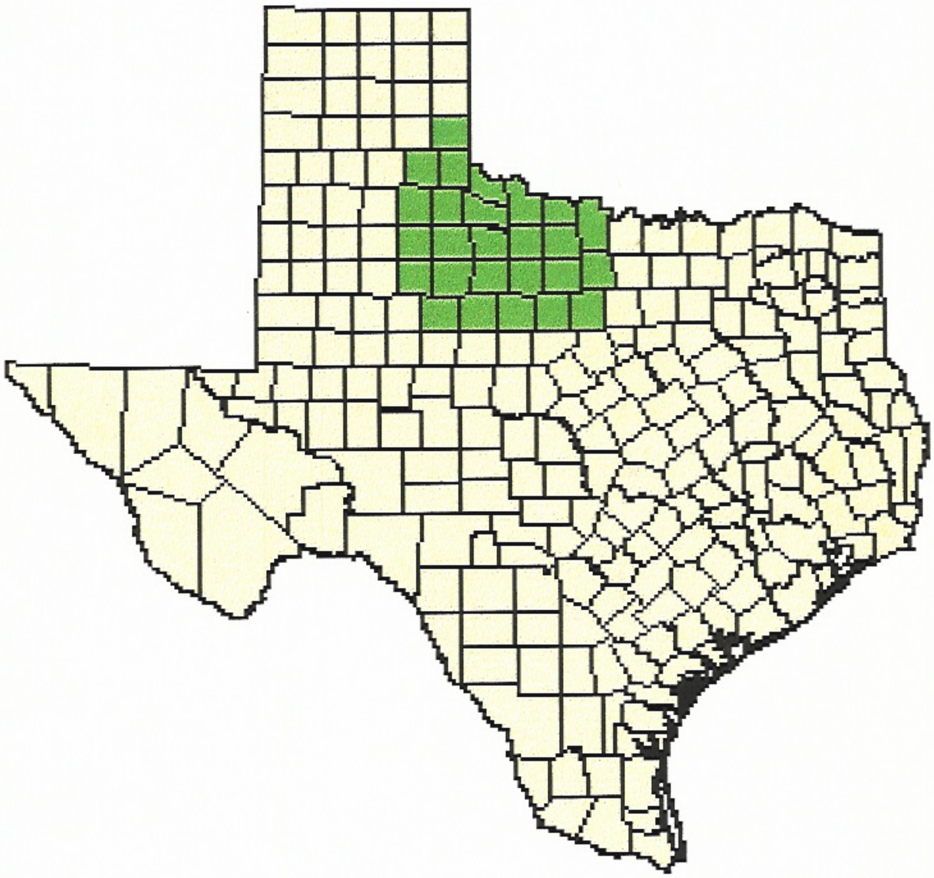
PGMA Study: NORTH-CENTRAL TEXAS

Evaluation Of Selected Natural Resources In Parts Of The Rolling Plains Region Of North-Central Texas



TEXAS PARKS & WILDLIFE

RESOURCE PROTECTION DIVISION
WATER RESOURCES TEAM

EVALUATION OF SELECTED NATURAL RESOURCES IN PARTS OF THE ROLLING PLAINS REGION OF NORTH-CENTRAL TEXAS

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EXECUTIVE SUMMARY

This report evaluates the potential effects of the designation of a Priority Groundwater Management Area (PGMA) on some of the natural resources of the North Texas Alluvium and Paleozoic Outcrop (North Texas) study area (PGMA study number 16). The report is in response to Senate Bill 1 (75^{th} Texas Legislature, 1997) which placed priority on the completion of pending PGMA studies mandated by House Bill 2 (69^{th} Texas Legislature) in 1985. The purpose of the PGMA process is to identify and evaluate areas of Texas that are experiencing, or are expected to experience, critical groundwater problems within the 25-year planning horizon. The PGMA process is intended to encourage local and regional governments to address identified groundwater problems and consider appropriate management options.

The North Texas study area includes parts of the drainage basins of the upper Red River, the upper Brazos River, and a very small portion of the upper Trinity River. The area lies within the Mesquite Plains subregion of the Rolling Plains Natural Region and includes Archer, Baylor, Childress, Clay, Collingsworth, Cottle, Dickens, Fisher, Foard, Hall, Hardeman, Haskell, Jack, Jones, Kent, King, Knox, Motley, Palo Pinto, Shackelford, Stephens, Stonewall, Throckmorton, Wichita, Wilbarger, and Young Counties; an area slightly less than 15 million acres. The ecology of the Rolling Plains today reflects a history of human disturbance including over-grazing, soil erosion, lowered water tables in some areas, declining native grasslands, and altered river ecosystems. The historic tall and midgrass prairies have become a mesquite-short grass savanna.

The human population density of the 26-county area is quite low (~ 13 people/square mile) and not projected to increase much by 2050. The most-likely-scenario projection for the area in 2050 is 320,000 people. However, the population of the Dallas-Fort Worth Metroplex, just east of the study area, is projected to exceed 8 million people by 2050. In the future, it is this enormous population that will impose ever-increasing demands and pressures upon the water-based natural and recreational resources of the study area. As the recreational demands of the Metroplex population grow, the water-based recreational resources of the study area will become more valuable to the people of the region. If the region's water resources are conserved and appropriately managed, the economic value of water-based recreational resources will greatly exceed present value and have the potential to become a major component of the study area's economy.

It is the quality, not the quantity, of some of the area's groundwater and surface-water resources that is of concern in the region. The high salinity of much of the area's water resources, largely due to natural salt deposits, presents a challenge to natural resource planners and managers. Municipal, agricultural, and industrial water users would like to lower the salinity of certain surface-water supplies. One way this is done is by intercepting and disposing of the highly saline flows of certain streams, usually issuing 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. These highly saline flows are natural in the region and have existed for millennia. Our native prairie stream fish faunas have evolved under these conditions and are uniquely adapted for life in these harsh aquatic ecosystems. The interception of saline flows can also significantly reduce the base flows of streams and rivers. Reduction of base flows alters aquatic ecosystems in many ways. These changes, as well as the segmentation of rivers by impoundments, have resulted in a decline in diversity and abundance of our native prairie stream fishes.

In the study area as elsewhere, groundwater and surface-water resources are not separate and cannot be managed separately without adverse environmental impacts. The potential for and desirability of conjunctive use of groundwater and surface-water resources in the study area was discussed in Texas Water Development Board Report 337. Conjunctive use ideally involves proactive management of all water resources to achieve maximum ***sustainable*** utilization of total water resources in the most economic and equitable manner. In the study area, where the quality of some groundwater and surface-water supplies is substandard for treatment and use, substantial benefits could result from conjunctive management of total water resources. The PGMA process should not overlook the economic and other values of the water-based natural and recreational resources of the study area. To do so would not be in the best long-term economic or other interests of the region's people.

INTRODUCTION

Purpose

The Texas Natural Resource Conservation Commission (TNRCC), working with the Texas Water Development Board (TWDB) and the Texas Parks and Wildlife Department (TPWD), is charged with identifying priority groundwater management areas (PGMAs)—areas in the State that are experiencing, or are expected to experience in the future, critical groundwater problems. The purpose of the PGMA program is to assist local and regional interests to address groundwater management issues; including shortages of surface and groundwater, surface and groundwater quality and contamination, and land subsidence.

Senate Bill 1 (75th Legislature, 1997) placed priority on the completion of pending PGMA studies that were called for by House Bill 2 (69th Legislature) in 1985. The TNRCC and TWDB identified a 26-county area in north central Texas for a PGMA study in 1990. The study was initiated in 1991 with TNRCC requesting a groundwater resource and availability study from TWDB. The TWDB completed the report *Evaluation of Water Resources in Parts of the Rolling Prairies Region of North-Central Texas* (TWDB Report No. 337, Duffin and Beynon) in March 1992.

The purpose of this report is to evaluate the potential effects of the designation of a PGMA on some of the natural resources of the study area.

Location and Extent

The North Texas Alluvium and Paleozoic Outcrop study area, in this report called the North Texas study area, includes 26 counties: Archer, Baylor, Childress, Clay, Collingsworth, Cottle, Dickens, Fisher, Foard, Hall, Hardeman, Haskell, Jack, Jones, Kent, King, Knox, Motley, Palo Pinto, Shackelford, Stephens, Stonewall, Throckmorton, Wichita, Wilbarger, and Young (Fig. 1). This area covers just less than 15 million acres or about 23,300 square miles, and comprises about nine percent of the total area of the State (TPWD, GIS Lab. Archives 1998).

Geography and Ecology

The North Texas study area is located within the Rolling Plains Natural Region (LBJ School of Public Affairs 1978; Fig. 2). The Rolling Plains region, along with the High Plains region, is the southern extension of the Great Plains of central North America.

Most of the study area is in the Mesquite Plains subregion, which typifies the Rolling Plains region. The region is a gently rolling plain of mesquite-short grass savanna. On the extreme western edge of the area, the Escarpment Breaks subregion of the Rolling Plains forms an ecotone or transitional zone between the grasslands of the High Plains and the mesquite-savanna. Steep slopes, cliffs, and canyons occur just below the edge of the High Plains Caprock.

The topography of the region is gently rolling to moderately rough and is a gently eastward-sloping plain dissected by well-established drainages flowing generally east to southeast. The northern half of the region is drained by the Red River and its major tributaries, the Little Wichita, Wichita, Pease, and the Prairie Dog Town Fork and Salt Fork of the Red River. The Brazos River and its major tributaries, the Salt Fork, Double Mountain Fork, and Clear Fork of the Brazos, drain the southern half of the region. The West Fork of the Trinity River (Fig. 1) drains a small portion of the eastern part of the region.

Elevations range from about 700 feet in the eastern river valleys to about 2,600 feet at the base of the Caprock Escarpment on the western edge. The region is bordered on the south by the Edwards Plateau, on the east by the Western Cross Timbers region, and on the west by the Escarpment Breaks.

Average annual rainfall ranges from 22 inches in the west to about 30 inches in the east. May and September are usually high rainfall months. A summer dry period with high temperatures and high evaporation rates (70 inches average evaporation) is typical. Average monthly low temperatures for January range from about 22 F in the northwest to about 32 F in the east. Average monthly high temperatures for July range from 95 F in the west to 99 F in the east.

Demographics

The 1990 census estimated the population of the study area to be slightly under 300,000 (Table 1; TWDB 1996). People are not distributed uniformly throughout the region. The largest city within the study area is Wichita Falls, with a population of just under 100,000, in Wichita County. In general, people are concentrated in the eastern part of the region (Fig. 3). Jones County, which contains a small part of Abilene, a city of just over 100,000, is the exception to this pattern. The most-likely-scenario projection for growth of the region predicts a 2050 population of just over 300,000. So, the region is not expected to experience much population growth.

However, there is only one county between the eastern edge of the study area and the Dallas-Fort Worth Metroplex. The Metroplex is a six-county area with over 3.6 million people in 1990, and a projected population of over 8 million by 2050 (Table 2). If this projection proves to be correct, future demands for all forms of water-based recreation in the study area will greatly exceed present demands. In the future, the economic value of the natural resources of the study area will be much greater than at present.

Economy and Land Use

The economy of the area consists primarily of farming, ranching, and petroleum production and the attendant service infrastructure. Service businesses include agribusiness, oilfield service, grain, fiber, and some food processing, and a variety of manufacturing including oilfield equipment, clothing, building and plastic products, electronics, aircraft parts, mobile homes and recreational vehicles, wood products, and livestock trailers.

Agricultural production includes cotton, wheat, feed grains, alfalfa, hay, peanuts, and some vegetables. In 1992, the area included an estimated 3.5 million acres of cropland with only 175,000 acres under irrigation (NRCS no date). Livestock production includes beef and dairy cattle, sheep, swine, and horses. The area includes some of the largest ranches in the State; and includes about 9.5 million acres of rangeland and over 300,000 acres of pastureland (Table 3). The land use category of Miscellaneous/Minor (almost 1 million acres) in Table 3 includes acreage that was formerly in cultivation but that was in the Conservation Reserve Program (CRP) in 1992. The CRP subsidizes landowners to convert highly erodible cropland to permanent grass cover for 10-year periods.

Mineral production in the area includes oil and gas, sand and gravel, stone, gypsum, and clays. Only four counties in the area, Childress, Cottle, Dickens, and Hall, do not support significant hydrocarbon production.

Extensive recreational facilities contribute significantly to the economy of the area. Numerous streams, rivers, ponds, reservoirs, and some wetlands provide boating, swimming, fishing, hunting, wildlife-watching, and other water-based recreational opportunities.

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SELECTED NATURAL RESOURCES

Vegetation and Soils

The Natural Regions of Texas were delineated largely on the basis of soil types and major vegetation types. Soils in the Rolling Plains region vary from coarse sands along river floodplains to tight clays or red-bed clays and shales, and soil reaction is generally neutral to slightly alkaline.

The original native prairie vegetation included tall and midgrasses such as bluestems and gramas. Buffalograss and species of three-awn grass, among others, tend to increase under heavy grazing. Mesquite is a common invader on all soils. Cottonwood-hackberry-saltcedar brush or woods often dominate the floodplains of rivers and streams. These corridors of riparian vegetation are exceptionally valuable wildlife habitats, particularly for both resident and migrating birds. The scientific names of the plants mentioned are found in Appendix A.

The Mesquite Plains subregion of the Rolling Plains is aptly named. The vegetation type map of Figure 4 shows that mesquite is a dominant or co-dominant in the majority of the major plant assemblages occurring throughout the study area. All these assemblages are disturbance types that have resulted from over-grazing, soil erosion, the lowering of ground water tables, and the decline of native grasslands. The Mesquite Brush (11b) type occurs extensively in the northwestern part of the region and less extensively in the east and south. Associated species include grama grasses, three-awn grasses, lovegrasses, buffalograss, other grasses, narrow-leaf yucca, grassland pricklypear, and red-berry juniper.

The Mesquite-Lotebush Shrub (12a) type occurs extensively over the entire area. The Mesquite-Lotebush Brush (12b) type is restricted to the southwestern corner of the area. Associated species include yucca, agarito, elbowbush, juniper, tasajillo, bluestem grasses, sand dropseed, grama grasses, buffalograss, three-awn grasses, tobosa, Texas wintergrass, bitterweed, broom snakeweed, and Engelmann daisy.

The Mesquite-Red-berry Juniper Brush (13b) type is extensive in the western part of the area on slopes, often over gypsum or caliche-influenced soils. Other plants include lotebush, shin oak, sumac, Texas pricklypear, tasajillo, agarito, yucca, grama grasses, three-awn, buffalograss, and other grasses.

The Mesquite-Saltcedar Brush / Woods (18) type occurs along intermittently flooded drainages, especially in the Brazos River Basin. Other plants include cottonwood, giant reed, seepwillow, common buttonbush, lotebush, wolfberry, tasajillo, alkali sacaton, Johnsongrass, saltgrass, cattail, and bushy bluestem. A number of these plants are wetland indicators and provide uncommon and valuable wildlife habitats in the Rolling Plains region.

The Havard Shin Oak-Mesquite Brush (21) type occurs primarily on sandy soils in the western part of the region. Associated plants include sandsage, catclaw, yucca, dropseed grasses, Indiangrass, bluestem grasses, featherplume, Illinois bundleflower, foxglove, and yellow evening primrose.

The Sandsage-Mesquite Brush (22) type occurs on sandy upland soils in Collingsworth County. Other plants include skunkbush sumac, Chickasaw plum, catclaw, bluestem grasses, sand dropseed, red three-awn, sensitive briar, wild blue indigo, wild buckwheat, and common sunflower.

Several types that have oaks as dominants occur on uplands on the eastern side of the area where the Rolling Plains region meets the Western Cross Timbers subregion of the Oak Woods and Prairies region. These include the Oak-Mesquite-Juniper Parks / Woods (23), Live Oak-Ashe Juniper Parks (26a), Live Oak-Mesquite-Ashe Juniper Parks (26b), and Post Oak Parks / Woods (30a). Associated plants include post, shin, Texas, blackjack, and live oaks, cedar elm, hackberry, agarito, Mexican persimmon, Texas pricklypear, grama grasses, sumac, purple three-awn, Texas wintergrass, and curly mesquite.

The Sandsage-Havard Shin Oak Brush (32) type is found in this area only on sandy soils in Collingsworth County. Associated plants include skunkbush sumac, Chickasaw plum, Indiangrass, bluestem grasses, grama grasses, sand dropseed, sand paspalum, sand lovegrass, and big sandreed.

The Juniper-Mixed Brush (34) type is found in Dickens and Motley Counties on slopes and in canyons along the Caprock Escarpment. Common plants include red-berry juniper, one-seed juniper, lotebush, mesquite, shin oak, yucca, tasajillo, mountain mahogany, grama grasses, lovegrasses, buffalograss, curly mesquite, tobosa, and bitterweed.

The Cottonwood-Hackberry-Saltcedar Brush / Woods (37) type occurs along drainages in the Red River Basin. Associated species include Lindheimer's black willow, buttonbush, groundsel tree, cattail, switchgrass, prairie cordgrass, saltgrass, alkali sacaton, spikesedge, horsetail, bulrush, coarse sumpweed, grape and ampelopsis vines, and Maximilian sunflower. Many of these plants are wetland indicators and provide wildlife habitats that are restricted to riparian zones in the study area.

Springs

The distribution and size, as of 1980, of springs and seeps in the area are given by county in Table 4 (Brune 1981). Springs represent a transition from groundwater to surface water. Most springs emanate from the top of the groundwater reservoir, so changes in the water table elevation generally have immediate impact upon spring discharge rates.

Permian gypsum, e.g., the Blaine gypsum, is an important spring aquifer in some parts of the study area. These spring waters usually contain calcium sulfate and are very hard and alkaline; they may also acquire sodium chloride from associated natural salt beds. Also, oil-field brines are a common source of contamination of groundwater and spring waters. Until 1969, when state law ended the practice, some oil-field brine was pumped into open, unlined pits where it could percolate into, and contaminate, the ground water. Chloride control projects are designed to contain the flow of highly saline waters in certain streams and rivers in the upper Red and Brazos River systems. These brine containment reservoirs have the potential to contaminate groundwater just as unlined oil-field brine pits do.

The springs of the study area do not appear to support rare or endangered endemic plants or animals such as the pupfish that were found only at Comanche and Leon Springs, in Pecos County, before the springs were pumped dry. Springs and seeps do provide valuable microhabitats for wetland plants and animals. Typical vegetation of springs and spring runs includes willows, cottonwood, hackberry, elm, saltcedar, plum thickets, rushes, and cattails. Springs contribute significantly to the base flows of the streams and rivers of the area. Declining groundwater tables, which are indicated by curtailed spring flows, along with over-grazing and soil erosion, are major causes for the decline of native grasses and the dominance of invasive plants like mesquite and saltcedar in the study area (Brune 1981).

A secondary issue relating to spring flows and chloride control projects has to do with endemic fish faunas in the study area. Natural populations of the Red River pupfish are restricted to saline waters in the upper basins of the Red and Brazos River systems (Ashbaugh et al. 1994). This species has evolved under conditions of high salinity and low competition from other native species. If man alters these conditions, the composition of the native fish faunas will also be impacted.

The implementation of a PGMA in this region could prevent the lowering of groundwater tables to the point where more springs dry up. In general, springs emphasize the fact that groundwater and surface-water supplies are not unrelated.

Hall, Briscoe, and Childress Counties contain many natural salt springs and seeps that contribute highly saline water to the Little Red River and the Prairie Dog Town Fork of the Red River. Similarly, springs in Cottle and King Counties provide saline base flows to the Pease and Wichita Rivers; and springs in King, Stonewall, and Kent Counties provide saline base flows to the Salt Fork Brazos River.

Freshwater Mussels

Freshwater mussels (Family Unionidae) are sensitive biological indicators of environmental quality and are often the first organisms to decline when environmental quality of aquatic ecosystems begins to degrade (Howells 1997a). Consequently, freshwater mussels have become important elements of environmental impact considerations. Surveys of mussels in Texas show many of the 52 species recognized in Texas have declined greatly in recent years. These population declines probably reflect poor land and water management practices and subsequent loss of mussel habitat (Howells et al. 1997). Over-grazing, the clearing of native vegetation, the design and construction of highways and bridges, and general land clearing and development have contributed to the increase of runoff and scouring floods. Scouring in upstream reaches often results in excessive deposits of soft silt or deep shifting sand on downstream substrates, eliminating mussel habitat. The reported distribution of mussels in the study area is shown in Table 5.

In the Brazos River in Palo Pinto County, the giant floater, fragile papershell, pink papershell, Tampico pearlymussel, Texas fawnsfoot, and the introduced Asian clam are found (Howells 1997b). Texas fawnsfoot is endemic to the Colorado, Brazos, and possibly Trinity River basins of central Texas. Until 1994, no living specimens had been taken in about 20 years (Howells et al. 1997). Recent collections suggest that populations persist at sites on the Clear Fork and mainstem Brazos River systems. Despite the confirmed survival of this rare endemic species, the regional unionid fauna is quite limited in both diversity and abundance (Howells 1997b).

Seven unionids and Asian clam are found in impoundments and tributaries of the Wichita River system (Howells 1997a). No living mussels were collected at sites where mean conductivity exceeded 3,000 uS/cm (~ 1 ppt NaCl). Eight unionids and Asian clam have been reported from Lake Arrowhead on the Little Wichita River. Only two unionids and Asian clam have been historically reported from the Pease River. No species included on federal or state protected lists are known or expected to occur in the study area. One species (Mapleleaf sp.) in both the Wichita and Little Wichita drainages has been harvested commercially as a source of raw material for the cultured pearl industry. None of the other mussels in the study area currently have commercial value.

Mussels are eaten by some fish, especially freshwater drum and catfish and by other animals such as map turtles, wading birds, and raccoons.

Fish

The upper Red and Brazos river systems both have characteristic fish faunas that include endemic species (Tables 6 and 7). All the rivers and streams of the study area are typical prairie stream ecosystems characterized by extreme fluctuations in environmental conditions and flow regimes such as floods and droughts (Matthews 1988). Native fish faunas in prairie streams are adapted to the variable flow regimes, turbidity, and salinity extremes typical of prairie streams. The life histories of prairie stream fishes incorporate strategies that allow survival in unpredictable and relatively unstable aquatic ecosystems. One example is the timing of reproductive cycles with increasing streamflow events (floods). When these ecosystems are modified by impoundments, chloride control projects, depletion of groundwater levels and spring flows, and erosion due to over-grazing and clearing of streambanks, ecosystem structure and function are altered (Matthews 1988, Moss and Mayes 1993). Species that are better adapted to more moderate and stable conditions such as lower salinity, less turbidity, fewer extremes in water temperature, and smaller fluctuations in flow regimes, tend to replace the native prairie stream species.

The smalleye shiner was historically endemic throughout the upper and middle Brazos River system, but now appears limited to the Brazos upstream of Possum Kingdom Reservoir (Moss and Mayes 1993). Another fish of special concern is the sharpnose shiner, historically found in the Wichita and Brazos River systems in Texas. Recent collections in the Wichita River have not included sharpnose shiner, and the species has become uncommon in the Brazos downstream of Possum Kingdom. Both shiners are listed as Category Two (in need of further information) by the U. S. Department of the Interior and appear on the TPWD list of special species (TPWD, Endangered Resources Branch 1998; see Table 12). Both are opportunistic invertebrate feeders and the diet of the sharpnose shiner also includes terrestrial invertebrates and seeds carried by the wind from riparian vegetation bordering the streams (Moss and Mayes 1993). Both species probably use flood events for spawning cues, as do other cyprinids of prairie stream ecosystems. The basic habitat requirements of both species are similar. Generally, they are found in shallow water of moderate flow over fairly clean shifting sand. This type of habitat is abundant in the upper Brazos system but has been greatly limited in the middle and lower Brazos system by mainstem impoundments. Impoundments have caused reductions of turbidity, dissolved oxygen levels, salinity, and water temperature fluctuations, along with reduced streamflow fluctuations. These alterations to the Brazos River ecosystem have affected native fish faunas. The more stable and benign environment in the middle and lower Brazos ecosystem does not favor the native prairie cyprinids such as smalleye, sharpnose, and chub shiners, the plains minnow, and the speckled and silver chubs. The altered conditions below the impoundments are more suitable for generalist species like the red and blacktail shiners, and the bullhead minnow.

The 1996 Consensus Texas Water Plan (TWDB 1996) recommends the construction of brine-retention reservoirs (Croton Creek, Dove Creek, and Kiowa Peak) to reduce the amount of brine water entering the Salt Fork Brazos River. These proposed Brazos River Chloride Control Projects, if implemented,would reduce the salinity of downstream surface water supplies. They would also reduce base flows in the Salt Fork and mainstem Brazos River and could alter the environmental conditions under which native fishes have evolved.

The fish fauna of the Red River system in the study area is somewhat more diverse than that of the upper Brazos River (Table 7). However, many of the fisheries issues are the same as for the Brazos basin. The Red River Chloride Control Project is designed to intercept and dispose of saline inflows to the Red River and its tributaries. Saline flows would be intercepted using a combination of dikes, inflatable weirs, and pumps, and disposed of by export to brine-disposal lakes or by deep-well injection. The purpose of the control project would be to reduce salinity in water entering the Red River, increasing its value for municipal, agricultural, and industrial uses, and coincidentally reducing base flows in the Red River and some of its tributaries.

As with the Brazos fauna, the Red River fish fauna is adapted to the variable salinities and flow regimes typical of the Red River system. The composition of local fish assemblages often is strictly defined by salinity tolerances (Echelle et al. 1972). Reductions in either salinity or its variability may alter species interactions and cause changes in fish assemblage structure and ecosystem function. Reductions in base flows due to chloride control projects, if implemented, or to declines in spring and seep flows, are expected to increase the average annual number of no-flow days for some drainages (Wilde et al. 1996). During periods of no flow, fishes are restricted to pools and backwaters. An increase in duration and intensity of competitive, especially predator-prey, interactions in these restricted habitats could affect the composition and structure of local fish assemblages. Also, impacts due to changes in water quality, such as temperature increases and decreases in dissolved oxygen, can be severe in isolated pools.

Natural populations of the Red River pupfish are restricted to saline waters in the upper reaches of the Red and Brazos River systems of west Texas and Oklahoma. The Red and Brazos River forms are genetically distinct and may represent cryptic species with independent origins (Ashbaugh et al. 1994). The Red River pupfish becomes less abundant in downstream reaches, perhaps a result of competitive interactions with the more complex fish fauna supported by the less saline waters and more benign environmental conditions.

Since the 1950s, the native cyprinids of the Wichita River system have suffered serious decline (Wilde et al. 1996). Sixteen cyprinid minnows are native to the Wichita River system. Seven of these (blacktail, emerald, golden, sharpnose, silverband, and chub shiners; and the silver chub) appear to have been extirpated since the 1950s. Two other species, the plains minnow and the ghost shiner, have shown consistent declines in relative abundance. The plains minnow, because of its relatively large size and extreme hardiness, supports an economically significant commercial bait-fish seining industry in the study area (J. E. Kraai, TPWD, Inland Fisheries, pers. comm.). The Red River shiner, although still widely distributed in upper parts of the river (Echelle et al. 1995), is not abundant and appears to have declined in relative abundance since the 1950s (Wilde et al. 1996).

The Wichita River has been highly modified. Two reservoirs, Lakes Kemp and Diversion, have divided the river into three segments since the 1950s. The installation of inflatable wiers on the North and South Wichita Rivers, a component of the Red River Chloride Control Project, has further segmented the river. In addition to the habitat changes associated with dams and impoundments, segmentation of the river increases the probability of local extirpations and limits or prevents natural recolonization.

The Prairie Dog Town Fork Red River is apparently undergoing changes in the structure of fish assemblages. The Red River shiner and plains minnow have undergone declines in relative abundance, whereas the relative abundance of the Red shiner is increasing (Wilde et al. 1996). These changes are worth noting since chloride control structures are proposed for Jonah and Salt creeks, tributaries of the Prairie Dog Town Fork.

The study area has a number of large reservoirs and impoundments (Fig. 1) that support fish species not as typical of rivers and streams. Freshwater drum, common carp, gizzard shad, smallmouth buffalo, warmouth, bluegill, longear sunfish, largemouth bass, white bass, white crappie, flathead and blue catfish, bullhead catfishes, striped bass, and walleye are found in some of the larger reservoirs. Lake Kemp, on the Wichita River, supports a noted striped bass fishery (Findeisen and Howell 1998). Most of the reservoirs and impoundments, as well as numerous small ponds, provide recreational fishing opportunity; as do the rivers and streams. The substantial commercial minnow-seining industry in northwest Texas supplies baitfish to licensed bait dealers and provides a valuable and needed commodity to sportfishers in the area.

Waterfowl and Wetlands

The Rolling Plains Natural Region is not usually thought of as an area rich in wetland habitats. However, the region is actually very important to both migrating and wintering waterfowl. The region, which closely corresponds to the study area, is surveyed annually by TPWD, using aircraft, to count migrating and wintering coots, ducks, geese, and sandhill cranes. Geese, which concentrate in a limited number of specific areas, are also counted by ground surveys. The duck and coot estimates are derived from aerial transect surveys using the 19 randomly selected, 70-mile-long transects shown in Figure 5 (B. D. Sullivan, TPWD, Waterfowl Program, pers. comm.).

Ducks and coots are distributed widely throughout the region, wherever there are ponds or natural wetlands. In mid-winter 1997, over 400,000 ducks and almost 90,000 coots were estimated to be wintering in the region (Table 8). The most abundant ducks were mallards, gadwall, and American wigeon; all dabbling ducks. Other dabbling ducks as well as the diving ducks that are typical of these habitats (ring-neck, lesser scaup, bufflehead, canvasback, and redhead) also were represented. The wood duck and mergansers are primarily associated with riverine habitats, oxbows, and forested wetlands. Estimates of waterfowl habitat quantity and rates of occupancy by ducks are given in Table 9. Most ducks were observed on stock ponds and other small impoundments. Natural marshes, forested wetlands, and oxbows, which are much less numerous than the estimated 78,000 ponds in the region, were also heavily utilized by ducks. It is often much more difficult to observe ducks from the air on natural wetlands as compared to open ponds. The riparian vegetation along river banks also often conceals ducks that are not observed from the air.

Geese wintering in the study area concentrate in Knox and Haskell Counties. The heaviest concentrations are found on a chain of natural water-table lakes in north-central Haskell and south-central Knox Counties known as Winchester Lakes (Table 10). Lesser numbers of geese also use the wheat fields and stock tanks of large ranches, as well as Lakes Davis and Catherine, near Benjamin in Knox County.

In TWDB Report 337 (Duffin and Beynon 1992), the Winchester Lakes are briefly discussed as follows: "Shallow depressions which naturally impound water during periods of heavy precipitation are common in north-central Haskell and south-central Knox Counties. They are less than 10 feet deep and generally cover an area of 10 to 150 acres. Some of the depressions appear to lose water rapidly, part of the water undoubtedly recharging the aquifer. If additional water could be diverted to these areas, recharge could be increased." Such a program would be very beneficial to waterfowl and other waterbirds because it would enhance one of the premier wetland habitats of the region (J. D. Ray, TPWD, Waterfowl Program, pers. comm.).

Large numbers of sandhill cranes winter in and migrate through the region. They use many of the same wetland habitats as waterfowl. Cranes forage in croplands and rangelands and like to roost at night in the shallows of large ponds or reservoirs. Sandhills, like ducks and geese, provide a highly valued recreational hunting opportunity on the Rolling Plains.

Many species of migrating shorebirds, raptors, Neotropical songbirds, and other birds stopover in the study area to feed and rest on the available wetlands. The trees and shrubs that grow along the rivers and streams, the riparian habitats, are of special importance to migrating songbirds and raptors.

Amphibians, Reptiles, and Mammals

There are at least 45 species of amphibians, reptiles, and mammals that are either aquatic, semi-aquatic, or in some way wetland-dependent, present in the study area (Table 11). Figure 6 shows the total number of these species resident in each county of the study area (TPWD, Endangered Resources Branch 1998). In general, this fauna is more diverse in the eastern half of the study area where rainfall is greater and aquatic and wetland habitats are more common and diverse.

Appendix B provides lists of the species that occur in each county of the study area. All the listed salamanders, frogs, turtles, water snakes, and the beaver and muskrat are aquatic. The mink is semi-aquatic. All toads require aquatic habitats in order to reproduce. A number of the listed snakes are restricted in the study area to riparian habitats adjacent to rivers, lakes, and ponds. These include: copperhead, rough green snake, eastern coral snake, Graham's crayfish snake, massasauga, western ribbon snake, and the three garter snakes (A. H. Price, TPWD, Endangered Resources Branch, pers. comm.).

Special Species

The county special species lists (TPWD, Endangered Resources Branch 1998) for the study area include 22 animals and one plant (Table 12). The distribution of these species by county is shown in Figure 7.

Several of the birds listed in Table 12 occur in the study area only as migrants (peregrine falcon, whooping crane) or as wanderers normally found on the Gulf coast (reddish egret, brown pelican). Migrating peregrines would utilize wetlands in the study area because they prey mostly on ducks and shorebirds. Migrating whooping cranes would also use wetlands for feeding and roosting. The golden-cheeked warbler and black-capped vireo are upland nesters on the Edwards Plateau found in the study area only in Stephens and Palo Pinto Counties. The white-faced ibis nests in the wetlands of the study area.

The study area includes some essential breeding habitat of the interior least tern. Historically, this endangered tern nested in Texas on sandbars and beaches along the Canadian, Red, and Rio Grande River systems. Now, its nesting habitat in Texas is restricted to the Prairie Dog Town Fork and parts of the mainstem Red River (Campbell 1995). The tern's sandbar nesting habitat has been negatively impacted by the construction of reservoirs on the Rio Grande and Canadian rivers. Mainstem dams, and the resulting curtailment of natural flooding and scouring of the river beds, allow vegetation to encroach on the bars rendering them unacceptable as nesting sites for tern colonies. Also, reduced low flows in summer allow access to the bars by predators and humans.

The smalleye shiner is endemic to the Brazos River but now appears restricted to the upper Brazos upstream of Possum Kingdom. The sharpnose shiner, once found in the Brazos and Wichita River systems, also now appears to occur in the Brazos primarily upstream of Possum Kingdom. The shovelnose sturgeon has apparently been extirpated from the Red River drainage system above Lake Texoma (Wilde et al. 1996).

The Brazos water snake is endemic to the upper Brazos drainage of central Texas. The Texas garter snake, although basically an upland species is largely restricted in its distribution within the study area to riparian habitats bordering rivers, streams, lakes, ponds, and springs.

TPWD REGIONAL FACILITIES

Within the study area, TPWD operates two state fish hatcheries, one wildlife management area, and five state parks; there are two state parks and one wildlife management area just outside the perimeter of the area (Figure 8). All of these facilities require water to operate (Table 13) and provide recreational opportunities to the public. As the population of the Dallas-Fort Worth Metroplex grows (Table 2), these facilities, and hopefully others to be established in the future, will require more water in order to serve the public.

The two state fish hatcheries, Dundee on the Wichita River and Possum Kingdom on the Brazos River, play an important role in maintaining the recreational fisheries of the region. These hatcheries will need more water in the future to increase their production of fish to keep up with growing recreational demand (Table 14). The TPWD Inland Fisheries Division wants and needs to amend existing water rights permits in order to obtain the required water. Some aspects of the economic importance of recreational fishing in the State and region are discussed below.

The Matador Wildlife Management Area, near Paducah in Cottle County, provides an example of how land management practices impact water resources; and a reminder that ground water and surface water are not unconnected resources. Since the inception of the Conservation Reserve Program (CRP) of the U. S. Department of Agriculture, many acres of highly erodible cropland have been removed from cultivation and returned to permanent (10-year contracts) cover such as native grasses (see Table 3, Misc. / Minor Use column). The change in land use from crops like cotton to permanent grass cover has resulted in rising water tables in parts of Cottle County. Historically, there has been very little irrigated cropland in Cottle County (Duffin and Baynon 1992), so the rising water tables are not simply the result of decreased pumping of ground water for irrigation. The cause appears to be related to the fact that land with permanent grass cover holds rainfall on the land allowing it to percolate into the ground. Rainfall runs off cultivated land quickly, causing soil erosion and heavy silt loads in rivers and streams. Since the implementation of the CRP, a number of small springs on the Matador WMA that have not flowed in many years have begun to flow again (D. Dvorak, TPWD, Wildlife Div., pers. comm.). This spring flow, in addition to providing additional aquatic and wetland habitats at the springs and spring runs themselves, will increase the volume and reliability of the base flows of the associated drainages. In addition to these water resource benefits, the CRP acreage also provides additional wildlife habitat for native and migrating grassland species.

WATER-BASED RECREATION

The water-related natural resources of the study area will become more economically important as recreational demand by the burgeoning population of the Metroplex increases. We have little data that are specific to the study area, most available data relate to the entire State. Nevertheless, the available data demonstrate the economic significance of our public fish, wildlife, and parks resources.

The economic impacts of the fishing, hunting, and wildlife-watching industries in Texas are significant (Table 15). Much of the expenditures shown in Table 15, especially those generated by fishing and wildlife-watching, are made by people making visits to publicly owned lands and waters. In the future, people who live in the urban and suburban Metroplex area, and who largely lack access to private lands, will place increasing demands upon the public resources of the study area. These people will also spend increasing amounts of money in the study area and cause the natural resources of the study area to become more economically valuable to the residents of the study area than they presently are.

In 1987, TPWD surveyed state park visitors to estimate direct annual economic impacts of state parks statewide (Goldbloom 1987). Table 16 gives these data for the parks in the study area. The standard economic adjustment of these figures to present value would be an average annual increase of about three percent (A. Goldbloom, TPWD, Parks Div., pers. comm). A state park, especially one that offers water-based recreational opportunity, can be an important local/regional economic asset.

Freshwater sport fishing is a very important industry in Texas (Table 17). The number of freshwater anglers in Texas is increasing. The fact that most large reservoirs in the State provide public access has fostered this growth. Lakes with associated state parks (Arrowhead, Possum Kingdom, and Mineral Wells) will certainly experience growth in public use and water-based recreational demands in the future.

Lake Texoma, an impoundment on the Red River east of the study area, is nationally recognized for its striped bass fishery. In 1990, Lake Texoma anglers contributed an estimated $25.6 million in fishing expenditures to the regional economy; nonregional anglers visiting the reservoir to fish for striped bass accounted for 77 percent of the total expenditures (Schorr et al. 1995). Lake Kemp in the study area also has a noted striped bass fishery.

On the other hand, hunting, which mostly takes place on private lands in Texas, is not growing in terms of numbers of participants. However, bird watching and other nonconsumptive uses of waterfowl and other birds is one of the fastest growing segments of the nature tourism industry. Table 18 gives economic data for these activities in the entire State. A TPWD waterfowl harvest survey showed the north-central region of Texas (including the Metroplex) had about 18,800 waterfowl hunters, about 30 percent of the State total, in 1995-96. The upper Texas Gulf Coast region has the largest number (37 percent of State total) of waterfowl hunters. Changes in agricultural land use are taking place on the upper Texas coast that may result in more geese wintering in the study area. The USDA is phasing out crop subsidies for rice growing on the coast and farmers are being encouraged to switch to other crops that will not support the unnaturally high numbers of geese that currently winter on the Texas coast. In the future, private landowners that maintain wetlands in the study area may experience greatly expanded opportunities to earn income from waterfowl hunting leases.

CONCLUSIONS

The current human population of the 26-county study area is relatively sparse; on average about 13 people per square mile. This density is not expected to increase much, perhaps to 14 people per square mile, by 2050. Most of this modest growth is projected to occur in Wichita (Wichita Falls) and Palo Pinto Counties in the eastern part of the study area. However, the population of the Dallas-Fort Worth Metroplex, just to the east of the study area, is projected to grow from 3.6 million in 1990 to over 8 million by 2050. In the future, it is the enormous Metroplex population that will impose ever-increasing demands and pressure upon the natural and recreational resources of the study area.

The ecology of the study area today reflects a high degree of human disturbance of the native tall and midgrass prairies of bygone days. The region has become a mesquite-short grass savanna. Most of the major vegetation types of the region are disturbance types dominated by invaders like mesquite, saltcedar, and those grasses that tend to increase under heavy grazing. The landscape of the Rolling Plains today reflects a history of over-grazing, soil erosion, lowered water tables in some areas, declining native grasslands, and altered river ecosystems.

Historically, at least 350 springs existed within the study area. As of 1980, 66 of those (almost 20 percent) had ceased to flow. This was due to excessive pumping of ground water. However, in some parts of the area improved land and water management practices have been implemented and some former springs have begun to flow once again. Flows from springs and seeps contribute to the base flows of many of the rivers and streams of the area. In the western part of the area, these spring and seep flows are often very saline due to natural salt deposits, and in some places contamination from oil-field brines. In fact, it is the quality, not the quantity, of the area's ground water that is of concern.

The high salinity of much of the area's groundwater and surface water presents a challenge to planners and managers. On the one hand, the municipal, agricultural, and industrial water users of the region, as well as some natural resource managers, would like to lower the salinity of surface-water supplies. One way of doing this is the existing and proposed chloride control projects of the Red and Brazos River basins. These projects aim to intercept and dispose of the highly saline flows of certain tributaries to improve the quality of the water in the mainstem rivers and impoundments. On the other hand, these highly saline flows have characterized the prairie streams of this region for millennia, and the endemic fish faunas that have evolved under these conditions are uniquely adapted for life in these aquatic ecosystems. Another problem associated with intercepting saline flows is that it reduces the base flows of the rivers and streams that formerly received those flows. Reduction of base flows can alter aquatic ecosystems in many ways, e. g., it can increase the number of no-flow days during the summer. Also, altered flow regimes can change the morphology of the streambed and the nature of the streambed substrate. For example, silt deposits can bury clean sand or gravel. Such ecological changes also cause changes in fish faunas, and it is likely that our native prairie-stream fishes would decline in diversity and abundance. These impacts, if realized, could exacerbate changes in the native prairie-stream fish assemblages observed and documented in the Red River and Brazos River drainages. Heightened concern for the health of these ecosystems is likely if responsible management is not implemented. For example, listing considerations for the most threatened species are certainly possible.

Mainstem impoundments that segment rivers, alter or eliminate the natural pattern of annual flooding, and cause changes in other ecological parameters, also cause the decline of many native prairie-stream fishes. However, the large reservoirs do support other fishes not typical of rivers, some of which, like the striped bass, have regional economic significance.

As the recreational demands of the Metroplex population grow, the water-based recreational resources of the study area will become more valuable to the people of the region. In the future, if the region's water resources are conserved and properly managed, the economic value of water-based recreational resources will greatly exceed present value and have the potential to become a major component of the study area's economy.

The TWDB Report 337 (Duffin and Beynon 1992) discussed the potential for and desirability of conjunctive use of groundwater and surface water in the study area. Conjunctive use ideally involves proactive management of both groundwater and surface-water resources to obtain maximum sustainable utilization of total water resources in the most economic and equitable manner. In the study area, where some groundwater and surface-water quality is substandard for treatment and use, substantial benefits could result from conjunctive management. The PGMA planning and management process should not overlook the economic and other values of the water-based natural and recreational resources of the study area. To do so would not be in the best long-term economic or other interests of the people of the region.

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