

The diagram developed by the landscape sub-team (Table 4-3) takes a multi-tiered approach, with ecological connectivity as the dominant feature of the system. The second tier is comprised of the major ecosystem components (*i.e.*, soils, hydrology and vegetation) as essential pieces contributing to connectivity. Below this, are the major community types found within the GE ecosystem: mangrove, ridge and slough and marl prairie. On this structure, individual projects and monitoring programs can be overlain; indicating potential overlaps or gaps in monitoring.

Additionally, questions specific to the individual component can be identified. Implicit to this type of diagram is the understanding of a how an integrated landscape program would be developed given that there are already many ongoing programs.

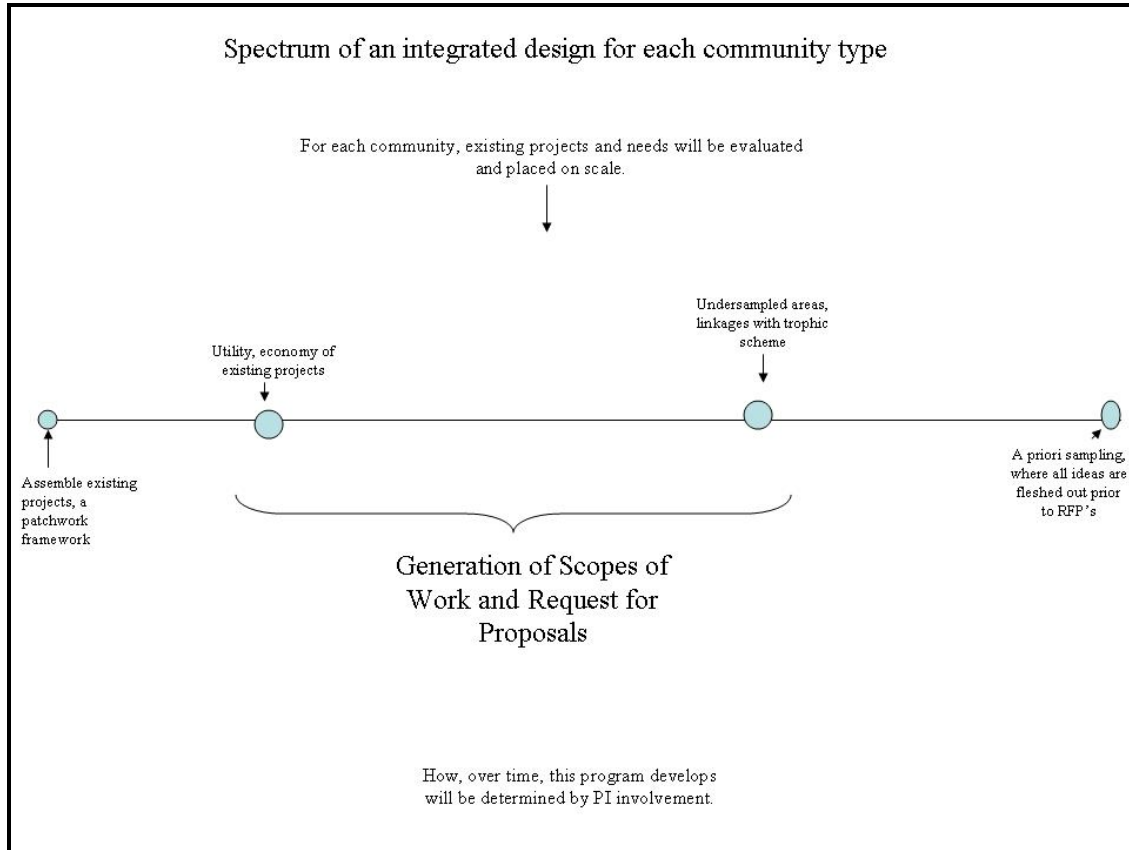
Additionally, the Water Quality-Hydrology efforts were merged with the landscape team in 2005 in an effort to integrate water column nutrient sampling into the landscape monitoring program. Initially, as a separate team, the existing water quality monitoring network was reviewed for redundancies or gaps. Ongoing programs were classified into three groups: 1) established programs with potential high priority CERP sites with long term funding in place, 2) established programs with long term funding but with less-high priority sites, and 3) programs with high priority CERP sites established, but with uncertain funding. Using these categories, several sets of existing stations were identified as those useful for inclusion into the monitoring network for CERP assessment. These include the Florida Department of Environmental Protection (FDEP) stations in WCA 1, FIU Long Term Ecological Research stations in ENP, USGS Coastal Gradient Stations throughout the southern Everglades, and the South Florida Water Quality Monitoring Network in the WCAs. In part, the team also identified major gaps in monitoring.

The current vision of the integrated landscape program has identified a set of key endeavors while acknowledging that optimization of the assessment of CERP effects may require changes in sampling design. A statistical ecologist, Dr. Tom Philippi of FIU, has been contracted to assist in the development of a statistically sound, and quantifiable landscape program that is sensitive to the spatial and temporal variability of the ecosystem components being monitored. A panel of expert ecological statisticians will be brought together in a workshop in the winter of 2006-2007 for consultation for this process. New and ongoing projects may be modified in future years according to the optimal sampling design developed by the panel.

**ECOLOGICAL CONNECTIVITY**

<b>MAJOR SYSTEM COMPONENTS</b>	<b>Vegetation Mapping</b>	<b>Hydrology</b>	<b>Soil Depth and Accretion</b>	<b>Soil Nutrient</b>	<b>Water Column Nutrients and Periphyton</b>	<b>Climate</b>
<b>Characteristics</b>			Long temporal scale			
<b>Major Questions</b>	Should exotics be monitored?	1. At what community level do you monitor? 2. What role does flow play?	1. What is the site variability?	1. What is the site variability?	1. What spatial coverage is needed?	What role do stochastic events like hurricanes have in landscape patterning (e.g., "soil mounding" events)
<b>Projects</b>	1. K. Rutchey	1. EDEN network	1. McVoy	1. S. Newman and S. Hagerthey	1.E. Patino and Zucker	
		2. Trophic projects		2. REMAP	2.E. Gaiser	
					3.S. Newman and S. Hagerthey	
<b>COMMUNITIES</b>	<b>Ridge Slough and</b>	<b>Marl Prairie</b>	<b>Tree Islands</b>	<b>Oligohaline-Mangrove Zone</b>	<b>Cypress Forests</b>	
<b>Characteristics</b>						
<b>Major Questions</b>	Role of flow and soil dynamics in landscape patterning		Role of flow and soil dynamics in tree island persistence	Encroachment of "white zone" into freshwater wetlands: anthropogenic influences vs. sea level rise		
<b>Projects</b>	1.W.Kitchens	1. M. Ross and Oberbauer	1. Miao, Sklar, and Coronado	1. T. Smith		
	2.D. Childers		2.Volin and Furedi			
	3. J. Volin					
	4. McVoy/ Nungesser					
	5. Harvey					
	6. Clark, Osborne, and Cohen					
	7. Sklar					

**Table 4-3:** Everglades Landscape Monitoring (ELM)



**Figure 4-37:** Above are two opposites: on one end existing programs are cobbled together and the other extreme, where there is all a priori sampling design, with projects established to specifically address CERP issues. The former is perhaps the quickest, and initially the cheapest, however, not the most effective at addressing the landscape hypotheses, whereas the latter is expensive, and may have a long period before enough data would be generated for trend analysis, however, the data would specifically address CERP issues. The module team envisions the landscape program to be developed somewhere in the middle of these two extremes: where it makes sense to take advantage of the economy of scale of a long term landscape monitoring program, but where new research and monitoring is initiated where needed.

#### 4.10 Conclusions

Upon the implementation and first full year of monitoring for the MAP, the PMs and working hypotheses in MAP Part 1 and MAP Part 2 have been sorted into eight areas of investigation in the GE Wetlands:

- EDEN
- Coastal Gradients of Flow, Salinity, and Nutrients
- Everglades Soil Nutrient Concentrations
- Everglades Periphyton Mat
- Predator-Prey Interactions of Wading Birds and Aquatic Fauna Forage Base

- Everglades Crocodylian Populations
- Everglades Landscapes: Everglades Ridge and Slough
- Everglades Landscapes: Coastal Ecotone

The first four areas track the physical and chemical driving forces of hydrology, nutrient status, and salinity that are prerequisite to assessing ecological status and trends before and after the implementation of CERP. Five groups of biological responses to physical and chemical changes are monitored: periphyton mat, wading bird/aquatic fauna predator-prey interactions, crocodylian populations, ridge and slough landscape dynamics, and coastal ecotone landscape dynamics. The periphyton mat represents both an integrated hydrology and a nutrient status indicator as well as a biological response. The eight groups of monitoring components comprise a minimum set of indicators that are needed to track and understand ecological changes in the GE wetlands with the implementation of CERP, although it is likely that each group can be refined to further reduce costs. All groups are presently implemented and coordinated, with the exception of Everglades Ridge and Slough Landscapes, as described below. Predator-Prey Interactions of Wading Birds and Aquatic Fauna Forage Base are treated first as a proof of concept of how integration within a working hypothesis can work.

### **Predator-Prey Interactions of Wading Birds and Aquatic Fauna Forage Base**

For this initial assessment report, a hypothesis from each MAP module was chosen as a proof of concept for the assessment process. The hypothesis chosen for the GE wetlands module relates the function of wading bird nesting to available aquatic prey populations. The collapse of wading bird nesting colonies in the southern Everglades is attributed to declines in population densities and seasonal concentrations of marsh fishes and other aquatic prey organisms. Monitoring of wading bird/aquatic fauna predator-prey interactions across the GE wetlands is based on the hypothesis that restoration of natural hydrologic conditions will re-establish distributions of prey densities and concentrations across the landscape that in turn will support the return of large, successful wading bird nesting colonies to the southern Everglades.

The predator-prey hypothesis cluster is used as a proof of concept for the assessment process in the GE wetlands because MAP monitoring of the key components of the hypothesis has been implemented, and a full year of data is available for 2005. Furthermore, this large and complex group of hypotheses for a major restoration goal of GE wetlands has high levels of uncertainty regarding how the biological components relate to each other and to hydrology. The following 2005 monitoring results provide the first system-wide overview of wading bird/aquatic fauna predator-prey interactions; they are consistent with the current predator-prey hypothesis.

*Wet Season Production and Dry Season Concentration of Aquatic Prey Organisms in the Southern Everglades.* Patterns of abundance of prey populations in the southern Everglades (ENP) during the 2005 wet season were largely due high crayfish biomass in the marl prairies to either side of Shark River Slough, and to low fish biomass in the southern half of ENP compared to areas to the north. The same marl prairie areas that supported high wet season prey populations also produced the highest prey concentrations of all areas sampled during the 2005 dry season. Prey concentrations in these areas consisted of high densities of Everglades crayfish compared to other areas.

*Contrasts between the Water Conservation Areas and the Southern Everglades in the Production and Concentration of Aquatic Prey Organisms.* Patterns of abundance and concentration of aquatic fauna prey populations in the WCAs were fundamentally different from those in the southern Everglades during 2005. Crayfish represented a minor component of aquatic fauna biomass throughout the WCAs during the 2005 wet season. Grass shrimp were generally abundant in the WCAs, although they were nearly absent throughout most of ENP. The most notable pattern in the WCAs during the 2005 wet season was the abundance of all major groups of aquatic fauna in WCA 1 compared to other areas.

The WCAs also differed from the southern Everglades in the concentration of aquatic prey during the 2005 dry season. Prey densities in concentration patches in the WCAs were lower than in ENP and were dominated by fishes rather than crayfish. The only area in the WCAs that came close to having high prey densities comparable to the southern marl prairies was southern WCA 2A.

*Correspondence of Wading Bird Nesting Initiation and Failure to Concentration and Dispersion of Aquatic Prey.* Nearly 29,000 wading bird nests were initiated in GE wetlands during 2005. The strong initiation of nesting in 2005 is characteristic of a resurgence in total numbers of nesting birds since about 1999. The strong onset of wading bird nesting during January-February 2005 corresponded to the period of concentration of aquatic prey. Higher than average water levels at the start of the 2005 dry season showed a steady and rapid drying rate November through February throughout most of the system. The combination of initially high water levels and desirable drying rates concentrated prey in drying slough habitats mostly in short-to-medium hydroperiod landscapes during 2005.

The abandonment of wading bird colonies in March 2005 corresponded to the dispersion and reduced concentration of aquatic fauna due to reversals in the receding water pattern. Rainfall events starting in March caused water level reversals throughout most of the system, which reduced or eliminated areas where drying slough habitat was previously suitable for concentration of prey. When prey concentration patches dispersed, the previously strong initiation of wading bird nesting ended in widespread nest failure by most species. This was true for great egrets, white ibises, wood storks and snowy egrets, and the trend occurred throughout the GE wetlands and Florida Bay. Successful nesting occurred only in roseate spoonbill colonies in northwest and southeast Florida Bay. Had it not been for the reversals in water level recession, 2005 would likely have been a year with a large number of successfully nesting wading birds.

*Comparison of the Distributions of Wading Bird Nesting and Aquatic Prey Population.*

Traditionally, large colonies of nesting wading birds in the Everglades formed along coastal areas of ENP prior to their collapse. During the 2005 nesting season, 1,990 wading bird nests were initiated in mainland ENP, compared to 24,249 nests in the WCAs.

A possible explanation for the low initiation of nesting in coastal regions of ENP in 2005, despite water recession rates conducive to prey concentration early in the nesting season, is that low wet season prey biomass was insufficient to produce dry season prey concentrations that were adequate to support nesting. This explanation is consistent with the finding that fish biomass

was low in southern areas of ENP compared to other areas of the Everglades during the 2005 wet season. The low fish biomass there is relevant to the hypothesis that collapse of traditional coastal nesting colonies is related to declines in prey populations along the freshwater/estuarine interface of the southern Everglades.

Areas of ENP with high wet season prey biomass, high dry season prey concentration, and high crayfish biomass (*i.e.*, Rocky Glades, Ochopee Marl Prairie, and Lower Lostman's Slough) may have been too distant from coastal colony sites to be important as foraging areas. The high prey population densities and subsequent concentrations that these areas produced did not appear to be a relevant factor in wading bird nesting in the coastal colonies during 2005.

*Reproductive Life History of Native Crayfish Species.* Crayfish monitoring data from 2005 illustrate what might be some of the first evidence of the reproductive life history of the native crayfish species in the Everglades. In comparison of densities of crayfish to the actual mass of the animals, general densities were highest when the mass was lowest. This indicates a surge in small-bodied animals (juveniles) in the summer months. Conversely, the highest mass was found when the densities were the lowest—indicating capture of fewer, but bigger animals. Until this point, there has not been clear quantitative evidence of when the pulse of juvenile animals occurs in the ecosystem.

*Importance of Freshwater Fishes in Seasonal Prey Population Density Fluctuations Along the Freshwater-Mangrove Interface.* Freshwater fish species accounted for most of the annual and seasonal fluctuations in fish population density and community composition in the freshwater-oligohaline zone of the interface between Everglades marshes and mangrove estuaries between 1990 and 1997. Freshwater species at estuarine sites increased in density during years of low salinity and decreased during years of high salinity. Gradual changes in community structure through time suggested that population recovery required a low salinity period of four years or more.

Freshwater fish species accounted for most of the 2005 seasonal change in fish community structure in Rookery Branch, a mangrove-lined creek linking freshwater marshes to estuarine habitats. This change resulted from an influx of freshwater fishes into Rookery Branch as marshes upstream dried. Fish community structure changed comparatively little in other creeks where influxes of freshwater fishes were less evident during the dry season.

These results are consistent with the hypothesis that the collapse of traditional coastal nesting colonies of wading birds is related to prey population declines along the marsh-mangrove interface of the southern Everglades as a result of altered volumes and patterns of freshwater flow (Ogden 1994).

### **Everglades Depth Estimation Network**

The EDEN supports assessment of all the MAP components and working hypotheses for the GE wetlands. Upon complete implementation of the network in September 2006, MAP PIs will be able to assess ecological responses to real-time and historical water depth and hydroperiod variables for any area of the GE wetlands. This capability will be available for the 2007 SSR.

### **Coastal Gradients of Flow, Salinity, and Nutrients**

Monitoring of coastal gradients in the southern Everglades is conducted to assess the working hypothesis that increasing seasonal freshwater sheet flow to the lower Everglades will provide salinity gradients that re-establish a broader oligohaline zone in the coastal wetlands. Restoration of freshwater flows and salinity gradients to coastal regions of the Everglades, without adverse nutrient impacts in Florida Bay, is a fundamental restoration objective of CERP. Related ecological objectives include the production and concentration of aquatic fauna prey populations in support of the return of coastal wading bird nesting colonies, mangrove forest production and soil accretion in the coastal ecotone, and re-establishment of estuarine crocodilian populations. Remaining work needs to be done to link the coastal gradient monitoring data to the Time and Inflows in the Mangrove Ecotone (TIME) hydrologic model for the southern Everglades in order to facilitate assessment of the coastal gradients.

### **Everglades Soil Nutrients**

P and N concentrations in soil and flocculent organic matter reflect patterns and trends in surface water concentrations integrated over time scales of months to years. Thus nutrient concentrations in soil, along with those in periphyton, provide measures of site nutrient status and extent of eutrophication that show less temporal variability and are more cost effective to monitor than surface water nutrient concentrations. The 2004 distribution of soil nutrient concentrations provides a pre-CERP reference state that will be used to assess changes with the implementation of CERP. Monitoring of soil nutrients will be repeated every five years. The synthesis of patterns of distribution of soil nutrients across the Everglades is combined with periphyton mat characteristics in the following section on periphyton.

### **Everglades Periphyton Mat**

Periphyton mat structure and community composition integrate hydrology and water quality across the entire wetland system. Periphyton responds quickly (weeks to months) to alterations in water management and can serve as an early indicator for ecosystem change. Periphyton monitoring also contributes to the working hypothesis that the floating mat comprised of the periphyton complex and various bladderworts provides critical support of the oligohaline Everglades food web, both as a food source and a refuge for aquatic invertebrates that are consumed by small fish, crayfish, and grass shrimp. Periphyton samples were collected concurrently with throw-trap samples for aquatic fauna prey populations.

*Periphyton Total Phosphorus in Comparison to Soil Total Phosphorus.* TP in both periphyton and soil showed similar general distributions across the most of the Everglades. Concentrations were lowest in the marl prairies of ENP and generally increased in the ridge and slough system with proximity to nutrient-enriched areas influenced by canal discharges of agricultural runoff water. However, there were two notable differences between the distributions of periphyton and soil TP. Periphyton TP was highly elevated in WCA 1 compared to most other areas of the ridge and slough landscape, but soil TP was not. A similar discrepancy occurred in western WCA 3A south of Alligator Alley, where periphyton TP was considerably higher than in most of the surrounding landscape, but soil TP was not. The generally similar patterns of periphyton and soil TP, and the two discrepancies noted above, support the combined use of these parameters to describe regional patterns and changes in nutrient status in the Everglades at different temporal

scales. The possibility of changing nutrient status in WCA 1 and western WCA 3A, as indicated by periphyton TP, but not yet by soil TP, deserves further investigation.

*Periphyton Cover, Biomass, and Organic Content in Comparison to Soil Organic Content.* There was a strong overlap in the distribution of periphyton organic content and soil organic content, both of which were elevated in the WCAs in comparison to most of ENP. This pattern corresponded to the predominantly peat soils of the WCAs, in contrast to marl soils in ENP. The exception was Shark River Slough, where high soil organic matter content reflected the peat-based ridge and slough landscape, but low periphyton organic content resembled levels found in adjacent marl prairies on either side of the slough.

Periphyton cover and biovolume showed patterns throughout most of the Everglades that were opposite to those for periphyton organic content and soil organic content. The predominantly peat-based environment of the WCAs supported low periphyton cover and biomass compared to the predominantly marl-based environment of ENP. Again an exception was Shark River Slough, where periphyton biomass was high in a peatland environment with a high soil high organic content.

### **Everglades Crocodylian Populations**

*American Alligator.* Monitoring of the American alligator in the Everglades is based on the working hypothesis that alligator distribution, abundance, reproduction, and body condition are controlled by hydroperiod and water table in the Rocky Glades, salinity in the mangrove estuaries, and water depth patterns in the ridge and slough system. American alligator population monitoring includes abundance, nesting ecology, body condition, and alligator hole mapping and occupancy. Alligator monitoring during 2005 provides pre-CERP data bases that continue and expand the coverage of nesting surveys in ENP initiated in 1985, and of abundance and body condition surveys initiated in 1999.

*American Crocodile.* American crocodile monitoring in coastal regions of the Everglades is conducted to assess the working hypothesis that crocodile relative density, and juvenile growth and survival, increase when salinity fluctuates below 20 ppt in shoreline, pond, and creek habitats in Everglades mangrove estuaries. American crocodile population monitoring includes nesting, growth, and juvenile survival. Crocodile monitoring during 2005 provide pre-CERP data bases that continue and expand nesting and juvenile growth surveys initiated in 1978.

### **Everglades Landscapes**

Unlike other monitoring components within the GE Wetlands, the integrated landscape program is in early developmental stages. The landscape aspect of the GE wetlands module includes four principal sections: system-wide vegetation mapping, integrated hydrology and nutrient status, coastal ecotone processes, and interior freshwater wetland processes. High resolution aerial photo interpretation for system-wide vegetation mapping based on 2003 imagery is scheduled for completion in 2009 and is to be repeated every five years. Integrated hydrology and nutrient status address the major stressors on Everglades landscape processes that are influenced by the implementation of CERP, and compliment and coordinate with the extensive hydrology and water quality monitoring programs already in place. The integrated hydrology and nutrient status section is closely linked to, and dependent upon, the MAP monitoring components

described earlier in this report for EDEN, coastal gradients, soil nutrient concentrations, and periphyton. Coastal ecotone processes focus on mangrove forest productivity and soil accretion in relation to freshwater flow and sea level. The interplay of these factors will determine the rate of incursion of coastal shorelines into the southern Everglades during this century. Interior freshwater wetland processes focus on the recovery and sustainability of the Everglades ridge and slough landscape including tree islands. An important aspect of this work in ENP pertains to the balance of ridge and slough landscape restoration in Shark River Slough with marl prairie restoration in the higher elevation marshes to either side of the slough.

*Everglades Ridge and Slough.* Sustainability and recovery of landscape patterns in the ridge and slough patterned peatlands of the WCAs and Shark River Slough are a fundamental restoration objectives of CERP. Major management questions regard how to maintain and restore linear patterns of co-existing sawgrass ridges, deeper-water sloughs, and higher-elevation tree islands in a landscape that in many areas has undergone soil elevation loss due to peat oxidation during the Twentieth Century. Sheet flow and oligotrophy are likely important driving forces in the creation and maintenance of the ridge and slough landscape features.

Current monitoring and research in the Everglades ridge and slough landscape involves relating and integrating the information being generated by ongoing projects. Previously, tree island research was generally disconnected from ridge and slough investigations. In remedy, both tree island research in WCAs and ENP have become better coordinated, and there has been a substantial effort by Everglades landscape ecologists from multiple agencies to identify overlap and gaps in the existing monitoring programs. The justification for continuation of the ongoing projects is that they provide data bases from previous years that will assist in determination of what needs to be accomplished in order to establish a pre-CERP reference condition.

Assessment of change in the landscape must consider ridges, sloughs, and tree islands as one holistic system. Work to date identifies three key elements to be monitored to detect structural changes in the ridge and slough landscape during the implementation of CERP:

- Elevation differences between sloughs, ridges, and tree islands (~20-30 cm difference between ridges and sloughs in a healthy system compared to negligible difference in an impacted system)
- Proportionality of ridge and slough spatial extent (~50 percent ridge and 50 percent slough in a healthy system, compared to predominance of one community over the other and loss of tree islands in an impacted system)
- Ridge, slough, and tree island pattern (linear in the direction of flow in healthy systems compared to more diffusion and loss of linearity in impacted systems)

In addition, a small number of parameters need to be identified that measure both key biological indicators, and the processes involved in formation, loss, and sustainability of ridges, sloughs, and tree islands. These parameters should provide an early indication of change in the ridge and slough landscape prior to longer-term structural changes, as well as provide insight as to why structural changes are, or are not, occurring. An objective of ongoing and future research is to succinctly identify this suite of structural, biological, and process parameters, which must be coordinated and consistent across the entire ridge and slough landscape. It cannot be overstated

that these efforts must also be of a nature that will remain financially sustainable through 2050. Until this system-wide coordination is achieved, it will be difficult to assess ridge and slough landscape change at a system-wide scale as CERP is implemented.

*Coastal Ecotone.* The Coastal Everglades Long-Term Ecological Research (LTER) program is addressing the MAP working hypotheses for the coastal ecotone. Monitoring and research on mangrove forest productivity and soil accretion in relation to freshwater flow, sea level, and nutrient dynamics is centered and coordinated in the LTER. Additional ongoing work is conducted by the USGS in Gulf of Mexico mangrove forests. Contributions of the MAP to coastal ecotone monitoring include:

- Support for the MAP monitoring component coastal gradients of flow, salinity, and nutrients
- Support for USGS sediment-erosion table sites and coastal transgression research in Gulf of Mexico mangrove forests
- Support for SFWMD research in coastal ecotone biogeochemical processes

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