SECTION 4: SEAGRASS MAPPING AND LANDSCAPE ANALYSIS MONITORING DESIGN

I. Mapping to Determine Seagrass Status and Trends

The current standard methods for determination of seagrass status and trends involve mapping from 1:24,000 scale true color, not color infrared, aerial photography (NOAA-CSC 2001). Analysis of this scale color photography for seagrass distribution has traditionally been performed by photointerpretation of 9" x 9" positive phototransparencies, followed by digitization of seagrass polygons from map overlays and compilation of digital data into a spatial database (i.e. normally GIS). Details of these seagrass photointerpretation and computer mapping methods are thoroughly described in Dobson et al. (1996), Pulich et al. (1997) and most recently by NOAA-CSC (2001). For seagrass mapping projects using aerial photography of all scales, these techniques would generally be utilized, although some technological modifications have greatly streamlined the delineation and digitization steps (e.g. optical transfer - georegistration instrumentation, and digital scanners are now available). Rigorous standards and specifications apply in all phases of the work; and all required procedures must be followed to ensure accuracy and quality of status and trends seagrass data derived from the aerial photography.

The main disadvantage of 1:24,000 scale photography is that the minimum mapping unit detectable is approximately 1/8-acre or a 75ft by 75ft ground feature. This means that ground features smaller than this size will generally be missed. Some aspects of seagrass health cannot be definitively assessed at this scale of photography (e.g. marginal, recovering seagrass beds currently in Galveston Bay or damage to beds in Redfish Bay from propeller scarring). Indeed, this "1:24,000 scale mapping" should be distinguished from landscape monitoring (below) despite the common data source from remotely sensed aerial imagery. The mapping technique would be used primarily to establish the presence or absence of seagrass beds above a minimum size of 1/8-acre on a coastwide basis. Mapping also implies a static condition, whereas monitoring in this case implies the capability of detecting dynamic changes over short time periods, such as over a single growing season (3-4 months perhaps). For detection of spatial changes and landscape patterns indicative of sublethal stress, the resolution required for landscape analysis is a photographic scale of at least 1:9,600.

II. Landscape Monitoring of Seagrass Health

Landscape Model for Seagrass Impacts

Landscape dynamics indicators are recommended as essential components of seagrass monitoring programs, although such indicators should be integrated where possible with microscale processes and field survey data (Neckles 1994, Dobson et al. 1995). An ecosystem model for Texas seagrass dynamics is proposed that explains macroscale changes in seagrass bed morphology and spatial patterns as responses to environmental stressors, just as individual plants show responses to stressors (i.e. processes) on a microscale (Pulich et al. 2003). These spatial features and landscape patterns are considered to reflect large-scale habitat responses integrated over time. Such responses would be considered indicative of sublethal stress, perhaps presaging changes in or disappearance of an entire seagrass bed. Observation of landscape change or spatial impacts over a large seagrass area indicates that stress processes are at work affecting the entire seagrass plant community, and conversely, that stress is not localized in one area (Robbins and Bell 1994' Fonseca 1996). Such parameters as seagrass species succession, the abundance of macroalgae (seaweeds), spatial distribution of vegetation in deep or light-limited water, overall bed patterns (patchiness or fragmentation features indicating disturbance processes), and temporal variations in plant cover (change or trend dynamics), represent examples of these types of holistic landscape seagrass bed indicators.

In other coastal states, seagrass monitoring protocols are based on a similar model of remote sensing coverage closely integrated with intensive ground surveys. These intensive monitoring surveys range from establishing preselected (fixed) field transects, to conducting probabilistic, random sampling of seagrass bed stations in photographed areas. Florida has proposed monitoring of "sentinel" target seagrass sites that are of major concern for conservation. (see Greening 2002.) The Florida Seagrass Working Group has identified a number of "target" or problem sites where seagrass loss is occurring, as well as "reference sites where seagrasses have remained stable or are increasing." Field monitoring in the Indian River Lagoon of Florida relies on fixed transects for target sites (Morris et al. 2000). Scanning and archiving electronic photoimages of historic and existing seagrass beds is recommended. Washington State (Norris et al. 2000) combines both underwater video surveys and diver transects to monitor eelgrass (*Zostera*) beds. This program is particularly concerned with dynamics of deepwater eelgrass and impacts to eelgrass from dredging and other shallow water disturbance. For Chesapeake Bay Estuary Program projects, submerged aquatic vegetation (SAV) has been monitored aerially for many years, but at the 1:24,000 scale to determine status and trends (Orth and Moore 1983).

Remote Sensing Data Sources and Scale Issues

Aerial remote-sensing media (e.g. color aerial photography or multispectral imagery) can readily provide the data to detect these macroscale (i.e. landscape) responses if the resolution and temporal frequency are sufficient. Recent evaluation of sampling scale (Robbins 1997, McEachron et al. 2001, Dunton et al. 1998) indicates that seagrass sites may be photographed with 9" x 9" film at 1:9,600 or larger scale, capable of detecting 1 ft. minimum ground feature changes in seagrass landscapes. This includes bed fragmentation features, species discrimination, or seagrass bed changes along the shallow- to deep-water gradient.

In the case of seagrass monitoring using 1:9600 scale or larger photography, computer processing techniques now allow for image analysis of spatial (i.e. landscape) features from digital imagery. The resolution, contrast, and color signatures ultimately determine the most effective aerial remote sensing data. Recently, high-resolution airborne digital imagery (multispectral and hyperspectral scanner data) has become available (Mumby and Harborne 1999), but acquisition costs and area of coverage are still prohibitive for routine monitoring projects. However, with today's advances in digital scanning and color processing technology, true color aerial photography is most affordable and produces more than sufficient data, based on TPWD's experience with test projects (see Figure 4-1). The key requirement is still the basic need for high quality, clear aerial photography obtained under almost ideal weather and calm water conditions (Ferguson et al. 1993). Once available, this type of photography can be scanned using a high-resolution digital scanner to provide the 1-2 ft. feature resolution. The scanned photography or digital imagery can then be processed to identify and delineate various features. These features are then subjected to spatial analysis using image processing or GIS/geostatistical software programs (Robbins 1997). In special regulatory cases or as part of experimental studies, the need for hyperspectral imaging data may justify the increased costs of this technology.

Landscape Sampling Grid Design for Texas Estuaries

The design of a landscape sampling scheme requires foremost consideration of monitoring objectives to select critical target sites. Strictly random sampling of seagrass landscapes does not lend itself to most desired monitoring applications. Trend analysis, for example, requires fixed phototargets so that aerial photos can be taken at the same seagrass sites at different points in time. As discussed earlier, in Section 2, a number of priority monitoring objectives focus on detecting seagrass stress or impacts to seagrass health from factors such as:

- Water quality degradation
- Physical/mechanical destruction by dredging or prop scarring
- Natural (storms, climatic) events vs. anthropogenic impacts
- Disease

Evaluating these disturbance factors along the Texas coast leads to the question of how to monitor the landscape so as to best detect the resulting seagrass impacts.

Water quality stressors often produce effects along a gradient, emanating from the suspected source of a discharge or runoff of materials. Often, the gradient may consist of nutrients (dissolved or particulate organics), light attenuating matter (suspended solids like dredged sediments, color material, phytoplankton blooms, etc.), or discharges of toxic/pollutant compounds. This geographic gradient lends itself to targeted landscape sampling monitoring; discrete sites can be chosen based on a scientific rationale for the gradient. In some cases, the source of the impact would serve as the focal point for designing the gradient of seagrass landscape sampling. In other cases, the depth gradient may serve as the guiding factor for sampling locations.

Using the Florida and Washington programs as a guide, there is considerable merit in establishing key “target” sites in Texas estuaries for landscape monitoring using high resolution aerial photography. A number of potential seagrass areas along the Texas coast are currently considered susceptible to large scale, incipient impacts from water quality degradation and nutrient loading. From earlier studies, sites have been identified in West Galveston/Christmas Bays, Aransas/Redfish Bays, Corpus Christi/Redfish Bays, and Upper and Lower Laguna Madre which may be experiencing such impact (Pulich et al. 1997, Dunton et al. 1998, Onuf 1994). By considering the known location of seagrass beds in these bays, it is reasonable to select “target” sites for landscape monitoring in proximity to suspected sources of runoff materials, or along a gradient of anthropogenic stress (e.g. extending from developed mainland areas toward the less-developed barrier islands, or following along water circulation and flow patterns in the bays). Corresponding reference sites for these “target” sites must also be selected where no impacts are expected; and then landscape indicator differences can then be compared and evaluated among the sites using high resolution aerial photography. Statistical analysis of landscape patterns is achieved based on random subsampled areas, nested within the original “target photograph” area.

As part of our current strategic planning exercise, two bay systems have been identified for establishing landscape sampling “phototarget sites” focused on the objective of water quality impact assessment. The Seagrass Monitoring Workgroup has proposed a landscape sampling design for two problematic estuaries on the middle and lower Texas coast: the Coastal Bend bays near Corpus Christi and the lower Laguna Madre (Figures 4-2 and 4-3). The hypothesis for locating these phototarget sampling sites is based on suspected gradients of nutrient loading from anthropogenic sources and subsequent impacts to seagrass areas. Phototarget sites were selected from a grid corresponding to the “footprint” of 9” x 9” 1:9,600 scale aerial photos, each of which covers a ground area of 2.2 km x 2.2 km or 4.84 sq. kms. When this photogrid was overlaid onto the known distribution of seagrass in the Coastal Bend bays or Laguna Madre systems, 17 potential phototargets of this size were located in each system. While these targets are fixed monitoring sites, they do in fact provide coverage of a large fraction (approximately 20% to 33%) of the entire seagrass acreage in each bay system.

As shown in Fig. 4-2 of the Coastal Bend area, six seagrass photosites in Redfish Bay may contrast with reference sites in Harbor Island and Aransas Bay because of the proximity of Redfish Bay to anthropogenic disturbances from mainland urbanization. Recent studies have suggested substantial fragmentation of seagrass beds, and changes in species composition in these beds, along the mainland; but these areas need regular monitoring to determine the temporal trends and longevity of changes. Sites in Corpus Christi Bay along Mustang Island are also expected to show increasing impact over time from shoreline development along this resort barrier island. Similarly, several sites in upper Laguna Madre are especially close to resort development on North Padre Island. Discharges from the channelfront developments may impact seagrass in this part of the upper Laguna Madre.

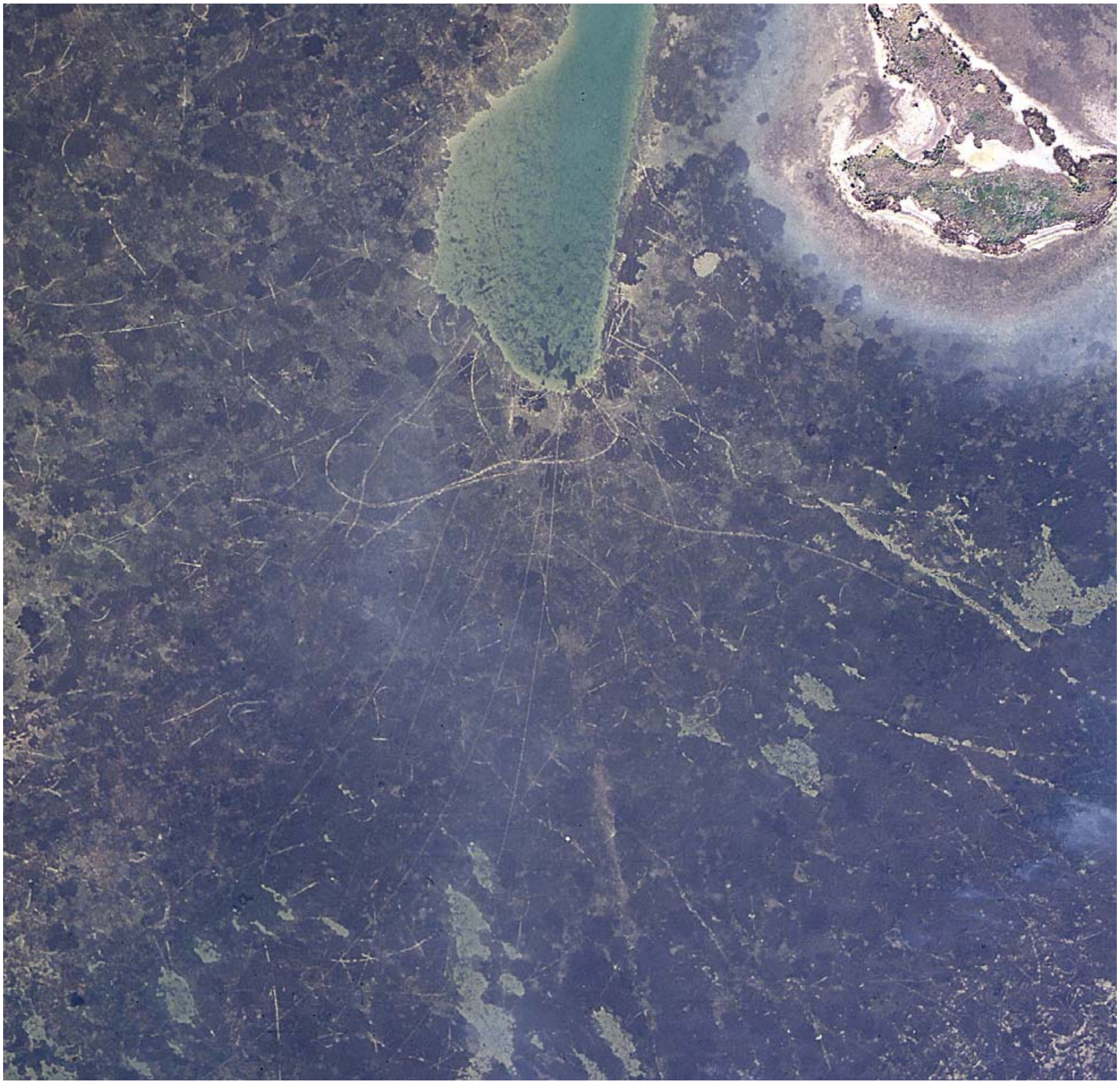


Figure 4-1a. Photograph of Terminal Flats, Redfish Bay, Texas, taken December 8, 2000. Scale 1:4800. Identifiable features are: turtlegrass areas, shoalgrass areas, bare bottom patches, propeller scars, deepwater channels, and patches of drift algae.

Figure 4-1b. Photograph of Terminal Flats, Redfish Bay, Texas, taken December 20, 2001. Scale 1:4800. Compared to Fig. 4-1a, this photograph taken a year later shows an increase in bare bottom patches corresponding to a decrease in shoalgrass and turtlegrass.

Fig. 4-2. Coastal Bend Region 1:9,600 Photo Monitoring Sites

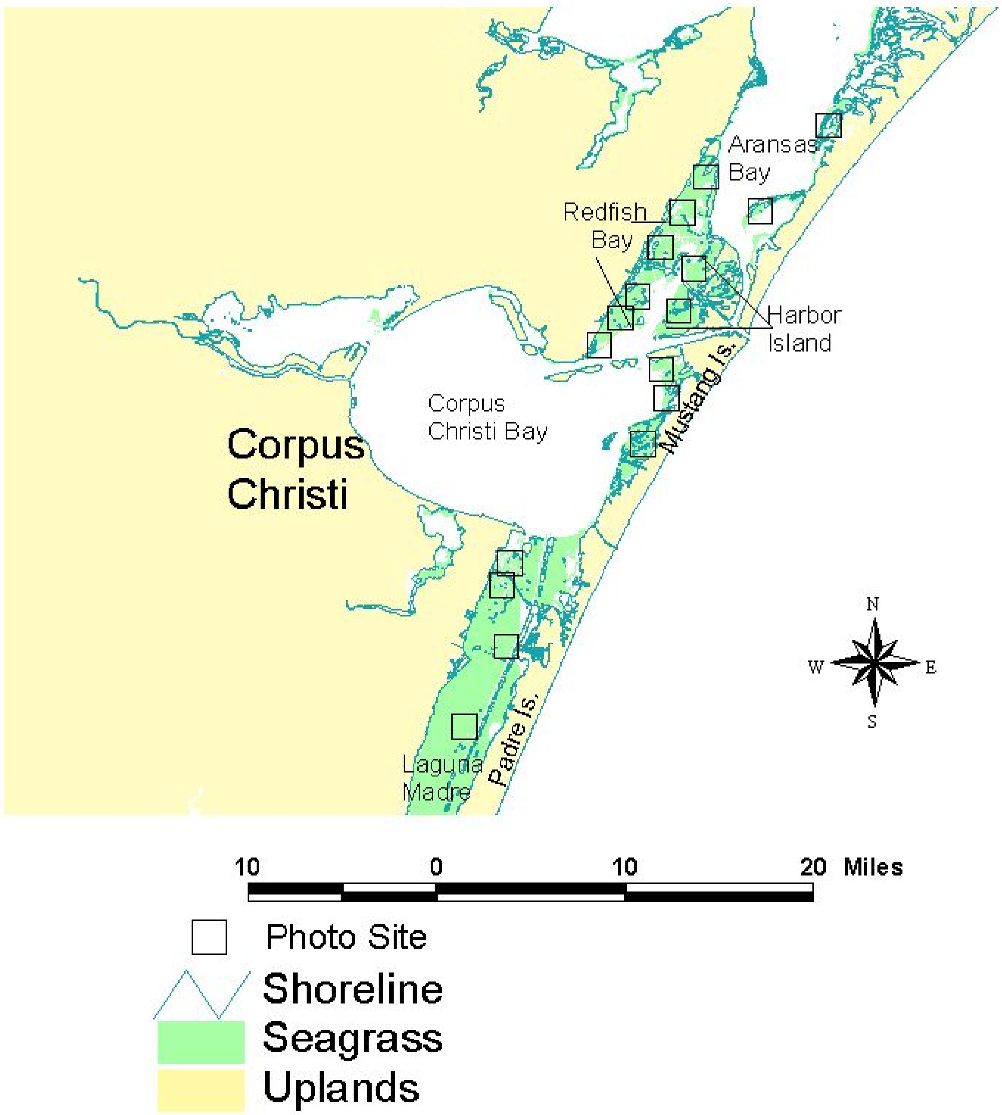
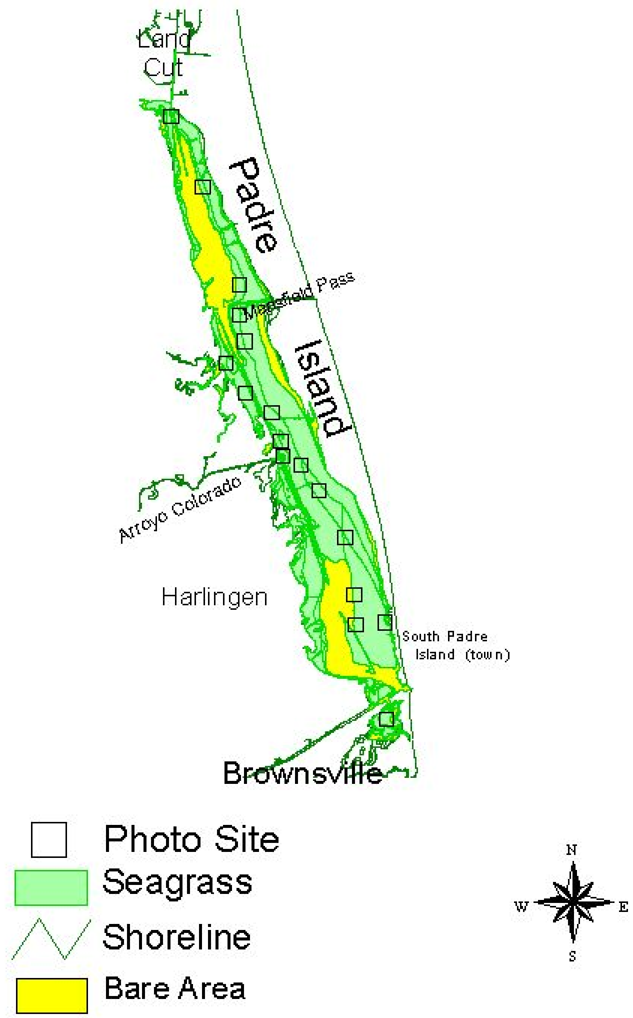


Figure 4-3. Lower Laguna Madre 1:9,600 Photo Monitoring Sites



As shown in Fig. 4-3 for the lower Laguna Madre, sixteen photomonitoring target sites are situated along the northward gradient of urban development and water quality discharges in this lower coast system. Several photosites near residential areas on South Padre Island and around Port Isabel may reveal localized seagrass impacts from wastewater treatment discharges, septic systems, and shrimp farms. These types of environmental stresses have been increasing greatly in the southern portion of the lower Laguna over the last 20 years. A reference photosite placed in South Bay near Brazos Santiago Pass should reflect pristine conditions of this protected Coastal Preserve. Other Laguna sites in the vicinity of the Arroyo Colorado (in the middle portion of the lower Laguna) may show seagrass impacts correlated with the water quality gradient produced by this drainage. A measurable nutrient discharge gradient is expected to extend northward from the Arroyo towards Port Mansfield, but should then disappear to the north of Mansfield Channel. This is due to the water circulation pattern in the lower Laguna, which is restricted from Port Mansfield towards the Land Cut, and predominantly flows out into the Gulf through Mansfield Pass. A decreasing gradient of impacted seagrass sites may extend north from the mouth of the Arroyo towards Port Mansfield. Several sites found north of Mansfield Channel are selected for monitoring as reference sites and predicted to be less impacted.

Landscape Indicators of Seagrass Ecosystem Health

The derivation of landscape monitoring criteria for assessing seagrass health is proposed using remote sensing classification procedures specialized for seagrass communities and spatial data analysis techniques (Pulich et al. 2003). Under proper conditions, digital color imagery has been shown to be amenable to the application of image processing techniques to accomplish classification analyses on emergent vegetation and marine habitats, including coastal plant identification (Everitt et al. 1999) and seagrass/coral reef associations (Mumby and Harborne 1999, Maeder et al. 2002). When similar spectral analysis procedures are applied to seagrass ecosystems, discrimination of landscape features such as seagrass species composition, macroalgae accumulations, and bare patch distributions (spatial bed patterns) within seagrass beds is also achievable. By linking intensive ground survey data based on high precision GPS points to such classified seagrass landscape coverages, landscape indices (analogous to bioindicators) which describe ecosystem health will be developed with geospatial analysis software (eg. ArcInfo, Landstats, ERDAS and ESRI Geospatial Analyst).

TPWD staff have collaborated with the US Department of Agriculture (USDA), Remote Sensing Research unit, at Weslaco, Texas to develop image processing techniques for classifying these simple landscape features in seagrass beds from color aerial photography (W. Pulich, R. Fletcher and B. Hardegree, manuscript in preparation). Figs. 4-1a and 4-1b provide examples of the type of feature discrimination that is possible when this technique is applied to properly enhanced, digital photography. The preliminary image analysis work has tentatively resolved a variety of seagrass meadow classes using ISODATA maximum-likelihood clustering algorithms and manual masking techniques. Feature classes separable in these two large scale photos include two dominant seagrass species (*Thalassia* and *Halodule*), macroalgae accumulations, bare bottom patches, and linear features in the grassbeds (prop scars and pipe lines). Photography taken in year 2002 from two sites in Redfish Bay is currently being analyzed to verify the accuracy of classification techniques developed on the photographs from the previous 2 years. This requires checking 20-30 GPS points (at +/- 1 m spatial accuracy) per feature class to conduct a statistical accuracy assessment. Qualitative results thus far indicate the protocol developed is close to meeting the desired 85% accuracy goal specified for such standard image classification procedures (NOAA-CSC 2001), and only minor refinements in protocol appear necessary.

Further investigations need to be conducted to assess patterns in the seagrass landscape, either of seagrass patches or bare areas within the grassbeds. Other studies have demonstrated statistical relationships between changes in seagrass landscape structure and biomass and various environmental factors such as siltation, currents, or competition from other species (Terrados et al. 1997, Vidondo et al. 1997). Extrapolating from these spatial landscape patterns, calculation of patch statistics, edge metrics or other landscape bioindices (species distribution patterns) should be attempted (Heggem et al. 1999; Robbins and Bell 1994). Specialized GIS software techniques (e.g. kriging) are also available to perform data manipulation and spatial statistical analysis of environmental parameters collected at discrete sampling points, for example water quality or light depth zones produced by contouring point sample data (Lathrop et al. 2001). When such polygon data derived from point samples of environmental parameters are overlaid onto spatial seagrass coverages (distribution) or classified features, spatial correlations may be determined. An urgent research objective is to derive quantitative relationships between environmental quality parameters associated with degrading seagrass landscape patterns. In this way, landscape indices (i.e. metrics) are anticipated that reflect seagrass habitat impacts due to water quality stressors, physical disturbances, or natural environmental factors (Dan Heggem, EPA-ORD, Landscape Ecology Branch, personal communication).