LANDSCAPE MONITORING FOR SEAGRASS CONSERVATION IN TEXAS COASTAL WATERS

QUALITY ASSURANCE PROJECT PLAN

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SUBCONTRACT PROJECT

For

Coastal Bend Bays and Estuaries Program
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Project Period:
November 1, 2004 – June 1, 2006

APPROVAL PAGE

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CBBEP Contract Number : 0401

Texas Commission on Environmental Quality

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List of Acronyms

CBBEP	Coastal Bend Bays and Estuaries Program
DGPS	Differential Global Positioning System
DOQ	Digital Orthophoto Quadrangle
EPA	Environmental Protection Agency
GCP	Ground Control Point
GRID	Raster file format for GIS data
GRS	Geodetic Reference System
NAD	North American Datum
PDOP	Position Dilution of Precision
PI	Principal Investigator
RMSE	Root mean square error
SHP	File format (shapefile) used in ArcView GIS
TIF	File format used to display images
USDA-ARS, IFNRRU	US Dept of Agriculture- Agricultural Research Service, Integrated Farming and Natural Resources Research Unit
USFWS	US Fish and Wildlife Service
UTM	Universal Transverse Mercator map projection

A3. DISTRIBUTION LIST

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A4. PROJECT/TASK ORGANIZATION
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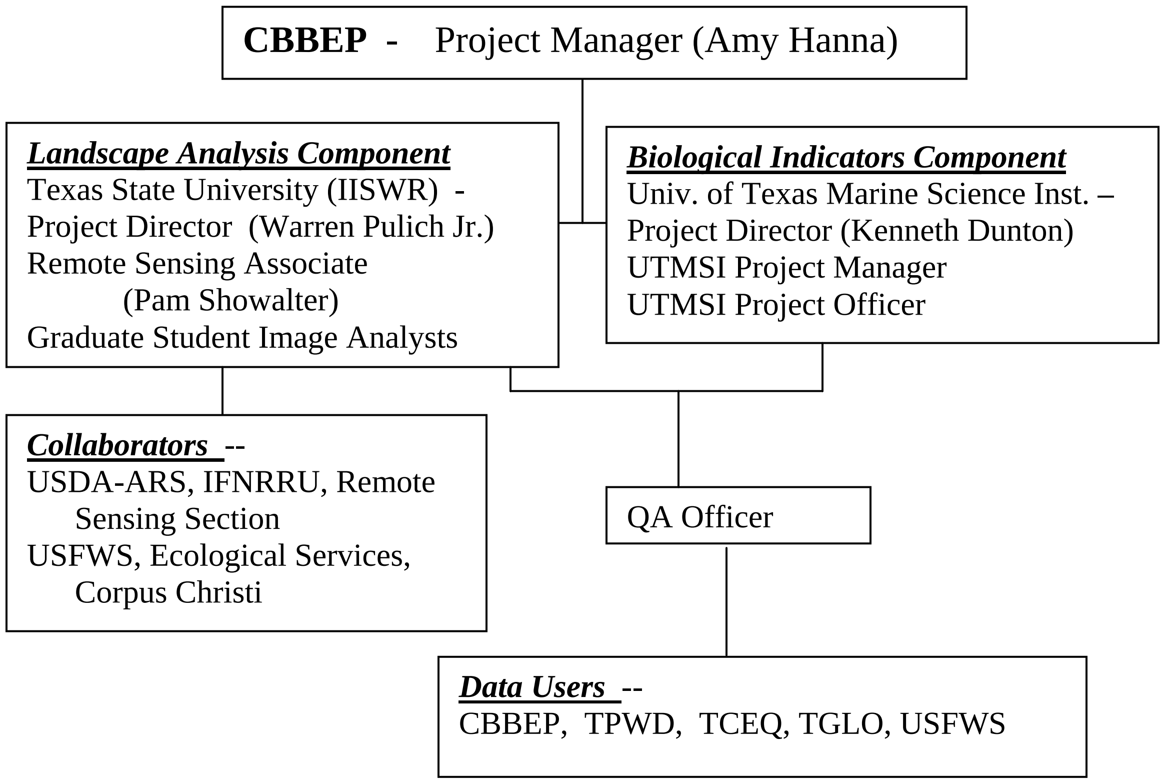


This seagrass monitoring study, funded by the Coastal Bend Bays and Estuaries Program (CBBEP), has two components. Dr. Kenneth Dunton, Marine Science Institute, University of Texas at Austin, will direct and supervise a component on field sampling and biological indicator monitoring. Dr. Warren Pulich Jr., Texas State University, Intntl. Inst. for Sustainable Water Resources (IISWR), will direct the component for remote sensing imagery acquisition and landscape indicator monitoring. The remote sensing project personnel include the Project Director, Doctoral and MS graduate students, and a Texas State University remote sensing faculty consultant (Dr. Pam Showalter). Graduate student thesis projects will be developed around this project, and lead to training in remote sensing, estuarine biology, GIS data analysis, and coastal management planning.

Three major collaborators will participate in technical aspects of the remote sensing project component. These include Dr. Reginald Fletcher at USDA-ARS, IFNRRU, Weslaco (photogrammetry, aerial videography, and georegistration); Dr. Pam Showalter in the Geography Dept. at TSU-San Marcos (digital image processing and remote sensing); and Mr. Beau Hardegree in the Corpus Christi Field Office of USFWS (GPS data collection).

The project will integrate and coordinate the efforts of various state and federal agencies, including the Coastal Bend Bays and Estuaries Program (CBBEP), the USGS/National Wetlands Research Center, US Fish &Wildlife Service (Ecological Services Offices), Texas Parks and Wildlife Dept. (TPWD, Coastal Fisheries Division), the Texas Commission on Environmental Quality (TCEQ), the Texas General Land Office (TGLO), USEPA, NOAA, and local academic institutions. CBBEP has been instrumental in facilitating regular meetings of the Texas Seagrass Monitoring Workgroup, which will also provide valuable input into the research effort.

A5. PROBLEM DEFINITION AND BACKGROUND

A5.a. Introduction and Background

Resource managers in Texas state agencies (TPWD, TGLO, and TCEQ), along with coastal conservation groups and research scientists, have recommended coastwide monitoring to assess the status of Texas seagrass beds and to detect sublethal stress prior to actual grassbed losses (Seagrass Conservation Plan for Texas 1998). The Texas Seagrass Monitoring Plan (TSMP 2003) recently proposed a combination of intensive field surveys (at microscale) and landscape monitoring with color aerial photography at grassbed scale to monitor and measure indicators of seagrass health and stress. The CBBEP, through its seagrass status and trends monitoring efforts, has actively promoted seagrass research to more clearly evaluate and identify stressers and disturbance factors (natural or human) at both the plant level (microscale) and landscape (bedscale) level. In the mid 1990s, CBBEP initiated a longterm status and trends assessment of seagrass dynamics in the Coastal Bend region from the late 1950s up through 1994 (Pulich et al. 1997) and supported the assessment of boat propeller scarring impacts on the same grassbeds (Dunton and Schonberg 2002). These studies documented changes in grassbed distributions, species composition, proliferations of macroalgae and epiphytes, and physicomechanical impacts to grassbeds (i.e. propeller scars, channel dredging). This work also clearly demonstrated the potential for using landscape indicators to assess stress to and degradation of seagrass beds from dredging, urbanization, boating/ship traffic, or high nutrient loading.

Intensive field sampling (at microscale) has traditionally been used to detect and quantify effects of specific factors related to seagrass stress or growth (Neckles ed. 1994). But, such plant level field sampling is very labor intensive and expensive. At the seagrass bed scale, landscape indicators and patterns will also reflect major effects of disturbances, including poor water quality, anthropogenic or natural physical disturbances, and hydrologic conditions. High resolution photography over wide areas would be very cost effective in identifying characteristic human or natural disturbances, and possibly water quality impacts (Ferguson et al. 1993, Dobson et al. 1995, Robbins 1997). If microscale measurements from field sampling were statistically correlated with specific landscape features and geomorphological patterns evident in grassbed photography, it would be possible to extrapolate the extent of altered seagrass dynamics over wide coastal areas.

Identifying factors responsible for seagrass plant dynamics (i.e. causes of seagrass stress or growth) can be difficult, even from carefully measured plantscale (microscale) indicators (e.g. plant biomass or root/shoot ratios). When landscape indicators are monitored (e.g. bed fragmentation and patchiness, macroalgae, species composition, etc.), the same problem exists; and inferring the causes of landscape changes from these effects must be approached cautiously (Dobson et al. 1995, Duarte 1999, Kirkman 1999). Environmental conditions and ecological factors may exert positive or negative effects, either singularly or in combination. Consequently, identifying stress factors and their effects on the seagrass bed involves deciphering complex interactions through both site specific and landscape level measurements. Extrapolation from specific field site measurements over large seagrass landscape areas requires integration of both remote sensing and field sampling data through geostatistical analysis (Heggem et al. 1999, NOAA-CSC 2001, Mumby and Edwards 2002).

A5.b. Goals and Objectives

The goal of this landscape analysis project is to integrate monitoring of seagrass bed landscape indicators (e.g. bed morphology patterns, vegetation species composition, and physical disturbance features) with monitoring of seagrass plant/habitat indicators (biomass, plant composition, water and sediment nutrients, etc.) for seagrass ecosystems management and conservation purposes.

The specific objectives are:

1. Establish 6 priority target sites in the Texas CBBEP study area for long-term seagrass monitoring as recommended by the Texas Seagrass Monitoring Plan (2003).
2. Acquire true color aerial photography at both 1:24000 and 1:9600 scales at all 6 sites, and determine seagrass status and trends by comparing 2004 acreage data with previous data from a 1994 CBBEP study.
3. At two sites (Terminal Flats and East Flats), conduct intensive landscape analysis studies to measure and develop seagrass landscape indicator parameters from the high resolution 1:9600 scale photography.
4. Evaluate landscape indicators at two scales of photography to determine the optimum spatial scale needed to monitor seagrass landscapes for management and conservation purposes.
5. From spatial and statistical analyses, correlate these landscape indicator measurements with microscale measurements from field sampling, leading to establishment of landscape indices of biological integrity.

A 6. PROJECT/TASK DESCRIPTION

This CBBEP-funded project will continue work on the development of seagrass stress indicators and health criteria that began under a R-EMAP project funded to Drs. Ken Dunton and David Maidment (2001), but new work will include and integrate a critical landscape indicator component proposed by Dr. Warren Pulich. **This landscape component will 1) update seagrass status and trends data between 1994 and 2004 for a number of target**

sites in the CBBEP study area and 2) investigate the application of landscape indicator analysis to seagrass monitoring. This approach should establish a protocol for evaluating stress indicators for seagrass systems from landscape features determined from aerial remote sensing data.

Landscape indicator monitoring will use high resolution, vertical color aerial photography to characterize and analyse seagrass bed morphology, fragmentation patterns, vegetative species composition, and human disturbance features of target seagrass beds in the CBBEP study area. After photographs are scanned and converted to high resolution digital images, computer image processing and GIS techniques will be applied to analyze the landscape indicators. Since landscape dynamics are often extrapolated from change analysis of photographed landscapes over strategic time periods (Dobson et al. 1995), the proposed project will compare seagrass landscapes at target sites over a 2-year growth cycle, and then correlate classified landscape features with discrete plant (microscale) data or process measurements for the same time period. Effects of plant or ecosystem processes will be correlated with change dynamics of landscape features between the end of the two annual growth cycles. In some cases this will also equate to before and after environmental disturbances (e.g. prop scarring or other mechanical disturbance).

In order to detect the desired landscape health indicators from seagrass landscape monitoring, high resolution remote sensing data is necessary, but the exact film scale needed is still equivocal. By acquiring photography simultaneously for study sites at both 1:24000 and 1:9600 scales, we will be able to compare the subsequent classification and interpretation accuracy for landscape indicators derived from each film scale. This will enable a decision on the relative accuracy of the 2 photo scales and the source data needed in future landscape monitoring work for seagrass management.

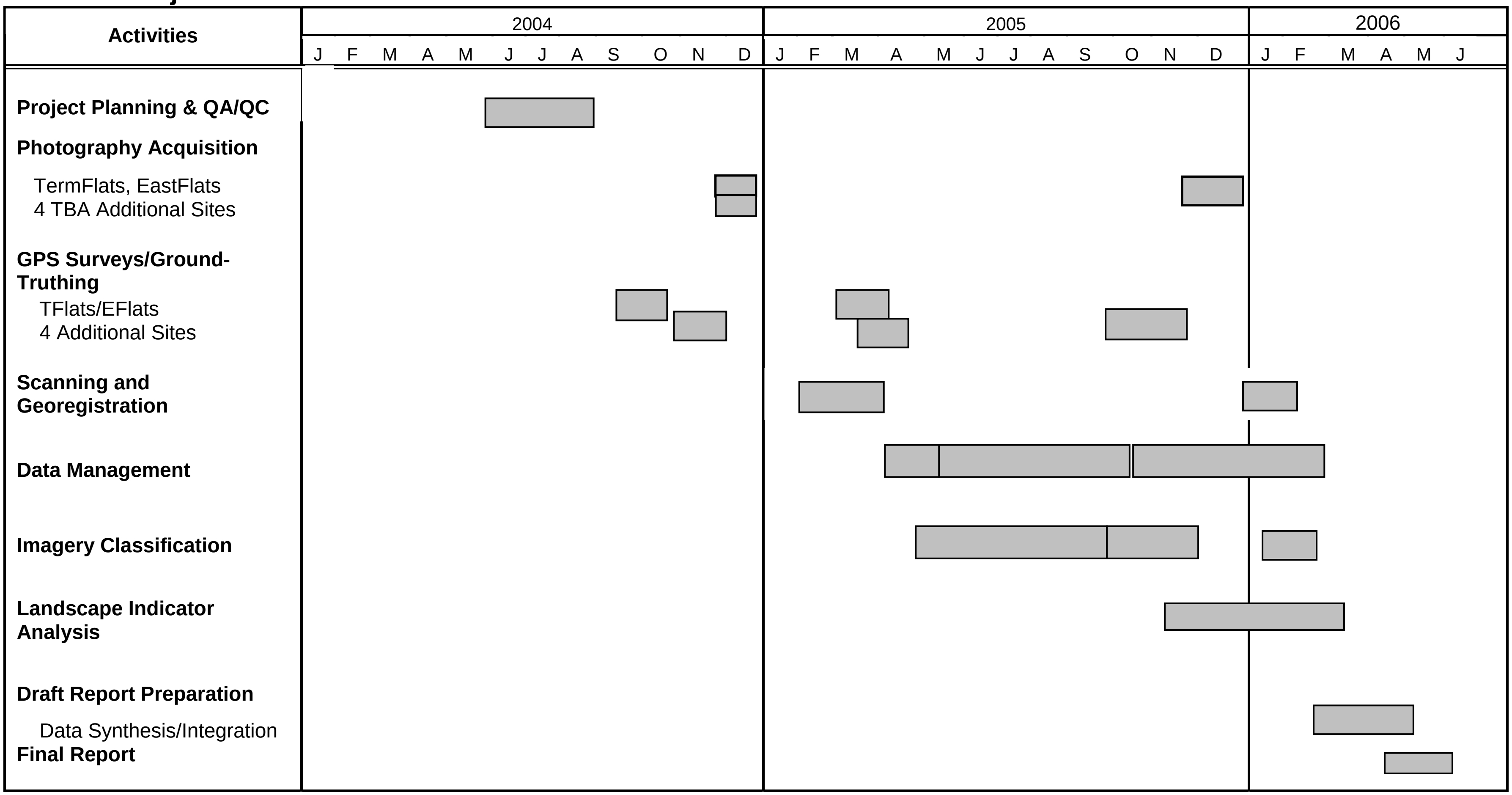
During intensive field surveys conducted at the photo target sites, measurements will be made of hydrographic and other environmental indicators (see Dunton QAPP for other component); and groundtruth data will also be obtained on the vegetation and landscape features. These landscape indicator and field survey data will be incorporated into a GIS database and form the basis for a model (using ARC-View geospatial analysis) to correlate seagrass plant indicators with landscape indicators. Statistical relationships between seagrass plant data and landscape features or patterns could provide the basis for deriving seagrassbed indicators of biological integrity. The project schedule with deliverables is given in Table 1.

A 7. QUALITY OBJECTIVES AND CRITERIA

A7.a. Remote Sensing Data

Detection of seagrass health/stress indicators from remote sensing datasets of seagrass beds will be performed with high resolution true color aerial photography. Previous studies document the precision and accuracy of standardized, vertical true color aerial photography for seagrass mapping (Ferguson et al. 1993, Dobson et al. 1995, NOAA-CSC 2001). This

Table 1. Project Time Line and Deliverables



Deliverables:

1. **Photography Acquisition:** Hardcopy, 9 in. x 9 in. aerial photographs at 1:9600 and 1:24000 scale.
2. **Scanning and Georegistration:** Digital, georegistered photoimages.
3. **Imagery Classification:** Photoimages classified to 5 landscape indicator class level.
4. **Landscape Indicator Analysis:** Geospatial analysis and calculation of landscape metrics.
5. **Final Report Document**

recommended mapping protocol relies on photointerpretation of color photographs (Aerocolor Kodak 2445 color-negative film), acquired according to strict weather and water conditions that maximize seagrass delineation. Photography must be taken with calm, clear water, under clear skies with full sunlight, usually moderate to low tides, and must have high spatial accuracy.

After acquisition, all 1:9600 scale photographs need to be scanned at high resolution (0.3 m or 1.1 ft per pixel) to create high resolution digital images. However, only the portion of 1:24,000 scale photos overlapped by the smaller 1:9600 scale photo will be scanned at this resolution. Entire 1:24000 photos will normally be scanned at a resolution of 3.3 ft per pixel.

The exact film scale needed for landscape feature resolution is still equivocal and this aspect constitutes a research objective of the project. It is expected that 0.3 m (1.1ft) ground resolution is required to discriminate prop scarring and other fine scale landscape disturbances. In contrast, 1:24000 scale photos can be enhanced only to about 1m (3.3 ft) maximum resolution. By acquiring photography simultaneously for study sites at both 1:24000 and 1:9600 scales, it will be possible to compare the subsequent classification and interpretation accuracy for landscape indicators derived from each film scale. This will enable a decision on the relative precision and accuracy of 1:24000 vs. 1:9600 photos and the source data needed in future landscape monitoring work for seagrass management.

Since large format photos (9" x 9") cover large seagrass areas of the bay, complete sampling can be achieved in one photo (e.g. 4.4 sq. km of area in 1:9600 photography or 10-12 sq. km in 1:24000 scale photo), thus ensuring representative variation for landscape analyses. Digital scanning for converting photos to digital imagery is highly reliable and efficient for manipulating and analysing photos using automated computer techniques at both 1:24000 and 1:9600 photo scales. The georegistration and rectification process is carefully controlled using 12 – 16 GCP's per photo to achieve high precision and locational accuracy, based on < +/- 1 m DGPS accuracy. The resulting root mean square error (RMSE) for registration transformations will be held to 1 m or less for acceptable results.

The sensitivity (i.e detection capability) of image processing to discriminate spectral signatures is very high because of the capabilities of current desktop image analysis software (viz. ERDAS™ and ENVI™). Previous studies by the PI have shown that classification algorithms (e.g. ISODATA) or spectral density slicing techniques will consistently separate and extract major categories of landscape features in seagrass photoimagery. Table 1 lists the 5 classes of seagrass landscape indicators that may be identified, as well as proposed spatial metrics which may be calculated, as a result of this photoanalysis.

At the two intensive study sites (Terminal Flats and East Flats), 2 sets of photos will be acquired for temporal change analysis: an end-of-year series showing high plant biomass taken in Dec. 2004 (Year 1), and a similar end-of-year series taken in Dec. 2005 (Year 2). At this time of year, seagrass biomass is still moderate and tides are low, providing high contrast for seagrass delineation. At 4 other target sites (described below in B1.a), Dec. 2004 photography only will be acquired. Photomissions will be scheduled during good weather with full sunlight, calm, clear water conditions and low to average tides.

For the 10-year change analysis, comparability between the earlier mapping data (Pulich et al. 1997) for the Redfish Bay area and the current 2004 data must be considered in terms of scale (or map) differences and minimum mapping unit. The earlier 1994 data were only accurate at 1:24000 scale, while current map data at 1:9600 scale will be of higher resolution. Small seagrass patches or bare areas < 0.125 acre (ca 0.05 ha) in size were not delineated in the 1994 photography, since the minimum mapping unit size limit was 0.125 acre (ca 72 ft x 72 ft). In order to correctly compare seagrass area changes occurring between the 10 years, therefore, this will require filtering the current 1:9600 seagrass coverage to eliminate bare areas less than 72 x 72 ft (22 x 22 m) in size (ca 66 x 66 pixels), prior to overlay analysis between the 2004 and 1994 datasets. In the 1994 seagrass map, such small bare areas within a seagrass bed would have been included as part of a surrounding seagrass polygon (although the polygon may have been classified as patchy seagrass).

Table 2. Seagrass Landscape Indicator Classes and Proposed Quantitative Metrics

Indicator Class	Landscape Metrics
1. Morphology and Patterns of Seagrass Plants	Shape, size, density, & edge symmetry of beds/patches per hectare.
2. Non-seagrass Natural Features	Acreage of macroalgae, bare patches, reefs, channels, sand bars & shoals per hectare.
3. Human Impact Features	Linear distance of propeller scars, pipelines, “industrial activities”, dredged channels per area of interest.
4. Spatial Distribution of Seagrass Species	Percent changes in species coverage over landscape area of interest; Depth limit.
5. Water Column Constituents	Zones (polygon areas) of turbidity, chlorophyll, other water chemistry.

A7.b. GPS Samples

DGPS (differential GPS) will be used to precisely locate landscape features and vegetation to a spatial accuracy of <+/- 1 meter. In order to achieve this precision and accuracy, GPS readings are acquired by averaging for 120 seconds with the GPS receiver unit at each ground point. PDOP readings for satellite reception must be 5.0 or less for acceptable points. This accuracy also requires that a 12-channel GPS unit equivalent to the GeoExplorer III (Trimble Navigation Ltd.) be available for use. Differential correction will be performed using post-processing software (Pathfinder Office™) to achieve a RMSE of < 1 m. Corrected GPS points will be converted to ArcView shape files in the UTM projection based on NAD 1983 as the datum and GRS 1980 spheroid.

A 8. SPECIAL TRAINING

Texas State Univ. is recognized for its Geography Dept., among other things, with excellent GIS, Cartography, and Remote Sensing faculty and facilities. This study will benefit from the services of Dr. Pam Showalter, a remote sensing faculty member, collaborating on the project. Dr. Showalter teaches courses in remote sensing and environmental studies, and she will train graduate students and research assistants on the project in image analysis software techniques. Dr. Pulich will supervise the GPS survey crews, oversee the digital photointerpretation analyses, and ensure that proper methods are applied to groundtruthing, seagrass classification, and landscape indicator analysis. Both Dr. Showalter and Dr. Pulich will provide training for project personnel by co-teaching a Special Topics course in Digital Photoanalysis Techniques, and by conducting special training sessions.

A 9. DOCUMENTS AND RECORDS

The Project Director (and supervised project assistants) will maintain project notebooks for all project phases. This includes hardcopies of all photomission logs, vendor camera certificates, and daily analytical work logs. Field notebooks will be used to log all groundtruth survey information for GPS data sets. All notebooks and logbooks will be retained permanently at Texas State University-San Marcos, IISWR. File versions and procedures will be controlled by a strict coding convention.

Complete metadata for all digital photography and GPS survey files will be recorded in both hardcopy and electronic format. A comprehensive library of electronic images (.TIF files) and GPS shapefiles (.shp) will be maintained for 5 years at TSU-Geography Dept./ IISWR. These files will also be distributed to CBBEP and TPWD as project deliverables. Original electronic files will be backed up and CD copies stored in a separate physical location from computers. Original raw photos will be archived permanently at TSU-IISWR.

B 1. SAMPLING PROCESS DESIGN

B1.a. Photography Acquisition

The exact locations of **seagrass "hotspots"** for photography were determined by consultation with the Texas Seagrass Monitoring Workgroup. The group reviewed recommendations in the TSMP (published 2003) and confirmed the decision to select six sites as photographic sampling targets. Most are considered sensitive seagrass areas where future human disturbances activities are planned or currently suspected to occur (e.g. channel dredging, shoreline urban development, or nonpoint source inputs).

Two priority study sites (Fig. 1, Terminal Flats in North Redfish Bay, East Flats in Corpus Christi Bay) were selected for detailed landscape indicator monitoring since work has been conducted there for previous 3 – 5 years by the PI's, and seagrass dynamics are fairly well understood (McEachron et al. 2002, Dunton and Maidment 2001). Fig. 1 shows the two target sites and relative areas covered by photo footprints of the 2 scales of photography. One site (East Flats area) is considered to be a control area (relatively undisturbed seagrass beds), as opposed to other more disturbed seagrass areas (e.g. north Redfish Bay). These areas will be photographed at 2 altitudes, resulting in 2 film-scale products: 1:9600 and 1:24000 photographs. Interpretation and analysis of the aerial film photography will be aided by simultaneous acquisition of multispectral airborne imagery at discrete wavelengths using digital videography. Multispectral band datasets will be derived from the videography data using color filters (Everitt et al. 1999). Intensive field sampling will be conducted at these sites by Dr. Dunton's group to complement this landscape studies work.

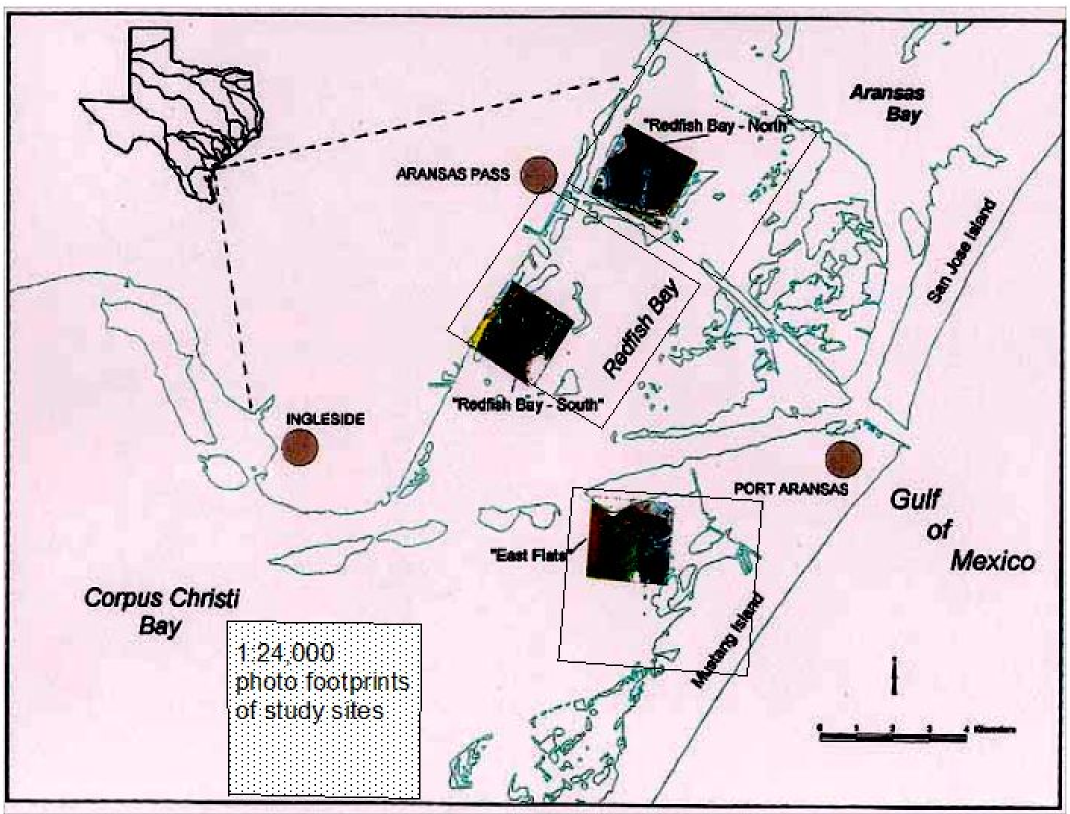


Figure 1. Site Map showing intensive sampling sites for integrated landscape and field seagrass studies in Redfish Bay-North and East Flats. The 1:9600 scale photographs are shown within a 1:24000 scale photo footprint.

Four additional sites will also be photographed for baseline data acquisition at both the 1:24000 and 1:9600 scale (Figure 2):

1. One adjacent to Packery Channel;
2. One adjacent to the Kennedy Causeway in upper Laguna Madre;
3. One near the Shamrock Island area of Mustang Island; and
4. One in the South Redfish Bay area.

These sites represent potential "hotspots" for seagrass change in the Texas Coastal Bend region and have been selected from target sites proposed in the Seagrass Monitoring Plan (TSMP 2003). However, intensive field studies will not be conducted at these 4 sites, rather only seagrass change analysis between 1994 and 2004 at the 1:24000 scale. A total of 4 - 1:9600 scale photographs will also be taken for these sites, which will be contained in the 4 additional 1:24000 scale photographic footprints.

Vertical aerial photography (large format 9" x 9" film camera) will be flown by a commercial aerial photography contractor at both 1:24000 and 1:9600 photo scales using Aerocolor Kodak 2427 color negative film. The dimensions of the 9" x 9" film cover a photoarea of 2.2 km x 2.2 km at 1:9600 scale, while the area covered at the 1:24000 scale is 5.5 km x 5.5 km. Four (4) complete 1:9600 scale photographs are contained within the area of a 1:24000 scale photo footprint (see Fig.1).

At the two intensive study sites (Terminal Flats and East Flats), two sets of photos for temporal change analysis will be acquired: an end-of-year series showing high biomass taken in Dec. 2004 of Year 1, and a similar end-of-year series taken in Dec. 2005 of Year 2. Seagrass biomass is still moderate and tides are low at this time of year, providing high contrast for seagrass delineation. At the 4 other target sites, only the Dec. 2004 photography will be acquired. Photomissions will be scheduled during good weather with full sunlight, calm, clear water conditions and low to average tides.

B1.b. GPS Surveys

"Ground-truthing" surveys are extremely critical to precisely locating and identifying features in the aerial photographs. Extensive DGPS-aided ground surveys of the Terminal Flats and East Flats sites will be performed over 2 seasons (winter and spring). This work will start in late 2004 and continue into spring of 2005 (but not past early April when seagrasses begin spring growth), to obtain 125 points at each site. These 125 points will provide the data needed to perform accuracy assessment, and to develop the landscape indicator metrics. The 1:9600 photo footprints (i.e. smaller photo areas inside the 1:24000 footprints in Fig. 1) define the areal extent of the beds and landscape targets to be ground-truthed in this manner.

For the 4 additional sites photographed in late 2004, GPS surveys will be conducted in the spring of 2005, but only 40 random points will be collected per 1:9600 photo footprint. These ground-truth data will be used merely to derive training sets used for limited landscape classification of these areas.

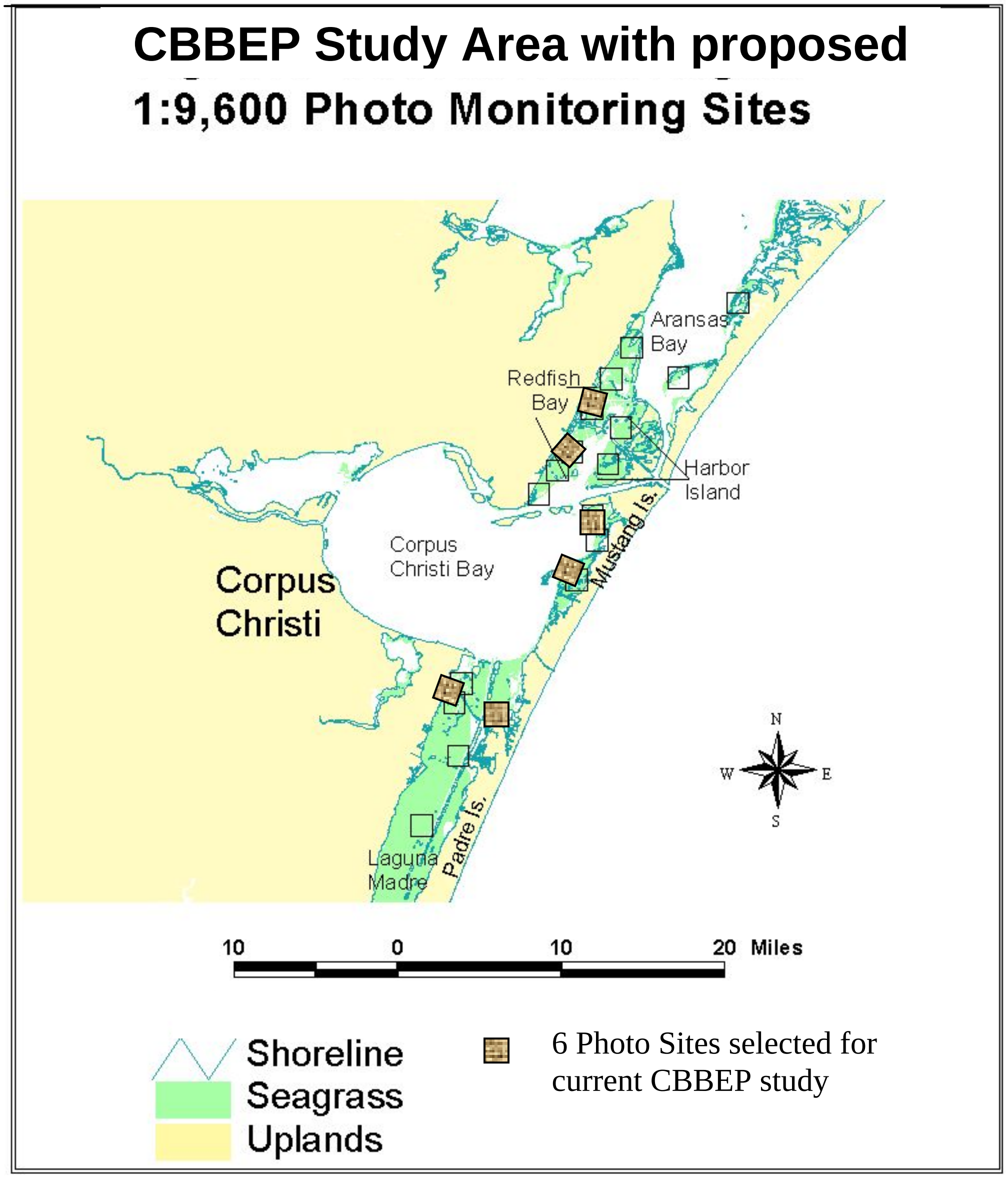


Figure 2. Target sites in CBBEP study area selected for 1:9600 scale photographic monitoring (modified from Texas Seagrass Monitoring Plan, 2003).

After the photography of the Terminal Flats and East Flats sites has been acquired, a field sampling design for hydrographic, environmental and plant-level surveys at these 2 sites will be developed based on the corresponding location of landscape features and the spatial and temporal coverage required for geospatial analysis. This intensive field sampling of biological and physicochemical parameters will be designed, coordinated and performed by Dr. Kenneth Dunton's group at UTMSI. The QA/QC for this sampling and parameters analysed is covered under the QAPP prepared by Dr. Dunton.

B 2. SAMPLING METHODS

B2.a. Aerial Photography Acquisition

Protocols for seagrass aerial photography have been carefully developed over the last 15 years with extensive input by expert seagrass mapping researchers. This project will follow the recommended procedures as compiled in Dobson et al. (1995) for the NOAA-CCAP Program , and recently reiterated by the NOAA-Benthic Habitat Mapping Program (NOAA-CSC, 2001). These methods, which are based on photointerpretation of large format (9 in x 9 in) 1:24000 photos and manual digitization to quantify seagrass coverage were employed in the earlier study for CBBEP (Pulich et al. 1997).

However recent work described in the TSMP (2003), Dunton and Schonberg (2002), Pulich, Fletcher, and Hardegree (manuscript in prep), and Pulich et al. (2003) indicates that 1:9600 scale photos, because of their higher resolution (< 0.3 m ground feature delineation), produce more accurately-identified landscape feature data. A recent similar study by Schull and Bulthuis (2002) in Padilla Bay Washington has also relied on digital photographic analysis of 1:12000 scale aerial photography to determine status and trends of Puget Sound area seagrass. Because of the interest in fine scale seagrass landscape features (e.g. prop scars and small bare patches of < 1m dimensions), 1:9600 scale photography has been chosen as the source media.

The large format film prints and positive transparencies will be acquired using an experienced commercial aerial photographer. Several vendors located in Texas take excellent seagrass photography based on previous contracting jobs with them, and one will be contracted for this work (e.g. Aerial Viewpoint Inc., Spring, TX and Krawietz Custom Aerial Photography, Bulverde, TX). Any vendor used must have a calibrated mapping camera that meets lens specifications of USGS, and the selected vendor must supply camera calibration documentation. The vendor chosen will fly the photography according to the Project Director's instructions and meet the specifications of scale, weather and clear water conditions for accurate seagrass delineation. For vertical photography of the bay water surface, a critical requirement is to take the photos between 1000 and 1130 CST to minimize sunglint off the water. Overlapping photographs at 1:9600 scale will be acquired to achieve 30% sidelap and 60% endlap.

In addition, several sub areas at the two intensive study sites will be flown with airborne multispectral digital video by USDA-ARS-IFNRRU collaborators to acquire narrow, color band imagery at similar high resolution.

B2.b. GPS Surveys

Ground-truthing sampling will be conducted from shallow-draft boats to *qualitatively* identify vegetation types and bottom cover (bare bottom, seagrass species or macroalgae), as well as non-vegetated bottom features at stations where potential landscape disturbance or other features are visible in the photos. Vegetation cover will be discriminated visually as either sparse (1-50% cover per m^2) or dense (51-100% cover per m^2) (Mumby and Edwards 2002; Schull and Bultuis 2002). DGPS (differential GPS) will be used to precisely locate landscape features and vegetation stations to spatial accuracy of <+/- 1 meters. In order to achieve this precision and accuracy, GPS readings are acquired and then averaged for 120 seconds by a 12-channel GPS receiver unit (e.g. GeoExplorer III, Trimble Navigation Ltd.) at each field point.

B 3. SAMPLE HANDLING AND CUSTODY

The Project Director will make arrangements with the aerial photography vendor to fly the photomissions, Subsequently, the analog film and digital images will then be delivered directly by the vendor to the Project Director and Officer via Priority or Overnight Mail. Digital imagery will be as image files on CD or DVD.

B 4. ANALYTICAL METHODS

B4.a. Photogrammetry and Softcopy Digital Processing

After acquisition, the 1:9600 scale photographs will be scanned on a flat bed scanner at high resolution (1.1 ft per pixel) to create digital photoimages. A portion of the 1:24000 scale photo overlapped by the smaller 1:9600 scale photo will also be scanned at this resolution. Entire 1:24000 photos will be scanned only at a resolution of 1m (3.3 ft) per pixel.

For a typical 9" x 9" photo at 1:9600 scale, this requires scanning at 1000 dpi and produces a TIF file of approx. 350 megabytes. Georegistration and rectification of scanned photoimages will be performed using ERDAS™ image processing software (Leica Geosystems Inc., Atlanta, GA). The image data will be registered to the UTM coordinate system, NAD 83 datum and GRS 1980 spheroid. Normally, a second order transformation will be used. At least 12 GCP's per 1:9600 photo area will be obtained and georegistration precision will be to an average RMS error of < 1 meter.

For the 1:9600 photos, actual ground control points will be derived from 1.3 m x 1.3 m (4x4 ft) square white reflective, plastic targets placed in the field prior to photography being taken, or from precise landmarks visible in digital orthophotoquads (DOQ's). Coordinates for the floating ground control targets are determined by DGPS accurate to < +/- 1 m. The 1:24000 scale photographs may be registered from additional field GPS points taken on highly visible landmarks and precise points off DOQ's (e.g. road intersections, piers, or small islands).

B4.b. Digital Photography Analysis and Feature Classification

Landscape features will be delineated from the scanned photos using standard image analysis software (e.g. ERDAS , ENVI™, and Image Analysis™ with ARC-View) to classify the digital imagery and to quantitate features (e.g. species distribution, plants vs. bare patches, drift macroalgae/wrack, human disturbance areas, shoals and channels, etc.). A procedure using spectral density slicing has been developed (Pulich, Fletcher and Hardegree, manuscript in prep) which initially separates the bare, disturbed areas in the landscape from vegetated features (seagrass and macroalgae/wrack), thus producing a 2-class image (see Figures 3 and 4). The 2 classes of bare area and vegetation can subsequently be classified separately using various unsupervised (e.g ISODATA) or supervised (based on training sets) algorithms. Classification and identification of spectrally-distinct features may also be aided by spectral band datasets (using color filters which cut off at 447-455 nm, 483-492nm, 555 – 565 nm, and 625-635 nm) derived from the USDA multispectral digital video data (Everitt et al. 1999).

Change analyses will be performed by quantifying differences for disturbance features or seagrass distribution between the 2004 classified images and seagrass maps from the 1994 CBBEP study. For change analysis, the classified vector polygon maps from the work by Pulich et al. (1997) for CBBEP will first be converted to raster GRID files using ERDAS or ENVI. As stated in Sec. A7.a (Data Quality Objectives), the 2004 classified imagery will first be smoothed to filter out bare areas 72 x 72 ft or less in size (66 x 66 pixels) to account for differences in minimum mapping unit size between the 2 time periods. Change between 1994 and 2004 seagrass distribution will then be evaluated by thematic overlays of the 1994 seagrass GRIDs to the photoimagery data from 2004.

B4.c. Landscape Indicator Classification/Identification and Metrics

The East Flats and Terminal Flats sites will be classified into 6 landscape classes (viz. Seagrass/ Bare patches/ Macroalgae-Wrack/ Prop scars/ Other Human impacts/ Open water) and the overall accuracy verified to 80%, since we will have the necessary GPS points (125 needed per time period). Because of limited ground-truth data, the 4 other sites will only be classified to 3 classes (Seagrass/ Bare areas/ Open water), and the accuracy will not be validated to 80%. The Landscape Classification scheme is based on a conceptual seagrass landscape model that distinguishes five distinct categories of seagrass bed indicators (Pulich et al. 2003):

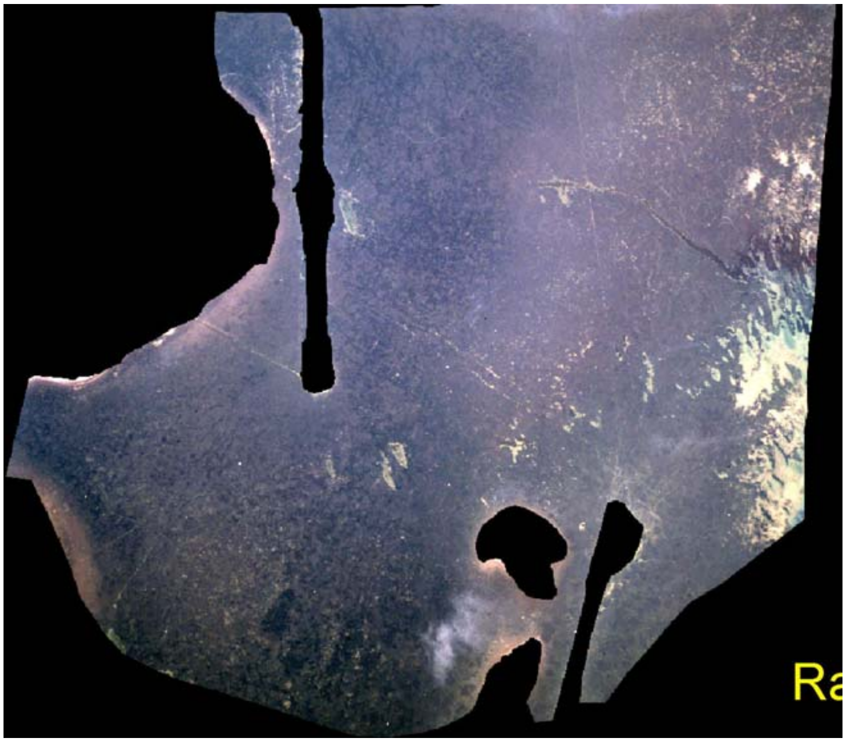


Figure 3. Sample digital photograph at 1:9600 scale of North Redfish Bay study site, unclassified for year 2003.

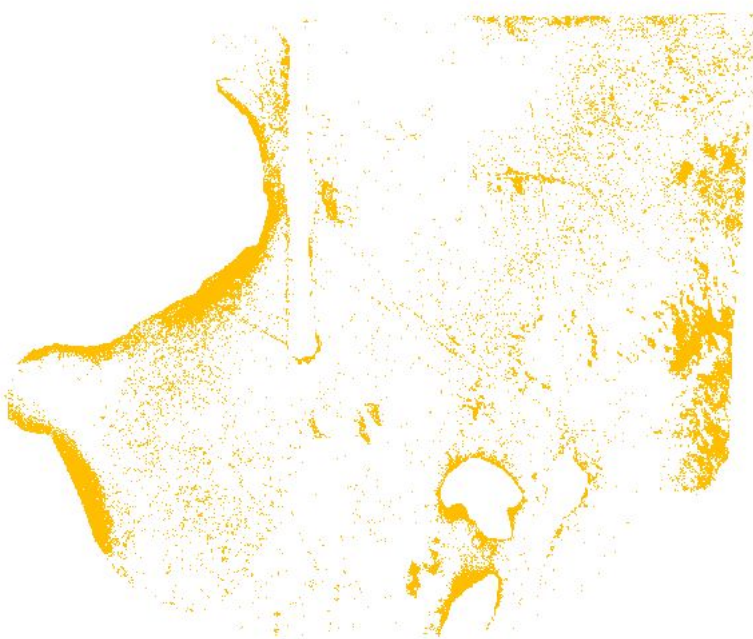


Figure 4. Bare image mask, extracted by image analysis density slicing

applied to Figure 3, showing bare, disturbed landscape features.

Five Classes of Seagrass Landscape Indicators:

1) *Seagrass bed morphology and patterns (including shape, size, density, and edge symmetry of beds). Edge shapes and patch sizes of plant beds are often a function of hydraulics (e.g. water currents), depth, and localized environmental disturbances. Patchy beds can reflect two types of disturbance responses: a) expanding or colonizing patches of plants, or b) localized fragmentation from physical disturbance, eg. wave energy or dynamics, light regimes.*
2) *Non-seagrass, natural features within the bed (such as bare patches, reefs, tidal channels, wrack or drift macroalgae accumulations).*
   Random bare patches within large grassbeds could result from storms, tidal currents or fetch, human activities (see below), or macroalgae and wrack deposition.
3) *Human impact features. Landscape features such as propeller scars, pipeline scars, dredged channels and spoil deposits, and industrial activities (e.g. aquaculture sites) are obvious examples of human impacts to grassbeds (Pulich et al. 1997, Dunton and Schonberg 2001).*
4) *Spatial distribution of seagrass species. Species composition can reflect successional processes which in turn can result from stressor impacts. Species delineation, however, requires extensive GPS field data to achieve satisfactory accuracy with the aerial photography. Multispectral imagery (digital video or airborne scanner) also enables more accurate delineation.*
5) *Water column physicochemical factors. Metrics such as currents (flow patterns), turbidity, chlorophyll levels, and chemical components are indicators of water quality or hydraulic stress. However, identification of these parameters usually cannot be done solely from interpretation of the imagery, but requires ancillary field data.*

Spatial statistics (i.e. landscape metrics) may also be derived for bed feature polygons such as bare patch size and density, edge/shape ratios, species diversity, etc. These measures will first require converting the raster images to vector format files, where pixel features are converted to vector lines or polygons. Using GIS procedures in software such as Geospatial Analyst™ or Landstats™, suggested metrics would be derived for the indicator classes. However, these GIS procedures will require research and analysis to work out, as they are not yet presently described for seagrass applications.

B4.d. GeoStatistical Analysis of Landscape Indicators (Integrating spatial data from Dunton's field monitoring project. See Dunton Component)

Using data obtained from Dr. Dunton's field sampling analyses, correlative geospatial relationships may be derived between classified landscape indicator metrics and disturbance or plant processes, in an attempt to produce landscape indices of biological integrity.

Based on GPS points for microscale processes data collected by Dr. Dunton's group, spatial modeling (using kriging to interpolate between data points) will be performed with Geospatial Analysis module of ARC-View 8.x. Model output layers can then be overlayed onto the classified seagrass landscapes to perform overlay analyses (e.g. Lathrop et al. 2001). Statistical relationships can be derived between classified landscape features (from the photoimagery layer) and disturbance indicator measurements (from GPS point sampling layers). The landscape features and patterns are expected to correlate with disturbance, fragmentation or expansion (growth) processes in the seagrass bed. Biotic integrity indices for seagrass beds would be developed by identifying the landscape indicators that correlate with biological processes or vegetative characteristics.

B 5. QUALITY CONTROL REQUIREMENTS

The vendor chosen will fly the photography according to project Director's (W. Pulich) directions and meet prescribed specifications of scale, weather and clear water conditions for accurate seagrass delineation (see section B4.a). The project Director reserves the right to accept or reject the photography based on these specifications. In particular, if photography does not clearly discriminate the seagrass, it will be rejected and additional photos will be requested. Because overlapping photographs at 1:9600 scale are acquired (due to 30% sidelap and 60% endlap), several photos of the same area will be available to provide replication and backup views of the same area under different light exposures.

Thematic accuracy of the classified digital photos will be to at least 80% overall accuracy as determined by an error matrix technique (Congalton 1992). Basically this value represents the average of the user's and producer's accuracy for the data, which are measures of the errors of omission and commission respectively. Classified pixels are compared to DGPS groundtruthing sample data which are determined as specified under Project Sample Design (B2.b). Ephemeral features such as drift macroalgae, floating wrack, or sparse seagrass make it imperative to perform some groundtruthing within a week (before or after) procurement of the photos. This issue requires careful synchronization of flying the photomission with some GPS survey observations. Identification of ephemeral features is most critical at the Terminal Flats and East Flats sites which will be classified to the Landscape Class level consisting of 6 classes (seagrass assemblages, bare patches, drift algae or wrack accumulations, human or natural disturbance features, and open water channels). Imagery for the additional 4 study sites will be delineated to a 3 class level, and accuracy will require discriminating only between vegetated and bare areas, or deep open water.

Georegistration accuracy of the digital photoimages will be checked first by overlaying them onto and comparing them to USGS DOQ's for the Texas coast. Since most (>95%) of the Ground Control Points for registration are generated from field surveyed GPS target points, consistent overlap provides an independent verification of locational accuracy of the photoimages. Second, one can also overlay GPS groundtruthing data points onto landmarks visible in the DOQ's, and this will help to verify that GPS points coincide with certified DOQ points. Another check of photogrammetric accuracy will come from comparison of the multiyear imagery for the Terminal Flats and East Flats sites. When images from 2004 and 2005 are overlayed, the degree of overlap for fixed landmarks and natural features provides a good measure of precision and accuracy of our techniques.

Spatial errors are relevant to properly identifying small features (< 2 m x 2 m ground dimensions or approx. 5 x 5 pixels) in the digital photos. Because of the limitations of the GPS point data (stated manufacturer locational error < +/- 1 m), the accuracy assessment of classified features must be limited to those 2m x 2m or larger in the final classified product. This decision necessitates running a 5 x 5 pixel smoothing filter on the classified photoimage and eliminating smaller size features from consideration in the accuracy calculation. It also requires that only GPS located field points be used in accuracy assessment that are taken in the center of homogeneous ground features larger than 2m x 2m. Despite this potential spatial location error, we have routinely taken GPS points on smaller features of interest (e.g. propeller scars; groups of scattered, small bare patches). Oftentimes these points actually coincide with landscape features observed in the photography, indicating that the GPS points are very accurate for features in the range of +/- 1 m.

B 6. INSTRUMENT TESTING, INSPECTION, AND MAINTENANCE

The vendor used must have a calibrated mapping camera that meets lens specifications by USGS, and the selected vendor must supply camera calibration documentation. All GPS units will be checked prior to each field survey for proper functioning; and such precautions as proper battery performance, are taken to ensure efficient field survey operations. At least once during every field survey, the GPS units will be checked against known USGS bench marks or reference points to test performance and accuracy. The USDA collaborator maintains its digital video camera system according to an annual maintenance and service schedule. A standardized equipment check is performed prior to every photomission.

B 7. INSTRUMENT CALIBRATION AND FREQUENCY

GPS units are only used to record positional data in the field when sufficient satellites are available. During field operations, a PDOP reading of 5 or less from the unit ensures this functionality. See also B6 above. The USDA video camera system is calibrated annually to meet lens specifications as prescribed by the manufacturer. All video camera filters used come with certified wavelength transmittance data.

B 8. INSPECTION /ACCEPTANCE OF SUPPLIES

For the most part, photographic supplies such as film, will be the responsibility of the commercial contractor. Any other supplies will be procured and accepted by the Project Director (Pulich) or Graduate Research assistants under supervision.

B 9. NON-DIRECT MEASUREMENTS
(Digital Data Acquisition Requirements)

As previously stated, certified USGS DOQ's are available for the entire Texas coast. Those for the Corpus Christi-Redfish Bays area will be used to check spatial and locational accuracy of the photoimages generated in this project and to provide ancillary coverage of ground features (especially land cover/land use) around the study sites. DOQ's can be readily obtained from Texas Natural Resources Information System (TNRIS) in Austin. The PI has previously used the Estes and Port Aransas DOQ's in UTM projection, NAD 1983, GRS 1980 spheroid, with no problems for displaying either digital photoimages or field GPS data.

An additional secondary data source is multispectral videography imagery to be provided by USDA, ARS-IFNRRU, Weslaco, TX. These researchers are highly experienced in acquiring this type of data and have developed a very reliable aerial digital video imaging system (Everitt et al. 1999). The video data are registered to the same ground control points used for the film photography, and thus the spatial accuracy and precision are identical. Certified Ealing™ filters are used for the digital video camera system thus ensuring the optical accuracy of the purported visible wavelengths being recorded by the camera.

B 10. DATA MANAGEMENT
(Operations, Transformations, and Analyses peformed on the Geospatial Data)

B10.a. Processing of geospatial photoimagery data sets

a. Prepare Data Dictionary: Define Landscape Indicator Classes and Attributes (see Section B4.c.)

b. Georeference and rectify digital photoimages using postprocessed GPS coordinates from ground control targets visible in photos. Perform with ERDAS or ENVI software.

c. Apply image processing techniques to photoimages using ERDAS or ENVI to separate bare areas and disturbance features from vegetated areas. Two basic methods will be applied: spectral density slicing or unsupervised classification algorithm (generally ISODATA).

d. Smooth and clean-up bare and vegetated masks from c) using 5x5 pixel filtering routine. Perform accuracy assessment on 2 masks using Error Matrix method per Congalton (1992).

e. Conduct further classification analysis on vegetated masks to identify and separate Seagrass from Macroalgae/Wrack at a minimum. Perform accuracy assessment at all stages of classification. Attempt to further delineate Seagrass Species based on spectral band data from aerial digital video imagery.

f. Attempt raster to vector conversion of bare mask so that statistics for bare polygons can be calculated (e.g. number and size frequency, shapes, etc.).

g. Convert 1994 vector seagrass maps to GRID files using Spatial Analyst™. Perform change analysis between 1994 GRID files and 2004 raster seagrass image masks by theme overlay technique.

B10.b. Processing of GPS geospatial data sets

a. Load Data Dictionary codes for collecting GPS data into the GPS units prior to field surveys, so that correct, valid class fields and attributes are used. Field notes at each GPS survey point are collected simultaneously by designated field staff, then checked and transcribed into .dbf files later at download stage.

b. Download GPS data from the units (back at the office) onto the GIS processing computer and perform postprocessing using Pathfinder Office™ software. Differential correction of coordinates is accomplished by comparing field unit values to reference station values from the Coast Guard radio beacon signal in Aransas Pass (for Geoexplorer III unit) or from WAAS satellite signal (for GeoXT unit).

c. Produce final GPS datsets by converting the coordinate data files into ArcView shapefiles (.shp), with the associated attribute data files (.dbf). Additional attributes from the field notes may be added by editing the shapefile Table (.dbf file).

B10.c. GeoSpatial Analysis of Landscape and GPS survey datasets

a. Use ArcView 8.0 with GeoSpatial Analyst™ to determine spatial correlations between landscape features and GPS point data.

B10.d. Data Storage and Distribution

An integrated GIS database will be created to store all geoprocessed photoimagery, as well as field monitoring data (plant and other biological data; hydrographic, environmental and water quality data). After QA/QC, electronic files (.tif format) of scanned photoimages and classified imagery of seagrass sites, along with GPS database files (.shp files), will be transferred to State agency custodial databases at CBBEP, TPWD and TGLO. These are the designated agencies and entities with responsibility for compiling seagrass datasets needed for protecting and managing coastal state lands. The Project Directors (Pulich & Dunton) will be coordinating with the State's Seagrass Monitoring Data Management Workgroup during the course of the project through regular briefings.

C 1. ASSESSMENT AND RESPONSE ACTIONS

The Project Director (Pulich) will routinely review all work operations plans, and inspect results at all stages of image classification or GPS data collection. The remote sensing consultant will oversee photoimagery analyses (including georegistration) and check for data quality and accuracy. For any discrepancies, causes of problems will be determined and computer analyses repeated until results are within the specified error limits. Questionable field GPS points will be discarded if necessary.

C 2. REPORTS TO MANAGEMENT

Quarterly reports will be submitted by the Project Director (Pulich) to the CBBEP Project Manager via Dr. Dunton. The general status of aerial photography acquisition and digital imagery analysis will be included under the Landscape Indicator Monitoring component. Any problems or discrepancies from the project work plan will be reported immediately to the CBBEP Project Manager. A preliminary report will be prepared and submitted to CBBEP in August 2005. The final report will integrate results for both the landscape indicator monitoring component and the field biological monitoring component.

D 1. DATA REVIEW, VERIFICATION AND VALIDATION

All raw film photography from the commercial vendor will be inspected and approved by the Project Director (Pulich), prior to acceptance and payment. The original film product must be deemed as suitable for use in this project.

Digital photoimagery and GPS data will be reviewed by the Project Director (Pulich) and collaborators on the landscape monitoring project where appropriate (including TSU-Geography Remote Sensing consultant, USDA-Weslaco Remote Sensing/Image Analyst; and GPS Survey cooperator, Beau Hardegree). Data sets will be checked to ensure their representativeness of the study sites, especially for spatial coverage. Completeness and accuracy of the data sets will be verified as previously specified (sections A 7 and B 5). All computer file attributes will be carefully double-checked against field notebook data where appropriate. Classification (analogous to photointerpretation) accuracy will be validated by both the Project Director (Pulich) and Image Analyst Research Assistants, who will perform independent inspections on analyzed image products and error assessment calculations.

D 2. VERIFICATION AND VALIDATION METHODS

National Map Accuracy Standards for positional accuracy will be checked by the Image Analysts for all digital photoimages of 6 target areas using at least one field target as a control in each area. Ground coordinates will be collected for the control field targets by DGPS, but data will be withheld until after georegistration is completed. As previously stated in B.5, comparisons between field measured coordinates of fixed landmarks and coordinates of the same features from the registered photoimagery will also be performed to check for locational discrepancies. These types of measurements will establish the positional error in the digital products. The Project Director (Pulich) will consult with Research Collaborators (both at Texas State and USDA-ARS, Weslaco) to make these verifications. Verification of GPS unit calibration and proper equipment functioning have also been described in Sections B6 and B7.

D 3. RECONCILIATION WITH USER REQUIREMENTS

This digital photoanalysis of seagrass bed landscapes is intended 1) to provide data for coastal management purposes (status and trends applications) and 2) to improve seagrass monitoring methodology (by detection of landscape indicators of health).

To that end, the status and trends data are constrained by the QA criteria presented, and this will limit their direct comparison with data from previous time periods. As stated earlier, the 1994 data were spatially accurate at the scale of 1:24000 photography, and the resolution was much less (minimum map feature ca 0.125 acre or 0.05 ha) than the 2004 data. Therefore the newer technique based on 1:9600 scale photography, which is more spatially accurate (+/- 1m locational accuracy) and has a higher resolution (ca 1m x 1m ground features), cannot be directly compared at this scale to the older photography. The resolution of the 2004 data will need to be decreased first, specifically by eliminating small bare patches below 72 x 72 ft in size, to make the comparison. This would be done by aggregating small bare pixel features to the larger minimum map feature size. Therefore, the percent of change that will indicate significant or real change between the two data sets will probably have to be greater than 10%.

However, for future trend analyses, change detection between similar 1:9600 scale photographs will certainly be much more accurate at this increased resolution, and it is estimated that a 2-5% change in seagrass coverage would be significant. In addition, other features delineated in the high resolution imagery are of obvious significance for monitoring and detecting disturbance and fragmentation in grass beds. The technique of separating bare area from vegetated features will allow coastal managers to rapidly assess the extent of human physical disturbance on grass beds. Change analysis can also be performed quickly and accurately at this high resolution to determine trends due to specific sources of impact.

The landscape monitoring technique is designed to determine landscape indicators of seagrass health or stress prior to loss of the grassbeds. This application, however, will require integration of landscape indicator data and metrics with the plant level and process measurements from field surveys. Geostatistical (and possibly multivariate statistical) methods are needed to produce these types of indices of biological integrity. The Project Directors (Pulich & Dunton) consider these types of statistical analyses on the data sets to be important objectives, but successful research and development will be needed to accomplish this.

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