Bay, where average salinities range between those found in the fresh and brackish-marsh assemblages. Typical species found in this environment include seashore paspalum (*Paspalum vaginatum*), marshhay cordgrass, Olney bulrush, cattail and California bulrush (*Scirpus californiensis*).

Fresh Marsh

Environments in which fresh marshes occur are generally beyond the effects of saltwater flooding, except perhaps during hurricanes. Freshwater influence from rivers, precipitation, runoff and groundwater is sufficient to maintain a fresher-water vegetation assemblage consisting of such species as cattail, California bulrush, three-square bulrush (*Scirpus americanus*), water hyacinth (*Eichhornia crassipes*), spiney aster (*Aster spinosus*), rattlebush (*Sesbania drummondii*), alligatorweed (*Alternanthera philoxeroides*) and pickerel weed (*Pontederia cordata*). Fresh marshes occur on the mainland and barrier islands along river or fluvial systems. They are found inland from the Chenier Plain and upstream along the river valleys of the Neches, Trinity, San Jacinto, Colorado, Lavaca, Guadalupe and San Antonio rivers. Here, salinities decrease and fresh marshes intergrade with and replace brackish marshes.

Swamps and Bottomland Hardwoods

Swamps are most commonly defined as woodlands or forested areas that are inundated by water during most of the year or contain saturated soils. In Texas, these areas contain bald cypress and water tupelo (*Nyssa aquatica*) in association with other species of trees such as sweetgum and willow species. Swamps are found principally in the entrenched valleys of the Sabine, Neches and Trinity rivers. At higher elevations, swamps transgress into river bottomland hardwood forest or streamside woodland. River valleys to the south, both entrenched and non-entrenched, are dominated by drier woodlands or forested areas.

Status and Trends of Texas Coastal Wetlands

Moulton et al. (1997) reported that an estimated 4,105,343 ac (1,662,664 ha) of coastal Texas wetlands existed in 1955. Approximately 84.6% of this total was palustrine (3,474,330 ac; 1,407,104 ha), 15.3% was saltwater estuarine (626,188 ac; 253,606 ha) and 0.1% was marine intertidal. In 1992, an estimated 3,894,753 ac (1,577,375 ha) of wetlands existed with 85.3% being palustrine, 14.5% estuarine and 0.1% marine.

Coastwide, recent estimates of wetland loss show that estuarine emergent wetlands decreased by 9.5% between the mid-1950’s and the early 1990’s; palustrine emergent wetlands declined by about 29%; forested wetlands or bottomland hardwoods declined by 10.9%; and palustrine scrub-shrubs increased by 58.7%. Overall, coastal Texas wetlands sustained an estimated net loss of 210,590 ac (85,289 ha) from 1955-1992, or an average of 5,700 ac (2,309 ha) per year (Moulton et al. 1997).

In comparison, White and Tremblay (1995) state that wetlands are disappearing rapidly in the Galveston Bay area. Extensive areas of salt, brackish and locally fresh marshes have been converted to open water and barren flats along the upper coast in the Galveston Bay system, the Neches River valley inland from Sabine Lake and interfluvial areas southwest of Sabine Lake. From the 1950’s to 1989, there was a net loss of 33,400 ac (13,527 ha) in the Galveston Bay system, or 19% of the wetlands that existed in the 1950’s (White, Tremblay, Wermund and Handley 1993). However, the rate of loss has declined over time from about 1,000 ac (405 ha) per year between 1953 and 1979 to about 700 ac (284 ha) per year between 1979 and 1989. The most extensive loss of contiguous wetlands on the coast occurred within the Neches River valley (White and Tremblay 1995). Between the mid-1950’s and 1978, approximately 9,415 ac (3,813 ha) of marsh were displaced primarily by open water along a 10 mi (16 km) stretch of the lower Neches River valley (White and Tremblay 1995). Total loss of marshes in the river deltas since the 1950’s was about 21,000 ac (8,505 ha), or 29% of the marsh area that existed in the mid-1950’s (White and Calnan 1990).

White et al. (1998) reported trends and probable causes of changes of wetlands in the Nueces, Aransas and Mission rivers from the 1950’s to 1992 for the Corpus Christi Bay National Estuary Program (CCBNEP). Wetland codes and descriptions were adapted from Cowardin, Carter, Golet and LaRoe (1979). In the Nueces River, approximately 371 ac (150 ha) of emergent wetland flats were converted to subtidal open water, due to a salt-marsh creation project. Due to changes in photointerpretation techniques, Aransas River-Chiltipin Creek marshes showed net losses of more than 741 ac (300 ha) from 1950’s to 1979. A net loss of 284 ac (115 ha) of estuarine intertidal flats was attributed to conversion to subtidal habitats, including open water and seagrass beds. Few changes were seen in Mission River marshes from the 1950's to 1979.

Sabine Lake

The Texas-Louisiana border divides Sabine Lake (12.6 mi (21 km) long by 7.8 mi (13 km) wide) and contains 45,320 ac (18,355 ha) of surface area at mean low water. The bay is connected to the Gulf by Sabine Pass which is 6.6 mi (11 km) long. Except in dredge areas, water depths average 5.1 ft (1.5 m). The bay bottom consists primarily of mud and silt. A few oyster reefs are found in the southern portion of the bay (Diener 1975). Two spoil disposal sites along the western shore enclose 5,053 ac (2,046 ha) of the bay bottom (T. Stelly, Texas Parks and Wildlife Coastal Fisheries Division, personal communication).

Average annual flow of fresh water into the bay is 11,511 cf/s (326 m^3/s), primarily from the Sabine and Neches rivers (Diener 1975). Rainfall in the area (Beaumont) averaged 55.9 in (142 cm) from 1961-1990 (SRCC 1997). Average annual salinity in Sabine Lake from 1986-2000 was seven ppt, and ranged from 4-14 ppt (Appendix A).

Marsh vegetation covers 425,000 ac (172,125 ha) in the Texas portion of Sabine Lake. Dominant species are smooth cordgrass, salt meadow cordgrass (*S. patens*), seashore saltgrass, black rush and bulrush (Diener 1975). The only submerged spermatophyte recorded for the bay is widgeon grass and acreage is unknown. The western portion of the bay is heavily industrialized and most of the marsh vegetation is found on the eastern side.

Galveston Bay

Galveston Bay contains 383,845 surface ac (155,457 ha) of water and is the largest estuary in Texas (Shipley and Kiesling 1994). The bay is separated from the Gulf by Follets Island, Galveston Island and Bolivar Peninsula. One man-made pass (Rollover Pass in East Bay) and two natural passes (San Luis Pass in West Bay and Bolivar Pass in Galveston Bay) connect the estuary with the Gulf. The Trinity River Delta, located at the northeast end of this bay system, is a growing delta and has the potential for marsh creation.

Average depth of the Galveston Bay system, which includes Galveston, Trinity, East, West, Dickinson, Chocolate, Christmas, Bastrop, Dollar, Drum and Tabbs bays and Clear, Moses and Jones lakes is 6.9 ft (2.1 m) or less, except in dredged areas (Diener 1975). The Houston Ship Channel leading from the Gulf into Galveston, Texas City, Baytown and Houston is 51 mi (81 km) long and dredged to 41.3 ft (12.5 m) (Shipley and Kiesling 1994). The GIWW is dredged to 12.2 ft (3.7 m) through the lower portion of the system. Bay bottom consists of mud, shell and clay. There are approximately 8,650 ac (3,503 ha) of oyster reefs in the system and many spoil banks occur along most dredged channels (Diener 1975).

Emergent marsh vegetation totals 231,400 ac (93,717 ha), consisting of smooth cordgrass, salt meadow cordgrass, bulrush, shoregrass, rush saltwort and seashore saltgrass (Diener 1975). Only 279 ac (113 ha) of seagrass beds remain in the Galveston Bay system as of 1989, with 275 ac (111 ha) occurring in Christmas Bay and consisting predominantly of shoal grass and widgeon grass. Small amounts of clover grass and turtle grass are also present in Christmas Bay (TPWD 1999).

Shipley and Kiesling (1994) reported average fresh water inflow to the Galveston Bay system for the period 1941-1987, was 10.1 million ac-ft/year (12,458 million m^3). Average annual rainfall at Houston averaged 50.59 in (128 cm) from 1961-1990 (SRCC 1997). Average annual salinity in Galveston Bay from 1982-2000 was 16 ppt, with a range of 13-23 ppt (Appendix A).

The Galveston Bay Estuary Program (GBNEP) was established under the Water Quality Act of 1987 to develop a Comprehensive Conservation Management Plan for Galveston Bay. The Galveston Bay Plan was created in 1994 and approved by the Governor of Texas and the Administrator of the US Environmental Protection Agency (USEPA) in March 1995 (Lane 1994, GBNEP 1995).

Matagorda Bay

The Matagorda Bay system, comprising East Matagorda, West Matagorda and Lavaca Bays, encompasses an area of 248,250 ac (100,541 ha) at mean low water (Diener 1975). The bay is separated from the Gulf by the Matagorda Peninsula and water exchange is through Pass Cavallo and Matagorda Ship Channel jetties, a manmade ship channel. The Colorado River, which flowed into the Gulf prior to its diversion in 1992, formed a delta that divides the bay into Matagorda Bay proper and East Matagorda Bay. Water exchange with the Gulf to the eastern portion is through Mitchell's Cut.

The average depth of the Matagorda Bay is about 3.5 ft (1.1 m) and bottom substrate is sand, shell, silt and clay. There are many oyster reefs in the area, but acreage is unknown. The GIWW and Palacios Ship Channel dredged to 12 ft (3.7 m) and the Matagorda Ship Channel, dredged to 38 ft (12 m), are the major waterways in the area (Diener 1975). Diener (1975) lists 120,000 ac (48,600 ha) of emergent vegetation consisting of smooth cordgrass, salt meadow cordgrass, saltwort, shoregrass and seashore dropseed (*S. virginicus*). Submerged vegetation consisting of shoal grass, clover grass and widgeon grass covers 3,828 ac (1,550 ha) of the Matagorda and East Matagorda Bay system (TPWD 1999).

Primary freshwater inflow into Matagorda Bay is from the Tres Palacios, Carancahua, Lavaca and Navidad rivers and averaged 3,072 cf/s (87 m^3/s) (Diener 1975) before the re-diversion of the Colorado River into West Matagorda Bay in the 1980's and creation of Lake Texana, and more recently the installation of a water pipeline from Lake Texana to Corpus Christi. Annual precipitation over the drainage area averaged 40 in (101 cm) from 1951-1980 (Longley 1994). Average salinity in Matagorda Bay from 1982-2000 was 24 ppt, with a range of 16-31 ppt (Appendix A).

San Antonio Bay

The San Antonio Bay system, comprising Espiritu Santo, San Antonio, Guadalupe, Hynes, Mesquite and Ayers Bays and Mission Lake, covers some 136,240 ac (55,177 ha) at mean low water (Diener 1975). The system is separated from the Gulf by Matagorda

Island. Water exchange is through Pass Cavallo (located in Matagorda Bay) and to a lesser extent Cedar Bayou Pass (located in Mesquite Bay).

Average depth of unaltered bay bottom is about 10.3 ft (3.2 m) and substrates generally consist of mud, sand and shell (Diener 1975). There are approximately 7,200 ac (2,916 ha) of natural oyster reefs in the area. Two major channels are the GIWW, dredged to 12 ft (3.7 m), and the Victoria Barge Canal, dredged to nine ft (2.7 m).

Emergent vegetation, covering about 25,000 ac (10,125 ha), consists primarily of smooth cordgrass, seashore saltgrass, shoregrass and salt meadow cordgrass (Diener 1975). Common reed has been reported in the upper portion of the region (Matlock and Weaver 1979). Texas Parks and Wildlife Department (1999) reported 10,600 ac (4,293 ha) of submerged grasses for the San Antonio and Espiritu Santo Bay system in 1989, consisting mainly of shoal grass and small amounts of clover grass and widgeon grass, with shoal grass being dominant.

Major sources of freshwater are the Guadalupe and San Antonio rivers that provide most of the average annual inflow of 2.3 million ac-ft/year (2,837 million m^3/year), averaged from 1941-1987. Annual precipitation over the drainage area varies from 28 in (71 cm) in the western regions of the Guadalupe and San Antonio River basins to 40 in (102 cm) near the Gulf coast (Longley 1994). Average salinity in San Antonio Bay from 1982-2000 was 18 ppt, with a range of 8-26 ppt (Appendix A).

Aransas Bay

The Aransas Bay complex, which comprises Aransas, Copano, St. Charles, Dunham, Port, Carlos, Mission and Mesquite Bays, covers approximately 111,880 ac (45,311 ha) (Diener 1975). It is separated from the Gulf by San Jose Island with major water exchange through Aransas Pass and to a lesser extent through Cedar Bayou Pass. Bottom sediments consist of mud, sand and shell; approximately 840 ac (340 ha) of oyster reefs are in the area. Average depth for the system ranges from two ft (0.6 m) in Mission Bay to 7.8 ft (2.4 m) in Aransas Bay. Major channels include the GIWW and the Aransas

Channel dredged to 12 ft (3.7 m) and Lydia Ann Channel that is dredged to 20 ft (6.1 m) (Diener 1975).

Emergent vegetation, consisting primarily of saltwort, shoregrass, glasswort (*S. bigelovii*), smooth cordgrass, salt meadow cordgrass and seashore dropseed, cover about 45,000 ac (18,225 ha) (Diener 1975). Submerged grasses cover 7,995 ac (3,237 ha) of Aransas, St. Charles and Copano Bay. In Aransas Bay, the dominant species is shoal grass, with minor amounts of turtle grass and manatee grass occurring. Clover grass and widgeon grass are also present (Pulich, Blair and White 1997).

The Aransas Bay receives an average annual freshwater inflow of 634,000 ac-ft/year (782 million m^3/year) that includes sheet flow and an average annual flow of 876 cf/s (24.8 m^3/s) from the Aransas and Mission rivers and Copano Creek (Asquith, Mosier and Bush 1997). Annual precipitation in Corpus Christi averaged 30 in (77 cm) from 1961-1990 (SRCC 1997). Average annual salinity in Aransas Bay from 1982-2000 was 22 ppt, with a range of 12-30 ppt (Appendix A).

Corpus Christi Bay

The Corpus Christi Bay system, comprising Redfish, Corpus Christi, Nueces and Oso Bays, contains 106,990 ac (43,331 ha) of water area at mean low water. Mustang Island separates the estuary from the Gulf. Water transfer is through Aransas Pass via the Corpus Christi Ship Channel. In April 1992, as a result of growing concerns about the health and productivity of Corpus Christi Bay, the Texas Coastal Bend Bays of the Laguna Madre (to Kennedy County including Baffin Bay), Corpus Christi Bay and Aransas Bay were nominated for inclusion in the National Estuary Program. The CCBNEP Program was established in late 1993 to develop a long-term comprehensive conservation and management plan, which was implemented in 1998 (CCBNEP 1998). This primary planning document is a four-year, community-based, consensus-building effort that identifies problems facing the bay system and develops a long-term comprehensive conservation and management plan to address those concerns (Raymond Allen, Coastal Bend Bays and Estuaries Program, personal communication).

Average depths in the system range from 1.6 ft (0.5 m) in Oso Bay to 10.5 ft (3.2 m) in Corpus Christi Bay. Bottom sediments consist of mud, sand and silt. Approximately 1,113 ac (451 ha) of oyster reefs are in the area. Major channels include the GIWW and the Aransas Channel, dredged to 12 ft (3.7 m), and the Corpus Christi Ship Channel leading to Aransas Pass, dredged to 45 ft (13.7 m) (Diener 1975).

Diener (1975) lists 45,000 ac (18,225 ha) of emergent vegetation consisting of saltwort, shoregrass, glasswort, smooth cordgrass, seashore dropseed, seablite *(Suaeda linearis*), sea oats (*Uniola paniculata*), salt marsh bulrush and seacoast bluestem (*Schizachyrium scoparium*).

Seagrasses covered about 2,359 ac (9,955 ha) in 1995 in Corpus Christi, Nueces and Redfish bays. Net seagrass acreage appears fairly stable over the last 40 years. Comparisons between 1958, 1975 and 1994, show evidence of seagrass bed fragmentation and seagrass loss in Redfish Bay and increases in bed acreage along Mustang Island, in the Harbor Island complex and in the Nueces Bay parts of the system. In the Corpus Christi Bay system shoal grass, turtle grass, manatee grass, clover grass and widgeon grass are present. Although shoal grass is dominant in Corpus Christi and Nueces bays, turtle grass is dominant in Redfish Bay (Pulich et al. 1997).

Freshwater inflow from the Nueces River averaged 378,000 ac-ft/year (466 million m^3/year) from 1983-1993 (Asquith, Mosier and Bush 1997). Annual precipitation in Corpus Christi averaged 30 in (77 cm) in 1961-1990 (SRCC 1997). Average annual salinity in Corpus Christi Bay from 1982-2000 was 31 ppt, with a range of 26-37 ppt (Appendix A).

Upper Laguna Madre

The upper Laguna Madre, including the Baffin Bay system, covers 101,370 ac (41,055 ha) of surface area at mean low water (Matlock and Ferguson (Osborn) 1982). The Baffin Bay system consists of Alazan Bay, Cayo del Infiernello, Laguna Salada and Cayo del Grulla.

The upper Laguna Madre is separated from the Gulf by Padre Island. Water transfer is through Port Mansfield Pass to the south and Aransas Pass adjacent to Aransas and Corpus Christi Bays to the north. The channel to Port Mansfield, approximately (125.4 ft (38 m) wide and 12.2 ft (3.7 m) deep, is bisected imperfectly by the GIWW (Diener 1975). Many spoil banks are found along the route of the waterway.

Average depth of the upper Laguna Madre is 2.8 ft (0.9 m). In the Baffin Bay system average depths range from 0.7-7.7 ft (0.2-2.3 m) (Diener 1975). Bottom sediments consist of mud, silt, sand and quartzose pebbles. In the upper Laguna Madre, rock composed of shells and shell fragments, sand and clay bound together by calcium carbonate cement are found. Large areas of ancient serpulid rock reefs, some of which still support live serpulid worms, are found in Baffin Bay.

The upper Laguna Madre contains emergent vegetation consisting primarily of glasswort, seacoast bluestem, seablite, sea oats and gulf dune paspalum (*Paspalum monostachyum*) (Diener 1975).

The total area covered by seagrasses in the upper Laguna Madre system as of 1994 was 67,700 ac. (27,419 ha) (TPWD 1999) with the dominant species consisting of shoal grass, widgeon grass, clover-grass and manatee grass.

No major rivers drain into the upper Laguna Madre and freshwater inflow is minimal. The average annual salinity in upper Laguna Madre from 1982-2000 was 38 ppt with a range of 26-50 ppt (Appendix A).

The upper and lower Laguna Madre are separated by an area of extensive wind tidal flats but are hydrologically connected by the GIWW in the area known as the “Land Cut”.

Lower Laguna Madre

Lower Laguna Madre, including the South Bay and La Bahia Grande complex, contains 179,540 ac (72,714 ha) of surface area (Matlock and Ferguson (Osborn) 1982). It is separated from the Gulf by Padre Island. Water transfer is through Port Mansfield Pass and Brazos Santiago Pass to the south. The area is bisected imperfectly by the GIWW, which is 125 ft (38 m) wide and 12 ft (3.7 m) deep (Diener 1975). Many spoil banks are along the route of the waterway.

Average depth of lower Laguna Madre is 4.7 ft (1.4 m) (Diener 1975). Bottom sediments consist of mud, silt, sand and quartzose pebbles. The only natural oyster reefs in lower Laguna Madre are in South Bay, the southernmost area of the lagoon.

The lower Laguna Madre contains emergent vegetation consisting primarily of shoregrass, glasswort, seacoast bluestem, seablite, sea oats and gulf dune paspalum (Diener 1975). The southern end of the lower Laguna Madre also has isolated stands of black mangroves. Over the last 20 years, there has been a decline of 38,400 ac (15,550 ha) in seagrass habitat in the lower Laguna Madre, which is equivalent to about 25% of the mid 1980's habitat. In 1994, the lower Laguna Madre seagrasses cover 118,600 ac (48,033 ha) with the dominant species consisting of turtle grass and manatee grass. Shoal grass, clover grass and widgeon grass also occur (TPWD 1999).

No major rivers drain into the lower Laguna Madre and freshwater inflow is minimal. However, the watershed of the lower portion of the lower Laguna Madre produces freshwater inflow into the Laguna Madre via the Arroyo Colorado. Annual precipitation in the lower Laguna Madre area (Brownsville) averaged 27 in (68 cm) from 1961-1990 (SRCC 1997). Average annual salinity in lower Laguna Madre from 1982-2000 was 34 ppt with a range from 31-37 ppt (Appendix A).

Gulf of Mexico

Texas has approximately 367 mi (612 km) of open Gulf shoreline. The marine ESH boundary is seaward of the coastal barrier islands or other lines of demarcation used after Pearcy (1959). This includes all waters and substrates within the US Exclusive Economic Zone seaward of the estuarine ESH boundary. The habitat types located in the marine environment in the Gulf are varied. Thriving coral reefs, seagrass meadows, non-vegetated bottom, drowned reefs related to ancient shorelines, manmade structures, salt diapirs and large rivers influence water characteristics on the inner continental shelf and contribute to the diversity of the marine habitat in the Gulf. This diversity directly influences the species associated with these varying habitat types (Rezak, Bright and McGrail 1985).

Runoff from precipitation on almost two-thirds of the land area of the US eventually drains into the Gulf via the Mississippi River. The combined discharge of the Mississippi and Atchafalaya (Louisiana) rivers alone accounts for more than half the freshwater flow into the Gulf and is a major influence on salinity levels in coastal waters on the Louisiana/Texas continental shelf. The annual freshwater discharge of the Mississippi/Atchafalaya River system represents approximately 10% of the water volume of the entire Louisiana/Texas shelf to a depth of 295 ft (90 m). The Loop Current and Mississippi/Atchafalaya River system, as well as the semipermanent, anticyclonic gyre in the western Gulf, significantly affect oceanographic conditions throughout the Gulf (Rezak et al. 1985). From 1985–2000 salinity in Texas waters of the Gulf ranged from an average of 29 ppt in waters bordering Louisiana to 33 ppt near Mexico. Salinity averaged 31 ppt for all Gulf waters sampled off Texas combined.

The Gulf of Mexico continental shelf varies in width from about 124 mi (200 km) off east Texas to 68 mi (110 km) off southwest Texas. The continental shelf occupies about 35% of the surface area of the Gulf and provides habitats that vary widely from the deeper waters. The shelf and shelf edge of the Gulf are characterized by a variety of topographic features (Rezak et al. 1985). The value of these topographic features as habitat is important in several respects. Some of these features support hard bottom communities of high biomass and high diversity and an abundance of plant and animal species. These features are unique in that they are small, isolated, highly diverse sections within areas of much lower diversity. They support large numbers of commercially and recreationally important fish species by providing either refuge or food.

The Texas shelf is dominated by mud or sand-laden terrigenous sediments deposited by the Mississippi River. Vertical relief of the banks on the Texas shelf varies from less than one foot to over 492 ft (150 m). These banks exist in water depths of 72-984 ft (22-300 m) (Rezak et al. 1985).

Rezak et al. (1985) conducted extensive research on the banks and reefs of the northern Gulf. They grouped the banks into two categories. The first were the mid-shelf banks, defined as those that rose from depths of 262 ft (80 m) or less and had a relief of 13-164 ft (4-50 m). They were similar to one another in that all were associated with salt diapirs and were outcrops of relatively bare, bedded tertiary limestones, sandstones, claystones and siltstones. Some of the named mid-shelf banks were Claypile Bank, 32 Fathom Bank, Coffee Lump, Stetson Bank and 29 Fathom Bank.

The other category of banks was the shelf-edge carbonate banks and reefs located on complex diapiric structures. They are carbonate caps that have grown over outcrops of a variety of Tertiary and Cretaceous bedrock and salt dome caprock. Although all of the shelf-edge banks have well-developed carbonate caps, local areas of bare bedrock have been exposed by recent faulting on some banks. Relief on shelf-edge banks ranged from 115-492 ft (35-150 m). Some of the named shelf-edge banks off Texas were East and West Flower Garden Banks (both within the Flower Gardens National Marine Sanctuary which prohibits harvest of any shrimp and other marine species).

South Texas Shelf

The Gulf continental shelf south of Matagorda Bay narrows to 68 mi (110 km) off southwest Texas and contains an area of drowned reefs on a relic carbonate shelf (Rezak et al. 1985). These carbonate structures, the remains of relict reefs, currently only support minor encrusting populations of coralline algae. The banks vary in relief from 3-72 ft (1-22 m). The sides of these reefs are immersed in a nepheloid layer that varies in thickness from 49-66 ft (15-20 m). The sediments around the reef consist of three main components, including clay, silt and coarse carbonate detritus. These banks are composed of carbonate substrata overlain by a veneer of fine-grained sediment around the base that reaches an approximate thickness of eight in (20 cm). These fine-grained sediments decrease to a trace on the crests. Carbonate rubble is the predominant sediment on the terrace and peaks of the banks (Rezak et al. 1985).

Rezak et al. (1985) described several shallow water reefs which also occur on the south Texas shelf. These reefs are East Bank, Sebree Bank, Steamer Bank, Little Mitch Bank, Four Leaf Clover, Nine Fathom Rock and 7.5 Fathom Reef. These reefs are located south of Corpus Christi down to Brownsville in water depths of 46-131 ft (14-40 m) and provide relief of up to 16 ft (5 m). They are thought to have different origins from the other banks located farther offshore on the south Texas shelf.

Southern Bank is a typical example of the relict reefs found on the deeper portions of the south Texas shelf. It is circular in view with a diameter of approximately 4,265 ft (1,300 m), and rises from a depth of 262 ft (80 m) to a crest of 197 ft (60 m). Approximately 14 banks are on the south Texas shelf in water depths ranging from 197-295 ft (60-90 m). The named south Texas banks are Big Dunn Bank, Small Dunn Bank, Blackfish Ridge, Mysterious Bank, Baker Bank, Aransas Bank, Southern Bank, North Hospital Bank, Hospital Bank, South Baker Bank, Big Adam Bank, Small Adam Bank and Dream Bank (Rezak et al. 1985).

Rezak et al. (1985) reported the diverse epifaunal communities surrounding these banks. The sea whip (*Cirrihpathes* sp.) is the most conspicuous epifaunal organism on the south Texas mid-shelf banks. Another conspicuous macrobenthic organism is the sponge (*Ircinia campana*). Comatulid crinoids are abundant everywhere on the upper portions of the banks. Large white sea fans (*Thesea* sp.) are also seen frequently along with other deepwater alcyonarians, mostly paramuriceids. The only stony corals are agariciid colonies near the top of banks that are in relatively clear water. Leafy algae are present at some banks. Large mobile benthic invertebrates such as arrow crabs, hermit crabs, black urchins, sea cucumbers and fireworms are also present.

Groundfish populations at the south Texas banks are dominated by the yellowtail reef fish (*Chromis enchrysurus*), roughtongue bass (*Holanthias martinicensi*), spotfin hogfish (*Bodianus pulchellus*), reef butterflyfish (*Chaetodon sedentarius*), wrasse bass (*Liopropoma eukrines*), bigeye (*Priacanthus* sp.), tattler (*Serranus phoebe*), hovering goby (*Ioglossus calliurus*) and the blue angel fish (*Holocanthus bermudensis)* (Rezak et al. (1985). Larger migratory fish observed included schools of red snapper (*Lutjanus campechanus*) and vermillion snapper (*Rhomboplites aurorubens*). Also present were the greater amberjack (*Seriola dumerili)*, the great barracuda (*Sphyraena barracuda*), small carcharhinid sharks and cobia (*Rachycentron canadum*). Dennis and Bright (1988) observed 66 species of fish on the south Texas banks with 42 species being primary reef species.

The southernmost mid-shelf carbonate banks on the south Texas shelf, apparently due to their relatively low relief above the surrounding mud bottom, suffer from chronic high turbidity and sedimentation from crest to base and all rocks are heavily laden with fine sediment (Rezak et al. 1985). Consequently, the epibenthic communities on these banks are severely limited in diversity and abundance.

Circulation Patterns

Britton and Morton (1989) discussed circulation patterns and tides for the Gulf. The pattern of sea surface circulation in the Gulf is created as major incursions of water from the tropical Caribbean enter the Gulf via the Yucatan Channel, circulate and exit via the Strait of Florida. While circulation of surface waters varies seasonally, it consists of two major elements: 1) a sweeping S-shaped element in the eastern Gulf, and 2) a complex double loop that focuses upon the south central Texas shore in the western Gulf. The latter has a strong influence upon the composition of barrier island beaches, such as south Padre Island.

From Mexico to the mouth of the Rio Grande and along central Padre Island, coastal sands move northward within a nearshore bar and trough system. About 50 mi (80 km) north of the Rio Grande and along central Padre Island, the longshore bar and trough system fails to parallel the shoreline. Here, a series of open grooves, called “blind guts” by local fishermen, create treacherous waters for mariners. This area is also called “Big Shell” after the large accumulation of shell debris that collects here. This is the northern limit of beach sands derived from the Rio Grande. From here northward, beach sands have the characteristics of sediments brought to the Gulf by central Texas rivers. The distribution of beach sands suggests that north of Big Shell, longshore currents push sand in a southwesterly direction.

Along the upper and middle Texas coast south to Big Shell, southeasterly winds cause a southwestern longshore current. Local current patterns are often moderated by the effects of prevailing seasonal and local winds. Winter cold fronts displace the subtropical airflow with strong northerly or northeasterly winds. Northernmost longshore currents are affected moderately by the wind change, but a more pronounced effect occurs as one moves southward along the coast. Offshore currents are also affected by wind and off Port Aransas, in 45 ft (14 m) of water, winter currents flow west southwesterly at a mean rate of eight in/s (21 cm/s) in response to northerly winds.

Element 3

Problems Affecting Habitat and Species

Miscellaneous factors that impact coastal wetlands include marsh burning, marsh buggy traffic, onshore oil and gas activities and well-site construction (MMS 1996). Bahr and Wascom (1984) reported major marsh burns resulted in permanent wetland loss. Even with wetland loss, federal and state legislation have had a positive influence on wetland conservation and management in Texas. This legislation includes: the 1948 "Clean Water Act" as amended, the 1969 National Environmental Policy Act, the1985 and 1990 "Farm Bills", the 1989 North American Wetlands Conservation Act, the 1981 Texas Waterfowl Stamp Act, the 1991 Texas Coastal Coordination Act (includes Texas Coastal Management Program), the 1997 Texas Senate Bill 1 (Water Planning) and others. In 1997, TPWD produced the Texas Wetlands Conservation Plan (TPWD 1997) which focuses on non-regulatory, voluntary approaches to conserving Texas wetlands.

In addition, the Texas General Land Office (GLO) has compiled available literature on wetland studies and ecology with an emphasis on Texas coastal wetlands, entitled *A Bibliography of Texas Coastal Wetlands*. This reference is the basis of the Texas Coastal Wetlands Conservation Plan (TPWD unpublished manuscript) which identifies and prioritizes coastal wetlands in need of restoration.

Water Quality

Water quality is a key environmental factor in maintaining healthy populations of estuarine species. Major activities affecting Gulf coastal water quality include those associated with the petrochemical industry, hazardous and oil-field waste disposal sites, agricultural and livestock farming, power plants, pulp and paper plants, fish processing, commercial and recreational fisheries, municipal waste water treatment, mosquito control activities, maritime shipping and land modifications for flood control and river development and for harbors, docks, navigation channels and pipelines.

Water quality conditions of the Gulf as a whole were discussed in the USEPA National Coastal Condition Report (USEPA 2001). It represented a coordinated effort among USEPA, the National Oceanic and Atmospheric Administration (NOAA), the US Geological Survey and the US Fish and Wildlife Service to summarize the condition of ecological resources in US estuaries and rates areas on a general scale ranging from poor to good from data collected by states during 1990-2000. The condition of estuaries Gulf-wide ranged from fair to poor: water clarity was fair, dissolved oxygen was good, wetland loss poor, eutrophic conditions poor (high chlorophyll-*a* in Laguna Madre), sediment contaminants poor (high concentrations in northern Galveston Bay and the Brazos River), benthic indicators poor and conditions based on fish tissue contaminants was poor. From a national perspective, the report states the overall condition of US coastal waters is fair to poor, varying from region to region.

Monitoring and Water Quality Standards

The TCEQ is the state agency charged with monitoring and maintaining water quality standards in the state. Section 305(b) of the federal Clean Water Act (CWA) requires states to produce a periodic inventory comparing water quality conditions to established standards (Surface Water Quality Standards, 30 Texas Administrative Code (TAC) Section 307 and Drinking Water Standards, 30 TAC Sections 290.101-121).

The TCEQ sets surface water quality standards in an effort to maintain the quality of water in the state consistent with public health and enjoyment, protection of aquatic life, operation of existing industries and economic development of the state, as well as to encourage and promote development and use of regional and area-wide wastewater collection, treatment and disposal systems. These standards can be found at Texas Administrative Code (TAC), Title 30, Chapter 307.

The 305(b) Water Quality Inventory is an overview of the status of surface waters in the state, including concerns for public health, fitness for use by aquatic species and other wildlife and specific pollutants and their possible sources. The inventory is maintained by the TCEQ.

Section 303(d) of the CWA requires each state to develop a list of waterbodies that do not meet established standards. These are referred to as "impaired waters". The state must take appropriate action to improve impaired waterbodies, such as development of total maximum daily loads (TMDL). The TDML is the amount of a pollutant that a lake, river, stream or estuary can receive and still maintain Texas Surface Water Quality Standards. It is a detailed water quality assessment that provides the scientific foundation for an implementation plan which outlines the steps necessary to reduce pollutant loads in a certain body of water to restore and maintain human uses or aquatic life.

TMDL's are developed by TCEQ staff or independent contractors working for the agency through a scientifically rigorous process of intensive data collection and analysis. Implementation plans are the basis for initiating local, regional and state actions that reduce pollutant loads to levels established in TMDL's. These plans include making wastewater permit limits more stringent. This may require wastewater treatment plants for communities and industry to implement additional and sometimes costly new treatment technology. Alternatively, farmers and ranchers may be asked to use new practices that prevent fertilizers, manure and pesticides from reaching lakes and rivers. Cities may be required to control and treat runoff from their streets. Local input in the TMDL process is essential to determining which controls will be the most effective to implement. Additional water sampling will also be required to determine the effectiveness of the chosen controls.

Upon adoption by the TCEQ, the TMDL's are submitted for approval by the USEPA. In 1998 the TCEQ committed itself to developing TMDL's for all impaired waterbodies within 10 years of their first placement on the *Texas 303(d) List.* This list included 240 waterbodies with 336 impairments in 2000. Texas has completed a number of TMDL's and submitted them to the USEPA. During the first part of 2001, the USEPA approved 26 TMDL's in 12 Texas waterbodies.

Federal regulations prohibit the addition of certain new sources and new discharges of pollutants to waters listed on the *Texas 303(d) List* until a TMDL is established. Under federal law, if Texas does not develop its own TMDL's, the USEPA must develop them. The first draft of the 2002 Texas 303(d) list was published in April 2002. A few coastal waterbodies, like the Houston Ship Channel in Galveston Bay, were listed as not within standards due to high levels of bacteria, PCB's and dioxins in fish and crab tissue and pesticide residues.

In Texas, as in many states, estuarine water quality standards are based on standards prepared for freshwater rivers and streams. This approach fails to deal with natural processes unique to estuaries such as tides and seasonal stratification. These processes can drastically affect estuary water quality. Many states assess water quality conditions based upon measurements taken at the surface, or at five ft (1.5 m) depths or mid-depth, whichever is less. This approach does not deal with conditions and processes in the deeper estuarine areas. These areas are coincidentally where stratification in warmer months can lower oxygen concentrations. Sediment oxygen demand can also be a factor in decreasing dissolved oxygen concentrations. The disconnect between standards and environmental conditions necessary for aquatic productivity becomes more severe as greater amounts of waste are added to the system from point and non-point sources.

Loss of Habitat for Human Uses

Some human uses are affected by certain types of pollution while others may continue at the same time. The difference is between contact (e.g. swimming) and non-contact uses (e.g. sailing). The most prevalent example of human use being curtailed by pollution in Gulf estuaries is coliform bacteria contamination, which is used as an indicator of shellfish suitability for human consumption. Elevated coliform bacteria counts in estuaries lead to prohibitions of shellfish harvest. Theses conditions can be temporal or permanent, depending on the situation. Many Gulf estuaries have oyster beds permanently closed to harvest that are otherwise biologically productive. A major part of the problem is the lack of meaningful septic tank regulations or the lack of enforcement of otherwise adequate regulations.

Another example for loss of human uses in the Gulf is the mercury contamination of a portion of Lavaca Bay within Matagorda Bay (see point and non-point source pollution section for additional information on this case). In April 1988, the TDH closed portions of the bay to all human uses, including fishing and swimming, because of mercury contamination of bottom sediments and a spoil island. In March 1994, the USEPA and ALCOA (Aluminum Company of America) signed an Administrative Order of Consent for ALCOA to conduct a remedial investigation, risk assessment and feasibility study of the site. In January 2000, the TDH reduced the size of the closed areas based on reductions of mercury contamination in fish tissue. Following the completion of a proposed plan for remedial action and a record of decision, cleanup measures will be determined. These cleanup measures should eventually result in TDH rescinding the fish closure order (USEPA 2001). The recreational and commercial finfish industry has been particularly hard hit and will continue to suffer from this prohibition on possession of any and all finfish and shellfish from this area until it is lifted. This includes such economically valuable species as red drum, spotted seatrout, southern flounder and blue crab. White and brown shrimp and oysters do not seem to be affected by the mercury contamination.

Holistic Estuary Water Management Problems

Watershed destruction, including non-point source pollution, has been identified as the greatest source of water pollution nationwide. Gulf estuaries and bays are experiencing this phenomenon. The GBNEP has identified this problem as a major contributor to degraded estuary conditions. Additionally, water managers have lacked needed planning for managing the ability of estuaries to assimilate wastes. The consequence of inadequate estuary water planning is less than optimal utilization of fish and shellfish resources.

Specific Bay Systems

Galveston Bay

In a study by Ward and Armstrong (1992), the water quality of the bay was summarized over the last several decades. Salinity declined around 0.1-0.2 ppt/year over the 30-year period of record and water temperature declined at 0.05°C/year. Dissolved oxygen is generally high throughout the bay, averaging near saturation over many areas. Exceptions to this are in poorly flushed tributaries that receive runoff and waste discharges (Shipley and Kiesling 1994). For these parameters there appears to be a steady-state condition.

In addition, total suspended solids declined in the bay to ⅓ of levels seen 25 years ago. Nitrogen and phosphorus concentrations throughout the bay declined over the past two decades to more normal levels; total nitrogen and ammonia nitrogen at 0.01 mg/L/year, and total phosphorus at 0.05 mg/L/year. Total organic carbon has declined to one-third of its concentration in the 1970's, and chlorophyll-*a* to one-half the level a decade ago. This data reveals an improvement in water quality over time.

Most metals found in the water column and sediment declined, particularly in the upper Houston Ship Channel. Chromium, mercury and zinc in sediment declined by a factor of two; copper and nickel by a factor of three; and arsenic, cadmium and lead by a factor of ten. Fecal coliform bacteria levels generally declined throughout the bay due to improved or increased sewage treatment. Exceptions occurred in a few isolated areas of West Bay and the western urbanized tributaries to the bay.

Overall, the geographical problem areas were found in regions of intense human activity, which includes urban areas, points of runoff, waste discharges and shipping.

Corpus Christi Bay

In research conducted for the Coastal Bend Bays and Estuaries Program in 1992, water quality within the Corpus Christi estuary system was deemed to be generally good to moderate (TCEQ 1992).

Some areas of fair to poor quality, however, were identified. The Inner Harbor had the highest levels of many pollutants including metals, PCB's, organic contaminants and fecal coliform. Nueces Bay was consistently high in metal concentrations in both the water column and sediment. Zinc levels were increasing in some bay regions and were 10 times higher in the Inner Harbor sediment than in portions of the Houston Ship Channel. Trends in concentrations of other metals could not be determined from available data.

The researchers concluded that metal contamination in the bays is unlikely to pose a threat to marine life. They also concluded that most point-source-loading of pollutants were found in the central portion of the Coastal Bend bays, primarily in the Nueces and Corpus Christi bays, while the upper bays received the least. However, pollutants from these sources have decreased over the past 25 years. The central bays received most of the non-point urban sources of pollutants while the upper bays received the majority of the agricultural non-point runoff. Chemicals in the water from these sources were found at levels similar to other Texas bay systems. The highest concentrations of pesticides occurred in Baffin and Copano Bays but did not exceed standards.

Other Waterbodies

In 1999, Texas produced the Clean Water Act Section 303(d) List and Schedule for Development of Total Maximum Daily Loads. The document listed 34 coastal Texas waterbodies that did not meet or were not expected to meet applicable water quality standards. In most cases only certain portions of these waterbodies were in question. These areas were evaluated based on independent assessments of criteria for dissolved oxygen, toxic substances in water and ambient water and sediment toxicity (TCEQ 1998, 1999, 2002).

Re-evaluating water quality assessments for the year 2000, the TCEQ updated the state's 303(d) list and removed a total of 10 coastal waterbodies, indicating that these waterbodies meet applicable water quality standards. Changes occurred in some cases due to newer methods of determining standards.

Salinity

Salinity is an important environmental factor affected by alterations in freshwater inflow. A change to the salinity structure of an estuary may cause impacts throughout the system, at scales many times larger than the impacts of wetland loss or pollutant discharge. To a great extent, distributions of organisms in an estuary are determined by salinity, which in turn is determined by a complex suite of interacting factors including rainfall, river discharge, tides, wind and basin configuration. Human alteration of river flow can significantly affect the salinity regime of an estuary, and thereby change its biota (USEPA 1994a).

Salinity is a fundamental environmental factor because all organisms are from 80-90% water, and internal salt concentrations must be maintained within a certain range in each species. Each species or life stage within a species is adapted to a particular external environment. Most estuarine organisms can tolerate a wider range of external salinities than oceanic species; however, even estuarine species have tolerance limits. Few estuarine species can function optimally within the entire salinity range from fresh to seawater. Most organisms are associated with either the higher end of the salinity range (25-36 ppt) or the middle range (10-24 ppt), but not both. Few estuarine organisms will tolerate salinity fluctuations greater than 15-20 ppt (USEPA 1994a).

Shifts in salinity distributions caused by changes in freshwater inflows can shut species out of formerly ideal refuges, feeding areas and nursery grounds. Alterations in freshwater inflow can dramatically change the distribution of salinities across an estuary. For example, changes in freshwater inflow can shift the boundary between fresh and salt water (usually considered the 1 ppt isohaline) several miles up or downstream. The result may be a drastic area reduction of bottom types that are suitable for a given species. Although many organisms are mobile, movement does not benefit them if no suitable areas with favorable salinities are available or if such areas have become so small that crowding occurs. Because of the effect on salinity patterns alone, changes in freshwater inflow can reduce the overall carrying capacity of an estuary (USEPA 1994a).

Surface salinities in the Gulf vary seasonally. During months of low freshwater input, surface salinities near the coastline range between 29 and 32 ppt. High freshwater input conditions during spring and summer months result in strong horizontal salinity gradients with salinities less than 20 ppt on the inner shelf. The waters in the open Gulf are characterized by salinities between 36.0 and 36.5 ppt (MMS 1997).

Bottom salinities were measured by Darnell et al. (1983) for the northwestern Gulf during the freshest and most saline months (May and August). During May, all the nearshore waters showed salinity readings of 30 ppt or less, and for all of Louisiana and Texas to about the level of Galveston Bay, salinity of the nearshore water was less than 24 ppt. Water of full marine salinity (36 ppt) covered most of the shelf deeper than 98-131 ft (30 m-40 m). During August the only water of less than 30 ppt was a very narrow band in the nearshore area off central Louisiana. The 36 ppt bottom water reached shoreward to the 66-98 ft (20 m-30 m) depth off Louisiana, but in Texas the entire shelf south of Galveston showed full marine salinity. The shallower shelf bottom waters off Louisiana tend to be fresher than those off Texas during both the freshest and most saline months, but the difference is not great, and brackish water extends no deeper than about 98 ft (30 m). Bottom waters of the mid to outer shelf remain fully marine throughout the year.

Estuaries on the other hand are typically less than 36 ppt. This is because of the dilution capacity of freshwater inflows from tributaries and local rainfall. The classic definition of an estuary is from Pritchard (1967): “An estuary is a semi-enclosed coastal body of water which has a free connection with the open sea and within which seawater is measurably diluted with fresh water derived from land drainage”.

In Texas, average salinities of estuaries are directly related to the number of annual inflow volumes each estuary receives. Lower salinity bays generally receive a greater number of inflow volumes than those with higher salinities. Estuaries display a salinity gradient that increases from the upper to the lower portion of the estuary. Organisms found in estuaries have developed a resistance to, or need for, the typically lower salinities found there. With each salinity change these organisms move, if possible, to areas containing their preferred salinities. Other organisms, such as plants and most benthos, cannot move, so, they adapt, suffer stress or die (Longley 1994).

Estuaries in Texas have evolved characteristic vascular plant communities in accordance with the decreasing gradient in precipitation from north to south that controls freshwater inflows. Dominant habitat types reflect the combined influence of basic physical and hydrological parameters, inducing coastline geomorphology, inundation and salinity regimes and nutrient loading. Freshwater inflows operate through these different factors to affect plant production depending on the habitat type. Vegetation communities integrate salinity, nutrient and sedimentation processes over time (Longley 1994).

Temperature

Water temperature determines not only which species are present in a population, but also much of the timing of their life cycles. Species demanding high dissolved oxygen (DO) are commonly associated with lower water temperatures since low temperatures allow more oxygen to be dissolved. The metabolic rate of most aquatic species is directly determined by water temperature. An increase in water temperature of 10 ºC causes a doubling of the metabolic rate. Thus, higher water temperature stimulates rapid growth, but can reduce the DO available to support it (USEPA 1994a).

Dissolved Oxygen, Turbidity and pH

The DO level in water is one of the primary factors determining which populations can survive in those waters. As DO drops from two ppm to 0 ppm, the number of species surviving tends to shift rapidly to favor anaerobic bacterial populations. The primary cause of DO depletion is metabolism of nutrient loads, mostly by bacteria. The primary sources of DO are surface mixing and photosynthesis of phytoplankton populations (USEPA 1994a). DO levels in Texas bay systems and Gulf waters off Texas are listed in Appendix A and averaged from 7-8 ppm annually from 1982–2000.

Turbidity is a function of suspended and dissolved material in the water column (organic and inorganic). High levels of turbidity can reduce or block light from penetrating beyond the upper layers of the water column. This reduces photosynthesis by aquatic plants and can cause layers of silt and other debris to impact marine organisms, especially sessile types. Turbidity in Texas bay systems and the Gulf varies greatly with water flow and runoff, but averaged 19–24 NTU in the bays and eight NTU in the Gulf annually from 1987–2000 (Appendix A).

Bay water pH averages ranged from 5-9, which is usually regarded as acceptable for most species, with a pH of approximately eight being preferred. Outside this range, pH becomes first a stressor, then lethal. In natural waters, a low pH is commonly associated with outflow from watersheds rich in digestible carbon, such as forests and bogs. These produce tannic acids, as well as the carbonic acid formed by metabolism. High pH can be associated with high phytoplankton loads in poorly buffered waters, with pH rising as carbonic acid is removed through photosynthesis (USEPA 1994a). Texas Parks and Wildlife Department Coastal Fisheries Division field surveys do not routinely monitor pH.

Hypoxia

Hypoxia or oxygen depletion occurs in some areas of the open Gulf (Rabalais, Smith, Harper and Justic 1995). Zones of hypoxia (commonly referred to as "dead zones") affecting up to 6,400 mi^2 (16,500 km^2) of bottom waters on the inner continental shelf from the Mississippi River delta to the upper Texas coast has been identified during mid-summer months. Researchers have expressed concern that this zone may be increasing in frequency and intensity. Although the causes of this hypoxic zone have yet to be conclusively determined, high summer temperatures combined with freshwater runoff carrying excess nutrients from the Mississippi River have been implicated. Benthic fauna studied within the area exhibited a reduction in species richness, abundance and biomass that was much more severe than has been documented in other hypoxia-affected areas (Rabalais et al.1995). At dissolved oxygen (DO) levels less than 2.0 ppm, a variety of physiological responses and behaviors occur among organisms. Motile fishes, cephalopods and crustaceans leave the area. Responses of non-motile benthic organisms range from pronounced stress behavior to death. At 0.0 ppm DO there is no sign of aerobic life. In areas affected by hypoxia annually, complete recovery of a climax community may not occur (Harper and Rabalais 1997).

Shrimp harvest in Louisiana has shown a negative relationship between catch and percentage area of hypoxic waters in shrimp catch sampling cells (Zimmerman, Nance and Williams 1997). Decreased catches of epibenthic and demersal fisheries species have been shown, through fisheries-independent sampling, to occur in areas of lower oxygen. Other potential fisheries impacts may include: concentration of fishing effort, leading to increased harvest and localized overfishing, low catch rates in directed fisheries and in recruitment due to impacts on zooplankton. Changes in distribution and abundance of fish species could result in loss of commercial and recreational fishing opportunities (Hanifen, Perret, Allemand and Romaire 1997). Diaz (1997), in reviewing hypoxic areas worldwide, found reduced or stressed fisheries populations to be common in areas where hypoxia occurs.

In 1999, the White House Council of the Environment and Natural Resources formed a multi-disciplinary "Hypoxia Assessment Work Group". Its purpose was to conduct an 18-month study to assess the causes of the hypoxia zone and propose management strategies. The work group included members of academia, tribal leaders and federal and state agencies with an interest in the Mississippi River and the Gulf and planned for the development of six interrelated reports:

1. Distribution, dynamics and characterization of hypoxia causes;
2. Ecological and economic consequences of hypoxia;
3. Sources and loads of nutrients transported by the Mississippi River to the Gulf;
4. Effects of reducing nutrient loads to surface waters within the basin and the Gulf;
5. Evaluation of methods to reduce nutrient loads to surface water, ground water and the Gulf; and
6. Evaluation of social and economic costs and benefits of methods for reducing nutrient loads.

The Hypoxia Group report (Report to Congress, the final Action Plan for Reducing, Mitigating, and Controlling Hypoxia in the Northern Gulf) was published by the USEPA in January 2001 (Mississippi River/Gulf of Mexico Watershed Nutrient Task Force 2001). It stated that scientific investigations document a zone on the Gulf's Texas-

Louisiana shelf with seasonally low oxygen levels (< 2 ppm). Between 1993 and 1999 the zone of midsummer bottom-water hypoxia in the northern Gulf was estimated to be larger than 4,000 mi^2 (10,000 km^2). In 1999, it was 8,000 mi^2 (20,000 km^2), approximately the size of the State of New Jersey, and in 2000, the zone was measured at only 1,700 mi^2 (4,400 km^2), resulting in a five year running average of 5,454 mi^2 (14,128 km^2) for 1996-2000. The hypoxic zone is a result of complicated interactions involving excessive nutrients (primarily nitrogen) carried to the Gulf by the Mississippi and Atchafalaya rivers; physical changes in the basin, such as channelization and loss of natural wetlands and vegetation along the banks as well as wetland conversions throughout the basin; and the stratification in the waters of the northern Gulf caused by the interaction of fresh river water and the saltwater of the Gulf.

Nutrients like nitrogen and phosphorus are essential for healthy marine and freshwater environments. However, an overabundance can trigger eutrophication. In the nearshore Gulf, excessive algal growth caused by excess nitrogen, can result in a decrease in dissolved oxygen in bottom waters and loss of aquatic habitat. In the Gulf, fish, shrimp, crabs, zooplankton and other important fish prey are significantly less abundant in bottom waters in areas that experience hypoxia.

In addition, the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force of the USEPA (2001) reported that water quality throughout the Mississippi and Atchafalaya rivers basins (the Basin) had been degraded by excess nutrients. Many states in the Basin have significant river miles impaired by high nutrient concentrations, primarily phosphorus, meaning that they are not fully supporting aquatic life uses. Groundwater supplies are threatened in some areas by excess nitrates, which can be a human health hazard.

Significant amounts of nutrients entering the Gulf from the Mississippi River come from human activities: discharges from sewage treatment and industrial wastewater treatment plants and stormwater runoff from city streets and farms. Nutrients from automobile exhaust and fossil fuel power plants also enter the waterways and the Gulf through air deposition to the vast land area drained by the Mississippi River and its tributaries. About 90% of the nitrate load to the Gulf comes from non-point sources. About 56% of the nitrate load enters the Mississippi River above the Ohio River. The Ohio River Basin adds 34%. High nitrogen loads come from basins receiving wastewater discharges and draining agricultural lands in Iowa, Illinois, Indiana, southern Minnesota and Ohio.

Approaches to reduce hypoxia in the Gulf are: 1) reduce nitrogen loads from watersheds to streams and rivers in the Basin and 2) restore and enhance denitrification and nitrogen retention within the Basin and on the coastal plain of Louisiana. Annual load estimates indicate that a 40% reduction in total nitrogen flux to the Gulf is necessary to return to average loads comparable to those during 1955-1970. Model simulations imply that nutrient load reductions of about 20-30% would result in a 15-50% increase in bottom water dissolved oxygen concentrations. Since any oxygen increase above the 2.0 ppm threshold would have a significant positive effect on marine life, even small reductions in nitrogen loads are desirable (Mississippi River/Gulf of Mexico Watershed Nutrient Task Force 2001).

The primary focus of this strategy is to reduce nitrogen loads to the northern Gulf, but many of the actions proposed through the plan will achieve basin-wide improvements in surface-water quality by also reducing phosphorus. Actions taken to address local water quality problems in the Basin should contribute to reductions in nitrogen loadings to the Gulf.

All nine states along the Mississippi River and federal agencies have agreed to work together to cut the hypoxia zone by half its average size over the next 15 years. The plan's participants agreed to develop strategies to reduce nutrients entering the Gulf, including nitrogen, by 30%. Although many state and federal programs of all agencies will be used to reach this goal, the Farm Bill conservation programs will be the major tools. Programs that compensate farmers to restore wetlands, retire sensitive lands, install vegetation buffers along streams and reduce fertilizer use will need to be expanded and funded (Mississippi River/Gulf of Mexico Watershed Nutrient Task Force 2001).

Historical Tracking of the Hypoxia Zone

In 1993, spring and summer flood waters from the Mississippi River doubled the hypoxia in the Gulf along the upper-Texas and Louisiana coasts. Low oxygen levels were found across 6,800 mi^2 (17,600 km^2). Effects on organisms in the area were unknown but the low dissolved oxygen levels were low enough to cause avoidance and/or death of animals (McEachron and Fuls 1996a).

During the summers of 1995-1996, the Gulf hypoxic zone off Louisiana and upper Texas was estimated at 7,000 mi^2 (18,100 km^2). Although about equal in size to the 1993 and 1994 events, the hypoxic zone was about double the average area documented during years prior to 1993 (Fuls and McEachron 1997). Low dissolved oxygen readings (<2 ppm) were observed in bottom Gulf water in June 1996 off Galveston in association with the dead zone but returned to normal levels by July (McEachron and Fuls 1996b).

The northern Gulf is the site of the largest (7,722 mi^2; 20,000 km^2) and most severe hypoxic zone in the western Atlantic Ocean. The hypoxic zone now ranks equal in size with the northwestern shelf. By early summer of 1997, low dissolved oxygen readings (1.0-2.3 ppm) were recorded at all Gulf trawl samples sites six mi (9 km) off Sabine Pass jetties. Numerous dead fish (spotted seatrout, menhaden, eels, others) and crabs were reported on Dunn's Beach (just west of Holly Beach, Louisiana) and Texas beaches on Bolivar Peninsula. In mid-June, nearshore Gulf currents switched from an easterly to a westerly direction, attributed to an El Niño weather pattern. This change returned normal dissolved oxygen levels to the Sabine Bank area, but temporarily pushed low DO level waters into Sabine Lake (Hensley, Spiller, Campbell and Fuls 2000).

From 1993-1998, the extent of bottom water hypoxia (6,200-7,000 mi^2; 16,000-18000 km^2) off the Louisiana coast was greater than twice the surface area of the Chesapeake Bay. Prior to 1993, the hypoxic zone averaged 3,100-3,500 mi^2 (8,000-9,000 km^2) (1985-1992). Since 1993, the hypoxic zones have been consistently greater than 5,800 mi^2 (15,000 km^2) (Rabalais 2001).

After the Mississippi River flood of 1993, the spatial extent of the hypoxia zone increased to over 6,600 mi^2 (17,000 km^2). In the summer of 2001, after heavy rains in the mid-western US, the largest hypoxia zone ever recorded was measured at 10,700 mi^2 (27,720 km^2), an area approximately the size of Massachusetts. The large size of the zone provided more evidence that nutrient inputs from the Mississippi River drainage basin were contributing to the creation of the hypoxic zone (Rabalais 2001).

Increases in nutrient inputs in watersheds draining to coastal areas cause problems such as oxygen depletion, habitat loss, fish kills and increased frequency of harmful algal blooms. Growth in population, changes in land cover and increases in fertilizer use have resulted in increases of 2-10 times the level of nutrient inputs during this century with dramatic increases since 1950 (Rabalais 1998). The numbers and extent of hypoxic episodes are increasing, especially in areas important to commercial fishing.

Algal Blooms

Brown tide was first documented in the Texas upper Laguna Madre (ULM) in early 1990. This organism has been identified as *Aureoumbra lagunensis* (order Pelagophyceae) and has persisted for over eight years. Brown tide reduces light available for seagrass photosynthesis and has caused seagrass losses in the ULM (McEachron et al. 1998, Chris Onuf, US Geological Survey-Corpus Christi, personal communication).

Within the past few years, the bloom has disappeared from the ULM-Baffin Bay system (McEachron et al. 1998). The disappearance may have been aided by the 25 in (64 cm) of rain that fell in four days during October 1996. This lowered salinities from greater than 50 ppt to less than 10 ppt in some areas. The brown tide organism is still present but not in bloom proportions demonstrated by counts from researchers (50-100 cells/ml vs. a previous 500,000 cells/ml) in the early 1990's (Chris Onuf, US Geological Survey-Corpus Christi, personal communication).

Researchers reported high densities of the larval dwarf surf clam (*Mulina lateralis*) a major grazer of the brown tide organism. While there has been some reduction of seagrass beds by brown tide, only 7% remain nonvegetated. These are deeper areas and are expected to take longer to recover.

Red tides are a natural phenomenon in the Gulf, primarily off Florida, Texas and Mexico. Of particular concern are red tides caused by blooms of a dinoflagellate (*Karenia brevis*, formerly *Gymnodinium breve*) that produces potent toxins harmful to marine organisms and humans. They can result in severe economic and public health problems and are associated with fish kills and invertebrate mortalities.

A significant red tide event began off the Texas coast on September 18, 1997 near Pass Cavallo and Sargent Beach (McEachron, Pridgeon and Hensley 1998). The bloom progressed southward into Mexico during October, with the majority of the bloom occurring in the Gulf waters off of Padre Island. The duration of the offshore bloom was September 18 through November 23, 1997. On November 21, 1997, red tide was reported inside bay waters near Corpus Christi and Port Aransas, Texas. The duration of this bloom lasted from November 21 through December 10, 1997, with areas of high cell counts lasting through January 19, 1998. A minimum estimate of mortality was 21.8 million aquatic organisms (16.5 million occurring in the surf and 5.3 million in the bays). The species killed (in millions) included: anchovies *Engraulidae* sp.(5.5), menhaden *Brevoortia* sp. (4.6), Atlantic bumper *Chloroscombrus chrysurus* (3.9), ghost shrimp *Callianassa* sp. (1.8), scaled sardines *Harengula jaguana* (1.7) and mullet *Mugal cephalus* (1.2) (McEachron et al. 1998). There are ongoing studies to determine whether human activity that increases nutrient loadings to Gulf waters contributes to the intensity of red tides (MMS 1996).

Meteorological Events

Texas Parks and Wildlife Department annually investigates meteorological data and other factors or conditions that may result in increases or decreases of finfishes and shellfishes in Texas waters. The major meteorological event that affects marine organisms in Texas is the occasional freeze.

Documented mass freeze mortalities occurred in 1886, 1917, 1924, 1940, 1951, 1983 and 1989 (lowest temperatures on record), for an average interval of 15 years. Less severe fish killing freezes were interspersed among these major freezes. Martin and McEachron (1996) report studies that estimated freezes alone reduced the "*fishable population*" in Texas bays by 50% in nine years out of 14 between 1940 and 1953; only in five years were coastal fish populations not adversely affected by cold weather.

El Niño and La Niña

The term El Niño was coined by South American fishermen to characterize the periodic arrival of unusually warm water in the eastern Pacific Ocean around Christmas time. El Niño means "The Little Boy" or "Christ Child" in Spanish. It is a periodic phenomenon that is caused by changes in surface trade wind patterns. The tropical trade winds normally blow east to west piling up water in the western Pacific and causing upwelling of cooler water along the South American coast. El Niño occurs when this "normal" wind pattern is disrupted. While this disruption tends to occur to some extent annually, an El Niño is an exaggeration of what is usually a brief disruption in the normal pattern (NOAA 1998a).

During an El Niño year the thermocline along Pacific South America is depressed and surface waters warm. Although normally cyclic over a number of years, El Niño has occurred in rapid succession during 1990-1994. In recent years, the El Niño of 1997-1998 was very intense.

However, the greatest ocean-atmosphere disturbance ever recorded occurred in 1982-1983. El Niño generally produces cooler and wetter weather in the southern US and warmer than normal weather in the north. During this time, the Gulf Coast states experienced heavy rains and flooding causing $1.2 billion in property and agricultural losses between December 1982 and May 1983. There is a pattern of fewer tropical storms during and after El Niño years, but major increases in tropical storms and hurricanes from 2-4 years following El Niño (NOAA 1998b).

La Niña means "The Little Girl", and is sometimes called El Viejo (Old Man), anti-El Niño, or simply "a cold event" or "a cold episode". La Niña is characterized by unusually cold ocean temperatures in the eastern equatorial Pacific, as compared to El Niño, which is characterized by unusually warm ocean temperatures.

La Niña tends to bring nearly opposite effects of El Niño to the US — wetter than normal conditions across the Pacific Northwest and dryer and warmer than normal conditions across much of the southern tier. In the continental US, during a La Niña year, winter temperatures are warmer than normal in the Southeast and cooler than normal in the Northwest. Direct effects to the Gulf can be very dry and hot conditions throughout the region and the possibility of more than the average number of tropical storms, and possibly hurricanes, occurring in the Gulf from June through October.

In both the El Niño and La Niña events, the natural state of ESH is disrupted, displaced or destroyed.

Atmospheric Deposition

Atmospheric deposition results when nitrogen and sulfur compounds, or other substances such as heavy metals and toxic organic compounds, are transformed by complex chemical processes. The transformed chemicals return to the earth in either a wet or dry form. Wet forms may be rain, snow or fog; dry forms may exist as gases or particulates. Once these transformed substances reach earth, they can pollute surface waters, including rivers, lakes and estuaries (USEPA 1994b).

The Clean Air Act established the National Ambient Air Quality Standards (NAAQS); the primary standard to protect public health and a secondary standard to protect public welfare. The Clean Air Act Amendments of 1990 established classification designations based on regional monitored levels of ambient air quality. These designations impose mandated time tables and other requirements necessary for attaining and maintaining healthy air quality in the US based on the seriousness of the regional air quality problem (MMS 1996).

When measured concentrations of regulated pollutants exceed standards established by the NAAQS, an area may be designated as a nonattainment area for a regulated pollutant. The number of exceedances and the concentrations determine the nonattainment classification of an area. There are five classifications of nonattainment that are defined in the 1990 Clean Air Act Amendments: marginal, moderate, serious, severe and extreme.

Ambient air quality is a function of the size, distribution and activities directly related to populations in association with the resulting economic development, transportation and energy policies of the region. Meteorological conditions and topography may confine, disperse or distribute air pollutants. Assessments of air quality depend on multiple variables such as the quantity of emissions, dispersion rates, distances from receptors and local meteorology. Due to the variable nature of these independent factors, ambient air quality is a dynamic process.

Demographic Trends

Texas is facing increasing pressures on natural resources, particularly population growth and urbanization. These pressures will result in more pronounced exploitation of plant, fish and wildlife resources, further loss and fragmentation of habitat; and decline in the quality of remaining habitat.

Water development projects and increased domestic, agricultural and industrial water use will reduce habitat quality and quantity, resulting in altered ecosystems, effluent-dominated streamflows that threaten aquatic life, and loss of associated wetlands and bottomland hardwoods. Urbanization and agricultural development will also threaten species and critical habitats in Texas.

Habitat Alteration

Physical alterations to habitat occur from man's activities and natural environmental events. Potential activities that adversely impact ESH can range from minor (possible recovery of the ESH to 100% functionality in months to years) to major (possible recovery of partial ESH functionality in years to decades) to catastrophic (loss of all ESH functionality to the foreseeable future).

Broad categories of activities which can adversely affect ESH include: dredging (ship channels, waterways and canals); fill; excavation; fossil shellfish dredging; mining; impoundment; discharge; water diversions; thermal additions; actions that contribute to non-point source pollution and sedimentation; introduction of potentially hazardous materials; introduction of exotic species; and the conversion of aquatic habitat that may eliminate, diminish or disrupt the functions of ESH.

Industrial/Commercial Development and Operations

Potential threats to habitat are directly and indirectly imposed from industrial and commercial development and operations. These threats include: conversion of wetlands to industrial and appurtenant sites such as roads, parking and administrative and distribution centers; point-and non-point-source discharge of fill, nutrients, chemicals, toxic metals, hot water resulting from cooling operations, air emissions and surface and ground waters into streams, rivers, estuaries and ocean waters; hydrological modification of ditches, dikes, water and waste lagoons; intake and discharge systems; hydropower facilities and cumulative and synergistic effects caused by association of these and other industrial and non-industrial related activities.

Industrial and commercial development and operations affect habitat in a number of ways. The most inexpensive land is usually sought for development near major shipping lanes such as rivers or ports. These lands usually contain wetlands that are generally filled for plant sites, parking, storage and shipping and treatment or storage of wastes or by-products. Many industries are also users of large quantities of water. Water often is a vital component of the manufacturing process, serves as a cooling mechanism, and is used to dilute and to flush wastes or other by-products, which often lead to highly contaminated estuarine and bay bottom sediments. Many heavy industries also produce airborne emissions which often include contaminants.

Commercial development and operations along the Gulf coast have been extensive. Most coastal areas or barrier islands have not been subject to some form of commercial development, targeting mainly the tourist trade. Past development practices have been especially abusive because, before adequate regulation, it was not uncommon for extensive nearshore modifications to take place for hotel and resort construction. This has now been abated largely because better information and regulations have helped resource managers decrease the damage to natural resources caused by this practice. However, it remains true that dry land or uplands are a decreasing commodity along the coast and that filling of wetlands is viewed as a less expensive alternative. Accordingly, there will continue to be proposals aimed at altering wetlands for commercial development and related infrastructure and these must be carefully assessed to minimize their impact on habitat.

The overall amount of ESH lost to or affected by commercial and industrial development is likely to be at least as important as that from urban and suburban development. In some situations, especially for industries that produce hazardous materials, non-point-source discharges can be a traumatic event, especially if there are accidental releases of chemicals. Of additional concern with industrial operations are contaminants that are emitted into the atmosphere. The types and levels of airborne contaminants reaching Gulf surface waters are unknown, but may have only a marginal effect because of dispersal by winds (GSMFC 1998).

Housing Developments

The coastal areas of the Gulf are highly sought after as places to live. The amenities of the coast and the water-related activities and climate that people enjoy lead to high human population growth rates. As the population increases so does urbanization. People require places to live as well as related services such as roads, schools, water and sewer facilities, power, etc. These needs often are met at the expense of habitat and may adversely impact the very values that brought people to the coast. Wetlands and adjacent contiguous lands have been filled for housing and infrastructure. Further, the demand for shoreline modifications (docks, seawalls, etc.) and navigation amenities have further modified the coast. Chemicals produced and used by people, such as oil from roads and parking lots, enter waters as non-point-source runoff. This has lowered water quality in waters and wetlands adjacent to urban developments.

Potential threats include: 1) conversion of wetlands to sites for residential and related purposes such as roads, bridges, parking lots, commercial facilities, reservoirs, hydropower generation facilities and utility corridors; 2) bulkheading of the coastal land/water interface; 3) direct and/or non-point-source discharges of fill, nutrients, chemicals, hot water resulting from cooling operations and surface waters into ground water, streams, rivers and estuaries; 4) reliance on septic tanks for onsite waste disposal; 5) hydrological modification to include ditches, dikes, flood control and other similar structures; 6) damage to wetlands and submerged bottoms; and 7) cumulative and synergistic effects caused by association of these and other developmental and non-developmental related activities.

Wetlands and other important coastal habitats continue to be adversely and irreversibly altered for urban and suburban development. One of the most serious of the adverse effects is filling areas for houses, roads, septic tank systems, etc. This directly removes ESH and degrades ESH that lies next to developed areas. While the total affected area is unknown, it has been extensive in much of the Gulf coast.

Another major threat posed by housing development is that of non-point-source discharges of chemicals used in day-to-day activities associated with operating and maintaining homes, septic tanks used for onsite human waste disposal, for maintaining roads, for fueling vehicles, etc. In addition to chemical input, changes that affect the volume, rate, location, frequency and duration of surface water runoff into coastal rivers and tidal waters are likely to be determinants in the distribution, species composition, abundance and health of Gulf fishery resources and their habitat. In the long-term, impacts of chemical pollution (e.g. petroleum hydrocarbons, halogenated hydrocarbons, metals, etc.) are likely to adversely impact fish populations (Schaaf, Peters, Vaughan, Coston and Krouse 1987). Despite current pollution control measures and stricter environmental laws, toxic organic and inorganic chemicals continue to be introduced into marine and estuarine environments.

Oil and Gas Operations in the Gulf of Mexico

Structures placed or anchored on the Outer Continental Shelf (OCS) to facilitate oil and gas exploration, development and production include drilling ships (jack-ups, semi-submersibles and drill ships), production platforms and pipelines. Such structure placement disturbs some area of the bottom directly beneath the structure. If anchors are deployed, the bottom habitat (immediately under the anchors and about one-third of the anchor chain) is directly impacted. Jack-up rigs and semi-submersibles are generally used to drill in water depths less than 1,300 ft. (400 m) and disturb about four ac (2 ha) each. In water depths greater than 1,300 ft (400 m), dynamically positioned drill ships disturb little bottom. Conventional, fixed platforms installed in water depths less than 1,300 ft (400 m) disturb about five ac (2 ha). Tension leg platforms, installed by tethers in water depths greater than 1,300 ft (400 m), disturb about 12 ac (5 ha). Placement of pipelines disturb an average of 0.8 ac (0.32 ha) per kilometer of pipeline (MMS 1996).

Each exploration rig, platform and pipeline placement on the OCS disturbs some surrounding area where anchors and chains are set to hold the rig, structure or support vessel in place. Exploration rigs, platforms and pipe-laying barges use an array of eight 20,000-lb (9,000-kg) anchors and very heavy chain to both position a rig and barge, and to move a barge along the pipeline route. These anchors and chains are continually moved as a pipe-laying operation proceeds. The area actually affected by anchors and chains depend on water depth, wind, currents, chain length and the size of the anchor and chain (MMS 1996).

Conventional, fixed multi-leg platforms, which are anchored into the seafloor by steel pilings, predominate in water depths less than 1,300 ft (400 m). During structure removal, explosives are used to sever conductors and pilings of these structures that were built to withstand probable hurricane conditions over an average 20-year life span. Upon removal, the US Department of Interior Minerals Management Service (MMS) requires severing at 16 ft (5 m) below the seafloor to ensure that no part of the structure will ever be exposed to and interfere with commercial fishing. Possible injury to biota from explosive use extends outward 3,000 ft (900 m) from the detonation source and upward to the surface. Based on MMS data, it is assumed that approximately 70% of removals of conventional fixed platforms in the Gulf in water less than 1,300 ft (400 m) deep will be performed with explosives (MMS 1996). Alternative methodologies such as mechanical cutting and inside burning that might be used to sever pilings of multi-leg structures are often ineffective and are hazardous to underwater workers.

Bottom debris is herein defined as material resting on the seabed (such as cable, tools, pipe, drums and structural parts of platforms, as well as objects made of plastic, aluminum, wood, etc.) that is accidentally lost or thrown overboard by workers from fixed structures, jack-up barges, drilling ships and pipeline placement operations.

Varying quantities of ferromagnetic bottom debris may be lost or thrown overboard during operation. The maximum quantity of bottom debris per operation is assumed to be several tons. Extensive analysis of remote-sensing surveys within developed blocks indicates that the majority of ferromagnetic bottom debris falls within a 1,500 ft (450 m) radius of a site. Current federal regulations require all bottom debris to be cleared from a defined radius around a site after its abandonment unless it is designated an artificial reef site.

Improperly balanced well pressures that result in sudden, uncontrolled release of petroleum hydrocarbons are called blowouts. Blowouts have caused the greatest number of fires, explosions, deaths, injuries, property damage or rig loss (Danenberger 1980, Fleury 1983).

Blowouts can occur during any phase of development: exploratory drilling, development drilling, production or work over operations. Historically, 23% of all blowouts result in oil spills; 8% result in oil spills greater than 50 barrels (bbl); and only 4% result in oil spills greater than or equal to 1,000 bbl. In subsurface blowouts, sediment of all available sizes is resuspended and disturbs the bottom within 1,000 ft (300 m). Sands settle within 1,300 ft (400 m), but finer sediments remain in suspension for periods of 30 days or longer. Fine sediments are distributed over large distances (MMS 1996).

Petroleum Products and Operations

The petrochemical industry along the Gulf coast is the largest in the US. It includes extensive onshore and offshore oil and gas development operations, tanker and barge transport of both imported and domestic petroleum into the Gulf region and petrochemical refining and manufacturing operations (MMS 1996).

As of January 1, 1993, approximately 30,000 oil and gas wells had been drilled, and almost 5,000 platforms were producing on the OCS. In 1993, approximately 300 million bbl of crude oil and 4.6 trillion cf of gas were produced and shipped to shore by pipeline. Although such activity seems extensive, the maritime industry's use of Gulf waters is even greater. Approximately 1.5 billion bbl of crude oil were imported through Gulf waters by tanker in 1993, about five times the volume piped from domestic production. In addition, about 236 million bbl of petroleum products were imported in Gulf waters and 175 million bbl were exported. Although petroleum, both crude oil and petroleum products, is the most common commodity shipped through Gulf waters, vessel traffic associated with other commodities is extensive; the Gulf has four of the top 10 busiest ports in the US, including Houston. All of these offshore activities discharge some form of treated wastewaters into the Gulf and have resulted in accidental spills of both oil and other chemicals (MMS 1996).

The major operational wastes of concern generated in the largest quantities by offshore oil and gas exploration and development include: drilling fluids, cuttings and produced waters. Other major wastes generated include the following: from drilling--waste chemicals, fracturing and acidifying fluids and well completion and work over fluids; from production--produced sand, deck drainage and miscellaneous well fluids (cement, blowout preventer fluid); and from other sources--sanitary and domestic wastes, gas and oil processing wastes, ballast water, storage displacement water and miscellaneous minor discharges (MMS 1996).

Major contaminants or chemical properties of concern in oil and gas operational wastes can include high salinity, low pH, high biological and chemical oxygen demand, suspended solids, heavy metals (including mercury), crude oil compounds, organic acids, priority pollutants and radionuclides. New restrictions on these waste streams were recently implemented by the USEPA (MMS 1996). These contaminants and properties can lead to direct loss and/or harmful effects on managed species, including prey species.

Accidental discharge of oil in coastal and offshore habitat can occur during almost any stage of exploration, development or production on the OCS. Oil spills occur as a result of many causes, e.g. equipment malfunction, ship collisions, pipeline failures, platform (or well) blowouts, human error or severe storms. Many oil spills are not directly attributable to the oil extraction process but are indirectly related to the support activities necessary for recovery and transportation of the resource. In addition to crude oil spills, chemical, diesel and other oil-product spills can occur in association with OCS activities.

Of the various potential OCS-related spill sources, the great majority of the spills have resulted from transportation activities (MMS 1996).

Loss of Barrier Islands and Shorelines

Coastal barriers consist of relatively low landmasses that can be divided into several interrelated environments. The beach consists of the foreshore and backshore. The nonvegetated foreshore slopes up from the ocean to the beach berm-crest. The backshore is found between the beach berm-crest and the dunes and may be sparsely vegetated. The backshore may occasionally be absent due to storm activity. The dune zone or a barrier landform can consist of a single dune ridge, several parallel dune ridges or a number of curving dune lines that are stabilized by vegetation. These elongated, narrow land forms are composed of sand and other unconsolidated, predominantly coarse sediments that have been transported and deposited by waves, currents, storm surges and winds (MMS 1996).

These habitats provide a variety of niches that support many avian, terrestrial and aquatic and amphibian species, some of which are endangered or threatened. Habitat stability is primarily dependent upon rates of geodynamic change in each coastal vicinity. Changes to barrier land forms are primarily due to storms, subsidence, delta abandonment, deltaic sedimentation and human activity. Barrier landform configurations continually adjust in response to prevailing or changing environmental conditions. Man-made obstructions to long shore sediment transport include jetties, groins, breakwaters and bulkheads (MMS 1996).

In Texas from east to west, coastal barriers are found at: the Chenier Plain of Louisiana and Texas; Trinity River Delta; Brazos-Colorado River Delta and its accompanying barrier islands; barrier islands of Espiritu Santo Bay and Laguna Madre; and the Rio Grande Delta (MMS 1996).

Efforts to stabilize the Gulf shoreline have adversely impacted barrier landscapes. Efforts to stabilize the beach with seawalls, groins and jetties have contributed to coastal erosion by depriving downdrift beaches of sediments, thereby accelerating erosion

(Morton 1982). Over the last 20 years, dune and beach stabilization have been accomplished more successfully by using more natural applications such as beach nourishment and vegetative plantings (MMS 1996).

Navigation Projects, Ports, Marinas and Maintenance Dredging

Potential navigation-related threats to habitat located within estuarine waters can be separated into two categories: navigation support activities and vessel operations. The following discussion was taken largely from the Gulf of Mexico Fisheries Management Council (GMFMC) (1998).

Navigation support activities include, but are not limited to, excavation and maintenance of channels (includes disposal of excavated materials); construction and operation of ports, mooring and cargo handling facilities; construction and operation of ship repair facilities; and construction of channel stabilization structures such as jetties and revetments. Potentially harmful vessel operation activities include, but are not limited to, discharge or spillage of fuel, oil, grease, paints, solvents, trash and cargo; grounding/sinking/prop scaring in ecologically/environmentally sensitive locations; exacerbation of shoreline erosion due to wakes; and transfer and introduction of exotic and harmful organisms through ballast water discharge or attachment to hulls.

The most conspicuous navigation-related activity in many estuarine waters is the construction and maintenance of navigation channels and the related disposal of dredged materials. The amount of subtidal and intertidal area affected by new dredging and maintenance dredging is unknown, but undoubtedly great. These activities have adversely affected and continue to adversely affect habitat by modifying intertidal and subtidal habitats. For more extensive dredged features and related disposal sites, hydrology and water flow patterns have also been modified. While the channel excavation itself is usually visible only while the dredge or other equipment is in the area, the need to dispose of excavated materials has left its mark in the form of confined and unconfined disposal sites, including those that have undergone human occupation and development. Chronic and individually small discharges and disturbances routinely affect water and substrate and may be significant from a cumulative or synergistic perspective. Observed effects on habitat include: direct removal/burial of organisms as a result of dredging and placement of dredged material; turbidity/siltation effects, including increased light attenuation from turbidity; contaminant release and uptake, including nutrients, metals and organics; release of oxygen consuming substances; noise disturbance to aquatic and terrestrial organisms; and alteration to hydrodynamic regimes and physical habitat. The relocation of salinity transition zones due to channel deepening may be responsible for significant environmental and ecological change.

The expansion of ports and marinas has become an almost continuous process due to economic growth, competition between ports and increased tourism. Elimination or degradation of aquatic and upland habitats is commonplace since port and marina expansion almost always requires the use of open water, submerged bottoms and riparian zones. Ancillary related activities and development often utilize even larger areas, many of which provide water quality improvement and other functions needed to sustain living marine resources. Vessel repair facilities use highly toxic cleaners, paints and lubricants that can contaminate waters and sediments. Modern pollution containment and abatement systems and procedures can prevent or minimize toxic substance releases; however, constant and diligent pollution control efforts must be implemented. The extent of the impact usually depends on factors such as flushing characteristics, size, location, depth and configuration. For example, it is common for a prohibition on human consumption of marine products taken from shellfish beds in proximity to marinas.

The GIWW serves as the primary route for barges carrying needed goods, supplies and energy. The cargo may be diverse and ranges from highly toxic and hazardous chemicals and petroleum products to relatively benign materials. Spills (major and minor) and other discharges of hazardous materials are not uncommon and are of constant concern since large and significant areas of wetlands and SAV habitat is at risk.

Maintenance and dredged material disposal to maintain navigable depths for vessels is a major issue at all port facilities and for many marinas. In many cases, dredged materials are contaminated and disposal locations for these sediments are not readily available. Often offshore disposal for clean and contaminated sediments is proposed and for some of the major ports, dredged material disposal sites have been used offshore. Still, contaminated sediments remain an issue as does the effects of these materials on offshore systems.

The operation of vessels, both commercial and recreational, also threatens habitat. The USEPA (1993) identified a suite of possible adverse environmental impacts and pollutants discharged from boats; pollutants generated from boat maintenance activities on land and in the water; exacerbation of existing poor water quality conditions; pollutants transported in storm water runoff from parking lots, roofs and other impervious surfaces; and the physical alteration or destruction of wetlands and shellfish and other bottom communities during the construction of marinas, ramps and related facilities.

The chronic effects of vessel groundings, prop scarring and anchor damage are generally more problematic in conjunction with recreational vessels. While grounding of ships and barges is less frequent, individual incidents can have significant localized effects. Propeller damage to submerged bottoms occurs everywhere vessels ply shallow waters. Direct damage affects multiple life stages of associated organisms including: eggs, larvae and juveniles, and indirect damages are caused through water column de-stratification (temperature and density), re-suspending sediments and increasing turbidity. Damage is particularly troublesome where SAV is found.

The effects of vessel induced wave damage have not been quantified, but may be extensive. The most damaging aspect relates to the erosion of intertidal and SAV wetlands adjacent to marinas, navigation channels and boating access points such as docks, piers and boat ramps. The wake erosion in places along the GIWW and elsewhere is readily observable and undoubtedly converts a substantial area of wetlands to less important habitat (e.g. marsh to submerged bottom). In heavily trafficked submerged areas, bottom stability is constantly in flux and bottom communities may be weakened as a result. Indirect effects may include the resuspension of sediments and contaminates that can modify ESH. Where sediments flow back into existing channels, the need for maintenance dredging with its attendant impacts may be increased.

Marinas and other sites where vessels are moored or operate often are plagued by accumulation of anti-fouling paints in bottom sediments, fuel spillage and overboard disposal of trash, sewage and wastewater. This is especially troubling in areas where houseboats have proliferated without authorization. Boating and operations at these facilities (e.g. fish waste disposal) may lead to lowered dissolved oxygen, increased temperature, bioaccumulation of pollutants by organisms, water contamination, sediment contamination, resuspension of sediments, loss of SAV and estuarine vegetation, change in photosynthesis activity, change in the nature and type of sediment, loss of benthic organisms, eutrophication, change in circulation patterns, shoaling and shoreline erosion. Pollutants that result from marinas include nutrients, metals, petroleum hydrocarbons, sewage and polychlorinated biphenyls. However, in areas where vessels are dispersed and dilution factors are adequate, the water quality impacts of boating are likely mitigated (USEPA 1993).

Marina personnel and boat owners use a variety of boat cleaners, such as teak cleaners, fiberglass polish and detergents. Cleaning boats over the water, or on adjacent upland, creates a high probability that some cleaners and other chemicals will enter the water. Copper-based antifouling paint is released into marina waters when boat bottoms are cleaned in the water. Tributyl-tin, which was a major environmental concern, has been largely banned except for use on military vessels. Fuel and oil are often released into waters during fueling operations and through bilge pumping. Oil and grease are commonly found in bilge water, especially in vessels with inboard engines, and these products may be discharged during vessel pump out (USEPA 1993).

Another problem associated with commercial and recreational boating activities in coastal environments is the discharge of marine debris, trash and organic wastes into coastal waters, beaches, intertidal flats and vegetated wetlands. The debris ranges in size from microscopic plastic particles (Carpenter, Anderson, Harvey, Milkas and Peck 1972), to mile-long pieces of drift net, discarded plastic bottles, bags, aluminum cans, etc. In laboratory studies, Hoss and Settle (1990) demonstrated that larval fishes consume polystyrene microspheres. Investigations have also found plastic debris in the guts of adult fish (Manooch 1973, Manooch and Mason 1983). Based on the review of scientific literature on the ingestion of plastics by marine fish, Hoss and Settle (1990) conclude that the problem is pervasive. Most media attention given to marine debris and sea life has focused on threatened and endangered marine mammals, turtles and birds. In these cases, entanglement in or ingestion of animals caught in the netting, fishing line, plastic bags or other materials is of great concern.

Pipeline Crossings and Rights-of-Way

Pipeline and navigation canals have the potential to change the natural hydrology of coastal marshes by: 1) facilitating rapid drainage of interior marshes during low tides or low precipitation, 2) reducing or interrupting fresh water inflow and associated littoral sediments and 3) allowing salt water to move farther inland during periods of high tide (Chabreck 1972). Saltwater intrusion into fresh marsh often causes loss of salt-intolerant emergent and submerged-aquatic plants (Chabreck 1981, Pezeshki, DeLaune and Patrick 1987), erosion and net loss of soil organic matter (Craig, Turner and Day 1979). Because vegetated coastal wetlands provide forage and protection to commercially important invertebrates and fishes, marsh degradation due to plant mortality, soil erosion or submergence will eventually decrease productivity. Vegetation loss and reduced soil elevation within pipeline construction corridors should be expected with the continued use of current double-ditching techniques (Polasek 1997).

Pipeline landfall sites on barrier islands potentially cause accelerated beach erosion and island breaching. A MMS study and other studies (LeBlanc 1985; Mendelssohn and Hester 1988) have investigated the geological, hydrological and botanical impacts of pipeline emplacement on barrier land forms in the Gulf. In general, the impacts of existing pipeline landfalls were minor to nonexistent. In most cases, due to new installation methods, no evidence of accelerated erosion was noted in the vicinity of the canal crossings if no shore protection for the pipeline was installed on the beach (MMS 1996).

Numerous pipelines have been installed on the bay side of barrier islands and parallel to the barrier beach. With overwash and Gulf shoreline retreat, many of these pipeline canals serve as sediment sinks, resulting in narrowing and lowering of barrier islands and their dunes and beaches. Such islands and beaches are more susceptible to breaching and overwash (MMS 1996).

Inland, pipelines cross open water, wetlands, levied-land and upland habitats. The number, type and length of pipelines that cross open water and wetlands are unknown but are estimated to be in the tens of thousands, up to 40 in (100 cm) in diameter, and from thousands of feet to hundreds of miles in length, throughout the Gulf Coast. New pipeline canals through wetlands are typically 10 ft (3 m) wide, which is necessary for the push-ditch method of pipeline construction (Turner and Cahoon 1988). Since 1970, backfilling newly dredged pipeline canals has been required by permitting agencies. Typically, installation of a new pipeline through wetlands disturbs a 100-ft (30-m) wide path through the vegetation. After being backfilled, the right-of-way may revegetate or remain as shallow open water. This remaining impact is estimated to be a water channel five ft (2 m) wide in wetland areas (MMS 1996).

Ocean Dumping

No legal ocean dumping of industrial and commercial waste material occurs in the Gulf. The Gulf-wide artificial reef building program instituted by the Gulf States is not considered ocean dumping.

Dredge and Fill

Dredging is the excavation of earthen materials from wetlands, open surface water areas or in uplands where wetlands or other surface waters are created. Filling involves the deposition of any material (such as sand, silt, dock pilings or seawalls) into wetlands or other surface water areas.

Dredge and fill activities are regulated to protect our surface waters from degradation caused by the loss of wetlands and from pollution caused by construction activities. Alterations of wetlands and other surface waters may have detrimental impacts on the environment. Degrading or eliminating can cause a reduction of beneficial functions provided by the wetlands. Texas has about 1,000 mi (1,800 km) of navigational channels (Lindall and Saloman 1977). Spoil disposed from these channels has created 86,900 ac

(35,200 ha) of fill in the state, and maintenance generates 1.3 trillion cf (36.6 million m^3) of dredged material per year.

Traditional dredging and dredged material disposal practices can directly eliminate, displace, or adversely modify habitat through conversion to deep-water coverage, erosion and turbidity effects. However, dredged materials can also be used in a variety of beneficial manners such as creating, restoring or enhancing estuarine habitats and building bird-nesting islands. Obstacles to the use of dredged materials such as agency regulation, public resistance, availability of dredged materials and costs can be overcome.

Under the Marine Protection Research and Sanctuaries Act (MPRSA), the USEPA and the Corp of Engineers (COE) share a number of responsibilities with regard to the ocean disposal of dredged material. This involves: 1) designating ocean sites for disposal for dredged material; 2) issuing permits for the transportation and disposal of the dredged material; 3) regulating times, rates and methods of disposal and the quantity and type of dredged material that may be disposed of; 4) developing and implementing effective monitoring programs for the sites; and 5) evaluating the effect of dredged material at the sites.

The principal authority and responsibility for designating ocean sites for the disposal of dredged material is vested with the Regional Administrators of the USEPA Regions in which the sites are located. The Regions are responsible for developing and publishing Environmental Impact Statements (EIS) and the rulemaking paperwork associated with ocean disposal site designations. The COE Districts provide the USEPA Region with the necessary information to prepare the EIS and identify any significant issues that should be addressed in the site designation process, generally through a scoping process.

Offshore dredging for sand, gravel and shell locally destroys bottom habitat that may eventually recover. Large-scale removal of coarse materials would eliminate protective cover and change the nature of the bottom habitat. Dredging near shores could remove protective barriers and result in greater erosion of the beach. In addition to extraction of substrate, addition of substrate, such as "beach replenishment" and "beach nourishment" can also be highly disruptive and destructive in the adjacent nearshore areas, especially if this substrate addition results in burial or sediment overlay of live/hardbottom, coral and/or seagrasses. Extraction of chemicals from seawater is not known to cause significant environmental damage except for loss of coastal habitat where the extraction plant is located. If solar evaporation of seawater is involved, extensive land areas may be utilized as evaporation pans (Darnell, Pequegnat, James, Benson and Defenbaugh 1976).

Hydromodification, wetland dredge and fill modifications, natural subsidence and apparent sea level rise, is strongly altering the Gulf's coastal water quality. These activities result in sediment deficit and saltwater intrusion. Saltwater intrusion is defined as the inland movement of offshore saline waters into more brackish and fresh waters. It is estimated that millions of cubic feet of material are dredged each year to support oil and gas projects in the Gulf area. Dredged material disposal results in temporarily increased turbidity and resuspension of released sediment contaminants into coastal waters (MMS 1996).

Exotic Species

The introduction of non-native species into an environment, including coastal and marine habitats, can have a variety of impacts ranging from benign to causing serious disruptions of biological communities. Some of these impacts may include: competition with, predation on, or displacement of native species; habitat disruption; introduction of diseases; and disruption of food webs. The National Research Council (NRC) in 1995 reviewed the most critical threats to marine biodiversity and stated that invasion of exotic species was among the top five issues facing coastal ecosystems (Carlton 1997). Exotic species can actually be viewed as a form of biological pollution; however, unlike chemical contaminants, exotic species may continue to proliferate long after they are introduced (GMP 1997). Some species may experience explosive population expansion since they may be unaffected by predators, parasites or competitors in their new environment.

Some exotic species may enter new environments through natural range expansion. However, of most concern environmentally are those introductions that are facilitated by human actions, either intentionally or unintentionally. Common mechanisms by which exotic species are introduced into coastal and marine environments include: vessel or other structural transport (i.e. on or within hulls or as ballast); aquaculture activities; fisheries stocking releases; research activities; and canals (Carlton 1997).

To date there have been few formal investigations of exotic species introductions into the Gulf and its coastal habitats. Balboa (1991) evaluated the potential harm of exotic shrimp (*Litopenaeus vannamei,* formerly *Penaeus vannamei*) on native shrimp populations and habitat, which were discovered in the Brownsville (TX) Ship Channel in 1989. Of six criteria used for determining potential harm, this species exhibited at least four: 1) potential for establishing self-sustaining populations, 2) potential for adversely affecting native penaeids and predators that feed on shrimp, 3) disease transmission, and 4) morphological similarity with native and other exotic penaeids. The discovery of this exotic shrimp and its potentially adverse effects on native shrimp populations led to the adoption of regulatory measures by the TPWD Commission in 1990. The Texas Legislature, in Parks and Wildlife Code (Chapters 61, 66 and 77), gives the Commission authority to regulate the possession and sale of exotic fish and shellfish and mandate health certifications of native penaeid shrimp.

Fishing Impacts

Bottom trawling and other fishing activities that involve direct contact between fishing gear and the bottom environment in the bays, estuaries and Gulf can alter the structural character and function of shrimp habitats. When the change is sufficient to preclude or limit use by fishery- directed or target species, declines in catch abundance and individual animal size may occur. Although a clear cause and effect relationship is evident, determination of the exact nature of this relationship is complex. Relevant factors, in addition to the magnitude of the direct physical change, may include disturbance frequency and duration, seasonality and other environmental, ecological and physiological processes that control recovery and recruitment of marine species of the community. As noted by Auster and Langton (1998) "... mobile fishing gear reduced habitat complexity by (1) directly removing epifauna or damaging epifauna leading to mortality, (2) smoothing sedimentary bedforms and reducing bottom roughness and (3) removing taxa which produce structure [i.e. taxa which produce burrows and pits].”

Environmental changes brought about by physical alteration of substrates and changes in species composition may create conditions that cannot sustain preexisting plant and animal assemblages or abundances. Auster and Langton (1998) state population response (and successful fishery management) may be linked to parameters that are closely correlated to “...ecological relationships (and) population response may be the result of : 1) independent single-species (intraspecific) responses to fishing and natural variation; 2) interspecific interactions such that, as specific populations are reduced by fishing, non-harvested populations experience a competitive release; 3) interspecific interactions such that as non-harvested species increase from some external process, their population inhibits the population growth rate of the harvested species; and 4) habitat mediation of the carrying capacity for each species, such that gear induced habitat changes alter the carrying capacity of the area.” As further implied by Auster and Langton (1998), the magnitude of environmental or ecological change needed to affect a fishery may not need to be monumental from a physical perspective.

In Texas waters, bottom trawling for shrimp is the dominant commercial fishing activity. The effects of bottom trawling have been discussed since the 14^{th} century (Jones 1992). This method of fishing disrupts the habitat by scraping the substrate to depths from a few inches to a foot or more. Many studies have documented this affect along with more direct impacts on the benthic communities (Rester 2000). Some of the effects documented include:

1. Disruption of vast areas of bay and Gulf bottom sediments,
2. Resuspension of sediments into the water column creating potential respiration problems for biota with gills,
3. Physical destruction of biota (flora and fauna) through direct contact,
4. Destruction of biota due to uncovering and exposure,
5. Changes in benthic communities, from short to long term (decades),
6. Elimination of species from some trawled areas,

7. Dumping and accumulation of dead bycatch,
8. Alteration of bottom topography,
9. Reduced biotic diversity,
10. Increased dominance by a few species.

Research has documented that these changes are dependent on several variables including weight of the gear, towing speed, sediment type, frequency of disturbance and currents and tides (Jones 1992). Some of the changes in the benthos can be permanent. This permanence may be related to the frequency of the disturbance and the attributes of the species involved. And in deep water (over 3,000 ft; 1,000 m), the recovery of these communities may take decades. Also, some epifaunal groups were more abundant in areas receiving the least amount of trawling. Norse and Watling (1999) described bottom trawling as similar to clear-cutting but more extensive, converting large areas of biologically complex communities into the marine equivalent of low-diversity cattle pasture. It is clear from the literature that the effects of bottom trawling on bottom habitat and the associated communities are complex and severe.

A recent review of the effects of trawling on bottom habitat and associated biota (NRC 2002) complemented earlier findings. The authors reiterated that fishing gears, "…will impact the flora and fauna of a given location to a certain degree, but the magnitude and duration of the effect depends on a number of factors, including gear configuration, towing speed, water depth and the substrate over which the tow occurs". Recovery times can be up to five times the generation time of the biota involved. Depending on the species this can be less than a month to decades or even centuries in the case of some corals. The more frequently an area is trawled the longer the recovery time could be. Finally, the more complex and stable the biotic community, the longer the recovery period can be expected to be. Short-lived, very mobile species can be expected to recover more quickly than long-lived immobile species.

Using data from TPWD and the National Marine Fisheries Service (NMFS), estimates were made on the area of bay bottom trawled by shrimping activities. These estimates are very conservative, since they did not include shrimp bait fishery activity. For 1998, it was estimated that a total of 8,726,336 ac (3,534,166 ha) of bay bottom was trawled in Texas bays. This included areas that were trawled numerous times. Data indicated that the impact is greatest along the upper coast relative to the lower coast, both in terms of repetition rate and area trawled. Clearly, bottom trawling represents a significant impact on public-owned bay bottom habitat (ESH) in Texas waters.

Similar estimates were derived for Gulf bottom habitat in Texas waters out to 10 fathoms (60 ft; 18 m). It was estimated that 19,075,281 ac (7,725,489 ha) were trawled in 1998, some of it repetitively. Typically, as in the bays, the portions covered repetitively are those areas where shrimp congregate, indicating habitat preferred by shrimp under some conditions. This likely means that other species also frequent the area and thus the trawling activity is affecting more than shrimp. This last aspect is held in common with bay trawling effects.

Repetition rates, the number of times an area was covered in specific time periods, were also estimated for both bay and Gulf shrimping fleets. Trawlable bay areas were trawled at least 4-8 times for each bay system each year. For the nearshore Gulf these estimates ranged from zero to more than six. It is apparent from these estimates that at certain times of the year bottom trawling for shrimp repeatedly disrupts certain areas. The literature suggests this could mean significant disruption in the bottom dwelling biotic communities, specifically the targeted species (shrimp), with possible long recovery times.

Aquaculture Effluent Discharges

Aquaculture is a rapidly growing industry that has been plagued with social, economic and environmental problems (Boyd 1999). Before 1999, shrimp farmers pumped hundreds of millions of gallons of water per day through production ponds to ensure clean water and high dissolved oxygen in the ponds. These flow-through systems exported most, if not all, of the burden of waste to the receiving waters. Aquaculture wastes consist primarily of uneaten fish food, fecal and other excretory wastes. These wastes are a source of organic matter (nitrogen and phosphorus) which result in high concentrations of biochemical oxygen demand (Goldburg and Triplett 1997, Boyd 1999).

The large volumes of water used in these flow-through systems also resulted in high discharges of total solids, siltation and increased turbidity in receiving waters. Increased turbidity and suspended solids shaded and suffocated grass beds and created siltation buildups in the effluent discharge area.

Since 1999, shrimp farmers have reduced the amount of water they pump through their farms for a number of reasons and realize that good yields can be obtained with little or no water discharge. Wastewater discharge also permits incentives to clean and reuse water. Farmers can lower their operational costs by pumping less water and they may achieve better production rates by reusing water and operating more cleanly. Reduced flow-through also decreases the possibility of introducing White Spot Syndrome virus into the wild shrimp population.

The water re-use method of production greatly reduces the need for the continuous flow of water through the production ponds even though the hatchery industry is still permitted to discharge millions of gallons each year. Shrimp farmers have been able to reduce the amount of effluent discharged into public waters through the use of artificial wetlands, settlement holding ponds and canals to clean wastewater. Water treated using this method has several advantages: 1) reduces the amount of water pumped from public waters, 2) reduces the amount of effluent discharged into public waters, 3) reduces the risk of introducing diseases from outside the farm, 4) continues production and harvest even if diseases are present on the farm, and 5) reduces waste and suspended solids before water is discharged into public waters.

Wetland Impoundment and Water Management

Coastal wetlands are highly productive habitats that are the transition zone between upland and open water. Since wetlands have both upland and aquatic characteristics, they are often more productive than other habitats (Moulton and Jacob 2000). Coastal wetlands reduce the frequency and severity of flooding, act as buffers reducing shoreline erosion and are important nurseries for recreationally and commercially important species including shrimp.

Texas coastal wetlands decreased about 9.5% between the mid-1950's and early 1990's, with an estimated net loss of 59,600 ac (24,130 ha) (Moulton et al. 1997). These losses were due to both natural and man-made causes. Natural causes for loss of wetlands include subsidence and sea level rise. The greatest threats to wetlands caused by man include industrial development; urban and suburban sprawl; subsidence caused from mining of oil, gas and water; and reduced fresh water inflow into deltas caused by reservoir construction (Duke and Kruczynski 1992, Moulton and Jacob 2000).

Hydrology

Hydrology in Texas bays and estuaries is influenced by climatic conditions, fresh water inflow and tidal exchange. Tidal exchange in Texas bays and estuaries is due to astronomical tides and weather conditions (primarily wind). Water exchange between the Gulf and estuaries is primarily the result of wind-driven tides. In addition, channelization has occurred in Texas tributaries and estuaries. This action has the effect of changing historical water flow patterns both spatially and temporally.

Freshwater Inflows

The crucial need for freshwater inflows to Texas bays and estuaries was first recognized by Hildebrand and Gunter (1953). An overview of the value of freshwater inflows to the estuarine habitat was presented by Powell (in Longley 1994) and is summarized below.

In summary, freshwater inflow affects estuaries at all basic levels of interaction with physical, chemical and biological effects. The functional flow of freshwater to the ecology of estuarine environments has been scientifically reviewed and effects on these living coastal systems were found to include:

1. Dilution of seawater to brackish conditions;
2. Dilution and transport of harmful materials and contaminants;
3. Creation and maintenance of low salinity nursery habitats for all biota;
4. Moderation of bay water temperatures;
5. Reduction of metabolic stresses and the energy required for osmoregulation (regulation of internal body salts) in estuarine-dependent organisms;

6. Provision of a medium for the transport of beneficial sediments and nutrients, the biogeochemical cycling of essential primary nutrients (carbon, phosphorus and nitrogen), and the removal of metabolic waste products from living organisms;
7. Modification of concentration-dependent chemical reactions, ion-exchange and flocculation (coagulation and precipitation) of particles in the saltwater environment;
8. Creation of a resource-partitioning mechanism among estuarine plants and animals as a result of the combined effects of inflow on salinity, temperature and turbidity of bay waters;
9. Distribution (horizontal displacement) and vertical movement of organisms in the water column related to the stimulation (release) of a positive phototaxic or negative geotaxic behavioral response;
10. Creation of a cutting and filling mechanism that affects both erosion and deposition in the bays and estuaries;
11. Creation of a salt-wedge and mixing zone in concert with tidal action from the ocean;
12. Transportation of allochthonous (external) nutritive materials (organic detritus from decaying plant and animal tissues) into bays and estuaries as a function of land surface topography, amount of rainfall and size of the drainage area;
13. Migration (timing of arrivals and departures) and orientation (direction of movement) of migratory organisms like the penaeid shrimps and many marine fishes and
14. Stimulation of some plants and animals that may be considered less desirable or even a nuisance to man such as red tide organisms (see algal blooms section), the Eurasian water milfoil, the South American water hyacinth and the Chinese grass carp.

As Texas continues with water planning it is becoming more evident that providing water for all user groups, including beneficial instream and estuarine uses, will be difficult. The needs of tributaries and estuaries are not universally considered to be of major importance. Powell (in Longley 1994) also described some of the major effects of reduced inflows due to droughts, dams or diversions:

1. Increased salinity of bay, estuary and neritic (nearshore) marine waters;
2. Reduced mixing due to salinity differences and stratification of the water column;
3. Penetration of the salt-wedge further upstream allowing greater intrusion of marine predators, parasites and diseases;
4. Saltwater intrusion into coastal ground and surface water resources used by man;
5. Diminished supply of essential nutrients to the estuary from inland or local terrestrial origins;
6. Increased frequency of benthic sediments becoming anaerobic, liberation of toxic heavy metals into the water column that had been sequestered in the benthic substrates and sulphur cycle domination;
7. Reduced inputs of particulates and soluble organic matter with flocculation and deposition of the particles locally rather than being more widely dispersed throughout the estuarine ecosystem;
8. Loss of economically important seafood harvests from coastal fisheries species for a variety of reasons related to high salinity conditions, reduced food supply and loss of nursery habitats for the young;
9. Loss of characteristic dominance of euryhaline species in the bays and estuaries to stenohaline species as natural selection occurs for species more fully adapted to marine conditions in general (see salinity section);
10. Increased populations of salt-tolerant mosquitoes and flies;
11. Increased incidence of human diseases such as cholera caused by the bacteria *Vibrio cholerae* in improperly cooked seafood;
12. Deterioration of salt marshes, mangrove stands and seagrass beds if under constantly elevated salinities;
13. Loss of sand/silt renourishment of banks and shoals resulting in erosion;
14. Alteration of littoral drift and nearshore circulation patterns and

15. Aggravation of all negative effects during low-flow (drought) periods with increasing severity as the frequency of occurrence increases.

Dilution of marine water by fresh water and the supply of nutrients and sediments are the three major influences that rivers and streams have on estuaries. Changes in dissolved oxygen, water temperature and pH are induced by altered inflows (USEPA 1994a). Accompanying these hydrological changes are the more substantial changes in nutrient and sediment loads associated with altered freshwater inflow that can result in disruption of the nursery function of an estuary by affecting food and habitat availability. Biodiversity and productivity of estuarine ecosystems are also disrupted by the lack of fresh water inflow (Longley 1994). Various studies have shown that changes in phytoplankton, zooplankton and benthos, as well as fish and invertebrates, are associated with alterations in freshwater inflow. Clearly the effects of fresh water inflows affect the entire marine ecosystem.

The influx of fresh water is also important for the process of circulation and flushing in estuaries. In some estuaries, horizontal density gradients established by freshwater inflows combine with winds and tides to drive circulation in the estuary. The resulting currents and related flushing rates not only influence water quality, but are also instrumental in transporting planktonic organisms throughout the estuary. Secondarily, planktonic organisms and detritus are flushed into the Gulf, providing food for those organisms that do not enter the estuaries (USEPA 1994a).

Construction of large-scale water development projects has the potential for depriving bays and estuaries of needed freshwater, with the concomitant nutrients, sediments and salinity buffering.

Of concern when evaluating applications for water diversions is the volume of water available. For each tributary there are estimates of the normal or average volume in the streambed. It is also known as to how much water is already “reserved” for other permits. The difference between these existing permit volumes and the known volume in the tributary is the volume available to be reserved for future permit applications. For these reasons it is imperative to accurately document water availability and current permitted volumes for each tributary. Specific mean annual freshwater inflows by Texas bay systems are shown below in Table 2.

Table 2. Mean annual freshwater inflows into Texas bay systems (TWDB 2002).

Texas Bay System	Mean Annual Inflows (ac-ft)
Sabine-Neches	13,809,408
Trinity-San Jacinto	10,041,210
Lavaca-Colorado	3,080,301
Guadalupe	2,344,140
Mission-Aransas	439,388
Nueces	598,126
Upper Laguna Madre	173,384
Lower Laguna Madre	434,543

In addition to having an adequate quantity of water to meet all user needs, timing of withdrawals is critical. For municipalities, reservoirs of some type are necessary to meet peak demand periods. Agricultural users most often need large volumes of water during the growing season and little or none during the cold months. A management tool to assure that instream and estuarine inflow needs are met when needed is to incorporate special conditions in state permits to store, take or divert water. In general, these conditions will regulate the quantity and timing of the permitted water use. Timing of water diversions and inflows for all users is critical and complicates the issue of satisfying all needs. Reservoirs alter the quantity and pattern of freshwater inflows over time. This is the normal mechanism that regulates the salinity of estuarine waters and the inflow of nutrients and sediments. Reservoirs are almost always destructive for the native environment, both instream and estuarine.

As the human population in Texas continues to increase, conflict between municipal and commercial water user demands and the freshwater inflow needs of the bays and estuaries will only escalate. The combined municipal, agricultural and industrial water use will grow and water managers will be pressured to reduce dam pass-throughs. When droughts occur, water managers will initiate drought release programs. This will result in estuaries receiving only the amount of water necessary to maintain safe water quality in the tributary. This volume of water will not maintain the salinity gradients within the estuary enough to allow biota to disperse spatially. The end result is that mobile animals requiring low salinities (e.g. white shrimp and blue crab) will congregate in the upper reaches of the estuary, near the mouths of tributaries, creating overcrowded conditions and extreme pressures on the local food supply and space. This effectively reduces the carrying capacity of the estuary for these species.

At the November 2000 Gulf of Mexico Fisheries Management Council (Council) meeting, the Council approved a recommendation by the Texas Habitat Protection Advisory Panel to develop a freshwater inflow policy. The policy was developed by the Gulf States Marine Fisheries Commission (GSMFC) Habitat Subcommittee (Appendix B). Once approved by the GSMFC Commissioners, the policy will go back to the Council for approval and adoption. Texas Parks and Wildlife Department has reviewed the policy and modified the draft to accommodate Texas' freshwater issues.

Channelization

Channels, such as the GIWW, have major impacts on navigation, commerce and marine habitat in Texas. The GIWW is a coastal canal from Brownsville, Texas, to the Okeechobee waterway at Fort Myers, Florida. The Texas portion of the canal system extends 426 mi (685 km), from Sabine Pass to the mouth of the Brownsville Ship Channel at Port Isabel. The GIWW is part of a national system of waterways that extends along the US coast. It originated in the federal 1873 Rivers and Harbors Act that called for detailed surveys of the Texas coast. Construction of the GIWW began in 1905 when canals were dredged to a depth of five ft (1.5 m) and a width of 40 ft (12 m) along some parts of the Gulf Coast. By 1909, the GIWW extended from Corpus Christi to Aransas Pass, from Aransas Pass to Pass Cavallo and from the Brazos River to West Galveston Bay. In 1934, the GIWW was extended from Galveston Bay to the Sabine River. Finally, in 1949, the last reach of the waterway was completed from Corpus Christi to Brownsville, thus forming a continuous waterway from Apalachee Bay, Florida, to the Mexican border. By 1961, nearly 90 tributaries had been incorporated into the GIWW system, more than half of these in Texas and Louisiana (Leatherwood 2002).

Navigational channels such as the GIWW, local ship channels and recreational navigation lanes alter circulation patterns. This can cause shoaling of natural passes as water follows the path of least resistance represented by the deeper channels. These channels can also facilitate intrusion of saltier Gulf water further into the upper estuaries. This reduces the amount of low-salinity habitat for shrimp species like white shrimp. Clearly, channelization, whether in the tributaries or in the bay, has the potential to disrupt the habitat and inhabitants.

The GBNEP determined that channelization for flood control "destroys wetland habitats, alters streamflow patterns and provides a speedy vehicle for transport of non-point source pollution to the Bay" (GBNEP 1998). The CCBNEP has identified spoil placement from channelization efforts as a cause of wetland loss. Altered circulation was also attributed to channelization and placement of spoils (Bearden 2001).

Dams and Springs

The effects of on-channel dams on estuaries are many. They function as nutrient and sediment traps; accentuate floods and droughts; change tributary temperature and flow regimes downstream; and interrupt migration upstream.

There are 80,000 mi (129,000 km) of rivers and streams in Texas that support unique and valuable estuarine communities (e.g. ESH). Texas, which has only one natural lake, Caddo, now has over 190 reservoirs that provide important recreational and fisheries benefits. However, 30% of Texas native fish are endangered, some now extinct, primarily because of that development. Native species are also endangered due to changes in their habitat resulting from the introduction of non-indigenous species. Changes in annual flooding patterns and interrupted flow impact both riverine and estuarine ecosystems. Continued water development, diversions and flood control will increasingly impact this habitat. Pollution from wastewater, non-point sources and spills are ongoing threats.

The timing, volume and quality of fresh water inflows have direct effects on the overall health of an estuary and its living marine resource habitats. Fresh water inflows to Texas bays have been drastically reduced through the construction of large reservoirs. For example, Nueces Bay often goes hypersaline. This condition has been attributed to reduced fresh water in the drainage from the construction of the Choke Canyon Reservoir. Continued population growth will place more demand on the state's limited fresh water supply. Reduced inflows will significantly alter salinity gradients, circulation patterns and nutrient levels within the bays and can affect habitat such as wetlands and oyster reefs. These alterations can also alter the distribution and abundance of fish and shellfish species that inhabit the bays.

Springs and spring runs have unique characteristics and are natural settings for many rare and unusual species. A significant number of Texas springs have gone dry from man's activities. Over-pumping of groundwater for irrigation and human use has led to lowered groundwater tables and decreased or ceased spring discharge (e.g. Edward's aquifer in the Austin area). Texas historically had 281 major springs. By 1973 only two of four very large and 17 of 31 large springs were still flowing. Increasing pressures on groundwater and aquifers will continue to impact existing springs affecting associated flora and fauna and indirectly, ESH.

Mitigation of hydrologic modification projects can be achieved by design modifications to minimize direct and indirect impacts. Modifications can make beneficial use of dredged materials and marsh management or flood control operations to reduce restrictions to fishery ingress and egress. Design modifications could also include avoiding construction which would alter water flow through estuarine wetlands (i.e. avoid ponding or draining wetlands), reducing the extent of dredging and filling, using dredged material to restore wetlands, gapping or degrading spoil banks and plugging canals.

Point and Non-point Source Pollution

Point-source discharges from commercial and industrial development and operations follow the same risks imposed for urban and suburban development. Industrial point-source-discharges are of greater concern because of their quantity and content. They can alter the diversity, nutrient and energy transfer, productivity, biomass, density, stability, connectivity, species richness, and evenness of ecosystems and the communities at the discharge points and further downstream (Carins 1980). Growth, visual acuity, swimming speed, equilibrium, feeding rate, response time to stimuli, predation rate, photosynthetic rate, spawning seasons, migration routes, and resistance to disease and parasites of finfish, shellfish and related organisms also may be altered. In addition to direct effects on plant and animal physiology, pollution effects may be related to changes in water flow, pH, hardness, dissolved oxygen, and other parameters that affect individuals, populations and communities (Carins 1980). Some industries, such as paper mills, are major water users and the effluent dominates the conditions of the rivers where they are located. Usually, parameters such as dissolved oxygen, pH, nutrients, temperature changes and suspended materials are the factors that an effect on healthy habitat. The direct and synergistic effects of other discharge components such as heavy metals and various chemical compounds are not well understood, but preliminary results of research are showing that these constituents will be a major concern for the future. More subtle factors such as endocrine disruption in aquatic organisms and reduced ability to reproduce or compete for food are being observed (Scott et al. 1997). Mercury was found to be high in Matagorda Bay, Texas due to major discharge of this element in the area in the 1960's (NOAA 1992a).

A report by NOAA National Status and Trends Program (NST) examined data from six different electronic information systems maintained by USEPA and NOAA and evaluated the spatial distribution of sediment contamination (Daskalakis and O'Connor 1994). The report concluded that the Gulf has more areas with high concentrations than other US coasts. It states that most of the six databases provide chemical concentrations that were measured near effluent discharge sites while the NOAA database provides chemical concentrations that were measured at randomly selected points along the Gulf coast. Given that the Gulf has the greatest number of waste discharge point sources; it is not surprising that the Gulf would show a larger number of sites with 'high' levels of contamination than do other regions (MMS 1996).

The cumulative effect of many types of discharges on various aquatic systems is not well understood, but attempts to mediate their effects are reflected in various water quality standards and programs in Texas. Industrial wastewater effluent is regulated by the USEPA through the National Pollutant Discharge Elimination System (NPDES) permitting program. This program provides for issuance of waste discharge permits as a means of identifying, defining and controlling virtually all point-source-discharges. The complexity and magnitude for administering the NPDES permit program limits overview of the program and federal agencies such as the NMFS and the US Fish and Wildlife Service (USFWS) generally do not provide comments on NPDES permit notices. For these same reasons, it is not possible to presently estimate the singular, combined and synergistic effects of industrial (and domestic) discharges on aquatic ecosystems.

The use of toxic chemicals such as Malathion, an organo-phosphate for coastal mosquito control spraying, is administered by USEPA under the Federal Insecticide, Fungicide, and Rodenticide Act (Amended 1988). In Texas, USEPA has delegated the oversight authority to the state of Texas, through the TCEQ, for the setting of application rates and amounts. Following major coastal spraying events public comments are received complaining of mortality to finfish, shellfish and other estuarine organisms. Texas has no program to respond to these reports or to test the estuaries for potential cumulative toxic impacts.

An illustration of the extremely toxic effects of industrial discharges of heavy metals into bays and estuaries is the current mercury pollution of approximately one-third of Lavaca Bay. The ALCOA Point Comfort Operations (PCO) began as an Aluminum Smelter in 1949 (ALCOA 1995). Mercury, used as a cathode in the chlor-alkali process area (CAPA), was ultimately discharged into Lavaca Bay as wastewater from the production of sodium hydroxide. Peak operation of the CAPA facility occurred between 1966 and 1970. After 1970, ALCOA purchased sodium hydroxide from an outside vendor and shut down the CAPA facility. During the four year period ALCOA operated the CAPA facility, it is estimated that about 700,000 lb (317,520 kg) of elemental mercury may have been discharged into Lavaca Bay and the Dredge Island. In 1980, Alcoa shut down all smelter operations at PCO; bauxite refining, however, still occurs today.

In July 1970, the TDH closed part of Lavaca Bay due to elevated mercury levels in oysters. In 1971, Lavaca Bay was reopened to oyster harvesting. In 1988, TDH closed the area around PCO to the taking of finfish and crabs due to elevated tissue mercury concentrations. On February 23, 1994, the ALCOA PCO site was placed on the National Priority List (Superfund) with an effective listing date of March 25, 1994. In late 1995, ALCOA began the remedial investigation phase of the study that included the collection and analysis of over 10,000 environmental samples from surface waters, sediments and biological organisms (ALCOA 1996, 1997a and 1997b) near the facility.

The results of the remedial investigation show that, in most areas, historical mercury contamination is being buried by sedimentation (both natural and man-made through active dredging of the nearby ship channels). Areas containing elevated surface mercury concentrations are limited to the areas directly offshore of the plant where the main source of the discharge occurred, and other small areas where sediment hydrodynamics have inhibited active sedimentation. Mercury tissue concentrations in fish and blue crabs within the TDH closed area average > 1 ppm total mercury, thus the area continues to be closed for public health reasons.

In January 2000, the TDH reduced the size of the closed areas based on decreases of mercury contamination in fish tissue. Following the completion of a proposed plan for remedial action, and a record of decision, cleanup measures will be determined. These cleanup measures should eventually result in TDH rescinding the fish closure order (USEPA 2001).

Mercury is considered to be one of the more readily bioaccumulated metals. It is volatile and is readily transformed into methyl mercury by marine bacteria (Belliveau and Tevors 1989, Bartlett and Craig 1981). There is also evidence of abiotic methylation of mercury in marine sediments (Belliveau and Tevors 1989, Moore and Ramamoorthy 1984). Biological membranes tend to discriminate against the absorption of ionic and inorganic mercury, but they allow relatively free passage of methyl mercury and dissolved mercury vapor (Boudou, Delnomdedieu, Georgeschauld, Ribeyre and Saouter 1991, Eisler 1987). Evans and Engel (1994) suggested that the most important mechanisms for mercury accumulation in a marine food web are via the consumption of sedimentary detritus and benthic invertebrates, including shrimp.

Mercury is toxic to all biota, including birds, mammals and aquatic organisms. Mercury causes lethal and sublethal effects on the central nervous, cardiovascular, immunologic, reproductive and excretory systems of mammals (ATSD 1993). Low doses of metallic mercury vapors have been associated with adverse effects on the kidney and central nervous system of mammals. In birds, mercury can adversely affect growth, development, reproduction, blood and tissue chemistry and behavior (Eisler 1987). In aquatic organisms, mercury can produce impairment, growth reduction, osmoregulatory disturbances, developmental effects or death.

Since methylation does take place in aquatic environments and bioaccumulates /bioconcentrates, it can be found in higher trophic level predators in areas with substantially elevated levels. Also, since mercury accumulation in fish and other aquatic organisms takes place in many organs, including muscle tissue, contaminated fish can serve as a pathway to the human population eating seafood from contaminated areas.

Despite the significance of point source contamination, non-point source runoff has had the greatest impact on coastal water quality. Non-point pollutant sources include agriculture, forestry, urban runoff, septic tanks, marinas and recreational boating and hydromodification. Waterways draining into the Gulf transport wastes from 75% of US farms and ranches, 80% of US cropland, hundreds of cities and thousands of industries not located in the Gulf's coastal zone. Urban and agricultural runoff and septic tanks contribute large quantities of pesticides, nutrients and fecal coliform bacteria (MMS 1996).

An excess of nutrients, primarily found in river runoff, is one of the greatest sources of contamination to Gulf coastal waters. Nutrient over-enrichment can lead to noxious algal blooms, decreased seagrasses, fish kills and oxygen-depletion events. Nutrient over-enrichment has been a particular problem for the lower and upper Laguna Madre in Texas.

A good indicator of coastal and estuarine water quality is the frequencies of fish kill events and closures of commercial oyster harvesting. Of the 10 most extensive fish kills reported in the US between 1980 and 1989, five occurred in Texas (3 in Galveston County, one in Harris County and one in Chambers County) (NOAA 1992a). Because oysters are bottom-dwelling filter feeders, they concentrate pollutants and pathogens. The oyster industry is a good indicator of impacts from septic tank runoff pollution. Approximately one-half of the harvestable shellfish beds in Louisiana are closed annually because of *E. coli* bacteria contamination. Most of the productive oyster reefs in Gulf estuaries are in conditionally approved areas or areas where shellfish harvesting is affected by predictable levels of pollution (MMS 1996).

Over 10 million lb (4.5 million kg) of pesticides were applied within the Gulf coastal area in 1987, making it the top user of pesticides in the country (NOAA 1992a). The Gulf ranked highest in the use of herbicides (6.6 million lb; 2.9 million kg) and fungicides, and second in the use of insecticides. The lower Laguna Madre and Matagorda Bay ranked in the top 10 estuarine drainage areas in the US for concentrations of pesticides found in coastal waters. Although ranking high, when NOAA normalized pesticide data based on risk to estuarine organisms, the Gulf fared better (NOAA 1992a).

Nitrogen and phosphorus loadings in the Mississippi River and Gulf coastal waters have risen dramatically over the last three decades (Rabalais 1992). The Nutrient Enrichment Subcommittee of the Gulf of Mexico Program estimated that more than 379,000 lb (172,000 kg) of phosphorus and over 1.87 million lb (849,000 kg) of Kjeldahl nitrogen are discharged into the Gulf on an average day, with 90% of both elements coming from the Mississippi River system (Lovejoy 1992).

Since 1984, the NOAA NST has monitored the concentrations of synthetic chlorinated compounds such as DDT, chlordane, polychlorinated biphenyls (PCB's), tributyltin, polynuclear aromatic hydrocarbons (PAH's) and trace metals in bottom-feeding fish, shellfish and sediments at coastal and estuarine sites along the Gulf (NOAA 1992b). Sites were randomly selected to represent general conditions of estuaries and nearshore waters away from waste discharge points. Eighty-nine sites were sampled along the Gulf coast and compared with more than 300 sites located throughout the US coastal areas. The following summarizes NOAAs findings for both sediments and shellfish (MMS 1996).

Oysters were sampled for five years as part of the NST National Mussel Watch Program. Examining the entire US coastal area, the highest chemical contamination consistently occurred near urban areas. Fewer sites along the Gulf were contaminated than along other coastlines. Sites located along the Gulf having oysters containing at least three compounds with "high" concentrations were Galveston Bay, Brazos River, Corpus Christi Bay and the lower Laguna Madre (O'Connor 1992). Moderately elevated concentrations of pesticides and PCB's appeared at isolated stations in Texas (Matagorda and Galveston Bays) (TAMU 1988). The DDT concentrations in oysters showed significant decreases over the five years sampled, primarily since DDT use is no longer allowed (MMS 1996).

Sediment data were also collected and examined (O'Connor 1992). As in benthic samples, higher levels of sediment contamination were associated with highly populated areas, and sites in the Gulf from 1984-1988 generally had lower concentrations of toxic contaminants than the rest of the country. Again, the likely reason for this finding was that sampling sites in the Gulf coastal area were away from urban areas, which are characterized as having large numbers of point-source discharges. The distribution of organochlorine loadings in sediment followed those observed in oysters (TAMU 1988). The number of sites in each state having concentrations among the top 20 nationally for selected classes of contaminant compounds in sediments was provided (NOAA 1992b). Texas had one site that had high DDT levels (MMS 1996).

Also, as part of the NOAA NST Program, petroleum hydrocarbons were measured in the Gulf oyster and sediment samples. The results showed: 1) total hydrocarbon concentrations were lower than hydrocarbon concentrations at east and west US coast locations, probably because the sites in the Gulf are farther removed from large point sources, such as large cities and industrial areas; 2) chronic petroleum contamination is taking place, possibly from oil and gas operations along the Gulf coastline, but also due to contamination of the discharge from the Mississippi River; and 3) water quality degradation from oil and gas operations is not taking place to such an extent to show marked increases over US coastal areas that do not have as many oil operations (MMS 1996).

Hazardous Waste Management

Government and industry use several methods to reduce or store hazardous waste. Management methods include land filling, land farming, incineration, chemical treatment, discharging, deep-well injection and recycling. Many hazardous wastes can be treated to render them nonhazardous, as through neutralization, or can be recycled to recover usable constituents, as through solvent recovery or metal reclamation (NOAA 1996).

Remediation of existing and pre-existing toxic chemical sites and proper management of toxic chemical wastes -- including reducing the total production of such wastes -- will lessen the potential for environmental degradation to bays, estuaries, wetlands and other coastal natural resources. Current efforts to improve waste management are expected to continue. These efforts are particularly essential within the coastal zone where the chemical and petrochemical manufacturing capacity is concentrated (NOAA 1996).

Chemical Contaminant Spills

Chemical contaminant spills occur predominantly in the GIWW and ship channels. They are caused by barges carrying chemicals colliding with other vessels, by weather-related accidents or being rammed by another barge in the GIWW. Chemical spill impacts on immediate and surrounding habitat are generally dictated by the type of chemical, time of day, weather conditions and geographic location. Most barge spills in the GIWW are extremely damaging to the marshes and estuaries due to the narrow confines of the GIWW itself and the isolated geographic location of the spill. This usually necessitates a long response time before clean-up crews can get to the spill site, allowing a large area to be impacted. This also leads to a long clean-up time period with subsequent impacts to the environment from the usually unavoidable clean-up operation impacts.

Chemical spills kill fish, crabs, shrimp, benthic animals, birds, mammals and most of the marsh plants. The degree of mortality is based on the chemical itself and its interaction with water and air, depth of water, time of year, time of day and local weather conditions. Recovery of the impacted area is usually measured in months or years.

Sea Level Rise

Relative sea level rise is usually attributed to global warming or excessive pumping of ground water and/or petroleum or gas. This apparent sea level rise has been reported to be on the order of 1.5 to a few millimeters per year and from 6-24 in (15-60 cm) per century. However, the rate of rise may be much greater in areas where excessive pumping is taking place.

Typically estuarine areas maintain their profile against this relative water rise through sedimentation and soil building processes. Processes that interrupt freshwater inflow or marsh growth can inhibit or interfere with this critical ability of estuaries to rebuff sea level rise. Among the predicted effects of sea level rise are barrier island drowning, estuarine salinity increase, species diversity reduction and wetland destruction.

Subsidence, a permanent and irreversible sinking of the ground surface, is primarily caused by the excessive withdrawal of subsurface fluids, principally groundwater. Coastal habitat has been lost in areas of the Galveston Bay estuary that are susceptible to flooding due to high tides, heavy rainfall and hurricane storm surge. Efforts of the Harris-Galveston Coastal Subsidence District have significantly reduced the rate of subsidence throughout shoreline areas in recent years, although subsidence remains a problem in the northwestern portion of the lower watershed (GBNEP 1998).

It has been estimated that along the Gulf and Atlantic coasts, a one-ft (30-cm) sea level rise is likely by 2050 and possible by 2025. By the end of the next century a two ft (60-cm) rise is likely, but a four ft (120-cm) rise is possible. Sea level will probably continue to rise for several centuries, even if global temperatures stop rising within a few decades (NOAA 1998b). How well coastal wetlands survive sea level rise depends upon the rates of relative sea level rise and marsh accretion. Relative sea level rise is a function of both land submergence and actual sea level rise. Since both processes lower land surface relative to water levels, it is often difficult to separate the relative magnitudes of each. Global estimates of sea level rise made in the 1980's do not recognize a significant variation in relative sea level change found in various regions of the US, ranging from over 0.04-in (10-mm) per year decline in the sea surface along the coast of southeastern Alaska to a 0.04-in (10- mm) per year rise along the northeastern Maine and Louisiana coasts (Stevenson, Ward and Kearney 1986).

In the face of rising relative sea level, coastal marshes may keep pace if vertical marsh accretion increases sufficiently. At historic rates of sea level rise, most coastal wetlands of the East and Gulf Coasts of the US have kept pace with sea level rise (Stevenson et al. 1986). Out of 18 US wetlands for which sufficient data on accretion rates and relative sea level rise are available, only four sites (encompassing the Mississippi River Delta and Blackwater Marsh in the Chesapeake Bay) have not accrued sediment fast enough to keep pace with relative sea level rise. In general, wetlands in regions with relatively small tidal ranges have lower rates of vertical accretion because less sediment is transported by tidal action (Stevenson et al. 1986). By the same token, coastal areas with higher tidal ranges are less vulnerable to sea level rise (Reid and Trexler 1991). It is estimated that a two ft (60-cm) rise in sea level could eliminate 17-43% of all US wetlands (NOAA 1998b).

As wetlands become inundated by sea level rise, estuarine marsh productivity may temporarily increase because of edge effects as marsh begins converting to open water and estuarine dependent organisms have greater access to the marsh. However, as sea level continues to rise, eventually most or all of the wetlands may be replaced by open water, with catastrophic decreases in production for these species (NOAA 1998b).

A synergistic effect of sea level rise and coastal development is that coastal beaches and shorelines that are bulkheaded and developed are less able to accrete sediment for new wetland creation (NOAA 1998b).

According to a recent study (Moulton et al. 1997), wetlands in coastal Texas are being lost through conversion to open water, uplands and palustrine emergents at an estimated annual rate of 1,600 ac (650 ha) or about 59,618 ac (24,145 ha) from 1955-1992. A primary cause of this loss has been associated with the submergence and erosion of wetlands most likely due to faulting and land subsidence resulting from the withdrawal of underground water and oil and gas (White and Tremblay 1995). The conversion of intertidal wetlands and shallow estuarine subtidal bottoms to uplands and palustrine emergents is primarily the result of ship channel construction and maintenance.

Conservation Actions

Development of Artificial Reefs

Element 4

Artificial reefs are important biologically, sociologically and economically. From a biological perspective, artificial habitat can function to: 1) redistribute biomass; 2) increase exploitable biomass by aggregating previously unexploited biomass; and 3) improve aspects of survival and growth, creating new production.

Resource managers have been involved in artificial reef development off the Texas coast for over 50 years. Crowe and McEachron (1986) documented that 68 intentional artificial reef areas had been created in Texas marine waters from 1947-1984, consisting of oyster shell, tires, automobiles, construction rubble and ships. The first successful reef development activity within Texas using stable, durable and complex material occurred with the donation of 12 Liberty Ships in 1975-76. Since then, the Texas Artificial Reef Program (Program) has received numerous material donations and created over 40 permitted reef sites encompassing over 2,768 ac (1,120 ha) in inshore and offshore waters. Past reef materials used have been oil platforms, concrete culverts, concrete reef modules, fly ash, granite blocks and vessels. The Program currently has received 52 obsolete petroleum jackets, one caisson and two decks placed at 31 of the 40 currently permitted reef sites in the offshore waters of Texas. Water depths at these sites vary from 36-305 ft (11-93 m), provide relief of 5-220 ft (1.5-67 m) and are located 6-120 mi (10-191 km) offshore. For a more detailed history of the Reef Program, including social and economic impacts of artificial reefs in Texas, refer to Shively, Culbertson, Peter, Embesi and Hammerschmidt (in press).

Oil and gas structures are the most prominent type of reef material used in Texas waters. These petroleum platforms provide an increase in the hard bottom area in the north-central Gulf. Gallaway (1980) estimated that a major platform in one Texas oil and gas field in 66 ft (20 m) of water provided about 40,903 ft^2 (3,800 m^2) or 0.009 ac (0.004 ha) of hard substrate. Shinn (1974) estimated that a typical platform in water 100-ft (30-m) deep provides about 88,000 ft^2 (8,173 m^2) or 2.0 ac (0.81 ha) of hard substrate. By using this average water depth and estimate of hard surface area, petroleum platforms provide an increase of approximately 9,139 ac (3,700 ha) of hard substrate. This represents an increase of 1.3% (686,660 ac; 278,000 ha) of the total reef habitat as calculated by Parker, Colby and Willis (1983) from Pensacola, Florida to the Mexican border in 60-300 ft (18-91 m) of water.

Other types of unintentional artificial reefs are the thousands of underwater obstructions and debris that litter the Gulf. Underwater obstructions in the Gulf are usually comprised of the same materials used in building intentional artificial reefs. Sunken barges, sunken vessels, metal drums, pieces of pipe and assorted oil and gas related debris all provide habitat for fish and hard substrate for invertebrate colonization, including the exotic Pacific tunicate (see exotic species section). More than 10,000 hangs and obstructions are listed by Graham (1996a and 1996b) along the Louisiana and Texas coasts, and there are over 3,500 wrecks and obstructions in the Gulf listed by the Automated Wreck and Obstruction Information System run by the Hydrographic Surveys Division of the National Ocean Service. The number of underwater obstructions in the Gulf could provide a significant amount of habitat to marine life. There is no knowledge of whether any of these hangs or obstructions have disappeared over time (G. Graham, Texas A&M University Sea Grant, personal communication).

The GMFMC estimated the total natural reef habitat in the Gulf to be approximately 9.6 million ac (3.9 million ha), with one-third offshore of Louisiana and Texas where 99% of the platforms in the Gulf currently exist. Gallaway and Lewbel (1982) and Gallaway and Cole (1997) estimated that petroleum platforms provide approximately 1.3 million ac (518,000 ha) of reef fish habitat, increasing the total amount of natural reef fish habitat by an estimated 27%.

Offshore Texas, the continental shelf is approximately 17,101,088 ac (6,925,940 ha) with 14,382,432 ac (5,824,885 ha) of the continental shelf being in federal waters and the remaining 2,718,656 ac (1,101,056 ha) in state waters. The Texas Artificial Reef Program has four reef sites within state waters occupying 520 ac (211 ha) of submerged lands and 36 reef sites in federal waters occupying 2,150 ac (870 ha). A total of 802 oil and gas structures exist offshore Texas with 505 of these structures in federal waters (unpublished MMS data) and 297 structures in state waters (unpublished GLO data). Assuming the Artificial Reef Program captured all the structures offshore Texas, made a 40-ac (16-ha) reef site around each structure and added the acreage of the program's existing sites, only 0.203% of the continental shelf offshore Texas would be covered by planned artificial reefs. If the continental shelf area offshore Texas was separated between state and federal submerged lands; planned artificial reefs would cover 0.456% and 0.155%, respectively.

Further Conservation Actions

- Marsh Rebuilding Projects - have shown some success in preventing subsidence, but the success rate of this action has so far been less than 100% effective in survival of new plantings. Subsurface and deep well water and oil/gas extraction along the Gulf coastal zone has been directly related to coastal subsidence in areas of Texas. This has led to the loss of large areas of coastal habitat in these subsidence districts. Coastal subsidence is a permanent geological action and when it happens, it is unalterable
- Man-made Marshes - Questions also remain unanswered in regards to the productive potential of the man-made marsh in relation to a natural marsh. So far, man-made marshes are significantly less productive than a natural marsh, even after 10 or more years of observation and measurement. As restoration techniques improve, so should success rates
- Prescribe Burning - Properly timed and managed marsh burns have the potential to enhance accretion rates (i.e. marsh build up) and decrease probabilities of catastrophic marsh fires. Marsh burns also increase plant diversity and production, and are necessary to prevent succession into non-grassland vegetative stages (Barry Wilson, Gulf Coast Joint Venture, personal communication)

- Develop New Water Quality Standards - In Texas, as in many states, estuarine water quality standards are based on standards prepared for freshwater rivers and streams. This approach fails to deal with natural processes unique to estuaries such as tides and seasonal stratification. These processes can drastically affect estuary water quality. Many states assess water quality conditions based upon measurements taken at the surface, or at five ft (1.5 m) depths or mid-depth, whichever is less. This approach does not deal with conditions and processes in the deeper estuarine areas
- Lobby for a more effective and inclusive Coastal Zone Management Program from the Office of Ocean and Coastal Resource Management (NOAA)
- Continue to monitor Section 404 Permit Applications submitted through USACE and TCEQ
- Marsh creation with marsh mounds, terracing, etc. using dredge material
- Manually move sediments from upshore sedimentation areas to downshore areas that need it. This is already being done by the Galveston District of USACE at the Old Colorado River Channel. Work on designing new systems that allow sediment transport at ship channel entrances
- Put in measures like shoreline protection to stop erosion (ex. Mad Island Marsh Preserve) of intertidal marshes along the GIWW. Enforce shipping traffic laws and pass legislation to slow vessels down or make shipping industry responsible. Use dredge material from channels in ways to build marsh, create bird islands, etc. (The widening and deepening of the Houston Ship Channel Project is a good example)
- Covering existing live oyster reef with sediments can be detrimental; find ways of protecting reefs or management practices to increase reef production and growth
- Work with subsidence districts. Develop proactive wetlands restoration and protection projects using USACE, Texas General Land Office, TPWD and USFWS programs
- Work with TWDB long-term planning groups to secure adequate future inflows. Support sand nourishment projects where appropriate
- Participate in federal navigation project review to insure proper jetty construction, sand bypassing, etc.

- Develop coastal wetland protection/restoration projects using Corps of Engineers, Texas General Land Office, Texas Parks and Wildlife, US Fish and Wildlife, NOAA and other funding programs
- Seek agreement with International Water and Boundary Commission and various water districts to limit brush eradication within floodways
- Continue to support scientific management of fisheries and establish and enforce appropriate fishing regulations
- Enforce Clean Water Act and restore hydrology
- Document resources that could be affected by disturbances at each location. Seasonal area closures and buffer zones could be implemented in areas where species are breeding or feeding. Any type of "unnatural" disturbance should not be allowed in these areas at fragile times. Provide recreational users with educational material that discusses the impact of disturbance on wildlife and provide them with alternative recreational suggestions
- Reduce or minimize the impact of dredging activities regarding the productivity of water resources (e.g. bay seagrasses, etc.) or bury existing faunal or floral communities
- Limit commercial fishing and stabilize shrimp and crab stocks, change harvesting practices to environmentally friendly methods. Encourage fisherman to use it once it is available. Protect fishery nursery habitat, TPWD is already doing so in the Eastern Arm of Matagorda Bay
- Fund research on invasive species such as with the Texas invasive species monitoring committee to assess risks and recommend policies that regulate importation of exotics
- Educate boaters concerning the transport of aquatic invasives on boat trailers, boat motors and fishing equipment, support additional research on management techniques for invasive species and actively apply control measures
- Institute water level fluctuations for the management of certain specie (i.e. properly timed freshwater inflows will keep both Dermo and the oyster drill populations down allowing oysters to thrive. Too much freshwater will kill oyster reefs too, so there must be a balance)

- Fund broad coalition (environmental and agricultural, industry and private foundations) support for ground water quality and conservation policies that may take form in statutory restrictions on 'right of capture'. Fund Joint Ventures and other partners that leverage resources to purchase or obtain conservation easements on surface and ground water rights that are most vulnerable to loss or degradation
- Prevention, Rapid Cleanup, Proper preparation/drills, develop innovative cleanup techniques
- Reduction of non-point pollutants and the monitoring of air, soil, water and plant and animal tissues for trends in non-point pollutants; Better monitoring of discharge permit conditions, BMP during construction, maintaining buffers to prevent direct runoff
- Increase awareness of the effects of groundwater and hydrocarbon pumping along the Upper Texas Coast
- Fund broad coalition (environmental and agricultural, industry and private foundations) support for water conservation policies that have application to insure instream flows to coastal estuaries and bays and healthy riparian ecosystems. Fund Joint Ventures and other partners that leverage resources to purchase or obtain conservation easements on critical or high priority sites (surface or water rights) vulnerable to loss or degradation
- State protection for isolated wetlands
- Using current GIS; analyze the landscape and identify critical corridors with high conservation needs, continue to participate in West Gulf Coastal Plain and other similar intiatives, support additional acquisition of lands for conservation, continue to promote LIP and PFW programs for private landowners and actively pursue identification of funding sources for these conservation purchases
- Identify critical bird-use areas and mark them as no wake zones and enact new or enforce existing regulations
- Reduce impacts to seagrasses (scarring), impacts to waterfowl esp. redhead ducks where a majority of the North American population winters

High Priority Conservation Strategies

Introduction

In the interest of creating the most useful strategy possible, it is important to define priority levels that are associated with Conservation Actions: primary and secondary priorities. The difference between the two is strictly in scope. Currently, Texas has several needs at the statewide level and by definition, these needs are considered primary. Once these primary priorities are addressed, regionally specific and smaller scope investigations and conservation actions (secondary priorities) can more effectively be implemented. Therefore, the conservation actions from previous chapters are considered secondary to the following initiatives.

Element 4,5

The following conservation actions are statewide actions that are of primary concern. By definition, all other priorities listed in the CWCS are secondary priorities until the primary actions are addressed. Several of the following primary priorities are already in progress. Monitoring programs should be considered "ongoing". Others, such as the statewide biological inventory, are periodic and should occur as often as needed to maintain a sense of the biodiversity and community status throughout the state. Primary priorities are critical to information gathering. By addressing them, we will begin to gain a cohesive vision of the state of Texas' biodiversity and the status of individual species.

The following actions or activities are considered primary priorities. Related actions are in proximity to one another, but order in this primary priority list should not be considered a ranking mechanism. All of these primary actions are high priority and are imperative to the gathering of information on nongame species and nongame wildlife conservation.

Mapping the State

There is an evident lack of information concerning the location of habitats and vegetation communities across the state of Texas. Currently, Texas biological planners are using vegetation data that are outdated and are not specific enough at the community vegetation level. It is important that we reevaluate the current status of our vegetation data and begin to "remap" the state using the most current and applicable technology.

Large, contiguous areas of natural or semi-natural vegetation communities throughout Texas shall be mapped with higher precision and accuracy than our current databases represent. This will allow us to accomplish three additional goals:

1. Texas Parks and Wildlife Department and partners will establish permanent or semi-permanent data collection points that would be used to collect vegetative data for ground-truthing aerial map data;
2. These points would be available for the biological survey of Texas (see below);
3. Texas Parks and Wildlife Department to begin working directly with private landowners to create maps and assist with inventories. Based on the high percentage of private land in Texas, it would be difficult to map and survey the state without the cooperation of private landowners. This project would allow us to not only to partner with other conservation organizations but also with the constituents that we serve.

Because of the large financial cost of the mapping project, it is imperative to begin the project regionally and follow with a biological survey. It may also be necessary to subcontract much of this work to regional Texas universities that have the personnel and resources to assist with mapping and wildlife inventories. Texas Parks and Wildlife Department has statewide Wildlife Diversity Biologists and regional Regulatory, Private Lands and Technical Guidance biologists and Wildlife Technicians that could facilitate efforts by coordinating University, TPWD Biologist and partner activities and offer guidance as the projects progress.

Objectives

1. Develop partnerships for improved information sharing and coordination of conservation actions among the project's cooperating organizations, in addition to their specific stakeholder groups.
2. Map at 1:12,000 scale all remaining natural and semi-natural vegetation in selected areas of the state of Texas in contiguous blocks of 500 or more acres.

3. Facilitate delivery of species-specific conservation and recovery through development of mapping products and the use thereof for conservation planning and delineation of recovery focus areas for affected species.

Statewide Biological Inventory and Monitoring for Herptiles, Invertebrates and Mammals

Currently in Texas there is a limited knowledge of the status of many of our terrestrial species. In order to combat this lack of knowledge it is important to use data collection points from the mapping project to collect inventory data on the mammals, herptiles and terrestrial invertebrates across the state.

It is critical that we take steps to develop coordinated and ground-truthed information concerning native species in order to know where to focus conservation actions on our collective species of concern and create efficient and cost-effective budgets. Spatial and geo-referenced vegetation data are critical to Texas' inventory and monitoring programs for species of concern. While migratory bird species typically have solid monitoring efforts already in place, herptile, mammalian and terrestrial invertebrates have very limited sources of consistent monitoring. It is imperative that we work with other states, private landowners and other conservation organization to follow the mapping project with a biological survey of the state. All care should be taken to keep sampling protocols similar so that conservation of species, which do not typically exhibit complete fidelity to one state, occurs seamlessly. It is also important that we review protocols based on differing habitats throughout the state. Overall, care must be taken to ensure that data collected are useful and therefore can populate the TPWD nongame database and provide useful information for later planning efforts and wise wildlife management decisions.

Data Collection, Management, and Sharing

Because of the critical nature of the statewide mapping project and the statewide biological survey, data management must be considered as we plan to move forward. Texas Parks and Wildlife Department and NatureServe maintain a database of information concerning nongame species. Texas Parks and Wildlife Department refers to this database as the Natural Diversity Database (NDD) and it is maintained by the

Science, Research and Diversity Program. This database is a conversion from the original Biological Conservation Database (BCD) that was developed in the mid to late 1970's by The Nature Conservancy. The BCD was upgraded to the Biotics system in the late 1990's which allowed for the collaborative use of Geographic Information Systems (GIS) software, which allowed for mapping applications to be used with those data that had already been collected and placed into the database. Texas Parks and Wildlife Department has recently updated this system and now maintains an Oracle-based system that is referred to as the NDD. This software allows TPWD to collect information on species and habitat and convey those data through reporting options or in mapping formats.

This information can be used to make decisions on conservation applications for nongame species and habitats. All data that are collected through the statewide mapping efforts and the statewide biological survey will be housed in this database (NDD). It will then be available to TPWD biologists and partners as advised by the *Land and Water Resources Conservation and Recreation Plan*. In addition, the NDD also incorporates functions that allow for the prioritization of conservation sites or lands that TPWD and our partners need to be aware of. Once identified, appropriate conservation organizations could be notified of potential partners with which they might negotiate conservation easements, purchase of development rights or fee-simple purchase of property. The property could then be maintained for wildlife by appropriate conservation organizations, land trusts, or simply held by the private landowners for the benefit of wildlife. Data collected and shared in this way provide numerous conservation and management opportunities for private landowners, stakeholders and government wildlife and habitat management agencies.

Support Conservation Easement, Purchase of Development Rights and Land Acquisition.

The land trust community in Texas is growing and the organizations associated with the Texas Land Trust Council are working toward the goal of protecting Texas lands. It is important that TPWD and other conservation organizations maintain positive relationships with these groups and support their efforts to maintain conservation easements, purchase of development rights and fee-simple purchase and management of land for the benefit of wildlife, habitat, water quality and outdoor recreation opportunities.

Land Trusts are uniquely positioned to affect conservation in Texas by protecting land and allowing access to that land for research and management. In that way, TPWD can sponsor research and management activities and work to advise individual land trusts on which areas or specific properties would be most useful to conserve and what species inhabit that range or vegetation community. The NDD should be used to assist with this advisory role. By using the NDD as well as personnel or other resources to support these decisions, TPWD can have an affect on the easement and acquisition process without having to maintain additional properties and/or acquire new tracts of land. This should not, however, restrain TPWD or other conservation organizations from acquiring new land.

Installation and Support of Texas All Bird Joint Ventures

Currently, Texas has four all bird Joint Ventures (JV) operating within the state and one Joint Venture that is still in the planning stages. Joint ventures are comprised of individuals, corporations, conservation organizations and local, state and federal agencies. Concerned with conserving migratory birds and their habitats, partners come together to accomplish collectively what is often difficult or impossible to do individually. Historically JV's focused on Wetland habitats and their importance to waterfowl under the umbrella of the North American Waterfowl Management Plan. In recent years JV's in Texas have broaden their focus to include all birds and promotion and advancement of integrated bird conservation. From the comprehensive landscape level, this will allow for biological planning to significantly improve delivery of habitat conservation.

The Lower Mississippi Valley Joint Venture (LMVJV) encompasses 22 million ac. in portions of 10 states and including east Texas. The Lower Mississippi Valley (LMV) Joint Venture is a self-directed, non-regulatory private, state, federal conservation partnership that exists for the purpose of implementing the goals and objectives of national and international bird conservation plans within the Lower Mississippi Valley region. The LMV Joint Venture partnership is focused on the protection, restoration and management of those species of North American avifauna and their habitats (endemic to the LMV Region) encompassed by the North American Waterfowl Management Plan (NAWMP); North American Land Bird Conservation Plan; United States Shorebird Conservation Plan (USSCP); North American Waterbird Conservation Plan (NAWCP); and Northern Bobwhite Conservation Initiative (NBCI). Collectively, these national and international plans are recognized as the North American Bird Conservation Initiative (NABCI).

The Playa Lakes Joint Venture's (PLJV) mission is to conserve playa lakes, other wetlands and associated landscapes through partnerships for the benefit of birds, other wildlife and people. The PLJV works in portions of six states - Colorado, Kansas, Nebraska, New Mexico, Oklahoma and Texas. National and international bird plans provide the foundation for the PLJV's Master Plan which gives direction for conservation activities at the regional level. The PLJV operates similarly to a business, devoting attention to communications, fundraising and infrastructure as well as biology.

The Gulf Coast Joint Venture is a regionally based, biologically driven, landscape oriented partnership for the delivery of habitat conservation important to priority bird species within the JV region. The Gulf Coast Joint Venture partnership is composed of individuals, conservation organizations and state and federal agencies that are concerned with conserving migratory birds and their habitats along the western U.S. Gulf of Mexico from Brownsville, Texas, to Mobile Bay in Alabama. The GCJV targets specific sites along the Texas coast including Laguna Madre, Texas Mid-Coast, the Texas Chenier Plain. The GCJV partnership is expanding its scope to coordinate and cooperate with habitat conservation initiatives for migratory birds other than waterfowl (Partners in Flight, U.S. Shorebird Conservation Plan and North American Waterbird Conservation Plan).

The Rio Grande Joint Venture (RGJV) is the most recent addition to the Joint Venture network in Texas. Primary goals and objectives have not been established. It is imperative that the RGJV be supported and funded in order to begin the process of conserving bird species and habitat along the Rio Grande corridor.

The Central Texas Joint Venture is also currently in the planning stages. A coordinator has not been chosen and goals have not been set for this Joint Venture. Once this organization is on course and functioning, Texas will have Joint Ventures delivering integrated bird habitat conservation throughout the whole state. These Joint Ventures will function to conserve habitat, assist landowners, conserve bird species and generally benefit Texas conservation. It is important that TPWD continue to partner with established Joint Ventures and provide support to the new organizations. To this end, TPWD is sponsoring the RGJV and the CTJV in their fledgling stages and providing resources to ensure success. JV's will become the backbone for future habitat conservation delivery by TPWD and partners across Texas.

Monitoring the Bays and Estuaries

Texas Parks and Wildlife Department currently maintains an excellent monitoring program of the bays and estuaries of Texas. This system should be maintained since it allows for the early response of TPWD to threats to the habitat and species in those areas.

Ensuring Water Availability for Wildlife

The Land and Water Plan has identified several methods by which TPWD can contribute to the increase of water quality and quantity throughout the state. These methods should be enacted and maintained indefinitely. It is imperative that TPWD and our partners ensure that water consumption and use by the citizens of Texas does not diminish the quality and quantity of water required directly and indirectly by species of concern. The citizens of Texas should have all of their water needs met and conservation and monitoring efforts should allow water use by people and wildlife. People will be able to enjoy wildlife and wildlife will have increased water supplies for survival.

Monitoring Rivers

The primary concern for Texas rivers, once water quality and quantity have been addressed, is overall floral and faunal species health. Texas rivers must be monitored to determine trends that will allow for quick response when species health is compromised. An emphasis needs to be put on the health and monitoring of those species that are of concern and listed for this strategy. It is also imperative that rivers be monitored for the encroachment of exotic plant and animal species that could threaten native species. Again, this is an issue of health for the wildlife residing in the aquatic and riparian habitats. If exotic species are monitored carefully, a quick response will be an option during periods of increased pressure on native species.

In addition to monitoring species, it is important that an emphasis be placed on restoration of riparian and riparian and aquatic habitats. Many rivers and streams have been compromised over the last several decades due to human interference in the natural ecology of the aquatic zones. This interference needs to me mitigated through a series of prioritized projects that aim to significantly rehabilitate river habitat back to natural state as defined by TPWD and conservation partners.

Urban Wildlife Biology

Texas has one of the largest and most successful Urban Wildlife Biology programs in the country. The Texas Urban program is described in another chapter, however it must be emphasized that greater than 80% of TPWD's continuants inhabit the cities and towns across the state. In order for conservation actions to be a success, TPWD needs to provide opportunities for all Texans to learn about and be a part of the process. Urban Wildlife Biologists assist in providing these opportunities as well as conduct research, provide technical assistance, offer information on native landscaping and habitat, develop school yard habitats and develop landowner workshops. These opportunities are extremely beneficial to individuals that live in the city and who have limited chances to visit a state park or Wildlife Management Area as well as those new, absentee, or longtime property owners changing from agriculture to wildlife use (1-d-1 valuation) and are eager to provide habitat for wildlife on their acreage. The Urban program meets the needs of Texans and provides these opportunities and it must be allowed to adapt to the changing needs of constituents.

Texas Parks and Wildlife Department should also promote the Urban Wildlife Biology program outside the state of Texas. Several other states have a desire to start a program like Texas' and should be able to use Texas' model as a rough template. Therefore, the Texas Urban program should be prepared to advise other states on successful programs and how to use those programs to address he needs of their constituents. Being a Texas landowner is a real responsibility that should be taken very seriously; being a Texan without a piece of property also carries responsibility. Texas Parks and Wildlife Department must invest time and funding into all of the citizens of Texas in order for conservation to be successful.

Wetlands (Used with permission, adapted from the Texas Wetlands Conservation Plan)
Wetlands are among Texas' most valuable natural resources. These lands provide many economic and ecological benefits, including flood control, improved water quality, harvestable products and habitat for our abundant fish, shellfish and wildlife resources. But Texas wetlands are disappearing. Approximately half of Texas' historic wetlands acreage has been converted to cropland and urban development in response to society's demand for food, fiber, housing and industrial development. If future generations of Texans are to enjoy the same economic vitality and quality of life as past and present generations, we must implement effective strategies for wetlands conservation. Although wetlands issues are at times controversial, broad support exists among diverse interests on many aspects of wetlands conservation and public responsibility.

The *Texas Wetlands Conservation Plan*, initiated in April 1994, focuses on non-regulatory, voluntary approaches to conserving Texas' wetlands. Development of the Texas Wetlands Conservation Plan has been coordinated by the TPWD and provides a guide for wetlands conservation efforts throughout the state. The Plan focuses on:

1. Enhancing the landowner's ability to use existing incentive programs and other land use options through outreach and technical assistance.

2. Developing and encouraging land management options that provide an economic incentive for conserving existing wetlands or restoring former ones.

3. Coordinating regional wetlands conservation efforts.

The Texas Wetlands Conservation Plan is nearly 10 years old and needs to be updated because of changes in technology and shifts in conservation priorities. Wetlands are vital resource and therefore Texas must adapt this plan to fit our current needs. To this end, a state wetlands planner must be supported and perhaps funded by TPWD in order to monitor wetlands throughout the state as well as update the plan.

Caves and Associated Habitats

Texas enjoys a rich yet poorly known cave fauna. Over 1,000 terrestrial and 150 aquatic species have been recorded from Texas caves. Of these, 160 terrestrial and 80 aquatic species appear to be sufficiently cave-adapted; to be considered troglobitic or cave obligates. Many of these troglobites are known from only one or a few caves in Texas and nowhere else.

This rich biodiversity resulted from Texas' geographic position at the crossroads of the tropics, the eastern forests and the southwestern deserts. The geological complexity of Central Texas further enhanced the biotic diversity by creating islands of karst separated by faulting and river downcutting.

The most remarkable aquatic fauna in the United States and the world exists in the vast underground Balcones Fault Zone of the Edwards Aquifer. Sampling of cave, well, spring and interstitial habitats has resulted in the discovery of at least 50 species in this aquatic ecosystem. Doubtless, many more species await discovery.

The aquatic fauna is derived both from freshwater and marine ancestors. The terrestrial fauna includes species derived, some probably recently, from ancestors still occupying the surface in or recently extinct from, the same area.

By far, the most diverse terrestrial fauna occurs in the Balcones Fault Zone. River incision and complex faulting have resulting in many isolated caves. As a result several animal groups have speciated to form numerous closely related species within a comparatively short geographic distance. Of particular interest are spiders of the genera *Cicurina, Neoleptoneta and Eidmannella*; pseudoscorpions of the genus *Texella*; millipedes of the genus *Speodesmus*; ground beetles of the genus *Rhadine*; and mold beetles of the genus *Batrisodes.* The Balcones Fault Zone is also one of the fastest developing urban regions in Texas.

The potential conflict between rapid urban growth and subterranean biodiversity along the Balcones Fault Zone is exemplified by Tooth Cave, west of Austin, which has the greatest biological diversity of any cave in Texas. Tooth Cave has 64 species. Of these, 11 species are terrestrial troglobites or cave obligates. Five of the cave species are protected under the federal Endangered Species Act. Only large cave systems like Mammoth Cave (with well over 300 mi. of passages) have more species, yet Tooth Cave is only 166 ft long and 18 ft. deep. This clearly illustrates the likelihood of continuing conflicts between urban development, allocation of water resources and small subterranean enclaves of diversity in this region.

The aquatic cave fauna of Texas is equally at risk. In fact, the first species to be placed on the USFWS endangered species list was the Texas Blind Salamander (*Typhlomolge rathburni*) in 1967.

No systematic survey of Texas' cave fauna existed prior to the formation of the Texas Speleological Survey (TSS) in 1961. James Reddell, Drs. Bill Elliot, Robert Mitchell, James Cokendolpher and Glenn Longley were all early contributors to the TSS. James Reddell is the editor of the Speleological Monograph which has been regularly published by the Texas Memorial Museum since 1986 and serves as a repository of many Texas cave faunal studies.

A 1996 report on the cave resources in Texas indicates that the known number of caves in Texas exceeds 4,000. This number does not include abandoned mines. The TPWD owns over 400 caves according to this report, more than any other entity in the state, but more recent documents indicate the number is under estimated and could exceed 900 caves. With this ownership comes a great responsibility for TPWD to manage and utilize this resource while at the same time sponsoring systematic surveys and sound scientific studies of the species of animals living in the caves, especially those that are found no where else.

Increasing our knowledge of Texas' cave fauna is vital to proper stewardship and management. Forming a long term partnership with TSS, the professionals who study caves and their fauna and flora, will be an excellent step in that direction.

A project to focus on the fauna found in karst habitats such as caves and springs is needed. Numerous Texas caves have yet to be biologically inventoried. A cave fauna specialist will be needed to assemble data on the distribution, biology and cave environmental requirements for the animals occupying the caves and springs of Texas. The greatest need is with the cave invertebrates. A literature database on karst features such as caves and springs will be needed. TSS currently has such a literature database. Access to this database must be obtained and the database kept current. Research projects dealing with the cave faunas will be developed. At the same time data on the caves themselves, especially geological and hydrological parameters that affect the suitability of the caves for the various cave inhabiting species, is critically needed. Finally, more data on the impact of exotics such as red imported fire ants on the native cave fauna are needed.

Monitoring endangered aquatic plants such as Texas wild rice must be continued and even expanded to study and potentially monitor other unique aquatic plants such as *Trichocoronis rivularis* in the San Felipe Springs. The impact of invasive exotic aquatic plants such as *Cryptocoryne* on native aquatic plants, especially endangered and threatened species, must be studied. This latter problem is increasingly becoming a major issue.

Conservation Partnerships

Perhaps the most critical role that TPWD can play in the future of Texas conservation is the role of facilitator and partner. Without a strong list of willing partners that are interested in putting their money and other resources toward focused conservation, the

CWCS will be an ineffective document that has little chance of meeting its conservation goals. Texas Parks and Wildlife Department can not conduct the business of conservation with finite resources. Texas Parks and Wildlife Department must have the support of other agencies, conservation organizations and the citizens of Texas. In the same vein, TPWD must be willing to commit its own resources to supporting the conservation activities of those much needed partners.

The support of projects such as the production of a Texas Conservation Directory that maintains a list of contacts that can be used to link one conservation organization to another would start the facilitation process. Biologists need a contact system that allows them to gain support for local and regional projects without being frustrated by spending valuable time searching unsuccessfully through the directories of individual organizations and depending serendipitous contacts. This information should be updated yearly and placed on the internet for easy access through simple search functions. This is one project that has the potential to greatly impact Texas wildlife.

Other forms of facilitation could apply and TPWD must take the lead on this process, showing good faith to other organizations. This is not to say that TPWD must lead all ventures or be the larger benefactor for all projects; however TPWD should lend support to ensure that conservation goals are met and quality projects are funded and completed. This role is critical to meeting the goals of this strategy as well as the goals of our partnering organizations.

Partnerships with Mexico

One of the most pressing partnership needs is to continue to conduct joint conservation projects with Mexico, especially the four northeast states of Tamaulipas, Nuevo Leon, Coahuila and Chihuahua. Unlike other states in the US, Texas shares a border of over 1250 mi. with these four Mexican states. This border cuts across numerous ecoregions with their variety of habitats beginning with the tropical mouth of the Rio Grande to the Chihuahuan Desert at El Paso. As such, while most species of concern in Texas are endemics, a sizeable portion are shared with Mexico, either with a peripheral portion of the geographic range of a Neotropical species just crossing into Texas or with most of the geographic range of the species occurring in Texas or adjacent states but a peripheral portion or the wintering range of the species occurring in Mexico or countries to the south. In the latter cases, Texas serves as the steward for the main part of the species' population or for the summer breeding population. What happens to the south directly affects the overall viability of the species.

New opportunities for collaboration with the Mexican states emerged in late 2004 when President Vicente Fox announced the inception of the process to decentralize the management of resident wildlife species to the border states in northern Mexico. Texas Parks and Wildlife Department and the new state wildlife agencies in the neighboring states met in early 2005 to develop an action plan for cooperation.

Current Conservation Actions:

- With partners such as Universidad Autónoma de Nuevo León, TPWD is conducting cooperative research projects on the conservation status of endangered species of birds such as the black-capped vireo, golden-cheeked warbler and piping plover in Texas and Mexico. This will enable TPWD and the USFWS to consider downlisting or delisting species
- Through the International Association of Fish and Wildlife Agencies (IAFWA), Texas and other states are supporting bobcat research in Mexico to estimate population densities which will assist Mexico in determining whether to support delisting the bobcat from CITES Appendix II
- Texas Parks and Wildlife Department helped to establish a bi-national bat conservation working group that has now evolved into a tri-national effort that includes Mexico and Canada. Texas Parks and Wildlife Department and the new state wildlife agencies are organizing a bat conservation workshop that will be held in northeast Mexico
- Texas Parks and Wildlife Department, Pronatura Noreste (a Mexican NGO), the Nature Conservancy and other partners have exchanged information on priority plant species and have conducted joint survey work to determine distribution patterns and conservation needs

- Under the leadership of USFWS, Nuevo León, Pronatura Noreste, TPWD and other partners are working on the conservation and restoration of an ecologically significant wildlife corridor from the lower end of Falcon Reservoir on the Rio Grande to Sierra Picachos in Mexico, which begins about 65 mi. from the border
- With the USFWS, Texas A&M University Kingsville and other partners, TPWD and Mexico have drafted a Texas-Northeast Mexico Strategic Plan for White-winged Dove. A number of time-sensitive conservation projects have been undertaken, including the georeferencing of historical and existing white-winged dove colonies and the development of harvest regulation information, in English, to improve compliance by U.S. hunters who comprise the majority of dove hunters in northeast Mexico
- Texas and neighboring state wildlife agencies are involved in a process to standardize wildlife survey techniques, and baseline inventory and monitoring procedures so that conservation and management of shared species can occur seamlessly. The first workshop was held in July 2005 at the Chaparral Wildlife Management Area in South Texas; the next workshop will be held in West Texas. New Mexico and Arizona have offered to assist in this workshop
- Mexico's Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT), Pronatura Noreste, corporations such as Cemex and other entities are involved in major habitat restoration projects in the region. To support these restoration projects, a SEMARNAT-Texas agreement is currently in effect to provide Texas surplus wildlife stock to Mexico. Currently, a protocol that includes animal health requirements is being developed to resume donations of Texas surplus wildlife stock
- Long-term success of restoration projects in Mexico will largely depend on law enforcement. To this end, the Mexican border states have been empowered to develop their own law enforcement bodies. Texas and its neighbors are working on logistics to use the Texas Game Warden Academy to train a handful of individuals from Mexico, who can then set up a game warden academy for northeast Mexico
- Mexican entities have expressed an interest in having sites in Mexico as part of the World Birding Center (WBC), a network of sites in Texas for bird

conservation and recreation. Texas Parks and Wildlife Department is working with Mexico to select the best sites, which in all likelihood are stopovers for Neotropical birds, and will benefit from additional emphasis on habitat conservation

- The new state wildlife agencies and Texas are exchanging information and literature on programs, including the Master Naturalist program, Texas Wildscapes Backyard Wildlife Habitat Program, Nature Trackers Program, and the Landowner Incentive Program. It is hoped that as the Mexican entities translate some of these materials for their use, that TPWD can use the Spanish versions for the Hispanic populations in Texas

Other Conservation Actions Needed:

- Research on the population status of Threatened and Endangered species of mammals, birds, reptiles and amphibians, fish and invertebrates that occur along the border must be developed. Surveying of known sites, finding new sites and then monitoring the species on both sides of the border, especially in northeastern Mexico, is required to gather base-line genetic data and to determine the phylogeographic relationships of the species. This is critically needed as some recent studies of this nature have show that the northern peripheral populations of Neotropical species entering Texas actually represent distinct species that are confined to these unique habitats so common in the border region
- SEMARNAT, the new state wildlife agencies, and TPWD are standardizing wildlife surveys and monitoring procedures as the first step to develop joint conservation and management plans for migratory and other shared species

Successes, Outcomes, and Deliverables

Because of the sheer scope of the primary priority conservation actions and developmental state of each action project, it is not possible to define all specific outcomes and deliverables that should be products of these projects, although many actions do list suggested successes, outcomes and deliverables. All of these ventures need to be developed more fully with specific outcomes defined that would constitute success. Success and deliverables will be different for each project. As each project is undertaken, care should be taken to define those specific variables appropriate for the project and time frame. The appropriate location to define these outcomes is within the grant application that is filed by each project manager. This gives the decision making body the ability to determine whether the project will meet the goals of the CWCS. This will be imperative to monitoring and assessing the fitness of the strategy over the five years between updates.

Education and Outreach Strategies

Introduction

A recent survey of public attitudes towards natural resources, conducted for Texas Tech University's *Texas Parks and Wildlife for the 21st Century* report, found that Texans strongly value natural resources and opportunities to participate in outdoor recreation. For instance, 97% felt it was important to know that wildlife exists in Texas, while 98% of the general population felt that it was important that people have the opportunity to visit state parks in Texas.

Yet, the growing urbanization of Texas has resulted in less involvement in local habitat and wildlife issues. In a predominately private-lands state, understanding the role of habitat, wildlife management and the role of individual citizens and landowners is critical. Texas Parks and Wildlife takes on this challenge as part of a fundamental premise that management of a resource must work hand-in-hand with management of people. How we achieve this is through regulations, carefully-designed strategic educational activities and partnerships.

Texas Parks and Wildlife envisions a Texas whose citizens understand the value of natural resources; appreciate that conservation and management of terrestrial and water resources are essential to wildlife, the outdoor landscape and the quality of life in Texas; and embrace and/or understand the importance of an active stewardship role of Texas' natural and cultural resources.

But conservation is not a spectator sport. It takes the commitment and involvement of those who care about Texas to pass on values that sustain and conserve this state's great natural resources. This cannot occur in a vacuum. There must be meaningful first experiences, a chance to learn and grow dedicated mentors and opportunities to practice and demonstrate new knowledge and skills.

Each year, TPWD-owned sites, programs and program partners reach over four million people or approximately one-fifth of all Texans. Outreach, education and interpretation are each specific methods that, in conjunction help the public get involved in outdoor recreation, hunting and fishing, conservation and responsible use of Texas natural and cultural resources.

Outreach provides that first introduction by bringing people and a resource together. Special events and coordination with specific, underserved audiences can serve as a recruitment tool for new experiences and activities. Targeted informational and marketing campaigns using multiple media can reach thousands, building awareness and interest for natural resources.

Conservation education programs build knowledge and skills that support long-term interest in and stewardship of natural resources. Through greater understanding and competency with concepts and skills, people are more likely to embrace and care for Texas natural resources. The department relies on partnerships with other conservation education interests to enhance and expand existing programs and to provide funding and support for its efforts.

Needs and Challenges

Element 3

Wildlife and habitats can't be managed without incorporating the people in and around the environment. With 86% of Texas being urbanized there is an inherent "disconnect" with nature and a growing lack of experience and understanding of the outdoors. Texas needs an involved and educated citizenry, willing to demonstrate their commitment to conservation. Nature must be of value for it to be conserved. Humans are essential to the conservation and management of a better Texas. Texas needs more than simple consensual conservation. The development of a "culture of conservation" will result in each Texan bearing personal responsibility for the management and conservation of natural resources.

In 2003, a team of TPWD staff and the Outreach and Education Advisory Committee, examined the current structure and programming of the agency's conservation education efforts and, as a result, developed a strategic plan, *Take Care of Texas!*

Element 4

Outreach, Education and Interpretation Strategic Plan Goals

This plan identifies several goals detailed below. Texas Parks and Wildlife programs and collaborative efforts with conservation partners address these goals but much work is still needed to provide effective conservation education that demonstrates real benefits to the natural resources of Texas.

- *Provide conservation education and interpretive opportunities that are consistent with the Department's mission and that enhance the state's economic vitality, sustain its natural resources, connect Texans to the outdoors and increase individual and community well-being.*

  Urban Program: Urban natural resource technical guidance is provided to city officials, community leaders, school officials and citizens on topics including native habitat restoration, conservation development, urban pond/stream and open space management and ecologically sensitive landscaping.

  Nature Tourism: Technical guidance provides private landowners and community assistance in developing conservation-based wildlife viewing opportunities that generate economic benefits. It is important to develop public-private nature tourism activities and products that generate recreational opportunities and tourism dollars.

  Priority Needs: Training workshops and educational products that increase the distribution of natural resource management information to community leaders and landowners who can enhance and increase the management of native landscapes for recreation and economic benefit. <u>Outcome:</u> Increased acres of native aquatic and terrestrial habitats conserved in urban areas for citizen enjoyment and additional nature-based recreational opportunities on public and private lands.

- *Increase public awareness and understanding of the benefits of conservation, especially the importance of active management of Texas' private and public lands, water, wildlife and historical resources.*

  Project WILD: This program is a supplemental curriculum of hands-on activities that teach ecology, wildlife management and environmental concepts.

  Wild about Texas: Issue-based community programs, information and activities related to regional Texas habitats and wildlife. This program compliments Project WILD by using specific habitats and species as topics and case studies.

  Wildlife Interpretive Program: Improves the quality and quantity of interpretive services to the public by providing planning, design and productions services to wildlife division staff, particularly those on Wildlife Management Areas.

  Priority Needs: Texas Parks and Wildlife Department and its partners need to increase regional community programs and training on issues related to habitats and species of concern. <u>Audience:</u> Community leaders, volunteer organizations, youth. <u>Outcome:</u> Awareness of natural resource and management issues, organization of community volunteer efforts to support TPWD education and outreach efforts.

- *Texas Parks and Wildlife Department and its partners need to target new and diverse audiences to involve more people in TPWD's mission, especially those from urban areas.*

  Urban Outreach Program: Texas Parks and Wildlife Department program specialists in the Dallas and Houston metropolitan areas assist community-based organizations to create outdoors programming.

  Becoming an Outdoors Woman: This is a self-funded weekend workshop that introduces women to outdoor skills and recreation.

CO-OP Grants: Texas Parks and Wildlife Department offers competitive grants to local governments and non-profit, non-political organizations. Grant sponsors use funds to introduce under-served persons to the programs and facilities of TPWD. Sponsors may use funds to buy outdoor recreation equipment, food, instruction or transportation.

Priority Needs: Coordination of training and volunteer opportunities. Audience: community partner staff, youth and volunteers. Outcome: inclusion of habitat and wildlife messages in community programs and related community service projects. Support for and awareness of local habitat and wildlife issues.

- *Promote public awareness and responsible participation in outdoor recreation, especially hunting, fishing and nature tourism and to foster an appreciation of natural, cultural and historical resources.*

State Parks Interpretive Program: State parks offer site-based educational and training opportunities. State Historic Sites feature Texas' cultural history and have frequent site-based educational and training opportunities.

Angler Education: Volunteer instructors train youth in basic fishing and aquatic stewardship.

TPWD educational centers: Sea Center Texas, Texas Freshwater Fisheries Center, Parrie Haynes Ranch, Sheldon Lake Learning Center, World Birding Center and Barton Warnock Environmental Education Center provide sites and coordination for service projects, exhibits, training and interpretive programs.

TPWD Communications tools: The Texas Parks and Wildlife Magazine, PBS television series, television news reports, and outreach to mainstream and targeted media continue to inform the public and extend the reach of agency programs.

Priority Needs: Continued infusion of habitat information in recreation programs with messaging, signage, training equipment and participation in related program activities. <u>Audience:</u> New and existing outdoor recreationists. <u>Outcome:</u> wise use of resources; understanding of issues and responsible stewardship.

- *Encourage cost-effective partnerships with other state agencies, universities, local, state and national conservation organizations, private landowners and citizens to coordinate and leverage outreach, education and interpretation efforts.*

Texas Master Naturalist: A network of chapters around the state produce corps of trained volunteers who provide education, outreach and service dedicated to the beneficial management of natural resources and natural areas in local communities.

Great Texas Birding Classic: A partnership with the Gulf Coast Bird Observatory to coordinate an annual birdwatching tournament along the coast of Texas to provide recreational opportunities for adults and youth and raise dollars for on-the-ground bird conservation projects.

Project WILD: Universities, zoos, nature centers and conservation programs partner with TPWD to use the Project WILD curriculum to train educators about habitat and wildlife management.

Priority Needs: Support of training programs and program materials related to regional activities that address habitats and species of concern. <u>Audience:</u> Community volunteers, wildlife watchers. <u>Outcome:</u> On-the-ground conservation activities implemented and/or sponsored by the public.

- *Regularly evaluate outreach, education and interpretation programs.*

Program Charters: Texas Parks and Wildlife Department requires all education and outreach programs to formulate an annual charter detailing goals, objectives and evaluation measures. Charters go through a formal review to ensure consistency and effective contribution to the TPWD mission, solid partnerships, lack of duplication of service and cost efficiency.

Staff Training: Texas Parks and Wildlife Department program staff are being trained internally in best practices and evaluation to ensure excellence in providing conservation education.

Priority Needs: Formal training in best practices, evaluation methods and actual program evaluation support. Audience: TPWD staff. Outcome: well-defined program goals and objectives that measure effectiveness in imparting understanding and fostering action related to habitats and wildlife of concern as well as an effective application of research on best practices.

Texas Parks and Wildlife Department seeks a dynamic, robust conservation education effort to deliver key messages, build knowledge and skills and involve citizens in stewardship activities. However, the department does not have the financial resources and staff to independently and completely realize these aspirations. Achieving these goals depends on building key alliances with a broad array of interests and partners. Working collectively to achieve these goals, more people will be able to enjoy, understand and conserve the state's natural resources. The need for conservation education has never been greater.

Nature Tourism Issues and Strategies

Introduction

Nature-based tourism is defined as responsible travel to natural areas, which conserves the environment and improves the welfare of local people. It is tourism based on the natural attractions of an area. Examples include hunting, fishing, birdwatching, photography and visiting parks. These experiential tourists are interested in a diversity of natural and cultural resources. They want what is real and they want to be immersed in a rich natural, cultural, or historical experience.

Interest in nature tourism is growing in Texas as rural communities look for ways to diversify local economies and landowners look for ways to diversify ranch income. Texas rangelands comprise 59% of the total land area of the state. As a state that is more than 94% privately owned, the wildlife resources of Texas are entrusted to the stewardship of private landowners. A basic tenet of wildlife management in Texas has been to empower private land managers with information, technical assistance and incentives to manage wildlife populations for the public good as well as for individual economic gain.

Many landowners in Texas currently derive substantial income from wildlife-associated recreation in the form of hunting and fishing on their private lands. The 2001 Survey of Fishing, Hunting and Wildlife-associated Recreation showed that fishing contributed $2.0 billion to the state's economy, while hunting contributed $1.5 billion and wildlife watching $1.3 billion. Interest in nature-based tourism is rooted in a growing understanding among landowners that providing recreational opportunities for emerging markets of experiential tourists is another important way to derive economic benefit from the natural resources found on private lands. Activities such as birdwatching, photography, backpacking, horseback riding, mountain biking, wildlife viewing and canoeing are increasingly popular as urban residents and visitors strive to connect with the outdoors.

From the standpoint of conservation, nature-based tourism provides incentives for local communities and landowners to conserve wildlife habitats upon which the industry depends; it promotes conservation by placing an increased value on remaining natural areas. As nature tourism becomes more important to the local economy, communities have additional incentive to conserve their remaining natural areas for wildlife and wildlife enthusiasts.

From a state perspective, the goals of nature-based tourism in Texas are to promote habitat conservation, promote sustainable economic development and build broad-based public support for wildlife conservation programs. Texas Parks and Wildlife has chosen to implement a nature-based tourism program that is uniquely suited to a private land state such as Texas. Our efforts are concentrated on providing a diversity of recreational opportunities to an increasingly urban population of Texans as well as to a growing number of visitors from other states and countries. We have done this by providing wildlife viewing driving trails such as the Great Texas Coastal Birding Trail and Great Texas Wildlife Viewing Trails, and by working with private landowners and communities to develop nature tourism enterprises. Our goal is to connect people with nature by making it easier for them to enjoy the natural resources of Texas and thus to care about conserving them.

The nature-based tourism efforts in Texas will continue to focus on achieving habitat conservation by providing information and assistance to private landowners, communities, businesses and local community leaders wishing to make nature-based tourism an integral part of their business and community. By empowering people at the local level, we hope to build and provide guidance to a growing industry that holds great promise for sustainable economic development and conservation of wildlife habitat.

Through partnerships with other state agencies and local organizations, TPWD has been able to do more for landowners and communities. Texas Parks and Wildlife Department is an active member of the Texas Nature Tourism Council (TNTC), part of the Texas Travel Industry Association. As part of the TNTC, TPWD is able to meet regularly with nature tourism counterparts in Texas Department of Agriculture, Texas Cooperative

Extension, Texas Historical Commission, universities, communities, landowners and others interested in nature tourism. The Council makes it possible for agencies to coordinate workshops and outreach efforts to prevent duplication of work. These partnerships are important to the continued success of nature tourism workshops and educating communities and landowners on incorporating nature tourism into their business plans.

Technical Guidance

Texas Parks and Wildlife Department is actively involved in nature tourism development on both the community level and the private landowner level through the work of the nature tourism coordinator. The nature tourism coordinator currently works one-on-one with landowners in a variety of ways. When possible, the coordinator meets with landowners when they initially have their site assessment done by private lands biologists from Texas Parks and Wildlife. The nature tourism coordinator supplements the biological site assessment with guidance on potential nature tourism ventures that could work on the property as the landowner implements suggested habitat management techniques.

Through presentations at landowner workshops, TPWD also provides assistance, answers questions, helps locate available resources and makes contacts with landowners throughout the state. The nature tourism coordinator speaks at workshops and works closely with the previously mentioned partners to ensure the workshops are as in-depth and informative as possible.

Texas Parks and Wildlife Department also provides site visits and assessments to communities interested in developing a nature tourism program. Site visits and technical guidance for communities involves a tour of potential or existing nature tourism destinations in an area, meeting with Chamber of Commerce or city officials and developing some practical goals for the community. When invited, the nature tourism coordinator also assists the Texas Historical Commission with site visits to their Main Street Cities as part of their Resource Team, providing the tourism expertise to the team. These are usually more in-depth site assessments.

Education and Outreach

In addition to working with landowners and community leaders, the nature tourism coordinator also oversees development and maintenance of the Great Texas Wildlife Viewing Trails, a driving trail system that guides nature tourists to the best wildlife viewing sites the state has to offer. In developing these trails, the nature tourism coordinator works directly with many landowners, site managers, public land managers and community leaders educating them about the benefits of nature tourism destinations, how to reach their market and possible site enhancements to make their site more readily accessible to wildlife viewers.

The Land Acquisition, Restoration and Monitoring

The Nature Tourism Coordinator oversees the partnership between TPWD and the Gulf Coast Bird Observatory (GCBO) to run the Great Texas Birdwatching Tournament. This tournament is a self-funded event co-sponsored by TPWD and GCBO that raises money for habitat conservation, restoration, acquisition and monitoring projects along a 41-county area of the Texas Coast. Restoring existing habitat and acquiring new habitat is essential to ensuring stopover habitat for Neotropical migratory birds as well as providing year-round habitat for resident animals.

Element 4

Conservation Actions

- Continue to work cooperatively with other organizations doing nature tourism work with landowners and communities. This allows cooperation in the use of resources where necessary and ensures the best technical guidance possible to landowners and communities both one-on-one and in workshop settings
- Develop a nature tourism certification program for public and private landowners and nature tourist destinations. A certification program would give incentives to tourism destinations to conserve and restore native habitat in Texas. Additionally, tourists visiting Texas would be able to research tourism destinations based on requirements met or exceeded by certified locations
- Develop workshops as needed in areas of the state that have landowners and communities interested in nature tourism. These workshops should follow proven formats, contain the top subjects from previous workshops and should be

marketed widely through all of TPWD's partners so as to reach the widest audiences possible

- Fund habitat acquisition or restoration through the Great Texas Birding Classic. This will benefit migratory birds and populations of other native species. If additional funding is available, TPWD would be able to contribute to the habitat projects funded through our partnership with the Gulf Coast Bird Observatory

Urban Wildlife Management Issues and Strategies

Element 3

Introduction

The rapid urbanization of Texas creates many wildlife challenges and opportunities. Where humans and wildlife meet, there is potential for conflict, but also opportunity for sustaining compatible terrestrial and aquatic wildlife populations and increasing people's awareness of and appreciation for wildlife.

According to the U.S. Census Bureau, Texas is expected to be the second most populous state in the nation by 2025. Some counties are growing faster than others, but regardless, effective planning and concentrated development should be encouraged across Texas to combat suburban sprawl and loss of wildlife habitat. Open spaces within the urban/suburban environment are crucial for populations of development-sensitive wildlife species. Open spaces are areas that are free of development pressures and may include fields, forests and riparian corridors. Open spaces serve many purposes, such as filtering pollutants from the air and water, conserving water and soil, supplying habitat for pollinators and the plants that require them for reproduction and furnishing adequate space and habitat for breeding, foraging, travel and cover for wildlife.

Even though urban and suburban areas often contain more generalist wildlife species and offer limited opportunities for land protection and management, wildlife conservation programs should not ignore these lands. Indeed, rapid development and urban/suburban sprawl spreading out and away from urban centers are resulting in significant impacts on natural resources across Texas. For these reasons, it is becoming increasingly important that natural resource management agencies proactively work with local governments in urban and urbanizing areas (especially those with a high percentge of annual population growth expected) to ensure protection of the public's fish and wildlife resources and to minimize primary and secondary impacts from development.

As urban populations often seem “disconnected” from nature, these people may not always perceive that wildlife or habitat loss are critical threats that could impact them directly. However, the same environmental degradation that threatens wildlife populations can degrade drinking water supply, air quality or other factors of immediate interest to city dwellers. Drawing those connections for urbanites may create a new constituency for wildlife and habitat protection based on enlightened self interest. Children especially benefit from the exploration of their natural world as it increases their knowledge of environmental issues, appreciation of nature and their potential willingness to participate in conservation actions as adults.

Texas Parks and Wildlife Department's Urban Wildlife Program strives to maximize biodiversity within urban areas, build critical public support for conservation efforts and assist in guiding development pressures to help ensure the conservation of species and habitats in presently rural areas. By conserving and helping to manage remnant tracts of wildlife habitat close to urban centers, the Urban Biologists help provide convenient outdoor recreation and education opportunities and begin to address the alienation from nature experienced by many urban residents. Furthermore, some of the development pressure on the rural fringes of urban centers is from people who wish to "get back to nature" and want to live in an area where outdoor recreation and wildlife viewing opportunities are easily accessible. Providing more natural public lands within or near urban areas will help to make cities more livable and may reduce the pressure to develop rural farms and woodlands.

It is encouraging to note that there is increasing cooperation between state agencies and local governments in Texas to encourage municipalities, citizens and developers to become better stewards of our natural resources. For example, Texas Parks and Wildlife's Urban Wildlife Program in Dallas/Ft. Worth is a member of an interagency "Stream Team". The "Stream Team" is made up of stream experts, bioengineers, city planners, ecologists, etc. from TPWD, Natural Resource Conservation Service (NRCS), Environmental Protection Agency (EPA), North Central Texas Council of Governments (NCTCOG), U. S. Fish and Wildlife Service (USFWS), USACE and representatives of private consulting firms. The Stream Team assists local municipalities in addressing stream problems through on site technical guidance as well as by hosting an annual conference regarding stream/watershed best management practices.

Element 7

The conservation and education needs in the urban areas of Texas are varied and differ according to specific cities, but the work of Urban Biologists can be grouped into several loose and interconnected categories with each category perhaps containing several subcategories. These categories include Technical Guidance, Education/Outreach, Research and Monitoring and Nature Tourism. The following sections outline the needs associated with each of these categories, identifies the target audiences with specific needs and discusses strategies that TPWD's Urban Wildlife Program (The Urban Program) employees to address the needs.

Element 4

Technical Guidance

In the urban areas of Texas, there is a tremendous need for technical expertise regarding function and management of local ecosystems, habitats and associated wildlife species. The need for such information arises from many target audiences, but the types of technical guidance can be further divided into two subcategories: site-specific technical guidance and policy-oriented technical guidance.

Site-Specific Technical Guidance

This type of technical guidance is tied to a particular site that is owned by an organization seeking advice on how to manage the property for conservation. The following is a list of representative target audiences, the methods the Urban Program employs to address the needs of that audience and priority conservation actions needed for future work.

Existing Public/Quasi-Public Lands - Many city and county parks in Texas have been developed with human recreation as the top priority, but opportunities also exist to improve habitat management and wildlife-related recreation and education on these public lands. Often, city parks and greenways are so manicured that they are devoid of the intermediate canopy layer as well as the shrub and herb layer, thereby reducing usage by wildlife species that may otherwise utilize the area. In addition, trails that are too wide create breaks in the forest cover and disrupt sensitive areas. Managers of these lands need someone to guide them toward better management of the natural resources under their care. To meet this need, the Urban Program currently conducts site visits and makes recommendations to shift the management of these parcels toward a more functional natural system. The Fort Worth Nature Center and Refuge (FWNCR) in Fort Worth and River Legacy Park in Arlington are prime examples of city parks that have made natural resource management a priority by conserving habitat integrity and educating the public by offering guided hikes and programs about the environment. These parks can serve as models for other city parks and recreation programs that wish to better integrate natural resources management into traditional programming methods.

Public lands aren't the only parcels that need technical guidance. There are also quasi-public lands such as homeowner association open space, corporate campus open space, golf courses, etc. Managers of these lands often find themselves responsible for the management and maintenance of habitats they do not understand. These spaces may be forests, prairies or wetlands (ponds). There is a need for someone to guide them in managing these spaces to maintain their ecological health. To meet this need, the Urban Program has been conducting site visits to assess the condition of the habitats at each site. Management plans, materials, brochures and techniques are developed to address needs that are universal to property managers.

- Priority conservation actions include continuing to offer site specific technical guidance to promote more ecologically sensitive management of existing public/quasi-public lands. As part of this effort, the urban program will perform ongoing assessments of the type of information land managers need, and will develop materials, techniques, etc. to meet those needs.

Development

Developers do not have training in natural resource management though they make many decisions that impact the land. There is a tremendous need for an ecological insight to be factored into the development planning process. The Urban Program is currently working with cooperative developers by providing site-specific technical guidance so that development is directed into the most suitable locations while conserving the best habitats (conservation subdivision design). The undeveloped acres are then placed under conservation easement and permanently maintained as open space (for more discussion, see Land Acquisition section).

- Priority conservation actions include expanding efforts to provide site-specific technical guidance to developers to ensure that habitats are considered during the project planning process. Additionally, the Urban Program plans to continue conducting workshops and conferences to promote more conservation development (for more discussion, see the Education/Outreach section).

Nuisance Wildlife Issues

Wildlife conservation in urban areas necessarily relates to managing human/wildlife interactions. Though most nuisance wildlife issues may not relate directly to a conservation concern (e.g. a listed species or an endangered habitat), our efforts to solve nuisance wildlife problems are critical to improving the perception of urban wildlife issues in general. Nuisance wildlife problems usually occur when wildlife are attracted to human dwellings for food or shelter, when some wildlife populations are enhanced by the presence of humans, and when wildlife is displaced by human development. Wildlife species that can be compatible with human development include bats, foxes, raccoons, opossums, squirrels, deer, pigeons, starlings, house sparrows, Canada geese and chimney swifts, among others. Many wildlife damage problems can be addressed by changing the perceptions and expectations of homeowners with regards to living with wildlife. Although nuisance wildlife issues are primarily handled by another agency (Texas Wildlife Services) as well as private business, the Urban Program is coordinating with these players to ensure that the methods and educational messages are acceptable and consistent.

Policy-Oriented Technical Guidance

Regional Land Use Policy

In Texas, there are several factors working against practical, statewide coordination of land use planning. The geographical size of the state, counties with no planning authority and the proliferation of municipalities all combine to make statewide land use planning extremely difficult. Accomplishing practical planning at the regional level is also filled with difficulties. The Dallas/Ft. Worth area is a good example. The metropolitan planning organization for the DFW area is the North Central Texas Council of Governments (NCTCOG). The NCTCOG's region covers 16 counties. The population of the region alone at (5.8 million) is larger than 30 states. The land area (12,800 sq. mi.) is larger than nine states. There are over 150 municipalities in the region. In Texas, only cities have planning authority. This makes regional planning coordination difficult and statewide planning next to impossible. There is therefore a tremendous need for coordination of regional policy to ensure proper management of natural resources on a practical, local level. To address this need, the Urban Program currently works with local planning organizations to impact regional policies. For example, the NCTCOG has recently developed a policy for integrated stormwater management (iSWM). This document seeks to unite the stormwater policies for all municipalities in the region. By being involved in crafting this regional policy, the Urban Program has directed the way the region will design and maintain stormwater wetlands, repair degraded streams, eliminate non-point source pollutants, reduce stormwater generation, etc.

- Priority conservation actions include expanding the influence the Urban Program has on regional policy. This will likely necessitate training for Urban Biologists to better understand the disciplines of engineering, landscape architecture, regional planning, etc. and to become more accustomed to presenting ecological concepts in terms those professionals can relate to.

Municipal Ordinances/Policies

- Municipalities have the authority given to them by the state to enact ordinances/policies governing various behaviors of citizens and businesses within the city limits. Ordinances which impact natural resources include landscape ordinances, tree preservation ordinances, subdivision regulations, etc. Often, these ordinances are written by individuals with limited training in natural resource management. As a result, the policies often promote the use of exotic plant species while mandating the elimination of native species and habitats. There is a need to make these policies more ecologically sensitive. To address this need, the Urban Program is working with local municipalities to craft new, more ecologically minded ordinances. The Urban Program is promoting the use of native plants as well as the concept of designing urban spaces around natural habitats.

- Priority conservation actions include expanding influence on local ordinances and policies and continuing to promote regionally appropriate native landscaping. Additionally, cities would benefit from standardized template ordinances that have been written for them. This would reduce the resistance to crafting new ordinances by providing cities with “turn key” templates they can use.

Nuisance Wildlife Policies

Nuisance wildlife issues will inevitable arise within any city. Most cities wait until a nuisance problem reaches a critical mass before acting. There is a need for Texas cities to develop a proactive strategy to avert nuisance problems. To address this need, the Urban Program is working with cities to develop urban wildlife management policies. Urban Biologists are working with the city of Lewisville to develop an educational program to encourage beneficial wildlife while also creating a system of municipal responses to observed nuisance behaviors of targeted species of wildlife (for more information, see the education/outreach section). City staff will work with citizens to monitor and report human/wildlife encounters. Encounters will be categorized and ranked according to the relative acceptability of the behavior. A series of “trigger” behaviors (an unacceptable behavior such as coyotes taking pets) will be outlined and corresponding municipal action will be identified in the plan. Should a particular population begin to exhibit trigger behaviors, then the management plan will dictate the municipal response. The municipal response at the different levels of trigger behaviors will be proactive in nature and designed to stop current behaviors as well as prevent the appearance of more aggressive trigger behaviors in the wildlife population.

- Priority conservation actions include conducting research to determine the most effective behavioral modification methods to employ for each species of concern. Additionally, standard recommendations need to be developed based on research as it becomes available.

Element 8

Education and Outreach

Developers

As mentioned in the technical guidance section, the Urban Program is working with individual development projects. However, there is a need to educate developers and government officials on a larger scale. The Urban Program is currently working with local and statewide partners to conduct conferences on conservation development. Several examples exist. In the Austin area, the Ladybird Johnson Wildflower Research Center has partnered with various agencies to present a conservation development conference for the last several years. The town of Flower Mound has done the same. There is a momentum building in support of conservation development. Priority conservation actions include continuing to conduct conferences to promote conservation development. However, there is a statewide need to define exactly what conservation development entails.

- Priority conservation actions include The Urban Program facilitating and promoting the push to create guidelines for conservation development in Texas. Additionally, the concept of conservation development has heretofore been limited to upper income developments. The Urban Program will seek ways to apply conservation development concepts to more affordably priced projects.

Schoolyard Habitats

Schools in Texas urban areas are hesitant to bus kids off-site for environmental studies. Therefore there's a need for schools to have outdoor classrooms on site for the students to study local habitats, wildlife, etc. To meet this need, the Urban Program works with local schools to create schoolyard habitats. The assistance offered ranges from personal one-on-one guidance between an Urban Biologist and school officials to several schools attending a schoolyard habitat workshop. Urban Biologists teach workshops on creating schoolyard habitats as well as workshops to teach teachers how to present ecological concepts in the classroom. As part of this effort, the Houston urban office has written a manual entitled "Creating a School Habitat". Following the Houston urban office's lead, many school habitats have been created across the state.

- Priority conservation actions include updating and reprinting the "Creating a School Habitat" manual as well as expanding the number of workshops offered.

Native Landscaping

The landscape/nursery industry as well as the average homeowner has a tremendous impact on the vegetation that gets planted in local landscapes. The historical trend in the landscape industry has been to promote exotic plants. Therefore, in urbanizing areas native plant communities are systematically replaced by predominantly exotic species. Habitat is lost along the way. To address this problem, the Urban Program developed the Texas Wildscapes Backyard Wildlife Habitat Program. This program encourages homeowners to provide food, water and shelter in their yard and certifies those who do so. The program promotes the use of native plants to not only provide food for wildlife, but to also provide native structure for nesting and cover. As part of this effort, the Urban Program produced a book entitled Texas Wildscapes: Gardening for Wildlife. To support Texas Wildscapes, the Urban Program conducts Wildscapes workshops across the state. These workshops teach homeowners various aspects and details of Wildscaping in their area. Using concepts from the Texas Wildscapes program, demonstration gardens have been created across the state.

- Priority conservation actions include converting the information in the Texas Wildscapes book into a web-based application.

Absentee Landowners

Texas is more than 94% privately owned. The profile of the typical landowner in Texas has been changing for some time now. Historically, land ownership in Texas was dominated by large ranches with the owner living in close contact with the property. Today, that picture has begun to change. There is now a proliferation of absentee landowners. The current trend is for urbanites living in Dallas, Houston, San Antonio, etc. to own property elsewhere in the state. The large ranch tradition is giving way to more landowners owning smaller parcels. This shift has generated associated problems. The absentee landowner no longer has the close connection with the property and is therefore less experienced with land management. To address the needs of these landowners, the Urban Program conducts landowner workshops in the major urban areas. In Houston as well as San Antonio, these workshops have met with great success and have been well attended.

- Priority conservation actions include expanding the workshop effort as well as developing materials specifically tailored to these new landowners. These new landowners are generally technologically adept and would therefore benefit from multimedia tools (videos, CDROM’s, etc.) to help educate them.

Next Generation Professionals

The Urban Program is involved in educating current professionals, but recognizes the value in training the next generation professional as well. Currently, Urban Biologists are partnering with local universities to lecture in landscape architecture as well as city and regional planning. The Urban Program has also helped to develop and teach Urban Wildlife Management courses at Tarleton State University and Texas A&M University. As part of the Texas A&M course, Urban Biologists assisted in the development of an urban wildlife management textbook that is currently in press.

- Priority conservation actions include expanding the number of universities teaching urban wildlife management courses as well as creating courses of study in landscape architecture that train students to design landscapes to mimic natural ecosystems.

General Public

There is a growing trend of urbanites becoming more and more disconnected from the natural environment. The amount to which people are aware of environmental issues varies greatly within the general public. As a result, the Urban Program has developed varying strategies to meet the differing outreach needs. For the general, disinterested urban audience, Urban Biologists rely heavily on the media. Television, newspaper, radio, etc. all serve to engage the masses with a general message. For audiences with some interest in natural resource issues (garden clubs, scout groups, civic organizations, etc.), Urban Biologists deliver presentations along general wildlife themes (Bats are Beneficial, Landscaping for Wildlife, etc.). These presentations are designed to casually educate the audience and create a desire to learn more. As an individual's awareness increases and the desire for more in-depth material increases, he/she finds other outreach opportunities more suitable. For these individuals, Urban Biologists offer volunteer training programs such as the Texas Master Naturalist Program and the Texas Nature Trackers Program. These programs offer more detailed instruction, but also require more action in return from the individual. Once a person has gone through these programs, he/she becomes a partner with the Urban Program in a sense and begins to help the program accomplish its goals by speaking to groups, manning educational booths, etc.

Professionals/Consultants

Consultants and professionals are often somewhat educated in natural resource management, but may lack background in particular areas (bioengineering, use of native plants in the landscape, etc.). To address specific needs of these individuals, the Urban Program conducts specialized workshops. As a member of the "Stream Team", the Dallas office helps present a workshop in Stream Dynamics/Bioengineering each year. This workshop is used as a forum to address problems specifically faced by professionals in the field and to educate them about techniques and methods uncommon to our area.

- Priority conservation actions include conducting research to determine how locally native plant materials perform in bioengineering techniques commonly used in other parts of the country. Additionally, regional curves for local streams need to be researched and generated. Lastly, pristine reaches of each stream type in our urban areas need to be located and measurements recorded to serve as templates for restoration projects.

Element 5

Research and Monitoring

University Partnerships

There is a great need for urban wildlife research. Urban wildlife management is a relatively new discipline so there is much that is unknown. To address this need, the Urban Program has been partnering with local universities to conduct urban wildlife research. The Austin office partnered with a local university to examine the impact of Wildscaping on native bird diversity. The Dallas office partnered with a local university to examine the ecology of urban white winged doves.

- Priority conservation actions include research to address various nuisance wildlife issues (grackle overpopulation, coyote behavior modification, etc.) as well as the impacts of various urban practices (mowing, trail building, etc.) on urban-sensitive species (Texas horned lizard, painted bunting, etc.).

Citizen Science and Volunteers

- In addition to research gained in partnership with universities, the Urban Program can also benefit from trained citizen volunteers. There is value in data collected by citizens who've been trained to gather such information. Urban Biologists are limited in the amount of time they can dedicate to research. An army of trained citizens can capture data in locations and at times unavailable to state agents. To capitalize on this, the Urban Program works with several volunteer programs including the Texas Master Naturalists and the Texas Nature Trackers. These programs train volunteers to monitor or “watch” species of concern or interest. Currently the most popular programs are the Hummingbird Watch and the Texas Horned Lizard Watch.

- Priority conservation actions include expanding the number and competency levels of citizen volunteers through additional training sessions as well as broadening the list of species that these volunteers are capable of monitoring.

Land Acquisition

Regional Planning Efforts

- Natural open space in urban areas is valuable psychologically, environmentally and ecologically, yet it is not as plentiful as many Texans would like it to be. There is a need for strategic regional open space acquisition. To assist planners and other officials, the Urban Program has become involved in land acquisition efforts. The San Antonio urban office helped assess lands to be purchased with the funding generated by a local bond election. The habitat values of the proposed lands, as well as aquifer recharge areas were given high priority.
- Priority conservation actions include expanding the Urban Program’s influence in regional planning organizations as well as better coordinating the open space systems of local governments within a region.

Park Grants for Land Acquisition

Local municipalities often employ planners in the parks departments who understand the need to purchase parcels to preserve them as open space. The Urban Program currently assists such planners in determine the best parcels for purchase. However, many cities do not have the funding to purchase sufficient amounts of natural open space. These cities rely on the TPWD to provide funding for land acquisition through grants. Additionally, there is a need to ensure that those lands that are purchased are managed as natural areas.

- Priority conservation actions include increasing the funding and personnel available for administering grants to assist in purchasing open spaces.

Conservation Easements

Land values of open space in urban areas often make outright purchase cost prohibitive. There is a need to use the private sector to broaden the open space network without draining the budget of the local municipality. The Urban Program is currently working with the private sector to ensure open space networks are considered during development. Using conservation subdivision design concepts and conservation easements, land is being set aside as open space without the need for public purchase.

- Priority conservation actions include expanding the public's awareness of available options for creating open space networks by conducting additional workshops and conferences on this subject.

Nature Tourism

Wildlife Viewing Sites

Many national surveys have indicated an increasing interest in wildlife viewing. Local municipalities often have several potential park sites that can be greatly enhanced to improve the wildlife viewing opportunities. Combine this with the general need to maintain wildlife habitats in the city and a great partnership emerges to create locations within our urban areas for meaningful wildlife viewing experiences. The Dallas and Houston areas have large international airports resulting in a high level of travelers passing through the area. It's not uncommon for these travelers to find themselves with layovers at these airports. Birdwatching enthusiasts may often look for a local, easily accessible location to spot native avifauna. The Urban Program currently works with municipalities to create urban habitats in local parks as well as provide viewing opportunities (blinds, etc.).

- Priority conservation actions include expanding this effort to get additional sites in place as well as creating a wildlife viewing guide locating sites within easy travel distance from the airports.

Monitoring and Adaptive Management

Element 5

Associated Maps

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Texas Rivers and River Basins…………….. 12

Texas Bays and Estuaries…………………...29

Introduction

Monitoring is an important part of the management of habitat, flora and fauna. Without a monitoring component to each management plan or strategic planning effort, the goals of that document can not be met. Monitoring allows for adaptive management, a principle in which management objectives and goals are maintained or amended based on information delivered through monitoring efforts. Monitoring allows managers to know whether changes are occurring on the landscape or within a population.

The Texas Parks and Wildlife Department monitors several different species and habitats in an effort to manage wildlife and adapt new strategies for habitat conservation and management. Many of these monitoring process are outlined below, however it is important that TPWD and its partners work together to spread a limited number of resources over more issues of concern. This strategy will deliver a monitoring package targeted to address the CWCS conservation priorities. The monitoring package shall be comprehensive enough to meet the needs of the strategy and still be easily evaluated and modified as needed. Prior to engaging in a comprehensive terrestrial monitoring effort, the statewide mapping and inventory efforts must be conducted to determine the state of species and habitats throughout Texas. The statewide biological survey will allow TPWD and its partners to collect data from consistent locations maintained indefinitely to provide information on species and habitat.

It is important to outline specific principles to ensure that the monitoring package meets the needs of the CWCS and the general goals of consistent, statistically sound management in Texas. The following principles must be applied to future monitoring efforts in order for them to be cohesive with this strategy and the needs created by the inventory process. These principles were developed primarily by the United States Forest Service (USFS), Defenders of Wildlife and the United States Geological Survey (USGS).

According to the USFS there are three types of monitoring efforts that should be used in order to truly determine the state of habitats or species (2004).

- Targeted Monitoring: "Monitoring the condition and response to management of species and habitats that are identified as being of concern or interest"

- Context Monitoring: "Monitoring a broad array of ecosystem components at multiple scales without specific reference to influences of ongoing management"

- Cause and Effect Monitoring: "Investigates the mechanisms that underlie habitat and species response to management and other forms of disturbance"

It is both strategically and operationally difficult to maintain a monitoring effort that meets the needs of all species and habitats. It must be noted that a strong program includes the use and interaction of all three of these methods, within the financial and personnel limitations existing in each wildlife agency. It is impossible to monitor every Species of Concern in the state of Texas based on financial constraints and personnel limitation, therefore the species list and hierarchy established in this strategy must be followed barring changes in priority based on imminent threat. It is also critical that TPWD work with all ecological partners to increase funding and personnel for monitoring. Many of these partners have land or access to land as well as resources that could assist with garnering a more comprehensive picture of the state natural resources. All data collected during these monitoring efforts must be based on sound research design and appropriate statistical methodology regardless of who or what organization is collecting data. This will allow TPWD to use monitoring data to populate the Natural Diversity Database (NDD). Texas Parks and Wildlife Department can then share those data with all interested partners without fear of providing an inferior or ineffective product to partners.

The USFS *Recommendations on Monitoring Terrestrial Animal Species and Their Habitats* (2004) was used to determine what elements should be incorporated into this document. With some slight modifications, these components should address the needs of TPWD and its partners.

Critical Elements for Successful Monitoring in Texas

- Make a commitment to improve monitoring of terrestrial animals and their habitats
- Ensure that all monitoring contributes to adaptive management by exploring the causes for trends and alternative scenarios that could reverse unfavorable trends
- Ensure that all monitoring protocols are sound and data collected are statistically useful in order to guarantee their appropriateness to be included in the Natural Diversity Database
- Implement monitoring strategies that integrate habitat and population monitoring. Monitoring habitat alone will rarely be sufficient for adaptive management because habitat relationships are not well understood and may not be predictable
- Recognize that monitoring will exist at different scales. Coordinate across ecological and administrative scales, with emphasis on the role of the Regions. Because TPWD will be working with partners, it would be beneficial to all groups if ecological regions were used for both communications and coordination
- Establish appropriate roles and coordination for other agencies, organizations and private landowners. If monitoring duties are split amongst partners a greater area can be covered in less time. With proper coordination, all data can be collected into the NDD and adaptive management can take place by creating a better decision making process that all partners can agree on
- Provide adequate staffing, skills and funding structures to accomplish monitoring objectives
- Adopt and integrate three types of monitoring (context, targets and cause-and-effect)
- Use sound ecological principles and risk assessment to prioritize and design monitoring activities

- Use partnerships and interagency coordination to accomplish monitoring objectives
- Ensure that individuals and teams responsible for monitoring development and oversight have appropriate skills

Texas Parks and Wildlife Department should work with partners to implement monitoring strategies based on the above components. While TPWD and its partners already have monitoring efforts underway, those efforts should be evaluated to determine whether they meet the above elements. They should also be evaluated to determine whether data collected from these monitoring efforts can be incorporated into the NDD.

Purpose of Monitoring in Texas

Texas is a large state with many species and habitats in need of monitoring; however, several issues need to be taken into account prior to continuing this process. Texas Parks and Wildlife Department has historically monitored multiple species using several different techniques that have been outlined by biologists working for the Department. In addition to terrestrial species and habitat, Texas is tasked with monitoring bays, estuaries and all of the inland reservoirs, rivers and many spring-fed catchments. The sheer size and need is difficult to measure, but a significant portion of the TPWD budget is dedicated to monitoring species and habitats.

In Texas, there are over 1,000 species of terrestrial vertebrates, 29,000 species of terrestrial invertebrates and greater than 4,000 species of vascular plants that potentially need monitoring. Monitoring efforts in Texas should include the continuation of some current monitoring efforts and combining other efforts into more habitat or species/guild monitoring efforts.

In addition to animal species, several plant species are also being monitored yearly to ensure the viability of their populations in different areas of the state. Knowledge of the vegetation of the state will enhance our overall ecological knowledge and allow us to refine the monitoring efforts of our faunal species.

Current Monitoring Efforts

The main monitoring document used by TPWD was developed to coordinate efforts on TPWD lands in 1996. The *Baseline Inventory and Monitoring Procedures on Texas Parks and Wildlife Lands* outlines the methods TPWD employees use to monitor or evaluate vegetation, herptiles, birds and mammals. At the time of its development, this document met several of the needs of TPWD and its land managers. Procedures should now be updated based on new technology as well as refined field techniques and data collection forms. An effort should be made to review this document and update it as needed to best accomplish the goals of this dynamic strategy. A special emphasis should be put on new technology such as GPS units and GIS software. These items were not widely used by TPWD in 1996 but are in frequent use by all field staff today. Information and education on the use of this newer technology should also be outlined in an updated version of this document.

Species and Habitat Monitoring

Group	Organization	Current Monitoring Efforts	Partners	Time Frame
Birds	Fort Hood - United States Army	Black-capped vireo monitoring	The Nature Conservancy of Texas, Various universities	Annual
		Golden-cheeked warbler monitoring	The Nature Conservancy of Texas, Various universities	Annual
		Turkey hen-poult count and survey	None	Annual
	TPWD	Bald Eagle surveys	Volunteers, United State Geological Survey	Annual
		Spring call counts (quail) - Matador and Gene Howe Wildlife Management Areas	None	Annual
		Black-capped vireo surveys at Kerr Wildlife Management Area	None	Annually in May.
		Breeding Bird Survey	100+ Volunteers from around the state; coordinated nationally by the U.S. Geological Survey	Annual
		Chachalaca surveys (TPWD Wildlife Division - Region 1)	None	Annual
		Christmas Bird Count	Coordinated by the National Audubon Society	Annual
		Colonial Waterbird Inventory	USFWS, Texas General Land Office, National Audubon Society, The Nature Conservancy, Center for Coastal Studies TAMU-CC, Coastal Bend Bays and Estuaries Program	Annual
		Dove reward banding study	United State Fish and Wildlife Service	Annual
		Fall Covey Counts (quail) - Matador and Gene Howe Wildlife Management Areas	None	Annual

		Lesser prairie chicken distribution survey	None	Annual
		Lesser prairie chicken harvest survey	None	Annual, Until 2005
		Lesser prairie chicken lek survey	None	Annual
		Mourning Dove (TPWD Wildlife Division - Region 1)	None	Annual
		Mourning Dove call count survey	United State Fish and Wildlife Service	Annual
		Red-cockaded woodpecker surveys	None	Annual
		Roadside observation surveys (quail, pheasant)	Audubon Texas	Annual
		Texas Hummingbird Roundup	Volunteers	Year round
		Turkey hen-poult count and survey	None	Annual, Until 2005
		Urban bird point counts	Texas State University	2005-2007, monthly
		Waterfowl surveys (goose, midwinter waterfowl)	United State Fish and Wildlife Service	December and January of each year
		Whitewing Dove production survey	None	
Mammals	Fort Hood - United States Army	Predator surveys	None	Ongoing
		White-tailed deer surveys	None	Annual
	TPWD	Black Bear - when trapped or collared (TPWD Wildlife Division - Region 1)	None	Periodic
		Chronic Wasting Disease survey	United State Fish and Wildlife Service	Annual
		Desert bighorn sheep population surveys	Foundation of North American Wild Sheep, Texas Bighorn Society	Annual
		Furbearers surveys	None	Annual

		Javelina (TPWD Wildlife Division - Region 1)	None	Annual
		Mountain Lion (TPWD Wildlife Division - Region 1)	None	Annual
		Mule deer (TPWD Wildlife Division - Region 1)	None	Annual
		Pronghorn (TPWD Wildlife Division - Region 1)	None	Annual
		Pronghorn population surveys	None	Annual
		River otter survey	None	Every 3 years
		White-tailed and mule deer - age/weight/antler development surveys	None	Annual
		White-tailed and mule deer population surveys	None	Annual
		White-tailed deer age, weight, antler harvest surveys	None	Annual
		White-tailed deer browse utilization surveys	None	Annual
		White-tailed deer surveys	None	Annual
Herptiles	TPWD	Alligator surveys (spotlight and nest - aerial)	None	
		Box turtles	None	Ongoing
		Houston Toad	Volunteers, Texas State University	Annual
		Texas Amphibian Watch	Volunteers	Ongoing
		Texas horned lizard - Matador Wildlife Management Area	None	Annual
		Texas Horned Lizard Watch	Volunteers,	Ongoing
Terrestrial Invertebrates	Balconian Naturalists' Group	Austin 10 county area butterfly fauna	C. J. Durden, P.I.	Since 1968: weekly to monthly

	Central Texas Melittological Institute	Bees of Texas survey	None	Annual
		Bees of the Brackenridge Field Lab (Austin Texas)	None	Annual
	Fort Hood - United States Army	Cave crickets	University of Illinois	Ongoing
		Status assessment 19 endemic obligate cave invertebrates	The Nature Conservancy of Texas	Ongoing
	Illinois Natural History Survey	Phylogeography of cave crickets in Central Texas (molecular study)	Zara Environmental, Buda Texas	Into 2007
		Plethodon sp. in cave and spring at Fort Hood, Texas	Zara Environmental, Fort Hood Natural Resources Branch	Into 2006
		Stable isotopes of cave crickets in central Texas (feeding urban vs. rural)	Zara Environmental, Buda Texas	Into 2007
	Zara Environmental LLC	Camp Bullis biomonitoring	James Reddell, Texas Memorial Museum and George Veni and Associates	3 times per year
		Lakeline Mall Habitat Conservation Plan	None	4 times per year
Terrestrial Habitats	National Parks Service	Fire and fuel dynamics	None	To be determined
		Forest health	None	To be determined
		Landscape dynamics	None	To be determined
		Non-native vegetation/early detection	None	To be determined
		Terrestrial vegetation communities	None	To be determined

	Orion Research and Management Services	Feral hog management - Protect Endangered Species habitat and sensitive riparian systems in the Bandera Canyonlands	Environmental Defense, The Nature Conservancy of Texas, Private landowners	Ongoing
Inland Aquatic Species and Habitats	National Parks Service	Water quality	United State Geological Survey, TCEQ	To be determined
	TPWD	Aquatic vegetation control studies	United States Army Corps of Engineers	Project specific
		Comanche Springs pupfish	None	Periodic
		Devils River minnow	United State Fish and Wildlife Service	Annual
		Fish kill/pollution complaint investigations	None	Event specific
		Golden Alga Survey	TCEQ, River Authorities	One time sampling
		Guadalupe bass	None	Annual
		Headwater catfish	None	Periodic
		Heart of the Hills freshwater mussel survey information	Volunteers	Annual
		Hydrological and biological assessment of selected Edwards Plateau springs: River basins: Nueces, Guadalupe, Colorado	Biological: 2/year Hydrological:3-4/year	31 springs sampled from October 2003 to May 2004 and 40 springs sampled from March 2005 to May 2005
		In-stream flow evaluations	TWDB, TCEQ	Project specific
		Lake Whitney golden alga bloom monitoring	BRA, TIAER, Texas State University	Weekly during bloom

		Mexican stoneroller	None	Periodic
		Natural resource trustee natural resource damage assessments	TCEQ, Texas General Land Office, United State Fish and Wildlife Service, NOAA	Event specific
		Pecos pupfish	None	Periodic
		Recreational fisheries contaminant study	TCEQ, DSHS	3 year study
		Reservoir recreational creel surveys	None	Periodic
		Reservoir recreational fisheries monitoring	None	Annual with reservoirs on a 4 year rotation
		reservoir sportfishes	None	Annual
		Rio Grande fish community	None	Periodic
		San Felipe gambusia	None	Annual
		State Wildlife Grant freshwater mussel survey	Stephan F. Austin State University, LCC	FY2005/ FY2006
		Texas Mussel Watch	Volunteers	Ongoing
Coastal Aquatic Species and Habitats	National Parks Service	Coastal dynamics	United State Geological Survey, TXBEG	Periodic
		Marine and estuarine SAV		To be determined
		Sea turtle nesting and stranding	TPWD, United States Fish and Wildlife Service, National Marine Fisheries Service	Annual
		Water Quality	United State Geological Survey, TCEQ	To be determined
	TPWD	Bag Seines (Juvenile finfish/Juvenile	None	Monthly

		Crustaceans)		
		Bay Trawls (Crustaceans/juvenile finfish)	None	Monthly
		Gill Nets (Juvenile/Sub adult finfish/crabs)	None	Seasonally (Spring/Fall)
		Gulf Trawls (Crustaceans/juvenile finfish)	None	Monthly
		Oyster DredgeMarket/submarket size oysters	None	Monthly
		Sportfish Harvest Surveys	None	High Use May 15 - Nov 15
		Sportfish Harvest Surveys	None	Low Use Nov 16 - May 14
Plants	TPWD	Beech-White Oak-Maple ravines (Southern ladies slipper orchid)	TPWD State Parks Divisions, United States Forest Service, Temple Inland Timber Corp. and The Nature Conservancy of Texas	Annual
		Bigtooth maple canyons (Carrs rattelsnake root)	The Nature Conservancy of Texas and private landowners	Annual
		Effects of white-tailed Deer management on recruitment of Quercus buckleyi	Texas State University, Plateau Integrated Land and Wildlife Management	Ongoing
		Longleaf pine xeric sandhills (Texas trailing phlox and white firewheel)	The Nature Conservancy of Texas, Big Thicket National Park and Temple Inland Timber Corporation	Annual
		Neches River rose mallow	United States Fish and Wildlife Service, Stephen F. Austin State University, USFS, Texas Department of Transportation	Annual
		Pitcher plant bogs (Chapmans yellow eyed grass, bog coneflower and tiny bog buttons)	TPWD Wildlife Management Areas, United States Forest Service, Temple Inland Timber Corporation and private landowners	Annual

	Saline barrens (earthfruit)	Temple Inland Timber Corp. and Arkansas Natural Heritage Program	Annual
	Star cactus	None	Annual
	Texas poppy-mallow	Texas Department of Transportation	Annual
	Texas snowbells	The Nature Conservancy of Texas, volunteers	Annual
	Texas wild-rice	Volunteers, United States Fish and Wildlife Service, Texas Department of Transportation	Annual
	Tobusch fishhook cactus	Texas Department of Transportation, TPWD State Parks Division	Annual
	Weches glades (white bladderpod and Texas golden gladecress)	United States Fish and Wildlife Service, The Nature Conservancy of Texas, Temple Inland Timber Corporation and private landowners	Annual
	Woody and herbaceous vegetation transects - Matador and Gene Howe Wildlife Management Areas	None	Annual

Additional Monitoring Efforts in Texas

Coastal bays and estuaries are monitored monthly (depending on need) and trend data is used to determine whether there are any critical needs within these areas. The methods that are currently employed have been successful and do not need to be amended at this time.

State reservoirs are also being monitored, with much of the effort focused on sportfish. However, additional data are collected that provide information on aquatic plant life, nongame species and exotic species that may affect native flora or fauna. Additional monitoring data are also collected on selected streams and rivers. It is important that aquatic nongame species receive and utilize additional monitoring efforts and that TPWD put an emphasis on particular waterways and species that are of immediate interest.

The major nongame bird monitoring in Texas occurs as part of Breeding Bird Surveys (BBS, Patuxent Wildlife Research Center), Christmas Bird Counts (CBC, National Audubon Society) and the Colonial Waterbird Surveys (Texas Parks and Wildlife Dept., USFWS, Texas General Land Office and Texas Colonial Waterbird Society). There are several other species-specific monitoring efforts underway in the state as well as several game surveys. While bird species are well represented in monitoring efforts, upgrades to the current monitoring systems should be adopted to increase the usefulness of the data. The first alteration would be that all bird monitoring data be stored in a centralized database hosted by the United States Geological Survey in Patuxent, Maryland. Texas Parks and Wildlife Department currently collects data through the above mentioned surveys as well as point counts conducted on TPWD-owned Wildlife Management Areas. All of this information must be used at the national level to determine trends in bird populations. Two additional needs must also be met for bird monitoring: additional points need to be added to the current breeding bird surveys and those points need to be staffed by trained personnel or volunteers. Texas nongame avian biologists should decide on how many additional points are needed and appropriate locations of those points.

Mammal and herptile populations are currently under-represented in Texas monitoring efforts. Once the Texas biological survey is underway, wildlife biologists will begin to understand these populations better. Using the biological survey points, both mammals and herptiles can be monitored to determine population health. These monitoring efforts should be used to make management recommendations for the habitat or ecoregions for species or guilds. Adaptive management techniques should be followed to ensure that appropriate amendments are made as habitat improves and species potentially stabilize.

Current invertebrate monitoring efforts in Texas generally focus on cave-dwelling species. Texas Parks and Wildlife Department needs to create opportunities for better understanding of all invertebrates in Texas and should start with those high priority species listed in this strategy. It is impossible to gain knowledge quickly in terms of terrestrial invertebrates because of the sheer volume of species that exist. Texas Parks and Wildlife Department must use the biological survey as an opportunity to establish a base of knowledge of invertebrate taxonomy, populations and life history. Caves should continue to be monitored with special interest being placed on those species of concern listed in this strategy.

Critical Components to Monitoring

Texas has not had a complete biological inventory since 1905, when Vernon Bailey and his fellow surveyors scoured the state collecting data on animals and plants for the United State Bureau of Biological Survey. The resulting publication is the Biological Survey of Texas and was published 100 years ago this year. It is important to establish this document as the precursor to an updated monitoring program. Without a continuation of the inventory it will be impossible to monitor temporal fluctuations of populations and attempt to correlate those fluctuations with variables. Continuation of a Texas biological survey will allow for renewed adaptive management efforts of Texas' wildlife and habitats. Information gathered from the survey and future monitoring efforts will allow TPWD and partners to determine the best course for the species and habitat monitored.

We have made tremendous biological and technological strides since the completion of the 1905 Biological Survey of Texas and many more tools are at the disposal of Texas biological agencies and organizations. Each of these groups is using this new technology for the betterment of Texas conservation and it is imperative that we work together to avoid duplication of efforts. Surveying and monitoring species of plants and animals is a way that the TPWD can partner with other organizations to ensure quality data, cover more of the landscape and spread already limited resources over a greater part of the state.

Prior to conducting survey efforts, it is important that available technology, in the form of database and spatial analyses and mapping software, are used to generate vegetative cover maps of the state. This priority was also analyzed in the priority conservation actions with a high priority being put on the ground truthing of those data and maps that are developed.

Once map data from habitats and ecoregions have been ground-truthed, the new biological inventory can begin. The inventory will be imperative to determining the priorities for Texas' future species conservation efforts. Currently, we are limited in our ability to prioritize. The survey methodology we are employing is useful based on our current level of knowledge but will be less adequate once new inventory and survey data are available. Texas Parks and Wildlife Department must take this into consideration and update established survey methods once the inventory results are analyzed.

Current Priority Habitats

The 2005 Land and Water Resources Conservation and Recreation Plan (Land and Water Conservation Plan) established priority ecoregions within Texas as the scale at which would be most appropriate for the making future decisions. In order to begin looking at a finer scale for on-the-ground management it is imperative that TPWD create priorities within these Tiered ecoregions. High priority ecoregions or Tier 1 ecoregions consist of the Blackland Prairies, Gulf Coast Prairies and Marshes and South Texas Plains. Within the Blackland Prairies the most important issue is the rate of conversion of native grasslands into crops or urban development. There are approximately 5,000 ac. of remnant prairies left in this ecoregion (Damude, Bender 1999). All other habitats in this region are also in decline, making the entire ecoregion a high priority for management and monitoring. Restoration is critical for the survival of this ecoregion.

The Gulf Coast Prairies and Marshes ecoregion has many conservation efforts underway with the coastal marshes and barrier islands being relatively well conserved. However, the inland prairies and coastal woodlands that are of greater concern. As in the Blackland Prairies, the coastal prairies are heavily converted for use as agricultural land and development to commercial or residential building. Population growth along the coast is high creating greatly fragmented lands and causing increased pressure on the coastal prairies.

Both the High Plains (Tier II) and the Rolling Plains (Tier III) have lost and are losing native grasslands to cropland conversion and other agricultural use. Much of the land has been converted for use as cropland with some of that land now being enrolled in the Conservation Reserve Program (CRP). Of all of the habitat types associated with the ecoregions of Texas, native prairie and grassland habitats were listed as one of two high priority habitats within the Land and Water Conservation Plan. Relatively little native habitat still remains here. However, there is still some potential for recovering a percentage of these areas and monitoring these areas for success in the future. Adaptive management techniques are critical in these areas to determine whether conservation is successful and adjusting to new techniques in the event that monitoring indicates one or more deficiencies.

The terrestrial inventory process that TPWD employs will be based on priorities that have been laid out in the Land and Water Conservation Plan. The broad, ecoregion-based variables used to derive these priorities are useful and will assist in decision making until such time as new data are available. Based on habitat information found within the Conservation Status, Threats, Rare Plants and Communities and Rare Animals sections (under the Priority Ecoregions for Conservation Efforts section of the Land and Water

Conservation Plan), priority habitats were extracted and will be used for making decisions on future inventory and monitoring programs.

Citizen Science in Monitoring (Defenders of Wildlife/Illahee)

The role of citizen science in habitat monitoring is evolving. Properly trained citizens not only reduce the cost of data collection and ground-truthing, but they can also become engaged supporters of fish and wildlife conservation. As the eminent ecologist Gordon Orians has observed, many citizen scientists may have more detailed and intimate knowledge of a particular landscape than professional biologists who may not spend as much time in the field. On the other hand, citizen scientists can present a challenging variable for the resource manager because they fall outside of the usual within-organization structure, may not be well-versed in established survey techniques and must be trained and potentially tested to ensure that they provide reliable information (http://www.birds.cornell.edu/LabPrograms/CitSci/). Despite these challenges, some of the most successful monitoring programs, such as the Christmas Bird Counts, are carried out by citizen scientists.

Texas Parks and Wildlife Department must use citizen science in order to meet the goals of this strategy. Currently, the Education and Outreach branch of the Science, Research and Diversity Program in the Wildlife Division of TPWD are utilizing Texans' observations to collect data on many different species. A major source of volunteers is the Master Naturalist program. Developed originally by Urban Biologists in San Antonio, the program has now expanded to every corner of Texas and is continuing to grow as a national organization. The Texas Master Naturalists™ offers interested citizens intense training on a variety of wildlife and habitat topics and asks for volunteer service in return. Through specialized training courses, the Master Naturalists take data on certain animal or plant species and provide those data to TPWD for analysis, distribution and storage. Texas Parks and Wildlife Department must take advantage of this resource and continue to incorporate these Texans into monitoring programs. They are valuable and trainable and can provide a large volume of data that could then be incorporated into the Natural Diversity Database. It will be at the discretion of the wildlife biologist in the state to decide which projects are most in need of this support and the onus is then on those biologists to sufficiently train and introduce quality control measures to ensure the validity of those data. For more information on the Texas Master Naturalist program, see http://masternaturalist.tamu.edu/.

Working closely with the Texas Master Naturalists, the Texas Nature Tracker program (TPWD) is a citizen science monitoring effort designed to involve volunteers of all ages and interest levels in gathering scientific data on species of concern in Texas through experiential learning. The goal of the program is to enable long-term conservation of these species and appreciation among Texas citizens. The Texas Nature Tracker program enables citizens to participate in gathering data on a variety of species and habitats, including box turtles, monarch butterflies, hummingbirds, prairie birds, monarch butterfly habitat, freshwater mussels, amphibians, horned lizards, and swallow-tailed kites. For more information on the Texas Nature Tracker program, see http://www.tpwd.state.tx.us/nature/education/tracker/.

Monitoring Conservation Actions

Every conservation action listed in this strategy should be carried out with the intent of monitoring post application or project in order to determine the success of the effort. Without this monitoring, the conservation action is without merit and should not be conducted. Simply creating a change is not enough. That change must have a level of success to call it viable methodology and the only way to determine that success is through habitat or species monitoring. This will allow manager to determine success and failure and adapt methodology accordingly.