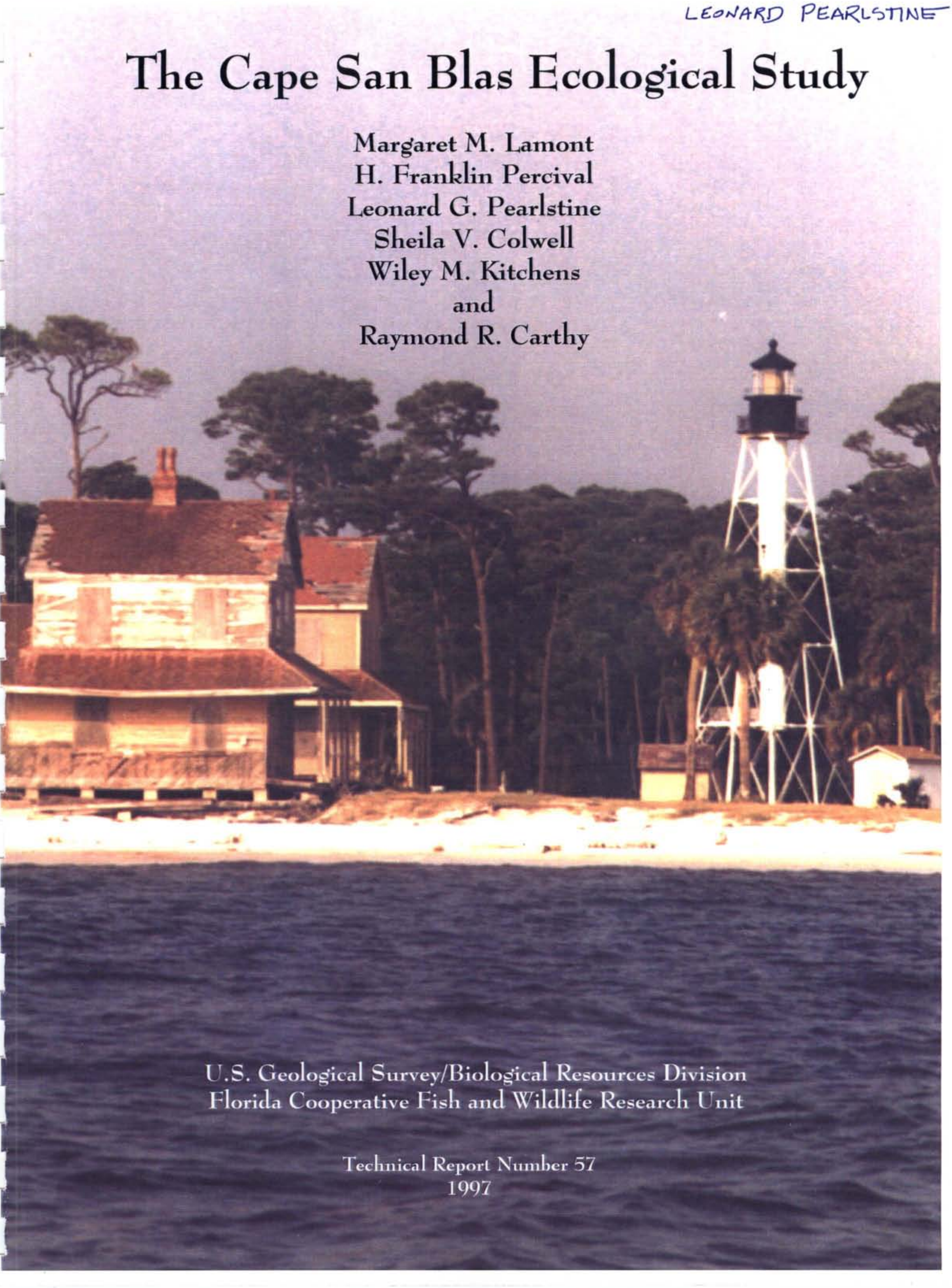
LEONARD PEARLSTINE

The Cape San Blas Ecological Study

Margaret M. Lamont
H. Franklin Percival
Leonard G. Pearlstine
Sheila V. Colwell
Wiley M. Kitchens
and
Raymond R. Carthy



U.S. Geological Survey/Biological Resources Division
Florida Cooperative Fish and Wildlife Research Unit

Technical Report Number 57
1997

ACKNOWLEDGMENTS

This research would not have been possible without the assistance of many people to whom we are grateful. Support for all aspects of this study was received from the Natural Resources Division of Eglin Air Force Base at Jackson Guard, specifically Rick McWhite, Carl Petrick, Bruce Hagedorn, Dennis Teague, and Debby Atencio. In addition, we are indebted to personnel at Tracor Corporation on Cape San Blas, particularly Don Lawley, Judy Watts, Billy Suber, Mark Collier, Carl Fox, O.P. Roney, Billy Griffen, and DeWayne Strader. Support from Debra Hughes, Barbara Fesler, and Caprice McRae at the University of Florida was also invaluable and is greatly appreciated.

The dedication and flexibility of our field technicians, Dave Huetter, Eric Egensteiner, Greg Altman, Shawn Diddie, Melinda Schaefbauer, Kris Fair, and Martha Maglothin made this project successful and enjoyable. In addition, we thank Michael Cook and John Stenberg for assistance with topographical and vegetation surveys and various GPS questions; special thanks to Lisa Ojanen for her assistance and patience with the GIS portion of this project. We are also grateful to Rick West for providing information and suggestions about neotropical migrant and shorebird sampling. For their willingness to assist and share data, we thank the sea turtle volunteers along the St. Joseph Peninsula and rangers within the St. Joseph State Park. We also received valuable information regarding tropical storms from Ralph Clark at the Florida Department of Natural Resources, Division of Beaches and Shores. In addition, we thank Jeff Gore at the Florida Game and Fish Commission, Panama City for assistance and advice regarding several aspects of this study.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Introduction

The main reservation of Eglin Air Force Base (EAFB) is located on approximately 200,000 acres in Santa Rosa, Walton, and Okaloosa Counties, Florida. A variety of natural resources are found throughout this area, including species of special concern such as Black Bears (*Ursus americanus*), Eastern Indigo Snakes (*Drymarchon corais*), Red-cockaded Woodpeckers (*Picoides borealis*), and stands of longleaf pine (*Pinus palustris*). Through cooperative research, EAFB has successfully managed these resources while also completing military missions. Eglin AFB also owns several areas outside the main reservation that provide support for military missions. One such area is located on Cape San Blas in Gulf County, Florida (Fig. 1). To properly manage this area, EAFB contracted the University of Florida to complete a three year characterization of the resources located along Cape San Blas.

Eglin AFB on Cape San Blas consists of approximately 250 acres located about 180 miles east of the main Eglin reservation. This area lies on the St. Joseph peninsula, part of a dynamic barrier island chain that extends across the northern Gulf of Mexico. Due to the natural forces that formed Cape San Blas and those that maintain this area, St. Joseph Peninsula has experienced severe landform change over time (see GIS landform change maps). These changes allow for fluctuations in habitat types along Cape San Blas (see GIS land cover change maps) that influence the floral and faunal species using this area.

The dynamic environment along Cape San Blas includes flatwoods, interdunal swale, rosemary scrub, and beachfront. These habitats support a wide array of species, including several threatened and endangered species such as the loggerhead sea turtle (*Caretta caretta*), Piping Plover (*Charadrius melodus*), Least Tern (*Sterna antillarum*), and Bald Eagle (*Haliaeetus leucocephalus*). Proper management of these species and their habitats require knowledge of their abundance and distribution, and the effects disturbances have on their survival.

In addition to threatened and endangered flora and fauna, Cape San Blas also supports tourists and recreationists. Although Gulf County is sparsely populated, with approximately 13,000 inhabitants throughout 578 square miles, summer tourism and heavy recreational use of beaches for fishing, crabbing, and shelling place continued and increasing pressure on the natural resources of these areas (Rupert 1991). Gulf County is also one of the few remaining counties in Florida that permits vehicular traffic on its beaches, including Cape San Blas. In addition to recreational use of these habitats, EAFB also uses the area for military missions. Air Force property on Cape San Blas is primarily used for radar tracking of flying missions over the Gulf of Mexico, although in recent years it has been used for missile launchings and other various military activities.

To allow continued military and public use of Air Force property while also protecting the unique flora and fauna of the area, EAFB proposed a characterization of the resources found along Cape San Blas. A complete inventory of the physical features of the area included investigating topography, soil chemistry, hydrology, archeology, and the dynamics of landmass and land cover change over time. Various thematic layers within a geographic information system (GIS) were used to spatially portray georeferenced data. Large scale changes over time were assessed using stereo aerial photography. Vegetation transects, soil samples, elevation transects, an archeological survey, freshwater wells, and a tidal monitor were used to investigate the remaining features.

The distribution of selected faunal species, such as shorebirds, seabirds, wading birds, neotropical migrants, sea turtles, and beach mice, were correlated to these physical features and to vegetation. Surveys for shorebirds, seabirds, and wading birds were conducted throughout the year along the cape point, whereas nesting sea turtles were monitored from May through October, point counts for neotropical migrants were conducted during spring and fall migration, and traps for beach mice were set during one week in winter. Historical data was also collected on storm events and fires. Finally, an extensive literature search and synthesis was completed.

Comprehensive investigation of this area allows for understanding of the relationships among factors influencing Cape San Blas. Each aspect of the environment influences the entire system, therefore all aspects must be researched before successful management is possible. A complete investigation of the forces forming and maintaining Cape San Blas, the system providing protection and nourishment to its habitats, the species using those habitats, and the endangered species relying on the habitats for survival was conducted to allow detailed, successful management of this unique and dynamic barrier island.

The sea turtle research along Cape San Blas that was initiated at the beginning of this study is being compiled as a separate final report and is referenced within this text. In addition, informal observations of events or species not originally included in our objectives were recorded and compiled as field notes. Information on these observations are included as appendices at the end of the final report.

Discussion

The features and dynamics of Cape San Blas are determined primarily by the formation and maintenance of this barrier island. Its location near the mouth of a major river and the direction of longshore drift along the coast influence the pattern of coastal change and the habitat types that regulate what resources will flourish along Cape San Blas. The Apalachicola River, approximately 20 miles east of Cape San Blas, has provided most of the sand to this section of the Florida panhandle coast. The quartz sands brought by the Apalachicola River have been reworked and redistributed through longshore drift and wave action (Johnson and Barbour 1990). The coarsest sands are dropped offshore creating shoals, whereas finer sands are carried in the current and dropped along the beaches. Many of the barrier islands along the northern Gulf of Mexico coast, including Cape San Blas, were created during the rise in sea level as these fine sands built over former nearshore deposits (see erosion chapter).

The formation of Cape San Blas in this manner assisted in determining the habitat types, and flora and fauna that now inhabit the region. Due to the great amounts of sand in the soils and the lack of saltwater intrusion into the surficial water table along Cape San Blas (see soil and hydrology chapters), habitat development on this barrier island is limited to those that consist primarily of xeric and mesic, freshwater species. Habitat types such as flatwoods, scrub, and coastal grassland, thrive in sandy, poorly drained soils, therefore they dominate the environment along Cape San Blas (see land cover maps). The habitat types available define the faunal species that inhabit the region by limiting the types of protection and nutrition offered. Threatened and endangered species, such as Least Terns and loggerhead sea turtles (see seabird chapter and sea turtle report), use the beach and dune habitats for nesting, and neotropical migrants and resident bird species are found throughout the flatwoods and scrub.

Forces maintaining this barrier island have controlled the land form change and habitat availability these species rely on for survival. The most obvious force directing the system along Cape San Blas is the consistent pattern of accretion and erosion along the beaches. A historic pattern of accretion along the east beach and severe erosion along the north beach continually alter the land form of this barrier island, as seen in the aerial photographs displayed in GIS format during this project (see land form change maps and erosion chapter). These long-term changes are occasionally exacerbated by tropical storms that cause immediate and often drastic changes to the topography and habitat along Cape San Blas (see storm history chapter). The dynamic alterations affecting this area result primarily from natural forces moving sand along the coast. Evidence from additional studies indicated these forces have influenced this area for over one hundred years and will most likely continue to alter this region, therefore maintaining the dynamic environment found along Cape San Blas (Tanner 1975, Balsillie 1985). Increased human disturbance, however, may intensify these natural forces, thereby increasing erosional rates beyond what is natural for the system. This may result in irreplaceable habitat loss.

The forces maintaining this barrier island also influence the fauna that rely on these habitats for survival. Loss of beach habitat from erosion has most likely contributed to the absence of St. Andrews beach mice along Cape San Blas (see beach mouse chapter). Restoration of dune vegetation along Cape San Blas may provide enough nutrition and protection for beach mice to allow transplantation of mice from St. Joseph State Park to Cape San Blas. This may allow for formation of a new population of St. Andrews beach mice outside of the St. Joseph State Park.

Changes in beach habitat may also influence shorebirds, seabirds, and wading birds that use Cape San Blas beaches (see shorebird, seabird, and wading bird chapter). Although Cape San Blas does not appear to be a primary stopover site for migrating shorebirds, it may be an important secondary site along the periphery of the primary migration route through Texas. Destruction of habitat along primary stopover sites due to natural causes or human disturbances makes peripheral sites essential for successful migration. Cape San Blas also provides nesting habitat for several shorebird and seabirds, such as Wilson's Plovers, Willets, and threatened Least Terns. Wading birds also use the habitat along Cape San Blas beaches. Reddish Egrets, a species that experienced severe declines in numbers due to plume hunters and loss of habitat in south Florida, are often found along Cape San Blas during post-breeding dispersal. Therefore, because a variety of species rely on Cape San Blas beaches, long-term changes in this habitat may result in severe consequences to several populations.

Inland habitats are not as negatively affected by the forces maintaining Cape San Blas as beach habitats. In many systems, pine flatwoods are maintained by fire, however lack of fire history along Cape San Blas indicated this system has most likely been controlled by tropical storms that regularly effect this area. These storms have created habitats that support a variety of neotropical migrants and resident bird species (see neotropical bird chapter). Habitat size and number of predators, however, may limit the number of transient neotropical migrants using Cape San Blas. These findings are supported by those of Hill et al. (1994) along Tyndall and Eglin Air Force Bases, Florida.

Eglin Air Force Base on Cape San Blas is a dynamic system that supports a wide variety of species. This barrier island's formation and present day location allow for maintaining forces that cause continual change and influence habitat types available. These natural, long-term forces have most likely been influencing this island since it's formation, therefore little can be done to prevent their effects along Cape San Blas. Management of this area may be best implemented by attempting to reduce activities that may exacerbate the effects of these natural forces.

Management Recommendations

Vehicular traffic along Cape San Blas beaches is the primary human influence in this area. Beaches along the St. Joseph Peninsula are popular for fishing, crabbing, and shell-collecting, however a large portion of the peninsula is privately owned, thus access to the area is limited. Although the northern end of the peninsula (approximately 10 miles) is owned by St. Joseph State Park, visitors must pay an entrance fee for beach access. A privately owned park (Billy Joe Rish Park) is located approximately three miles south of St. Joseph State Park, however this area is reserved primarily for use by handicapped visitors. The only areas that allow free access to beaches along the St. Joseph Peninsula are one legal beach access point just north of EAFB property, Salinas Park located approximately three miles south of EAFB property at the southern edge of the peninsula, and EAFB.

Historically, the residents of this area have had a strong connection to the Gulf of Mexico. Although the town of Port St. Joe began as a harbor for cotton export, an outbreak of yellow fever in 1840 decimated nearly 75% of the city's population, thus ending the cotton industry (Burnett 1988). When the town was rebuilt it was centered around a paper mill located on the banks of St. Joseph Bay. Logging, fishing, shrimping, and oystering became the primary industries, thus beginning the reliance on St. Joseph Bay and the Gulf of Mexico (Burnett 1988).

The waters off Cape San Blas provide many resources. Fish species, such as shark, flounder (*Paralichthys albigutta*), and red snapper (*Lutjanus campechanus*) are prevalent, along with shrimp (*Panaeus* sp.) and scallops (*Argopecten irradians*; pers. obs.). Two lagoons along the Cape provide striped mullet (*Mugil cephalus*), shrimp, and blue crabs (*Callinectes sapidus*; pers. obs.). Although in the past this area provided income for local fisherman, more recently, use of Cape San Blas for tourism and recreation has dominated. Increased use of Cape San Blas has resulted in more intense impact on the habitat and the species that rely on that habitat for survival.

Because residents of this area have strong connections with the Gulf of Mexico, complete restriction of human activity along Cape San Blas would have a major impact on residents. Therefore, all efforts towards allowing continued human activity while properly managing the natural resources should be attempted before complete closure of the beach is implemented. Educating the local people about the wildlife and habitats along Cape San Blas and the effects of human disturbance to these resources may encourage voluntary cooperation. In addition, allowing residents the chance to decrease human disturbances themselves along Cape San Blas may assist in their understanding of the need for protection of this area. These programs may greatly decrease destruction of habitats along Cape San Blas, however they will most likely not result in a complete end to human disturbances. Enforcement of violations should therefore be strict and consistent. These activities, public education, a probationary period, and strict enforcement, may allow continued human use of Cape San Blas without negative impacts to the natural resources relying on this area.

The greatest human disturbance to Cape San Blas beaches is vehicular traffic. Vehicles driven on the beach within and above the drift line may prevent or slow growth of dunes that inhibit erosion and protect inland habitats during a tropical storm. Dune vegetation assists in growth and maintenance of dunes by trapping sand and reducing the amount of sand available for wind and water transport. Because much of these plant species' life cycles occur underground, avoidance of adult plants may not provide adequate protection for dune vegetation. Therefore, limiting vehicular traffic within and above the drift line may aid in protecting dune-building vegetation, thereby assisting in slowing erosion and preserving this vital habitat.

1. Limit vehicular traffic along the beaches to below the drift line. Complete closure of the beach is not necessary as long as restrictions are followed and enforced. For effective implementation of these management recommendations the following points should be addressed:

- **Public education:** This should include speaking to schools and local clubs, holding public meetings, writing articles for the local papers, creating fliers for dispersal by the chamber of commerce, and placing several interpretive signs around the property.
- **Probationary period:** The public should be made aware that if restrictions are not followed the beach may be closed completely to vehicular traffic or human activity. A specific amount of time may be designated as a probationary period, such as one or two years. The public should be well

aware that if restrictions are not followed during that probationary period, the beach will be closed to vehicular traffic.

- **Enforcement:** Restrictions should be enforced consistently. The county sheriff's deputies may be enlisted to patrol the area, a security guard may be hired, or personnel from nearby areas, such as Tyndall Air Force Base may be utilized. Possibly, a collaboration between Eglin and Vitro could be established to allow Vitro security guards to expand their responsibilities to include patrolling the beach and writing citations when necessary (or submitting license plate numbers to the sheriffs department). They are already on the property and have local knowledge of the area and residents. Eglin may be able to provide additional monetary support for the guard or equipment support, such as a four-wheel drive vehicle or all-terrain vehicle. In addition, a "neighborhood watch" type program may be set up in which local volunteers (such as those that perform sea turtle monitoring on adjacent beaches) patrol and provide enforcement officers with license plate numbers or information about those people disobeying posted restrictions.

Habitats along Cape San Blas that are severely impacted by off-road vehicles (ORV) are salt marshes, sand flats, and mud flats (Godfrey et al. 1980). Along Cape San Blas, shorebirds often feed on exposed salt marsh and sand flats. Godfrey et al. (1980) suggested that of all the ecosystems studied along Cape Cod National Seashore, Massachusetts, salt marsh and sand flats were most severely impacted by ORV's. They also found ORV traffic on open sand and mud flats affected the survival of marine organisms often fed upon by migrating shorebirds, such as worms, clams and other mollusks. Besides direct destruction of organisms, vehicular traffic may also compact the sand, which would interfere with normal exchange of sea water within sediments and create anaerobic conditions in the substrate (Godfrey et al. 1980). Also, compacted sand may prevent clams from extending their siphons to the surface for food and water, resulting in death (Godfrey et al. (1980). Therefore, to protect shorebird habitat, driving should be prohibited in sensitive ecosystems such as salt marshes, sand flats, and mud flats.

Shorebird nesting areas should also be restricted to vehicular traffic during nesting season. Along Cape San Blas, shorebirds nest primarily in the vegetated area between the two lagoons and along the dunes. Both of these habitats are sensitive to disturbance. Godfrey et al. (1980) suggested ORV's have substantial effects on dune vegetation. They found maximum damage to vegetation occurred during the first few passes of a vehicle, therefore even minimal traffic through vegetation may destroy the habitat. In addition, shorebird nests and eggs are highly camouflaged, therefore they are difficult for drivers to locate and avoid. Shorebirds incubating eggs may also be flushed from their nests by vehicles driving nearby. Repeated flushing may prevent proper incubation and protection for eggs, which may result in unsuccessful nesting. Thus, along Cape San Blas, shorebird nesting areas should be marked clearly and restricted to human activity during the nesting season.

2. Restrict activity, including vehicular traffic, on the sand and mud flats along the lagoons on the cape to protect critical shorebird, seabird, and wading bird foraging and nesting habitat (Fig. 2). The following implementation of management recommendations should be conducted:

- **Signs:** Signs should be posted around the closed area indicating the restrictions. In addition, an interpretive sign explaining the need for the closure should be posted near the area. Wiring or rope should be tied among signs so drivers could not travel through signs to gain access to the restricted area.

Several plant species assist in dune building, and they flourish under a variety of conditions. The north beach of Cape San Blas is a low to moderate energy coast that experiences severe erosion. It is consistently overwashed by saltwater, therefore species that are not salt tolerant would not thrive in this area. One salt tolerant species used often to promote dune-building in highly eroding areas is smooth cordgrass (*Spartina alterniflora*). Along the north beach of Cape San Blas, transplanting *Spartina alterniflora* and protecting the new plants with a breakwater may assist in revegetating the coast thereby slowing erosional rates.

A breakwater may also have many negative effects, however. Placing obstacles near the shoreline may interfere with species using the beach, such as nesting sea turtles. A breakwater may impede the turtle's movement to her nesting beach, thereby forcing her to drop her eggs in the water or nest in a less desirable place.

In addition, altering the pattern of sand movement along the north beach of Cape San Blas may impact the entire St. Joseph peninsula and adjacent barrier islands. The pattern of erosion and accretion observed along Cape San Blas is not an isolated incident but is part of a larger barrier island system. Sand removed from the north beach of Cape San Blas is deposited on other areas along the St. Joseph peninsula, particularly along the tip of the peninsula. Ending all erosion along north beach would severely decrease the amount of sand available to the remainder of the peninsula. Altering one portion of this barrier island system may destroy neighboring coasts, thereby indirectly impacting Cape San Blas. Therefore, because this beach experiences severe erosion caused primarily by natural forces, limiting non-natural disturbances (beach driving) and monitoring species using the beach (sea turtles) may allow for protection of this habitat without disturbing natural processes influencing this dynamic barrier island.

3. Limit beach driving to below the drift line and continue monitoring species that use the beach, such as sea turtles. Revegetation efforts are not recommended due to the costs of this effort, its effects on sea turtles and shorebirds, and its influence on the St. Joseph peninsula and neighboring barrier islands. Erosion along Cape San Blas is caused by a system of natural forces that create and maintain barrier islands. Altering these forces in one location may slow erosion in that location, but will adversely influence remaining portions of the St. Joseph peninsula.

Restricting beach driving may also benefit dune inhabiting species, such as beach mice. Beach mice rely on dune vegetation, such as sea oats for nutrition, and they use the dune systems for protection. The dune system along the east beach of Cape San Blas experiences accretion, and has grown considerably since Hurricane Opal affected the area in 1995. A stable population of St. Andrews beach mice inhabits St. Joseph State Park, however few mice are found outside the park. Transplanting mice from the state park to the east beach of Cape San Blas may result in a successful population of St. Andrews beach mice outside of St. Joseph State Park.

4. Relocate St. Andrews beach mice from St. Joseph State Park to the east beach of Cape San Blas to encourage formation of a new population.

In addition to public use of Cape San Blas, military activities also influence habitats in this area. Military activity is typically confined to four compounds on EAFB property: 1. the main site (D3), 2. the Coast Guard Station (CGS), 3. D3-A, and 4. D3-B. Protection of the remaining habitat requires isolation of military activities to already disturbed sites. The main site is situated approximately ½ mile from the coast, and D-3B is located along the coast near the eastern EAFB boundary, therefore these areas are relatively protected from erosion. The Coast Guard Station and site D3-A are, however severely threatened by erosion. Both were established approximately 0.3 miles apart along north beach in an area that eroded approximately 2 meters from June 1994 to September 1995 (see erosion chapter). Damage has occurred to the CGS primarily due to severe storms, however erosion is beginning to influence structures within this area. Future building within these two compounds should occur well inland of the current dune line to protect the dune system and military structures. If possible, construction should be limited to site D-3 or D3-B which are not influenced by erosion. Additional erosion surveys may allow modeling of annual loss of beachfront along the CGS and site D-3A. This may permit prediction of where safe building areas are within these sites and how long they will remain unaffected by erosion.

Long-term military projects that require large numbers of personnel may also negatively impact the water table along Cape San Blas (see hydrology chapter). The number of longterm projects that require many personnel should be limited and water use during these missions should be restricted so as not to lower the natural water table and allow saltwater intrusion.

5. Construction of new military structures should be limited to sites not influenced by erosion, such as sites D-3 or D-3B. If construction is necessary within the Coast Guard Station or site D-3A, structures should be built as far inland of the dune line as possible. Additional erosion surveys may assist in prediction of safe building locations. In addition, longterm projects that require large numbers of personnel should be limited and water use during these missions should be restricted so as not to cause saltwater intrusion into the water table.

Inland habitats along EAFB on Cape San Blas experience less human impact, therefore they require less management. Although the flatwood and scrub habitats are utilized by relatively few transient neotropical migrants, typical management efforts in this area may not be successful. Flatwood and scrub are often maintained by prescribed burning, however along neighboring habitats (Tyndall and Eglin AFB), few transient neotropical migrants were found within burned areas (Hill et al. 1994). Slash pine forests along the Florida panhandle are typically dominated by open-coned trees that indicate some force other than fire, such as tropical storms, may maintain the habitat. Therefore, prescribed fires are not recommended along Cape San Blas.

6. Prescribed burns within the flatwood and scrub are not necessary to maintain the habitat.

Numbers of bald eagles in the mainland United States have experienced severe declines in numbers due to pesticides and human hunting. Because of this decline, the US Fish and Wildlife Service (USFWS) placed the bald eagle on the threatened and endangered species list (Odum and McIvor 1990). Greater than half of the bald eagle's breeding population in the southeastern United States is located in Florida (Wood and Collopy 1995). Currently, primary management emphasis and protection in Florida is focused on active bald eagle nest sites because it has been recognized that disturbance at nest sites can decrease productivity (Wood and Collopy 1995).

A pair of bald eagles has nested along EAFB property on Cape San Blas since 1994 (Wood 1997; see appendix). In 1996, the pair incubated 2 eggs, however it appears that neither egg hatched (Wood 1997). Both eagles returned to Cape San Blas in late summer of 1997 and have been observed nest-building, which indicates these eagles may continue to use this nest for egg incubation (pers. obs.). The USFWS requires a primary protection zone of 750 to 1500 feet (0.14 to 0.28 miles) around any eagle nest used for breeding in Florida. Residential, commercial, or industrial development, tree cutting, logging, and use of chemicals toxic to wildlife are prohibited within this zone (Wood and Collopy 1995).

The bald eagle nest along Cape San Blas is located at approximately the 2.28 mile marker (see Cape San Blas map). The primary protection zone around this nest includes the area between mile marker 2.00 to 2.56. This area encompasses the entire Coast Guard Station and parts of the north beach of Cape San Blas often used by the public for fishing and camping (pers. obs.). Site D3-A, however, utilized primarily for launches during military missions, is not encircled within this protection zone. In addition, an area of intense public use, locally called the "stump hole", is located at mile marker 2.7 to 2.9 therefore it is also outside the protection zone. The bald eagle nest is, however built in a tree located approximately 35 feet above mean high water (pers. obs.). Activity on the beach within the protection zone will, therefore, directly influence the birds using this nest.

Because it appears this nest is supporting an active breeding pair of bald eagles, a protection zone around the nest should be enforced. Throughout the year, activities, such as tree cutting and construction within the primary protection zone (mile marker 2.0 to 2.6) should be restricted following USFWS standards. During bald eagle nesting season, the area should be closed to vehicular traffic, camping, and fishing. The area should be posted with signs indicating the closure and explaining the harm disturbances may cause to an active bald eagle nest. Foot traffic may be allowed through the area, although prolonged visits (remaining within the area to fish, picnic, etc.) should be restricted. In addition, military activities during bald eagle nesting season should be restricted to sites D-3, D3-A, and D-3B.

6. Activities within the primary protection zone should be restricted throughout the year following USFWS recommendations. During bald eagle nesting season (September through April) the primary protection zone should be closed to vehicular traffic, camping, and fishing. The area should be posted with signs indicating the closure and informing the public of the harm caused by disturbing an active bald eagle nest. In addition, military activities during this time should be limited to the main site, site D3-A, and site D-3B.

- **Signs:** Signs indicating restrictions should be placed at the entrance to the primary protection zone. An interpretative sign explaining the basics of bald eagle ecology should also be installed at the entrance to the restricted area. Vitro guards or volunteers may be recruited to maintain the signs because they will most likely be influenced by the changing shoreline. Ropes may be placed through the signs during nesting season when complete closure of the beach is implemented. During the remainder of the year, ropes may be removed but signs should be kept in place.

Although Cape San Blas is a dynamic system that encompasses a variety of habitats and supports several species, primary management requirements are limited to the beachfront. This habitat supports many species, including several threatened and endangered species, and it is severely impacted by natural and human disturbances. Inland habitats are protected from wind and wave erosion by the dune system and are not influenced greatly by human disturbances, therefore they require less management. Continued restriction of public use and monitoring of the habitats along EAFB on Cape San Blas will insure proper management and protection of this unique barrier island.

Literature Cited

Balsillie, J. H. 1985. Long-term shoreline change rates for Gulf County, Florida - a first appraisal. Florida Department of Natural Resources, Division of Beaches and Shores Report no. 85-3.

Burnett, G. M. 1988. Florida's Past, Vol. 2. People and events that shaped the state. Pineapple Press, Sarasota, FL. 234-236.

Godfrey, P. J., S. P. Leatherman, and P. A. Buckley. 1980. ORVs and barrier beach degradation. Parks 5: 2, 5-11.

Hill, G. E., N. R. Holler, J. W. Tucker, Jr. 1994. Habitat use by Neotropical migrants on Eglin and Tyndall Air Force Bases, Florida. Preliminary report to Eglin Air Force Base. 15 December 1994. 39 pp.

Johnson, A. F. and M. F. Barbour. 1990. Dunes and maritime forests *in* Ecosystems of Florida. R. L. Myers and J. J. Ewel, eds. University of Central Florida Press, Orlando, Florida. 765 pp.

Rupert, F. R. 1991. Geology of Gulf County, Florida. Florida Geological Survey Bulletin No. 63, Tallahassee, Florida. 51 pp.

Tanner, W. F. 1975. Historical beach changes: Florida's "Big "bend" coast. Transactions of the Gulf Coast Associations Geological Society 25: 379-381.

Wood, D.A. 1997. Northwest Florida Bald Eagle Survey. Florida Game and Freshwater Fish Commission, Division of Wildlife, Tallahassee, Florida. 27 pp.

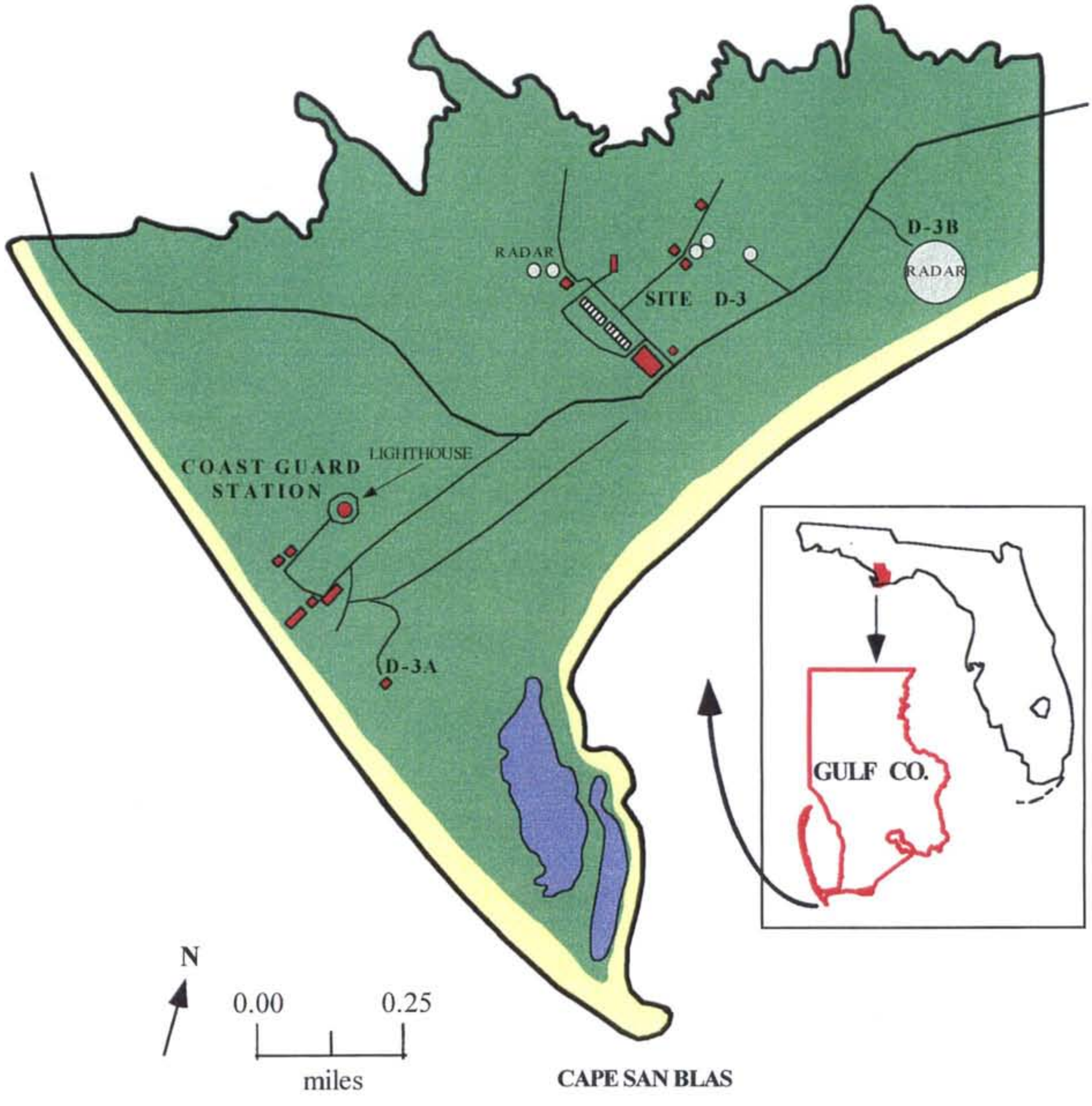
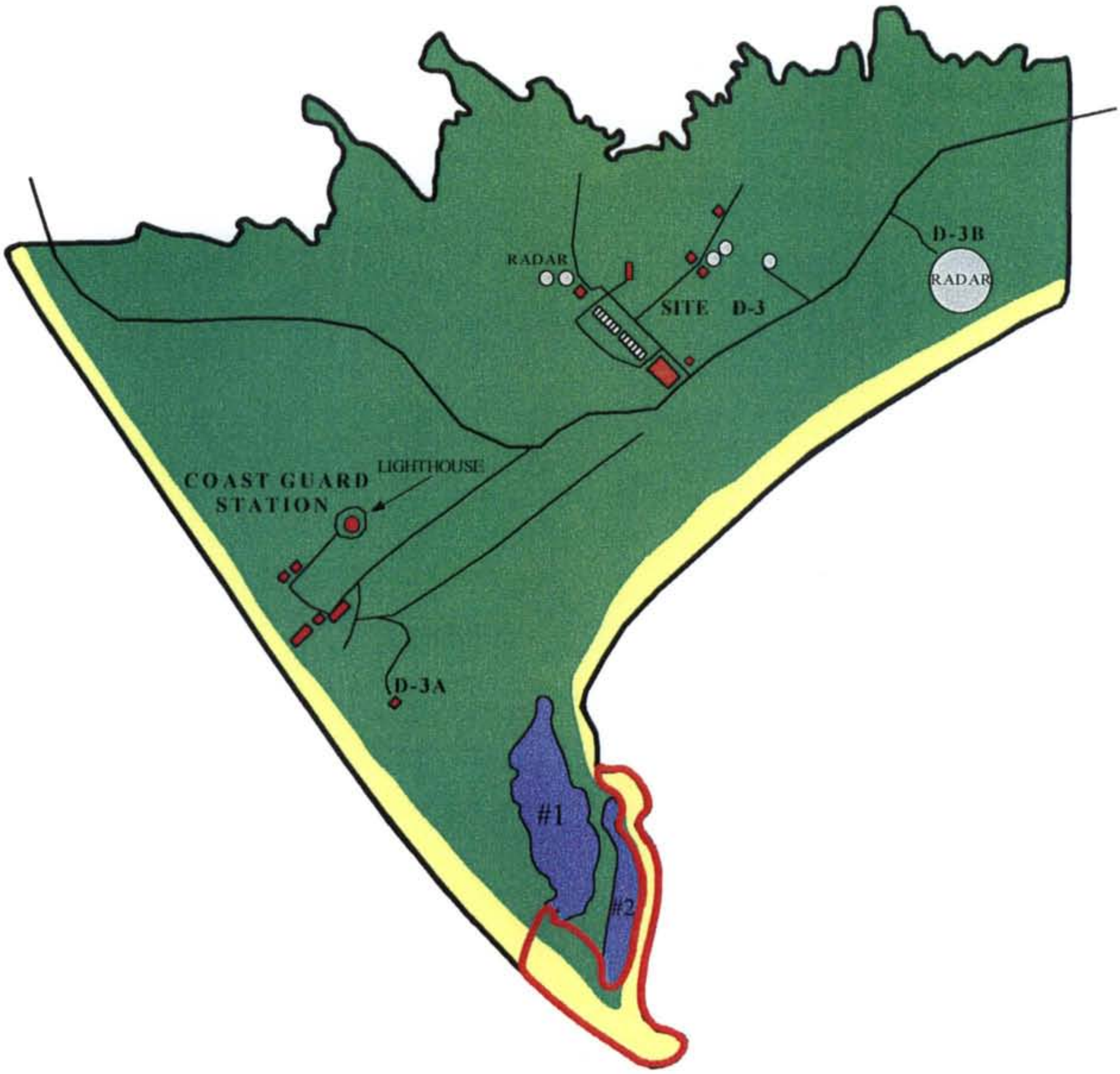


Figure 1. Eglin Air Force Base on Cape San Blas, Florida where the Cape San Blas Ecological Study was conducted from 1994 to 1996.

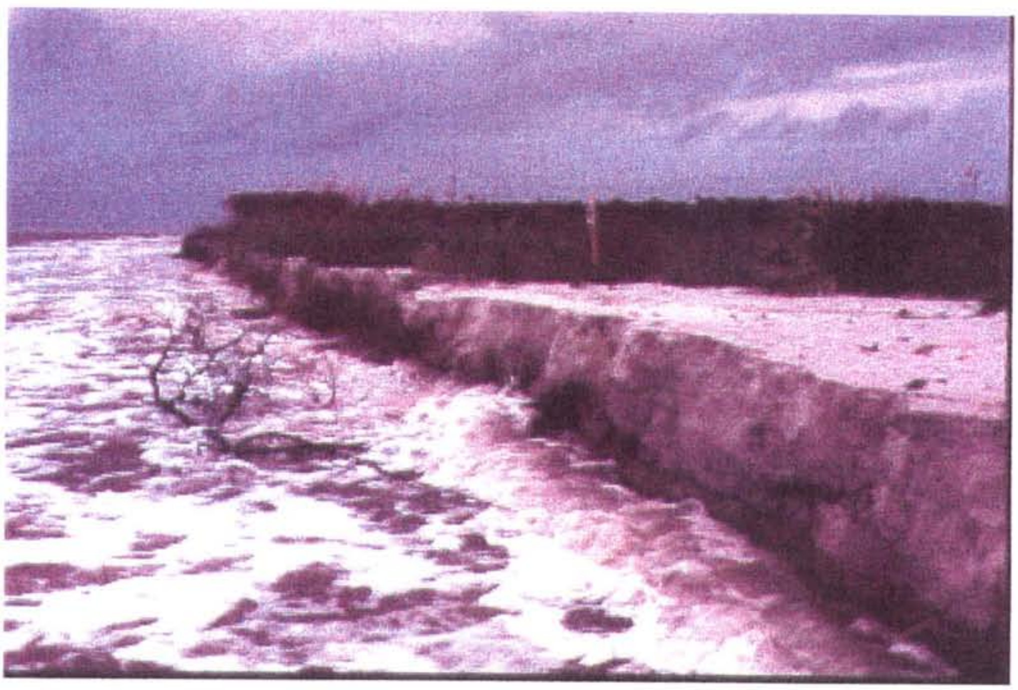


CAPE SAN BLAS

Figure 2. Eglin Air Force Base on Cape San Blas, Florida where the Cape San Blas Ecological Study was conducted from 1994 to 1996. Surveys for shorebirds, sea birds, and wading birds were conducted within the area encircled in red along the edges of lagoons #1 and #2.

CHAPTER 1

EROSION



Introduction

Formation and maintenance of barrier islands require abundant sand supplies. Since present sea level has stabilized in the past 4,000 to 5,000 years, there has been very little new sand added to barrier islands along the northern Gulf of Mexico. The result is that portions of these barrier islands are being eroded by several forces, which severely impact coastal habitats and human development along barrier islands. These forces include winds, tides, and waves (Hayes 1979, Campbell 1984).

Winds influence barrier islands primarily by building dunes. Offshore winds move sand along the coast or into the water, therefore dune formation occurs mainly when winds are blowing onshore. Because the Florida panhandle coast faces south, it receives light southerly onshore winds in summer and is protected from the stronger northwest offshore winds of winter. The fine quartz sands of the Florida panhandle can be moved by lighter winds than coarser shell sands of the Florida peninsula, thus dunes along the Florida panhandle are often larger than those along the peninsula (Johnson and Barbour 1990). Larger dunes help protect the coast from extreme high tides, waves, or tidal surge, especially during tropical storms. This may help prevent erosion.

Another force influencing barrier islands is tides. Barrier islands do not occur on coasts with tidal ranges greater than four meters (m), and are best developed along coasts with tidal ranges less than two meters (Hayes 1979). Coasts with small tidal ranges are usually greatly influenced by wave energy, whereas coasts with large tidal ranges are dominated by tidal currents and tidal-level fluctuations (Hayes 1979). Typically, coasts with greater tidal ranges are better protected against storm surges than those with low tidal ranges, except when a storm strikes at high tide (Hayes 1979, Johnson and Barbour 1990). Although the Gulf coast of Florida has had a lower frequency of hurricane strikes than the Atlantic coast, the Gulf coast is more dynamic and unstable because it experiences smaller tidal ranges and has a lower wave energy regime (Johnson and Barbour 1990). Because barrier islands experience small tidal ranges and are dominated by wave-action, they are often highly eroded during storms.

Waves are constantly eroding barrier islands, either through continuous processes, such as longshore drift, or through single events, such as winter storms or hurricanes (Johnson and Barbour 1990). Along the barrier islands of the northern Gulf of Mexico, longshore drift causes long-term changes in the barrier island, such as sand deposition in lagoons, offshore, or as spits at the ends of barrier islands (Campbell 1984). Immediate changes occur, however, during storms, including opening and closing of inlets, overwash of narrow parts of barriers, and formation of new barriers from submarine shoals (Johnson and Barbour 1990).

Wind, tide, and wave induced erosion alters coastal habitats in Florida. Erosion along Jupiter Island has removed approximately 500 m of sand since 1950 and has exposed mangrove roots along much of the coastline (Johnson and Barbour 1990). Fourteen years after Hurricane Donna separated Peterson Island from mainland Florida, the new island had only 50% cover of many plant species, including sea oats (*Uniola paniculata*), beach elder (*Iva imbricata*), and beach berry (*Scaevola plumieri*; Johnson and Barbour 1990). Much of the vegetative cover along Perdido Key and Santa Rosa Island was destroyed in 1979 during Hurricane Frederick, and Hurricanes Elena and Kate destroyed much of the foredunes from St. Joseph State Park to Dog Island in 1985 (Doyle et al. 1984, Clark 1986).

Human development along barrier island coasts has also been affected by erosion. Erosion has destroyed six lighthouses on Cape San Blas between 1838 and 1918, and along the St. John's River mouth in Jacksonville, the outer set of beachfront lots has been lost to erosion (Pilkey et al. 1984, Lehr 1975). Resort areas, such as St. George and Captiva Islands have also been affected by erosion. The center of St. George Island has eroded approximately 1.6 km from 1855 to 1935, and Captiva Island has receded about 0.3 km landward from the late 1800s to the mid-1900's (Johnson and Barbour 1990).

Erosion influences most barrier islands, although those along the Florida panhandle experience especially large rates of erosion. Perdido Key grew westward 6.4 km in 108 years, and Santa Rosa Island grew westward 0.8 km in the 67 years before 1935 (Price 1975, Doyle et al. 1984). One of the greatest erosional rates in Florida occurs along Cape San Blas, located along the southern end of St. Joseph Peninsula. Tanner (1975) found the tip of St. Joseph Peninsula experienced accretion between 1875 and 1970, whereas along the peninsula south to Cape San Blas, erosional rates increased. The western shore of Cape San Blas has continually experienced one of the largest erosional rates, retreating landward at 11 m/yr (Tanner 1975).

The purpose of this study was to assess beach erosion along Eglin Air Force property on Cape San Blas to document vertical shoreline change and assist with management of the area.

Methods

Surveys were conducted from June 1994 to September 1995 along selected transects across the beach and dunes to document vertical shoreline change (Table 1-1). Transects were located along four Florida Department of Natural Resources (DNR) benchmarks installed on Cape San Blas (Fig. 1-1), and were placed at constant compass readings from the benchmark. Surveys were repeated approximately once a month using a laser beacon (Southern Laser Inc.) and standard topographic techniques. Elevations were taken every 20 feet or every 5 m, as far as possible into the Gulf of Mexico. Where possible, elevations were also recorded landward of the transect, as far as habitat permitted. Elevations were recorded to the nearest one-hundredth of a meter. Elevations recorded in the field were corrected to height above mean sea level at each benchmark, and then graphed to present profiles.

Because the cape point was so severely eroded, benchmarks were continually lost, making long-term measurements difficult. Only two transects were completed along the cape point, one on June 16, 1994 and another on July 7, 1994. One each sampling date a transect was conducted at an 18 degree compass bearing (west) and a 90 degree compass bearing (east).

Results

All areas surveyed along Cape San Blas experienced accretion and erosion throughout the study period, except for the cape point which underwent continual erosion (Fig. 1-2).

Cape Point

From June 16 to July 7, 1994, along the northern facing transect (18 degrees) the cape point lost approximately 23 m of beach (Fig. 1-2a and b). Along the eastern facing transect (90 degrees) the cape point lost about five meters.

During this time, the north beach lost about one meter and the east beach gained approximately four meters. From June to August, 1994, the CGS beach lost nearly two meters.

North Beach

Throughout the entire study period (June 1994 to September 1995) the net movement of sand along north beach was a loss of approximately 10 m (Fig. 1-2c). The greatest amount of erosion (12 m) occurred from October 1994 to June 1995. The greatest amount of accretion was recorded from August to October 1994, when the beach gained approximately 6 m. From June 1994 to August 1994, the north beach remained nearly stable. During the same time span in 1995 (June to September 1995), the north beach lost about four meters.

1994

From June to July 1994 the north beach gained approximately one meter. A meter was then lost from July to August 1994. From August to October 1994, the greatest amount of accretion along north beach occurred totaling 6 m. Therefore, the net movement of sand along north beach from June to October 1994 was a gain of approximately 6 m.

1995

From October 1994 to August 1995, however, the north beach experienced erosion. Approximately 12 m were lost from October 1994 to June 1995. This pattern continued with three meters lost in one month, from June 1995 to July 1995. In the following month, from July to August 1995, about two meters were lost. The north beach experienced accretion again from August to September 1995, gaining slightly less than one meter of beach. The net movement of sand along north beach from October 1994 to August 1995 was a loss of 16 m.

Coast Guard Station

The beach along the north side of the cape, in front of the Coast Guard Station (CGS) also experienced accretion and erosion throughout the study period (June 16, 1994 to September 23, 1995). The net movement of sand along this transect was a loss of approximately two meters (Fig. 1-2d). The greatest amount of erosion occurred from July to August 1995 when about 8 m were lost. The greatest amount of accretion (9 m) was recorded in the month (August to September 1995) following the greatest amount of erosion.

1994

From June to August 1994, the CGS beach lost approximately two meters of beach. This erosion continued from August to October 1994, when the beach eroded about one meter. Therefore, net movement of sand along the CGS beach in 1994 was a loss of approximately three meters.

1995

From October 1994 to September 1995, erosion and accretion occurred along the CGS beach. The beach grew about one meter from October 1994 to June 1995, however the beach lost about one meter from June to July 7, 1995. In two weeks (July 7 to July 13), the CGS beach lost approximately four meters, and this pattern of erosion continued from July 13 to August 1995 when an additional four meters were lost. From August to September, however, the CGS beach experienced accretion, gaining about 9 m. Thus, the net movement of sand along the CGS station beach in 1995 was a gain of about one meter.

East Beach

Throughout much of the study period the east beach experienced accretion. The total movement of sand along east beach throughout the entire study period (June 16, 1994 to September 23, 1995) was an increase of approximately 6 m (Fig. 1-2e). The greatest amount of accretion occurred from June 14, 1995 to August 13, 1995, when the east beach gained approximately 12 m. Erosion was greatest from July to August 1994 and August to September 1995 when four meters of beach were lost during each time period. From June 16, 1994 to August 31, 1994 the east beach gained and then lost about one meter, therefore remaining nearly stable. During the same time period in 1995 (June 14 to August 13) the east beach gained about 12 m.

1994

Throughout four surveys from June to October 1994, the east beach experienced accretion and erosion. About four meters of beach were gained during the first three weeks of sampling (June to July). Throughout the last 16 weeks, however, the east beach experienced erosion. From July to August, approximately four meters of beach were lost and from August to October the beach eroded about three meters. Therefore, the net movement of sand along east beach from June to October 1994 was a loss of approximately three meters.

1995

Erosion and accretion occurred on east beach again in 1995 during the four sampling periods. From October 1994 to June 1995, the east beach experienced accretion, gaining about five meters. This pattern of accretion continued through 1995 with about four meters gained between June 14 and July 14. The east beach accreted about 9 m from July to August, however from August to September, the east beach eroded approximately four meters. In 1995, the net movement of sand along east beach was a gain of about 9 m.

Discussion

Physical properties

Results of this study are typical of barrier island dynamics. Where and how barrier islands formed and how they are maintained are determined by several factors including submarine geology, tides, ocean currents, and winds (Swift 1975, Otvos 1980). The submarine geology off the Florida panhandle influences barrier island formation and maintenance by determining the ocean currents and wind patterns of the northern Gulf of Mexico. The geology of the northern gulf is determined by the geomorphology of the Atlantic Ocean. A submarine plain of low relief, the Atlantic Plain, extends along the eastern coast of North America and contains several provinces. One province, called the Atlantic Coastal Plain, is a low, hilly to nearly flat, terraced plain on soft sediments, of which the submerged portion is the Gulf of Mexico Continental Shelf (Fig. 1-3). Relief of the continental shelf, which extends from the southern tip of Florida to the point of the Yucatan Peninsula, Mexico, is low due to smoothing effects of sedimentation and because of planation by waves and bottom currents. The area of the continental shelf on which Cape San Blas lies borders the entire west coast of Florida and is called the West Florida Shelf. This shelf is divided into two sections: 1) a large, smooth inner shelf, and 2) a small, more terraced but more gently sloping outer shelf (Bergantino 1971).

The low relief and gentle slopes of much of the sea floor in the Gulf of Mexico result in the current pattern, and low wave and tidal action that characterize the gulf. Because the continental shelf is generally smooth and flat, most of the Gulf of Mexico is shallow, covered by water of less than 180 m. This causes sea surface circulation throughout the gulf to be mostly wind driven (Jones et al. 1973). Winds influencing major currents within the Gulf also originate in the North Atlantic Ocean (Fig. 1-4). The Atlantic trade winds drive the Caribbean Current westward until it eventually enters the Gulf of Mexico through the Yucatan Channel. Once this current enters the gulf, seasonal winds control its flow, thus creating the dominating current in the Gulf of Mexico, the Loop Current (Fig. 1-5; Jones et al. 1973).

The Loop Current flows clockwise throughout the gulf and eventually exits through the Florida Straits. Although the Loop Current predominantly flows east along the northern Gulf of Mexico, along the Florida panhandle net transport of water is in a westward direction (Bruno 1971, Jones et al. 1973). This reversal of current is due mainly to seasonal winds and tidal currents. Seasonal variations in wind direction often cause a reversal of current direction, resulting in an westward flow typical in spring and fall (Bruno 1971). Reduction of winds in summer and early winter allow the Loop Current to dominate, therefore nearshore flow is often easterly during these times of year (Bruno 1971, Jones et al. 1973). This flow of nearshore water, westward in spring and fall and eastward in summer and early winter, is called longshore drift, and is greatly influential in formation and maintenance of barrier islands.

There are three major theories of barrier island formation: 1) coastwise spit progradation, 2) mainland-beach detachment, and 3) upward growth of offshore bars (Swift 1975). Because of the low relief of the coast and the shallow, sandy sea floor of the

Gulf of Mexico, it is apparent that barrier islands along the Florida panhandle most likely formed through offshore bar aggradation during the Holocene, approximately 5,000 years ago (Otvos 1980, Campbell 1984). Throughout the Holocene and until recently, sea levels have been rising. Along the Florida panhandle, sea level has risen approximately one foot every 125 years (Provost 1973/74). This rising sea provided sediments to newly forming barrier islands by eroding exposed shelves along the sea floor. After sea levels began to stabilize, the shelf that had been providing much of the sediment to new islands along the northern Gulf of Mexico was too deeply submerged to be eroded, therefore the sand supply was reduced and addition to barrier islands slowed or stopped (Wilkinson 1975).

Yearly Comparisons

Although all beaches surveyed throughout this project experienced accretion and erosion, net movement of sand differed among beaches (Fig. 1-6). The cape point recorded the greatest erosional rate. North beach recorded the second greatest, with the CGS experiencing the smallest rate of erosion. East beach differed from all other transects, recording a net gain throughout the study. Although only one mile apart, the north beach and CGS beach experienced erosion and accretion at different times throughout the year. The north beach gained sand from June to July 1994, August to October 1994 and August to September 1995. The CGS beach recorded a long period of accretion from October to June 1995 and then a month of gain from August to September 1995. Both beaches gained in late summer 1995, however net movement throughout the winter and spring 1994/1995 differed between beaches resulting in a loss for north beach and gain for CGS beach. Possibly, local ocean currents or wind patterns differed during this time resulting in the local variation in sand movement along the beach.

In 1994, the net sand movement along north beach was a gain of beach, whereas along east beach the net movement of sand during 1994 was a loss of sand. These results are opposite the historical movement of sand along these beaches. This trend reversed in 1995, when the north beach experienced severe erosion and the east beach accreted. The amount gained by north beach in 1994 was less than that lost in 1995, therefore the net movement was erosion. The same pattern was found along east beach, although in the opposite movement of sand. Possibly, severe erosion and accretion along these beaches in 1995 were the result of a severe storm season in 1995. These storms may have exacerbated already existing oceanographic conditions, thereby increasing the natural erosional or depositional forces influencing these beaches.

The general pattern of net movement, erosion along the north and accretion on the east, are historical and consistent patterns on Cape San Blas. Seasonal and yearly trends, however, were not evident during our study. This may be due to our short survey period which did not allow for duplication of seasons among years, therefore limiting yearly comparisons. Surveys ended in September 1995 because benchmarks were destroyed on October 4, 1995 when Hurricane Opal struck the Florida panhandle. Benchmarks have yet to be replaced by the DNR, therefore further surveys could not be completed. Upon replacement of benchmarks, additional, more detailed erosion surveys should be conducted that would allow comparison of beach dynamics among years.

Cape Point to North Beach

With the stabilization of sea level, forces that once worked to build barrier islands now work to erode them. Because of the submarine topography and the direction and magnitude of currents and winds off Cape San Blas, the pattern of erosion and accretion we found during this study were expected. This was also supported by findings of Stapor (1971), Tanner (1975), and Balsillie (1985; Fig. 1-7). From June 1994 to September 1995, erosion along Cape San Blas was evident on the northern shore, with the greatest erosional rates recorded on the cape point. Surveys conducted by the Florida DNR from 1973 to 1983 also indicated erosion along the north beach of Cape San Blas (Balsillie 1985). Along DNR monument 107 on north beach, Balsillie (1985) reported a loss of 3.38 m from September 13, 1973 to December 3, 1983. Along the same benchmark throughout this study (June 1994 - October 1995) we recorded a loss of approximately four meters. This indicates the net rate of erosion along north beach is fairly consistent at about three to four m/yr.

The erosional rate along DNR benchmark 110 (in front of the Coast Guard Station), located about 0.5 miles south of benchmark 107, was not as consistent however. From September 1973 to December 1983, Balsillie (1985) reported a loss of approximately five meters per year, and from 1875 to 1942, Tanner (1975) recorded erosional rates of nearly 11 m per year. Throughout our study, however, we recorded a loss of only about two meters. Our study period (one year) was much shorter than Balsillie's (1985), therefore the difference may be attributed to natural variation in the system. We may have surveyed in a year with less storm activity or human disturbance, and with different wind or ocean current patterns. Erosional rates may also be decreasing along this section of beach on Cape San Blas, possibly due to change in sea level, current direction or sand supply. Although the amount of beach loss differed throughout the three studies, all results indicated erosion along this benchmark, which indicates erosion is the consistent pattern of change along this beach.

Although erosion was expected along north beach, the amount of erosion that was documented is greater than most areas throughout Florida. In the past few decades the average erosional rate throughout most of Florida has been 0.3 - 0.6 m/yr., whereas we documented as great as 16 m/yr along north beach (Johnson and Barbour 1990). There are several reasons why the north beach of Cape San Blas has experienced such severe erosion, including current and wave direction, shape of the coast, vegetation, and human disturbance.

The cape spit is a sand shoal that has built above sea level. Sediments from the Apalachicola River are carried west by ocean currents away from the river delta, and while finer particles remain in the currents along the coast, heavier sediments are dropped offshore. These heavier sediments shoaled and eventually formed the Cape San Blas spit (Johnson and Barbour 1990). Much of the time, the spit is only inches above sea level, and it's length and shape are constantly being altered by tides, storm surges, ocean currents, and winds. It also has no supportive structures, such as dunes or vegetation, which makes it more susceptible to erosion. Therefore, it is expected this shoal would experience great amounts of erosion. The currents and winds that allow accretion along east beach and erosion on north beach also contribute to the extreme erosion along the cape spit.

Beach physiography may also contribute to erosion along the north beach. Erosion is often greatest along updrift ends of barrier islands and capes (Johnson and Barbour 1990). North of Cape San Blas, longshore drift is primarily westward which means the north beach of Cape San Blas is along the updrift side of the cape and may be more susceptible to erosion (Stapor 1971, Johnson and Barbour 1990). May and Tanner (1973) described the dynamics of a coastline influenced by longshore drift and wave refraction. When waves approach normal to a coast, wave refraction will cause greater wave energy on the headland beaches with a corresponding reduction on the bay beaches (Fig. 1-8). The sand transport rate would be greatest between the point of maximum wave energy and the point of maximum breaker angle. If this occurred over a long period of time, a curved shoreline would result with a small spit protruding at the point where the change in longshore drift discharge over time equaled zero. Daily variations in direction of wave approach and locations of zero drift discharge, however, often preclude anomalies such as spits from forming, and the results are typically smooth straight shorelines where net erosion and accretion are equal along the entire coast (Swift 1975).

The above scenario is only relevant, however to straight coasts that experience normal wave approach. On a coast with a large degree of embayment and where waves strike the beach obliquely, a pattern of erosion and accretion may occur similar to the one found along Cape San Blas (Fig 1-8b; Swift 1975). On a straight coast with normal wave approach, wave energy is linear, but on coast with a large embayment and an angled wave approach, wave energy becomes more of a step function. The point of maximum deposition will occur at the step in the wave energy where drift deposition continues but wave energy greatly decreases. This may result in shoaling, which would allow for a curved spit to form (Fig. 1-8c; Swift 1975). This is similar to the pattern of wave energy, deposition, and wave approach found on the point of Cape San Blas. Possibly, on the north beach of Cape San Blas erosion occurs because wave energy is greater than longshore drift deposition, whereas accretion occurs on the east side of the spit because wave energy decreases and deposition becomes greater than erosion.

The habitat along north beach may also contribute to erosion. In this area the beach is relatively narrow and is bordered by flatwoods. During storms and periods of severe high tides, trees are often up-rooted. Root systems of vegetation, including trees, help anchor sand, therefore up-rooting of trees may loosen sand, freeing it to be carried away by erosional processes (Lorang and Stanford 1993). Lack of dune-building vegetation along the north beach may also contribute to erosion. Vegetation, such as sea oats (*Uniola paniculata*) and smooth cordgrass (*Spartina alterniflora*) help anchor sand as it is blown on onshore, thus allowing for dune formation (Johnson and Barbour 1990). Sea oats and cordgrass typically grow on the foredunes and along upper salt marshes (Johnson and Barbour 1990). Although these species are adapted to sea spray and salt water intrusion, the water table beneath the dune system is most often fresh, and it has been suggested that persistent saltwater around the roots of these species may injure the plants (Seneca 1972). Because the north beach of Cape San Blas is narrow, the entire beach is consistently washed over by high tides. Possibly, this amount of salt water intrusion limits the propagation of dune-building vegetation, such as sea oats and cordgrass.

Continual wash by tides may also preclude growth of sea oats through constant removal of sand. Sea oat growth and tillering is stimulated by sand burial (Wagner 1964). Possibly, because persistent tidal washover along north beach constantly removes any recently added sand, sea oats are not able to root. Therefore, vegetation is not present to trap sand brought onto the beach, which allows tidal washover to carry sand back to the gulf.

Human impact may also increase erosion along north beach. Sea oat seedlings are most likely established in drift lines just seaward of the primary dune (FSU thesis). The debris that gathers along these drift lines is essential to encourage germination and survival of seedlings (thesis). The shearing and compressional effects of vehicle passage over a drift line extends to a depth of approximately 20 cm. The shear stresses of the turning wheels disaggregate the drift and break underground plant stems (Godfrey et al. 1980). Vehicular traffic also crushes and kills seeds and young plants. As few as 10 passes of a vehicle over a drift line is sufficient to break up the drift and kill vegetation (Godfrey et al. 1980). Many dune species, such as sea oats, colonize by seeds that wash onshore and settle in the drift line. Once settled on the beach, seeds propagate through spreading of rhizomes. After rhizome growth in early fall, buds develop off the nodes of the rhizome where they remain dormant just below the sand surface until the following spring. At that time they emerge and develop into tillers which form a new plant (Anders and Leatherman 1987). Plants will not colonize and propagate if seeds, rhizomes, and tillers are destroyed, and these life-stages most often occur underground making them extremely difficult to avoid. Vehicular traffic is permitted along the north beach of Cape San Blas. Because the beach is narrow, vehicles travel near the foredunes on the beach and often drive over or through the drift line (pers. observ.). Possibly, dune-building vegetation, such as sea oats, are not able to germinate because seeds and young plants are being destroyed by vehicular traffic.

Vehicles may inhibit growth by direct destruction of plants or plant life-stages, or may inhibit growth by changes in appropriate habitat for plants. It has been reported that sea oat seedlings propagate best when surrounded by vegetative fragments, seaweed and debris that has washed up and settled in the drift line, and the seedlings tend to flourish where sand is drifting and accumulating (Plant book). Possibly, vehicular traffic through the drift line disaggregates the debris that naturally builds in this area and loosens sand that piles along the drift line. This disaggregation of the drift line may make the habitat less suitable for sea oat propagation.

In addition, vehicles may contribute to erosion by increasing surface roughness of the beach. Increased surface roughness creates greater surface area, making more sand available for transport and erosion (Godfrey et al. 1980). With an offshore wind, this sand may be blown to sea and lost to longshore drift (Godfrey et al. 1980).

Sand eroded from the north beach along the westward side of Cape San Blas is most likely redeposited at the end of St. Joseph peninsula. Deposition of sand along St. Joseph peninsula has also been recorded by Tanner (1975) and Balsillie (1985). Tanner (1975) documented accretion along the spit of St. Joseph peninsula at a rate of 8.84 m/yr from 1875 to 1970, and Balsillie (1985) indicated accretion along the spit at rates as great as 10.26 m/yr along some benchmarks. These data indicate a continual process of sand removal from the north beach of Cape San Blas and redeposition on the spit of St. Joseph peninsula. This is most likely due to wave action and longshore drift. When waves strike the shore obliquely, particles picked up in suspension on the beach are carried at an angle along the shore, therefore there is a net transport of material along the beach in the direction of the current. As previously stated, the direction of the nearshore current (longshore drift) off the Florida panhandle coast is most often in a westward direction, which would carry sand from Cape San Blas to the St. Joseph peninsula.

East Beach

On the east side of Cape San Blas, the same forces that erode north beach add to the east beach. This pattern of accretion along the east side of Cape San Blas has also been previously recorded. Between 1973 and 1983, Balsillie (1985) documented accretion along the east beach. He reported rates of accretion were greatest within the bight just east of the Cape and decreased further east, which is congruent with Swift's (1975) pattern of accretion and erosion (see Fig. 1-8). Within the bight, approximately 0.5 miles east of the cape, Balsillie (1985) recorded accretion rates of 19.69 m/yr, whereas just outside of the bight about 2 miles from the cape, rates of accretion were 2.34 m/yr. Near Indian Pass, approximately 8 miles east of Cape San Blas, accretion decreased to 0.18 m/year. Balsillie (1985) surveyed along DNR benchmarks 120 and 122, whereas our surveys occurred along DNR benchmark 121. Accretion decreased between benchmark 120 and 121 during Balsillie's study, from 16.60 to 11.93 m/yr. Along benchmark 121 throughout our study, rates of accretion were less than Balsillie's (1985), at approximately 6 m/yr. These differences may be attributed to natural variation due to our short sampling period, or to diversity among the benchmarks. Although the amount of accretion differed, both studies reported growth of the beach which indicates accretion is a consistent force along east beach.

Although current and wave direction, shape of the coast, vegetation, and human disturbance contributed to erosion along north beach, these factors may not cause erosion along east beach and may even promote accretion. Longshore drift, which contributes to erosion of the north beach, works to promote accretion along the east beach. Erosion that typically occurs along updrift ends of barrier islands and capes is often accompanied by accretion parallel to the coast or at the downdrift ends (Johnson and Barbour 1990). This pattern of accretion was also described by Swift (1975; see Fig 1-8). At the point where wave energy becomes less than longshore drift deposition, accretion may occur on a coast with a large embayment and waves that strike the shoreline obliquely, such as the east beach of Cape San Blas.

Other factors that contribute to erosion on north beach may cause much less erosion along east beach and may even promote accretion, such as vegetation and human impact. The east beach is wider than north beach and is bordered by coastal interdunal swale rather than flatwoods and scrub as is north beach. Therefore during storms, high tides, and winds, trees do not uproot and displace sand as is found along north beach. Instead, east beach is inhabited by dune-building vegetation such as sea oats and cordgrass. Because east beach is wider than north beach, it is not regularly washed over by high tides, therefore vegetation may not be subjected to as much salt water intrusion as is north beach. This reduction in tidal overwash may also reduce removal of sand by tidal backwash and allow sand build-up. This may help stimulate sea oat growth and promote sand entrapment by vegetation that would aid in dune building.

Off-road vehicles are also present along east beach, but because this beach is wider than north beach, most vehicles are able to drive below the drift line thus reducing the impact to dune-building vegetation. Godfrey et al. (1980) reported that areas seaward of the drift line are subject to the greatest natural variation, therefore they are less likely to be permanently damaged by human disturbance. They also suggested this area may recover from disturbance quicker than other habitats. Vehicles driving on east beach may also contribute to erosion by creating greater surface area therefore making more sand available for wind-blown transport, however this amount of erosion may not be enough to counteract the amount of sand brought onshore by longshore drift. Therefore, along the east beach of Cape San Blas erosion may be limited because off-road vehicles are able to drive below the drift line which may allow dune-building vegetation to grow, thus promoting accretion.

Re-vegetation

It may be possible to not only help prevent destruction of dune-building plants, but to encourage growth of these species. Along high energy coasts, smooth cordgrass is often used to encourage sand accumulation (Allen and Webb 1983, Webb and Dodd 1983, and Webb et al. 1984). Cordgrass can be grown from seeds or transplants , although keeping seeds in place until they germinate is often a problem when seeds are sown in an intertidal zone because they are often washed away by high tides (Webb and Dodd 1983, Webb et al. 1984). Seeds often germinate more successfully, however, when sown in areas protected by adult plants. Therefore, seeds appear to be the best option for propagation in areas where tidal ranges are low and plants are already present. Along the north beach of Cape San Blas, because erosion rates are great and vegetation is sparse, seeds may not propagate and grow as successfully as transplants.

Along the north beach of Cape San Blas, transplanting *Spartina alterniflora* adult plants may be more successful than germinating seeds. Transplants are more tolerant of waves and currents than seeds and young seedlings (Webb et al. 1984). On Galveston Bay, Texas transplants survived best when moved during winter than spring, most likely because seasonally low tides occurred in winter (Webb et al. 1984). In 1995, lowest tides along Cape San Blas were recorded in winter and spring. Therefore, transplanting adult cordgrass along the north beach of Cape San Blas during winter may allow for successful growth of dune-building vegetation.

Erosion rates were so great along north beach that transplants may be lost before protective dunes are able to build. In similar cases, breakwaters have been used to protect transplants and allow sand to accumulate within the new vegetation (Webb and Dodd 1983). Along Galveston Bay, Texas, most transplants below mean high water had been washed out or died within three months of transplant. In areas of Mobile Bay, Alabama that had no breakwater, only four percent of transplants survived. In plots protected by a breakwater, however, survival of transplants was 24.3%. Various types of breakwaters have been used, including tires, wooden posts, metal planks, and polyurethane modules (Allen and Webb 1983). Although a breakwater may greatly increase survival of vegetation, they may also be costly and may interfere with other aspects of the environment such as nesting shorebirds or sea turtles. Although shorebirds do not often nest along the north beach of Cape San Blas, loggerhead sea turtles nest along the beach during summer. If cordgrass plants were transplanted during winter, breakwaters may be useful in protecting plants during winter and spring. In summer and early fall, however, breakwaters may interfere with sea turtle nesting and hatching. In addition, because erosional rates are so great along the north beach of Cape San Blas, transplants may not survive even with protection from a breakwater.

Management Recommendations

Natural Erosion

Cape San Blas beaches, especially the cape point and north beach, have historically experienced some of the greatest erosional rates in Florida, and data collected during this study supported those findings. There are several factors that may be contributing to this great rate of erosion along Cape San Blas, including natural forces and human disturbance. The St. Joseph peninsula is a barrier island formed by sand accumulation during rising sea level. Where and how the sand accumulated was determined in part by ocean currents and wind patterns. The forces that created the barrier islands are now working to erode them, and little can be done to prevent this form of erosion. Data indicated this erosion has been occurring since the mid-1800's at rates similar to those recorded during this study, which indicates human disturbance has not caused this erosion (Tanner 1975).

Neighboring barrier islands, such as Dog Island and St. George Island, are also dynamic systems that have experienced alternating periods of erosion and deposition (Fig. 1-9). Dog Island has experienced human habitation and use for only the past 40 years, therefore historical erosion on this island cannot be attributed to human disturbance (Anderson and Alexander 1985). The original lighthouse on Dog Island, in use during the 19th century, is now submerged approximately 125 m offshore in the Gulf of Mexico (Anderson and Alexander 1985). Presently, two littoral cells are eroding the central gulf shore of Dog Island, with one cell moving 70,000 m^3/yr of sediments southwesterly and the other cell moving 12,000 m^3/yr of sediments northeasterly (Anderson and Alexander

1985). St. George Island has experienced similar changes as Dog Island, with the central portion of St. George Island eroding and the ends accreting. From 1855 to 1935, a 1.6 km long spit has developed along the east end of the island as a result of this deposition (Johnson and Barbour 1994). St. George Island State Park is located on the eastern end of St. George Island and has been included in the Apalachicola Bay River and Estuarine Sanctuary, therefore vehicular traffic is not permitted on St. George Island beaches (Campbell 1984). This indicates the erosion that has been occurring on St. George Island is primarily, if not entirely, attributed to natural forces and not human disturbance.

1. Most likely, much of the erosion that occurs along Cape San Blas is similar to erosion that occurs along Dog Island and St. George Island, and is due primarily to natural forces, such as sea level changes, longshore drift, and wind, and not due to human disturbance.

Beach Driving

Human disturbance has been shown to decrease dune-building vegetation and increase the amount of sand available for wind and water borne erosion, however, which may increase erosional rates beyond what is natural for the system (Godfrey et al. 1980). Along a broad beach, such as east beach of Cape San Blas, vehicular traffic may have less of an impact than on narrow beaches, such as north beach, because drivers are able to travel below the drift zone. Disturbance to the vegetation and its habitat may not be the primary cause of erosion along Cape San Blas, but may be exacerbating the natural erosional forces influencing these beaches. To prevent this contributing factor, vehicles driving on the beach should not be allowed to travel within or above the drift line. Signs should be posted at the entrance of beach access roads and along the beach informing drivers of the closure. Informative signs explaining the importance of dune vegetation and the significance of protecting the drift line may encourage adherence to the posted signs. Specific sections of the beach may require temporary closure during periods of extreme high tides or if some other obstacle forces drivers to travel through vegetation. This is most applicable to the narrowest portions of north beach and the beach between the Coast Guard Station and the cape point. In addition, public education, such as articles in local newspapers, talks to local schools and clubs, or interviews by local television stations may encourage public awareness and assist in voluntary adherence to restrictions. Enforcement of these restrictions is imperative to success of these recommendations. If beach driving restrictions cannot be enforced, all beach users will be penalized, even those adhering to the limitations. Success of restrictions or closures is dependent on adherence by beach users and enforcement by beach owners.

2. Limit vehicular traffic to below the drift line along the beach. An intensive effort at public education, such as signs along the beach, articles in newspapers, and talks to local schools and groups is suggested. The year following this effort should serve as a probationary period. If restrictions are followed during that year, beach driving may continue within limits. If adherence does not occur, re-evaluation of the situation at that time may require complete closure of the beach to vehicular traffic.

Re-vegetation

Limiting vehicular traffic may slow erosion and encourage growth of dune-building vegetation. To encourage quicker colonization and growth, transplanting vegetation, such as smooth cordgrass may be effective, although severe erosional rates caused primarily by natural forces may limit revegetation efforts along north beach. Because the north beach experiences such great erosion rates, transplanting adult plants rather than sowing *Spartina* seeds may allow for greatest success rates. Once cordgrass becomes established, additional vegetation such as sea oats, may colonize and propagate which may increase potential for sand accumulation.

Cordgrass transplants may be most successful if protected from wave and tidal action by a breakwater. At least two lines of tires threaded on a cable attached to poles driven into the substrate has worked as a successful breakwater along Galveston Bay, Texas (Webb and Dodd 1983). Unfortunately, this system may also interfere with species using the nearshore waters and the beach, such as sea turtles. A breakwater may be used during winter and spring to increase survival rates of transplanted *Spartina*. It may be removed during summer and early fall to prevent interference with sea turtles and hatchlings.

Because this beach is presently unsuitable for successful turtle nesting, leaving a breakwater in place until beach habitat has improved may allow for more immediate restoration and increased hatching success of sea turtle nests in future nesting seasons. Severe erosional rates that occur along this beach are most likely the result of natural forces, however, and may make attempts at restoration futile. Possibly, continued monitoring of this beach, including sea turtle nest relocation, will allow for successful sea turtle nesting in addition to natural beach dynamics.

If transplanting were attempted, cordgrass transplants may be most successful if planted during appropriate locations and times of year. Smooth cordgrass grows best during periods of low tides, in areas of lower salinity (approximately 15-30 ppt), and at or above mean high water (Webb and Dodd 1989). Along the Texas coast, Webb and Dodd (1989) found survival rates for transplants were greatest when planted in summer however resulting stands were thicker when planted in winter. In 1995, Cape San Blas experienced the lowest tides in winter and spring. Therefore, along the north beach of Cape San Blas transplanting smooth cordgrass in winter may be ideal to produce vegetation that could assist in sand accumulation and dune formation. Possibly, planting again in summer would assist in growth of thicker stands of cordgrass than a winter planting. Although success rate of a summer planting may be low, survival of these plants may contribute greatly to slowing the rate of erosion along north beach.

3. Because this beach experiences severe natural erosion, revegetation efforts may be futile. Continued monitoring of this beach, including sea turtle nest relocation, may provide better protection for species using this area than expensive revegetation efforts. Further research into transplanting adult *Spartina alterniflora* plants to assist in revegetating the north beach, in addition to investigating the use of a

breakwater to protect transplants from wave action may allow for better assessment of this problem.

Further research

Continued documentation of erosion and accretion along Cape San Blas beaches may assist in determining the best form and timing of management. Additional surveys may help establish a seasonal pattern of erosion and accretion along Cape San Blas. Although east beach experienced net accretion throughout our surveys, the beach gained and lost sand within that period. This also occurred along north beach. If erosion is consistently greatest during one season or month, beach driving may be prohibited only during that time period. More detailed surveys may allow better prediction of when erosion and accretion occur throughout the year, making it easier to encourage accretion and prevent erosion. Surveys would also allow determination of the success of management, such as limiting beach driving or transplanting dune building vegetation.

4. Conduct long-term and more detailed surveys of beach dynamics along Cape San Blas to assist in determining seasonal or yearly erosional and accretional patterns.

Natural variation in winds and ocean currents may result in an unpredictable but consistent pattern of erosion and accretion, which would make preventing erosion by targeting specific seasons or years or attempting revegetation difficult. Slowing of erosional rates and protecting beach habitat along Cape San Blas may be best accomplished through further research and continual efforts, including limiting beach driving, posting signs, and monitoring species that use the beach such as shorebirds and nesting sea turtles.

Literature Cited

Allen, H. H. and J. W. Webb. 1983. Erosion control with saltmarsh vegetation. Proceedings of the Third Sympsium on Coastal and Ocean Management ASCE/San Diego, California, June 1-4, 1983.

Anders, F. J. and S. P. Leatherman. 1987. Effects of off-road vehicles on coastal foredunes at Fire Island, New York, USA. Environmental Management 11(1): 45-52.

Anderson, L. C. and L. L. Alexander. 1985. The vegetation of Dog Island, Florida. Biological Sciences 48(4):232-243.

Balsillie, J. H. 1985. Long-term shoreline change rates for Gulf County, Florida - a first appraisal. Florida Department of Natural Resources, Division of Beaches and Shores Report no. 85-3.

Bergantino, Robert N. 1971. Submarine regional geomorphology of the Gulf of Mexico. Geological Society of America Bulletin 82: 741-752.

Bruno, R. O. 1971. Longshore current system Panama City to Pensacola, Florida. Master's thesis, Florida State University, Tallahasse, Florida. 169 pp.

Campbell, K. M. 1984. A geologic guide to the state parks of the Florida panhandle coast. Florida Geological Survey Leaflet #13.

Clark, R. 1986. Hurricane Kate, November 15-23, 1985. Florida Department of Natural Resources, Beaches and Shores Post-Storm Report No. 86-1.

Doyle, L. J., D. C. Sharma, A. C. Hine, O. H. Pilkey Jr., W. J. Neal, O. H. Pilkey Sr., D. Marin, and D. F. Bleknap. 1984. Living with the West Florida shore. Duke University Press, Durham, North Carolina.

Godfrey, P. J., S. P. Leatherman, and P. A. Buckley. 1980. ORVs and barrier beach degradation. Parks 5: 2, 5-11.

Hayes, M. O. 1979. Barrier island morphology as a function of tidal and wave regime. *in* Barrier Islands from the Gulf of St. Lawrence to the Gulf of Mexico, S. P. Leatherman. Academic Press, New York, New York.

Johnson, A. F. and M. F. Barbour. 1990. Dunes and Maritime Forests *in* Ecosystems of Florida. R. L. Myers and J. J. Ewel, eds. University of Central Florida Press, Orlando, Florida. 765 pp.

Jones, J. I., R. E. Ring, M. O. Rinkel, and R. E. Smith. 1973. Physical oceanography of the Northeast Gulf of Mexico and Florida Continental Shelf Area, *in* A Summary of Knowledge of the Eastern Gulf of Mexico. Coordinated by The State University System of Florida Institute of Oceanography. J. I. Jones, R. E. Ring, M. O. Rinkel, and R. E. Smith, eds. 74 pp.

Lehr, D. E. 1975. Basic Plan. Subject: US Coast Guard Loran Station at Cape San Blas, Florida. Armament Division. Eglin Air Force Base, Florida. Eglin Air Force Base, Niceville, FL. pp 1-13.

Lorang, M. S. and J. A. Stanford. 1993. Variability of shoreline erosion and accretion within a beach compartment of Flathead Lake, Montana. Limnology and Oceanography 38(8): 1783-1795.

May, J. P. and W. F. Tanner. 1973. The littoral power gradient and shoreline changes. *in* eds. D. R. Coates, Publications in Geomorphology, State University of New York, Binghamton, New York. 404 pp.

Otvos, E. G. 1981. Barrier island formation through nearshore aggradation - stratigraphic and field evidence. Marine Geology 43: 195-243.

Pilkey, O. H., Jr., D. C. Sharma, H. R. Wanless, L. J. Doyle, O. H. Pilkey, Sr., W. J. Neal, and B. L. Gruver. 1984. Living with the East Florida Shore. Duke University Press, Durham, North Carolina.

Price, D. J. 1975. The apparent growth of Gulf Beach, extreme western Florida. Transaction of the Gulf Coast Associations of the Geological Society 25: 369-371.

Provost, M. W. 1973/74. Mean high water mark and use of tidelands in Florida. Earth and Space Sciences 36(1): 50-65.

Seneca, E. D. 1972. Seedling response to salinity in four coastal dune grasses from the outer banks of North Carolina. Ecology 50: 465-471.

Stapor, F. W. 1971. Sediment budgets on a compartmented low-to-moderate energy coast in northwest Florida. Marine Geology 10: M1-M7.

Swift, D. J. P. 1975. Barrier-island genesis: evidence from the central Atlantic Shelf, Eastern U.S.A. Sedimentary Geology 14: 1-43.

Tanner, W. F. 1975. Historical beach changes: Florida's "Big "bend" coast. Transactions of the Gulf Coast Associations Geological Society 25: 379-381.

Wagner, R. H. 1964. The ecology of *Uniola paniculata* L. in the dune-strand habitat of North Carolina. Ecological Monograph 34: 79-96.

Webb, J. W. and J. D. Dodd. 1983. Wave-protected versus unprotected transplantings on a Texas bay shoreline. Journal of Soil and Water Conservation 38(4): 363-366.

Webb, J. W. and J. D. Dodd. 1989. *Spartina alterniflora* response to fertilizer, planting dates, and elevation in Galveston Bay, Texas. Wetlands 9(1): 61-72.

Webb, J. W., J. D. Dodd, B. H. Koerth, and A. T. Weichert. 1984. Seedling establishment of *Spartina alterniflora* and *Spartina patens* on dredged material in Texas. Gulf Research Reports 7(4): 325-329.

Wilkinson, B. H. 1975. Matagorda Island, Texas: The evolution of a Gulf coast barrier complex. Geological Society of America Bulletin 86: 959-967.

Table 1-1. Dates when beach erosion transects were conducted off four DNR monuments along Eglin Air Force Base on Cape San Blas, Florida.

	NORTH	CGS	CAPE	EAST
	JUNE 6	JUNE 6	JUNE 6	JUNE 6
1994	JULY 7	JULY 7	JULY 7	JULY 7
	AUGUST 30	AUGUST 30		AUGUST 31
	OCTOBER 13	OCTOBER 13		OCTOBER 12
	JUNE 14	JUNE 15	JUNE 14	JUNE 14
1995	JULY 14	JULY 13	JULY 13	JULY 13
	AUGUST 13	AUGUST 13	AUGUST 13	AUGUST 13
	SEPTEMBER 23	SEPTEMBER 23	SEPTEMBER 23	SEPTEMBER 23

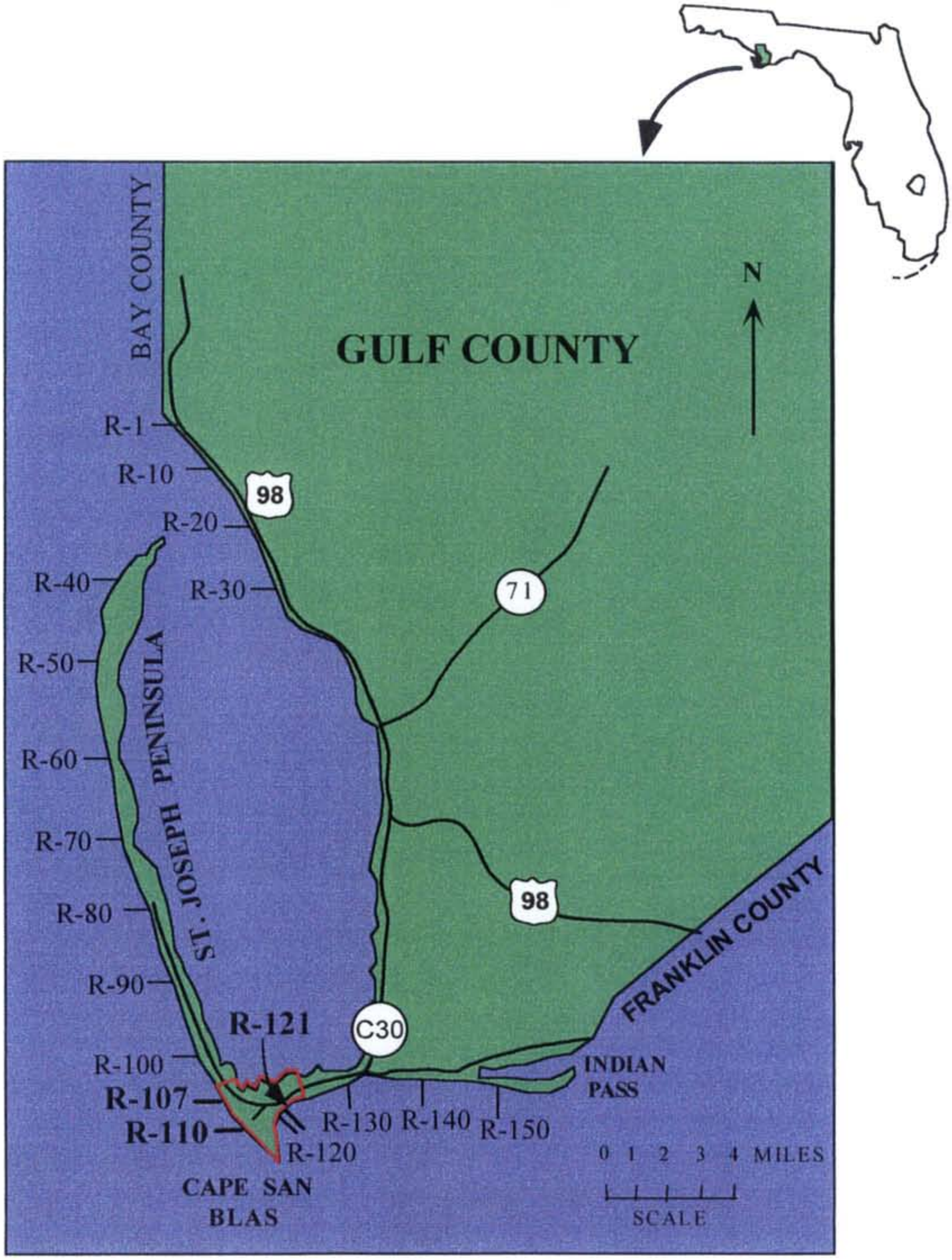


Figure 1-1. St. Joseph Peninsula along the Florida panhandle, with locations of Department of Natural Resources benchmarks. Highlighted benchmarks are those used to measure erosion along Eglin Air Force Base property on Cape San Blas (outlined in red) from June 1994 to September 1995.

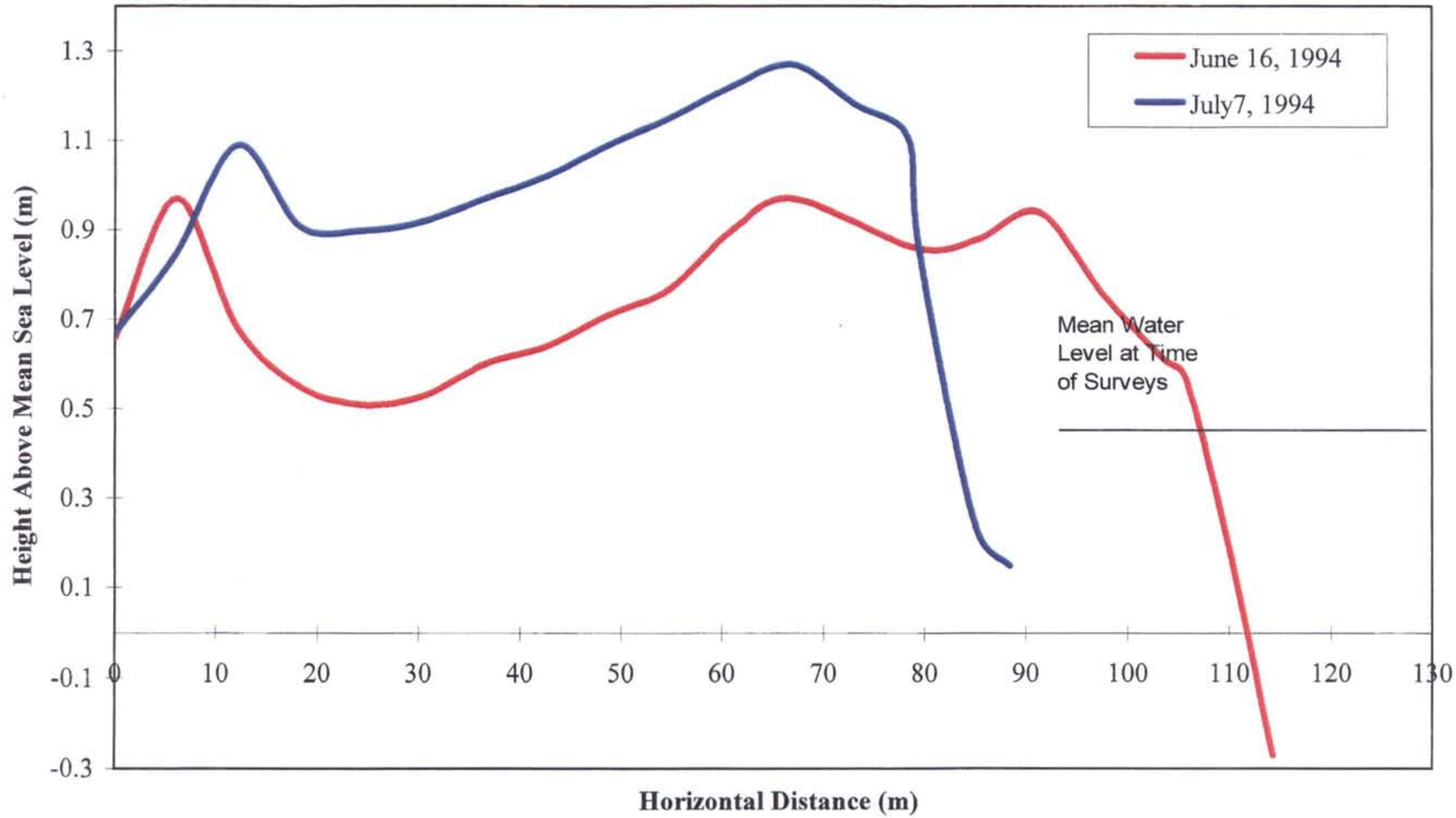


Figure 1-2a. Beach profile of the cape spit along Eglin Air Force Base on Cape San Blas, Florida indicating severe erosion from June 16, 1994 to July 7, 1994. Transects were conducted along DNR monument 115 at a 112° compass heading.

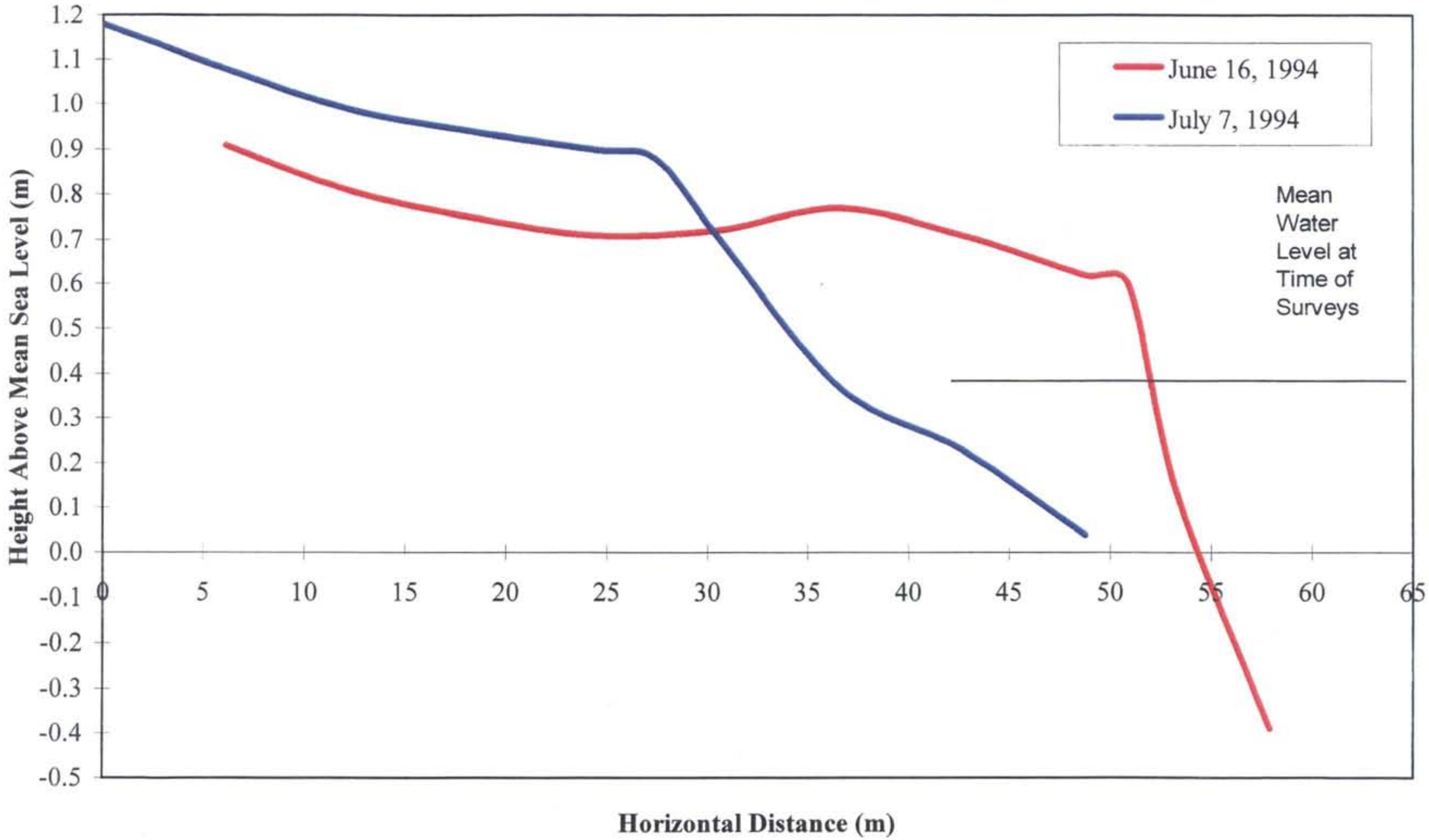


Figure 2b. Beach profile of the cape spit along Eglin Air Force Base on Cape San Blas, Florida indicating severe erosion from June 16 to July 7, 1994. Transects were conducted along DNR monument 115 at a 220° compass heading.

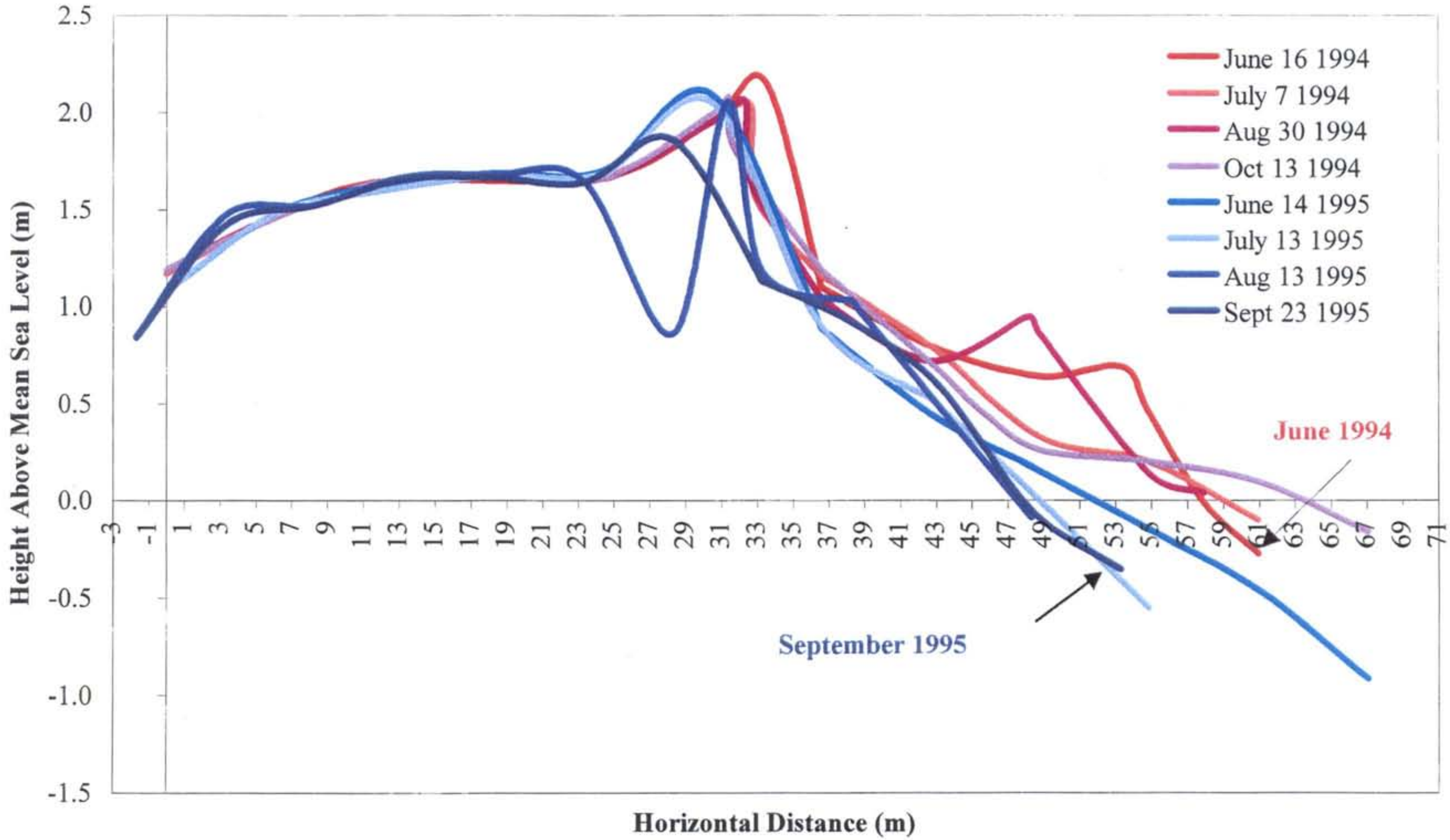


Figure 2c. Beach profile of the north beach along Eglin Air Force Base on Cape San Blas, Florida indicating severe erosion from June 16, 1994 to September 23, 1995. Transects were conducted along DNR monument 107 at a 40° and 220° compass heading. The red/purple lines represent 1994 data and the blue lines represent 1995 data.

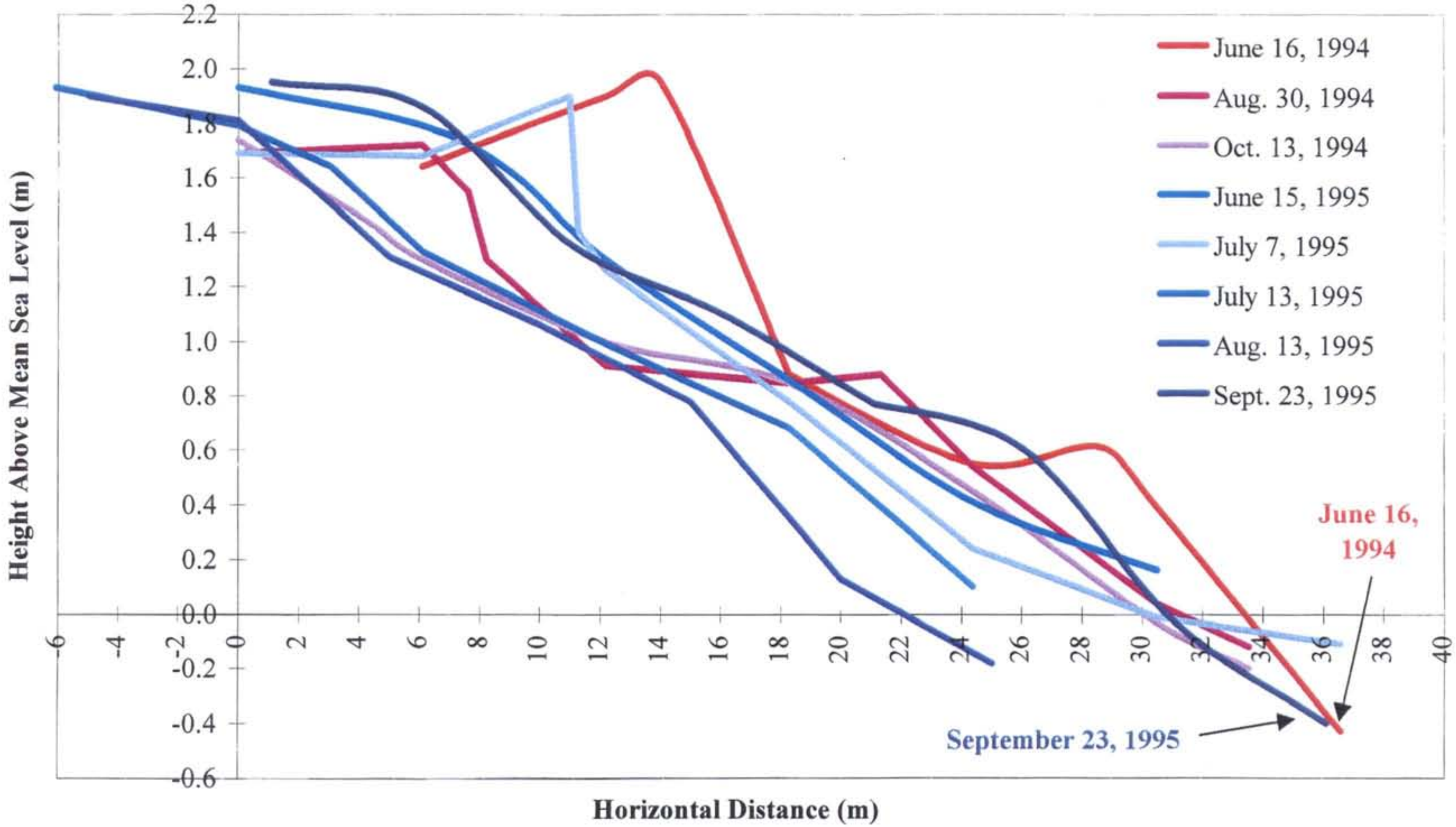


Figure 2d. Beach profile of the Coast Guard Station beach along Eglin Air Force Base on Cape San Blas, Florida indicating erosion occurred between June 16, 1994 and September 23, 1995. Transects were conducted along DNR monument 110 at a 234° and 54° compass heading. The red/purple lines represent 1994 data and the blue lines represent 1995 data.

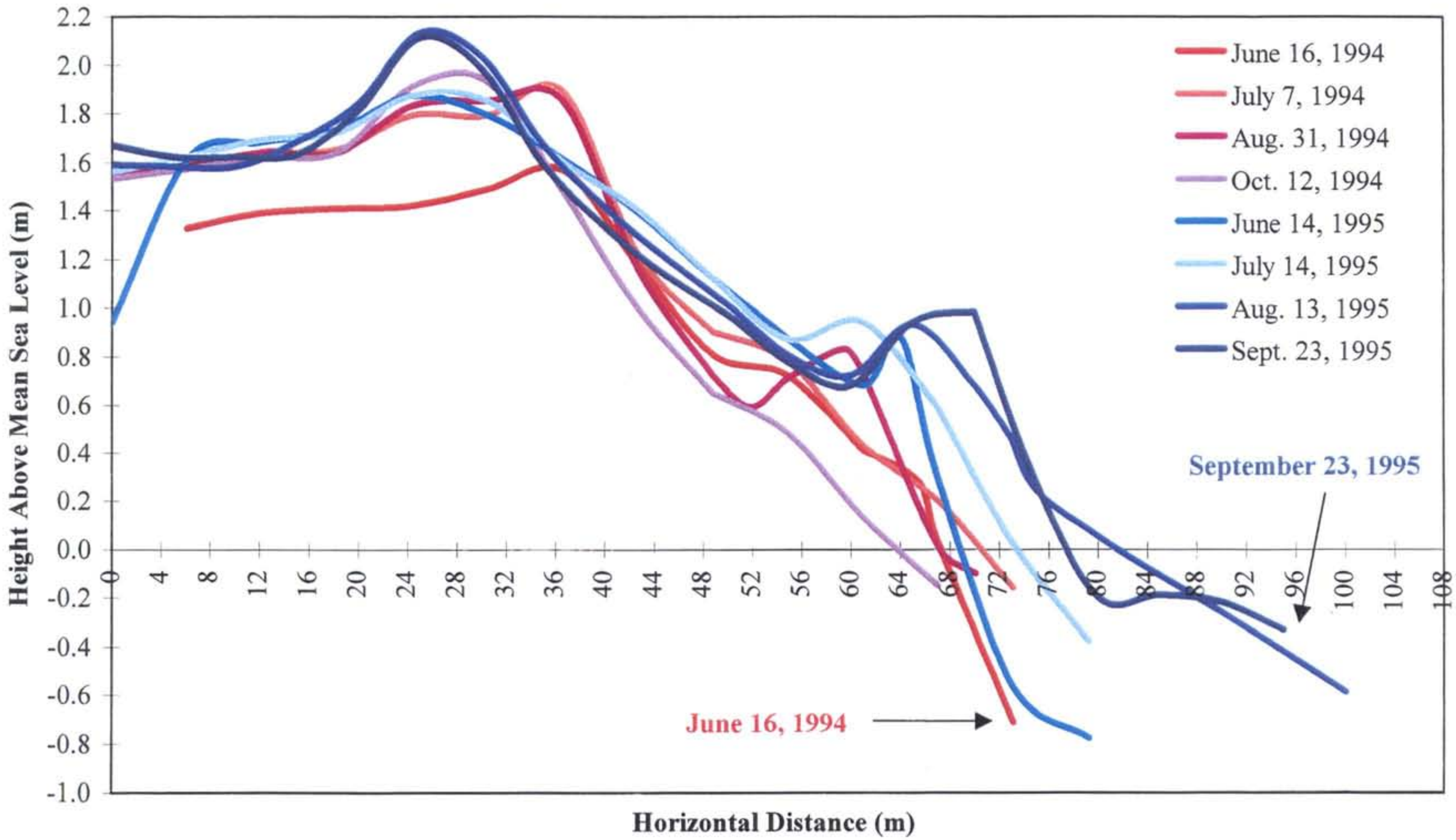


Figure 2e. Beach profile of the east beach along Eglin Air Force Base on Cape San Blas, Florida indicating accretion from June 16, 1994 to September 23, 1995. Transects were conducted along DNR monument 121 at a 143° compass heading. The red/purple lines represent 1994 data and blue lines represent 1995 data.

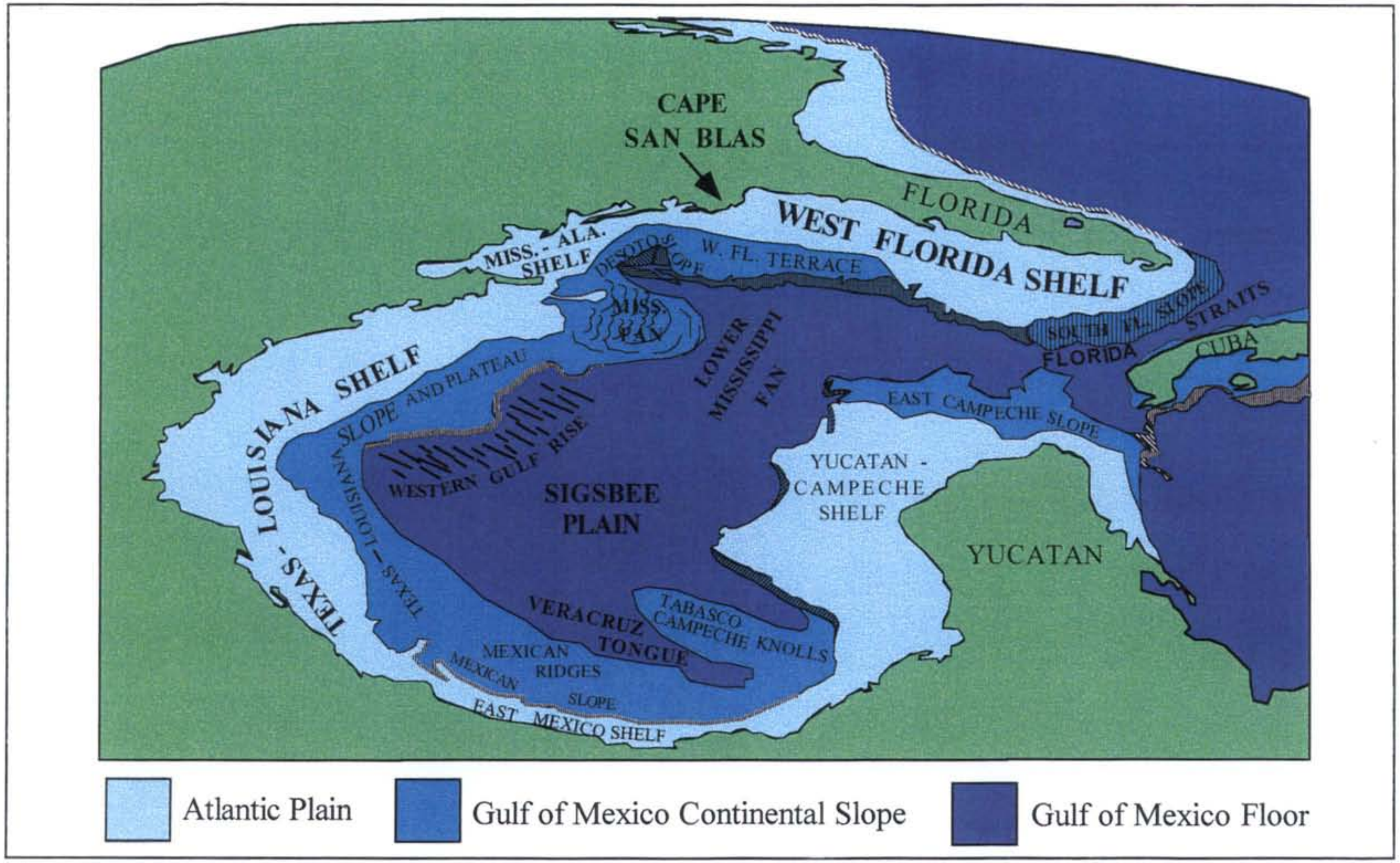


Figure 1-3. Submarine physiography of the Gulf of Mexico showing the shallow continental shelves that effect current and wind patterns along the Florida panhandle. These conditions contribute to the pattern of accretion and erosion influencing barrier islands along the northern Gulf of Mexico, including Cap San Blas where the Cape San Blas Ecological Study was conducted from 1994 to 1996 (from Bergantino 1971).

a.

b.

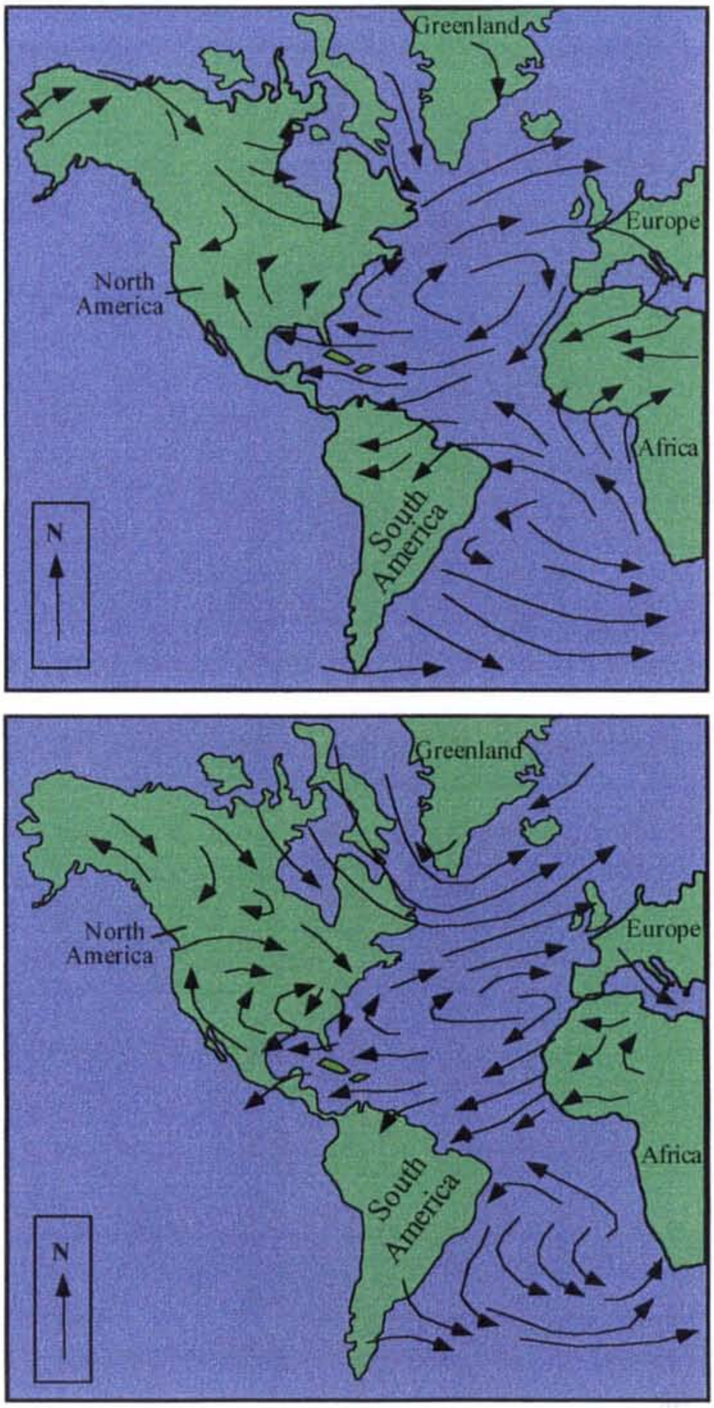
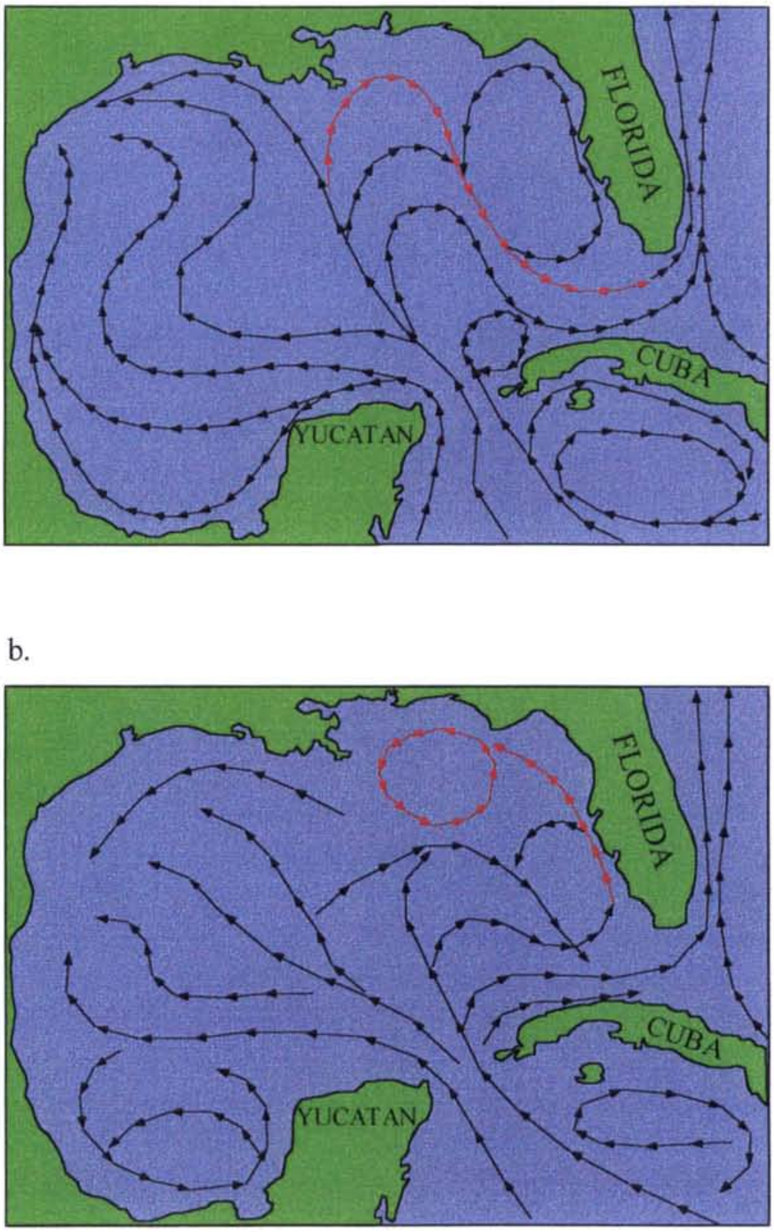


Figure 1-4. Prevailing winds at the Earth's surface over the Atlantic Ocean in June (a) and January (b). These wind patterns influence oceanographic conditions in the Gulf of Mexico that contribute to erosion and accretion along barrier islands in the northern Gulf.

a.



b.

Figure 1-5. Surface currents in the Gulf of Mexico in June (a) and December (b; from Jones et al. 1973). The primary current within Gulf, termed the Loop Current (highlighted in part as red), is influential in controlling acceretion and erosion on barrier islands in the northern Gulf. It predominantly flows westward in spring and fall and eastward in summer and early winter.

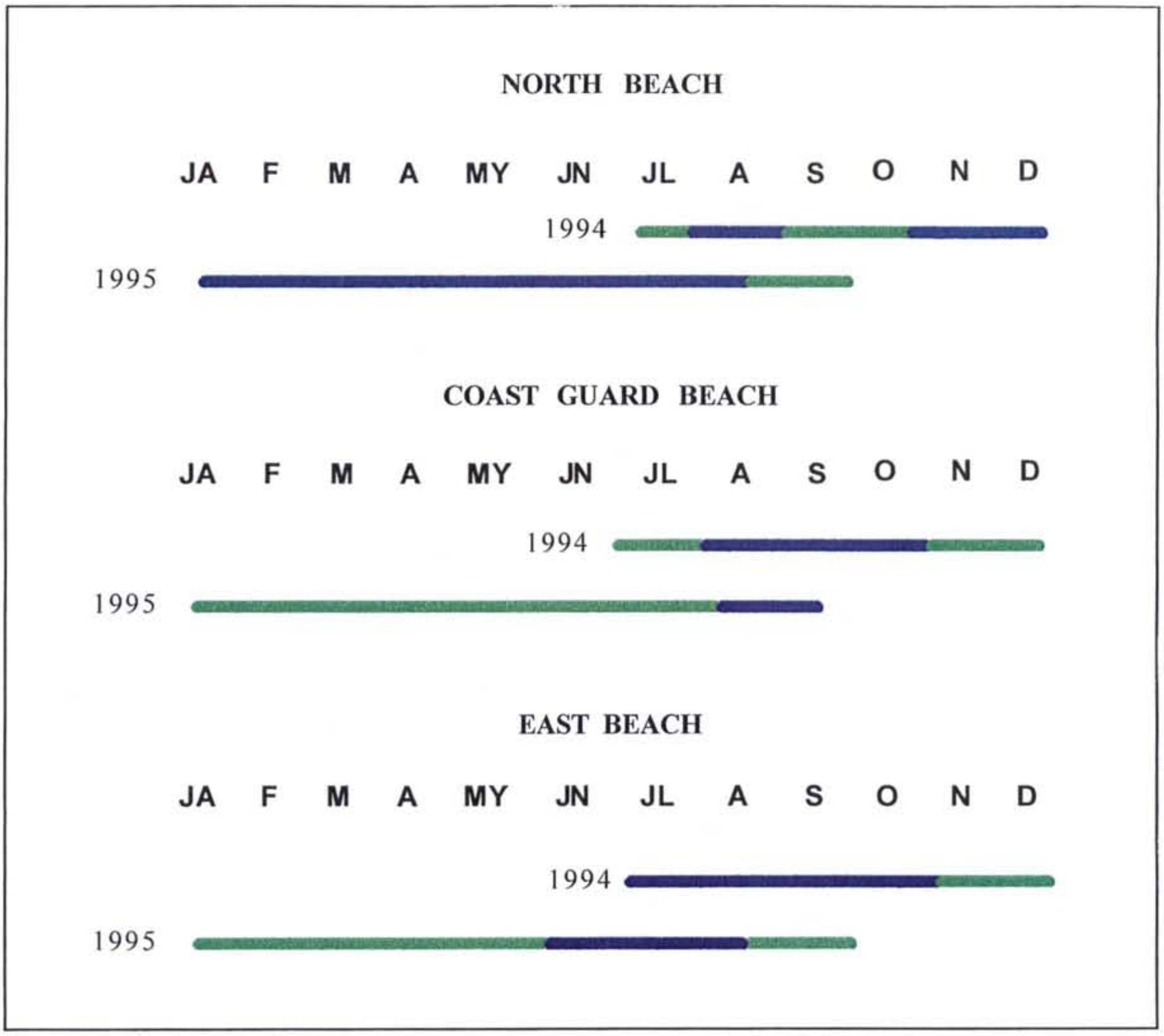


Figure 1-6. Accretional (▬) and erosional (▬) patterns along Eglin Air Force Base beaches on Cape San Blas, Florida from June 1994 through September 1995, indicating severe erosion along the north beach and accretion along the east beach.

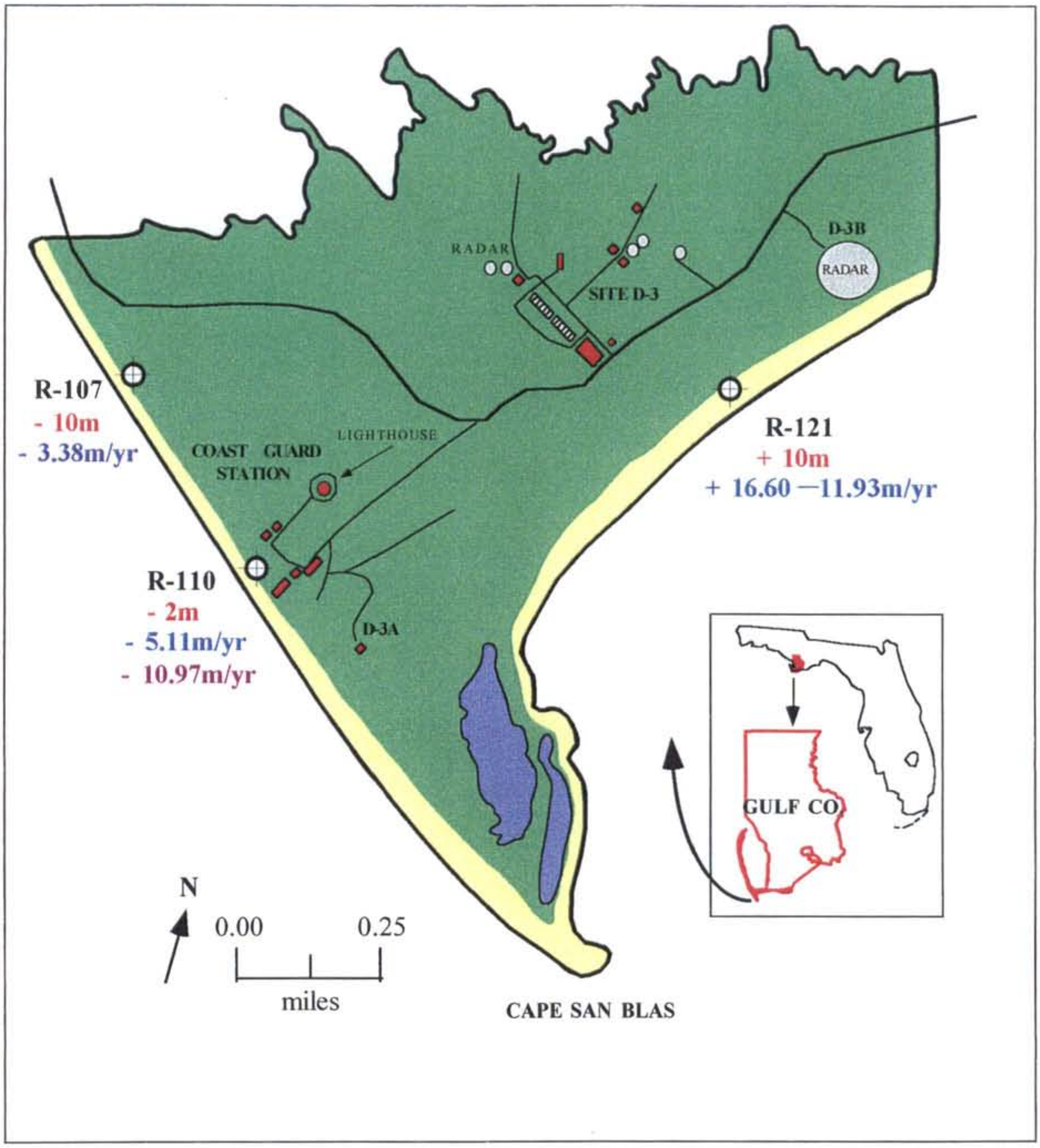


Figure 1-7. Location of Department of Natural Resources benchmarks used from June 1994 to September 1995 to measure erosional rates along Eglin Air Force Base on Cape San Blas, Florida. Numbers in red indicate amount of beach lost (-) or gained (+) during our study period; those in blue are rates measured by Balsillie (1985) from July 1973 to December 1983 and in purple are rates recorded by Tanner (1975) from 1875 to 1942. Balsillie's (1985) numbers for benchmark 121 were actually recorded along benchmarks 120 and 122.

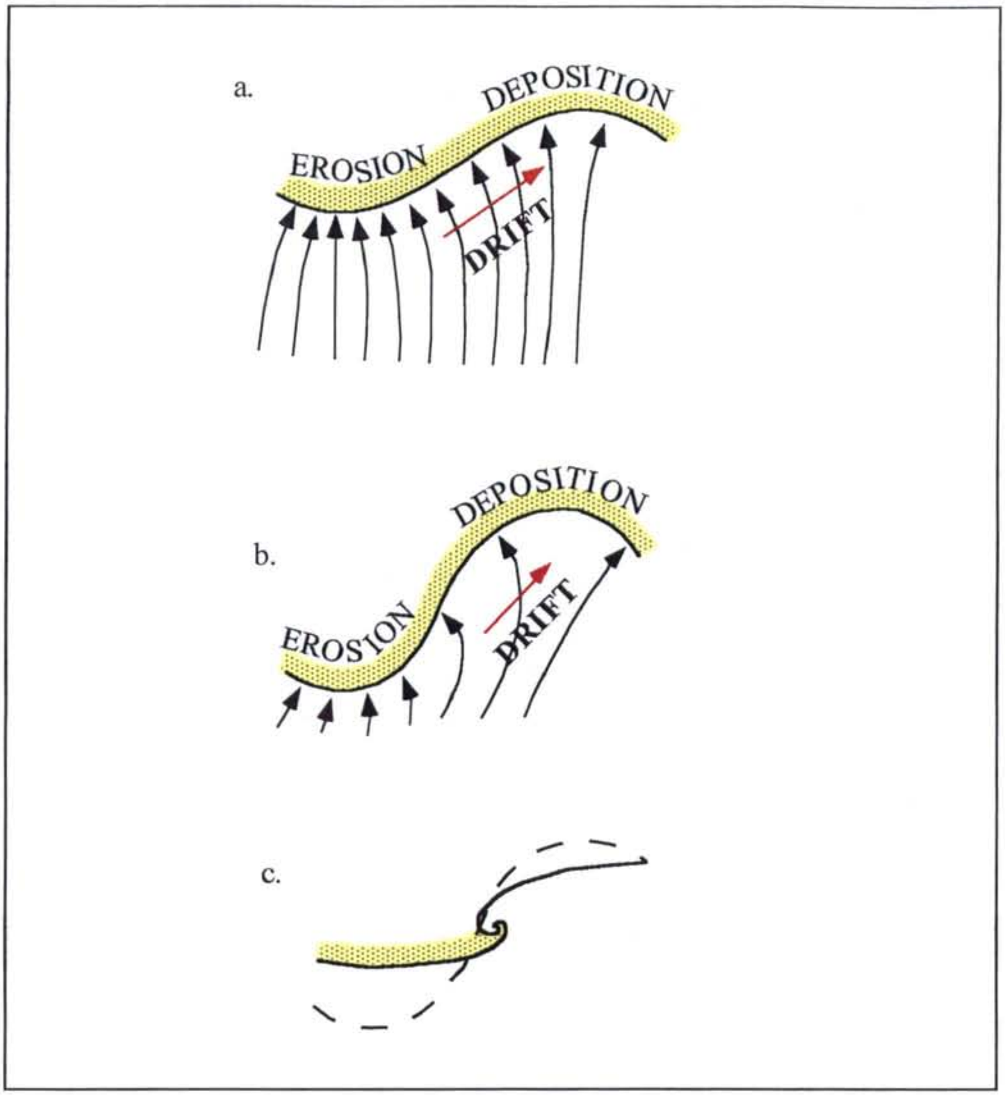


Figure 1-8. Model for littoral sediment transport. (a) Wave refraction pattern with wave approach normal to coast (b). Wave refraction pattern with a more deeply embayed coast and an oblique direction of wave advance and (c) the resulting coastline, similar to the pattern found along Cape San Blas, Florida. The direction of longshore drift is shown in red (from Swift 1975).

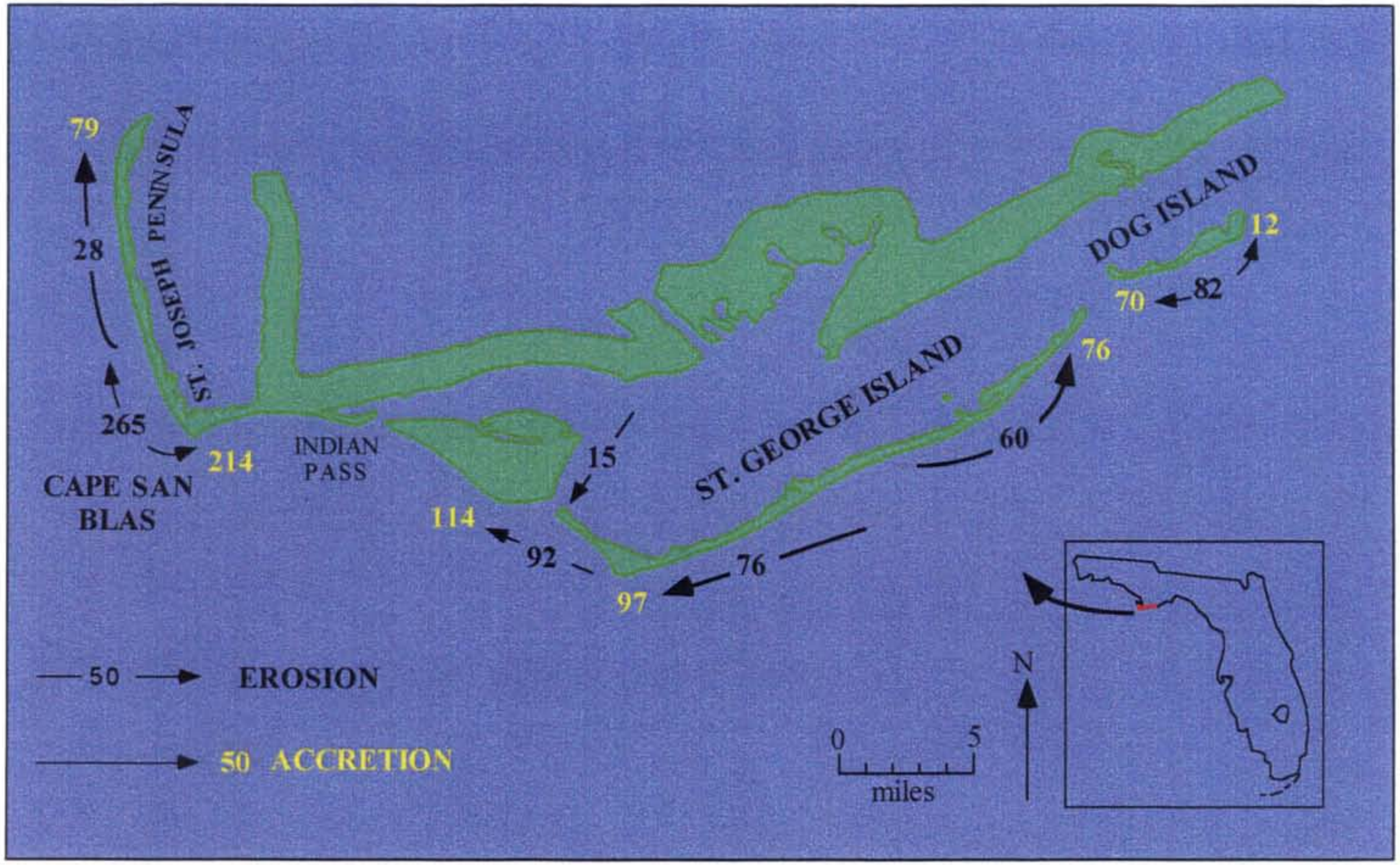
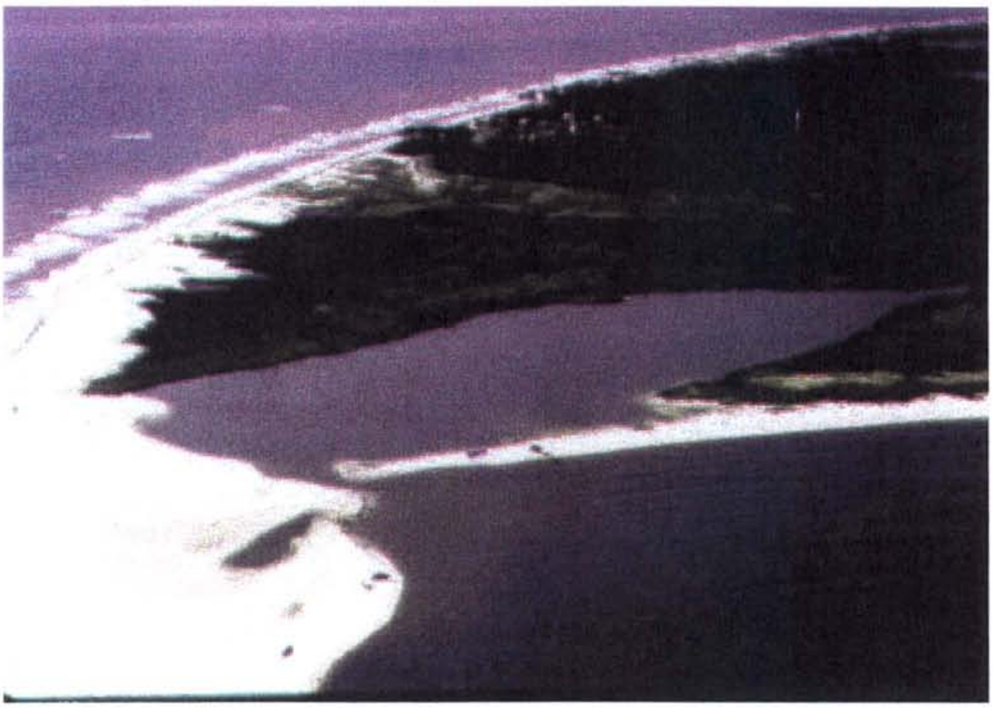


Figure 1-9. Rates of erosion and accretion influencing barrier islands along Gulf and Franklin Counties off the Northwest Florida coast, indicating some of the greatest erosional rates along the St. Joseph Peninsula. Numbers in black indicate erosion and in yellow represent accretion in 10^3 m^3 per year (from Stapor 1971).

CHAPTER 2

LANDFORM AND LAND COVER CHANGE



Introduction

Eglin Air Force Base (EAFB) on Cape San Blas is part of a dynamic barrier island system located along the northern Gulf of Mexico. Its formation and location allow for natural forces to continually alter the landform of this barrier island (see erosion chapter). These long-term changes in the form of the land influence habitat types and floral and faunal species that are able to survive in this area.

Cape San Blas has experienced land form change for over 100 years. Tanner (1975) recorded a loss of 36 feet per year from 1875 to 1942 along the spit on Cape San Blas and a gain of 29 feet per year from 1875 to 1970 along the northern tip of St. Joseph Peninsula (see erosion chapter). These changes occur due to natural forces and are described in detail in the erosion chapter of this final report.

Peninsula (see erosion chapter). These changes occur due to natural forces and are described in detail in the erosion chapter of this final report.

The objectives of this study were to gather historical data on landform and land cover change along St. Joseph Peninsula to visually display landform and land cover change over time along this barrier island.

Methods

Sets of aerial diapositives were obtained for 1942, 1959, 1967, 1971, 1977, 1981, 1990, and 1994. Varying sources of the photography resulted in scales ranging from 1:20,000 to 1:40,000 and included panchromatic, natural color, and color infrared diapositives. Each set of photography were sent to Science Applications International Corporation in Melbourne, Florida to be photogrammetrically scanned to one meter ground resolution. Imagery was scanned on a Vexcel 3000 flatbed scanner and was unrectified.

Photography scale and flight line determined the number of scanned images necessary for full coverage of the study area in any give year. Adjacent images were digitally mosaiked using common image identifiable points, and then georeferenced to a common coordinate system (universal Transverse Mercator; UTM). Because absolute geographic accuracy was not as necessary as relative spatial accuracy, United States Geological Survey quad maps provided a sufficient source for the ground control points used in georeferencing.

To create the digital vector layers, the georeferenced images were used as base maps for photointerpretation and on-screen digitization. Polygons delineating the land cover and landform of Cape San Blas and St. Joseph Peninsula were labeled and attributed interactively and were then compared visually to locations of landscape feature evident on the imagery. Relative accuracy of land cover delineation is estimated to less than five meters for all line work. Image processing steps were performed using ERDAS Imagine 8.2. Vector layers were created using ESRI SRC/Edit GIS software. Variations between maps and natural landform and land cover are due primarily to accuracy of ground control and distortion present in the unrectified imagery which may effect the absolute horizontal positional accuracy of the line work.

Topography of EAFB on Cape San Blas was measured using standard topographic techniques. Horizontal positions and their respective elevation s were determined within the EAFB boundary. Conventional survey techniques were employed with the resulting traverses tied to established monuments. Only one Department of

Natural Resources (DNR) monument recovered from Hurricane Opal (Octover 4, 1995) was usable, therefore National Geodetic Survey (NGS) monuments were used. Each traverse started and ended at points of known location or looped back. The resulting errors were measured. These errors were assumed to have been uniformly accumulated and the corrections were applied accordingly. Data from this survey was transformed to a continuous spatial surface in Arc/Info™ and Microstation™. This data set is comprised of coordinates expressed at UTM Zone 16 meters using the North American Datum of 1927 (NAD27) and the Clarke ellipsoid of 1866.

Traverses began at station Spit (#AS0770). Spit was established by the Coast and Geodetic Survey in 1959 as a first order horizontal control mark and is frequently used by the EAFB survey personnel. An elevation for Spit was established by running a conventional loop from National Geodetic Survey benchmark number (#AS0378), a second order class 1 mark, to station Spit. The resulting error was 0.61 centimeters. An approximately 200 meter swath along the beach, spaced at about 100 meter intervals, was surveyed from station Spit to the eastern boundary. The traverse was tied into DNR monument number R123. The horizontal error of closure was 20.0 centimeters and the vertical misclosure was 13.2 centimeters. The approximate length of this traverse was 2,000 meters. A similar design was employed for the traverse from station Spit to the western boundary of the property. Due to a tremendous amount of beach erosion there were no monuments in the vicinity ot the western boundary line, therefore this traverse was looped back to station Spit. this resulted in a horizontal error of closure of 26.7 centimeters and a vertical error of closure of 9.9 centimeters. This traverse was also approximately 2,000 meters in length. Additional data for the interior of the property was provided by creating two ties to State Road 30-E (comprised of project number #51001-3502-010-41 and #51001-3501-010-41). This provided elevations spaced at approximately 30 meters along a strip that cuts through the middle of the property. In addition, spot elevations were determined form Global Positioning Satellite (GPS) observations located throughout the property. The data were post processed using base station data from the DNR Tallahassee station. Elevations were determined by using the National Oceanic and Atmospheric Administration's (NOAA) 1993 geoid model.

Results

Landform and land cover change images have been displayed in Geographic Information System (GIS) format maps (Fig. 2-1a-h).

Discussion

Maps produced in GIS indicate Cape San Blas has undergone landform change since 1942 and these maps support results of beach transects conducted during this study (see erosion chapter). This was also evident in the findings of Tanner (1975) and Balsillie (1985). Discussion on the forces regulating and maintaining the pattern of accretion and erosion evident on Cape San Blas beaches and recommendations of how to manage this habitat can be found in the erosion chapter of this report.

Literature Cited

Balsillie, J. H. 1985. Long-term shoreline change rates for Gulf County, Florida – a first appraisal. Florida Department of Natural Resources, Division of Beaches and Shores Report No. 85-3.

Tanner, W. F. 1975. Historical beach changes: Florida's "Big Bend" coast. Transactions of the Gulf Coast Associations Geological Society 25: 379-381.

THE CAPE SAN BLAS ECOLOGICAL STUDY

Margaret M. Lamont, H. Franklin Percival, Leonard Pearlstine,
Sheila V. Colwell, Wiley M. Kitchens, and Raymond R. Carthy

U.S. Geological Survey/Biological Resources Division
Florida Cooperative Fish and Wildlife Research Unit

Technical Report #57

1997

Recommended Citation:
Lamont, M.M., H.F. Percival, L.G. Pearlstine, S.V. Colwell, W.M. Kitchens, and R.R. Carthy. 1997. The Cape San Blas Ecological Study. U.S.G.S. Biological Resources Division, Florida Cooperative Fish and Wildlife Research Unit. Tech, Rep. No. 57.

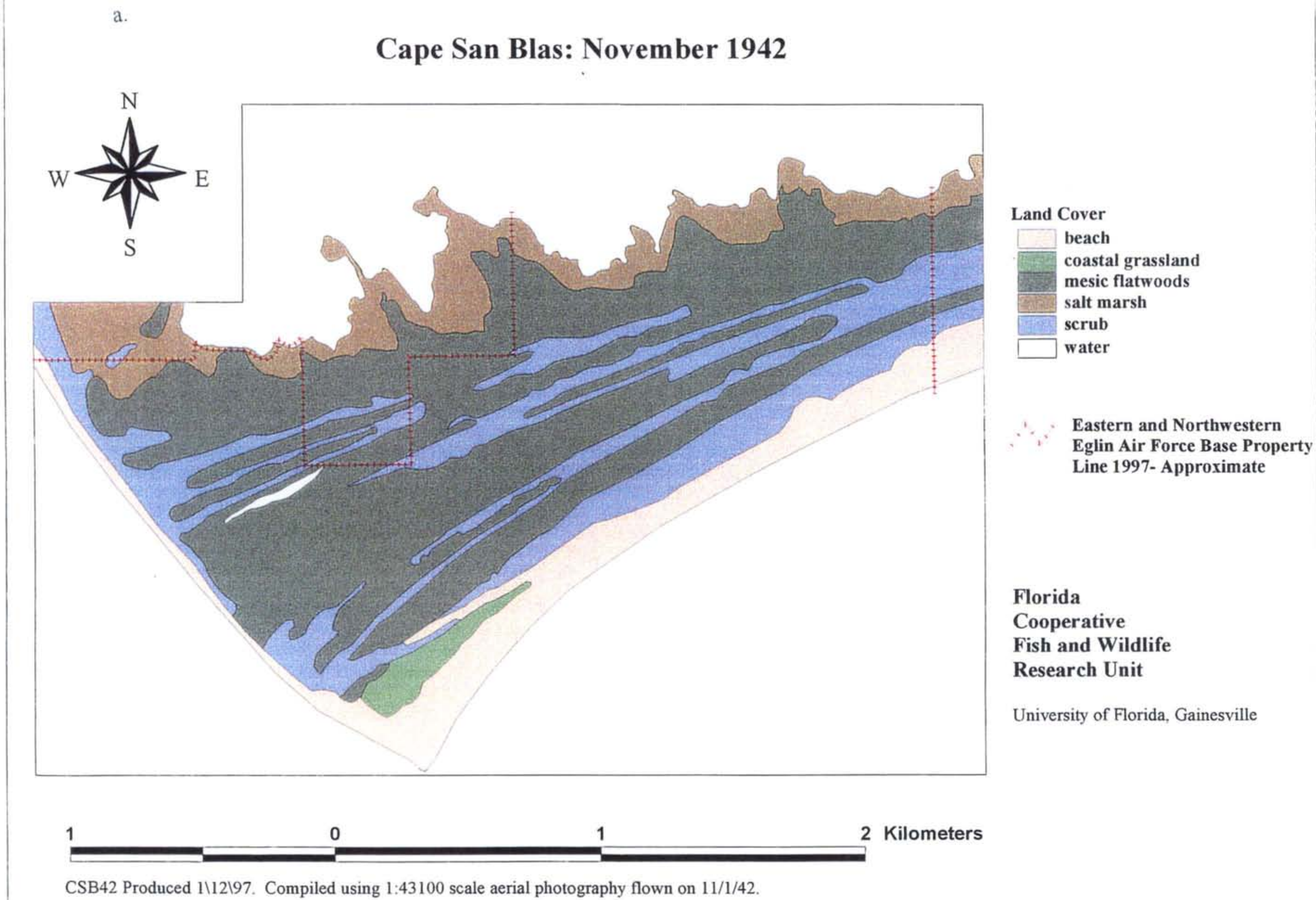
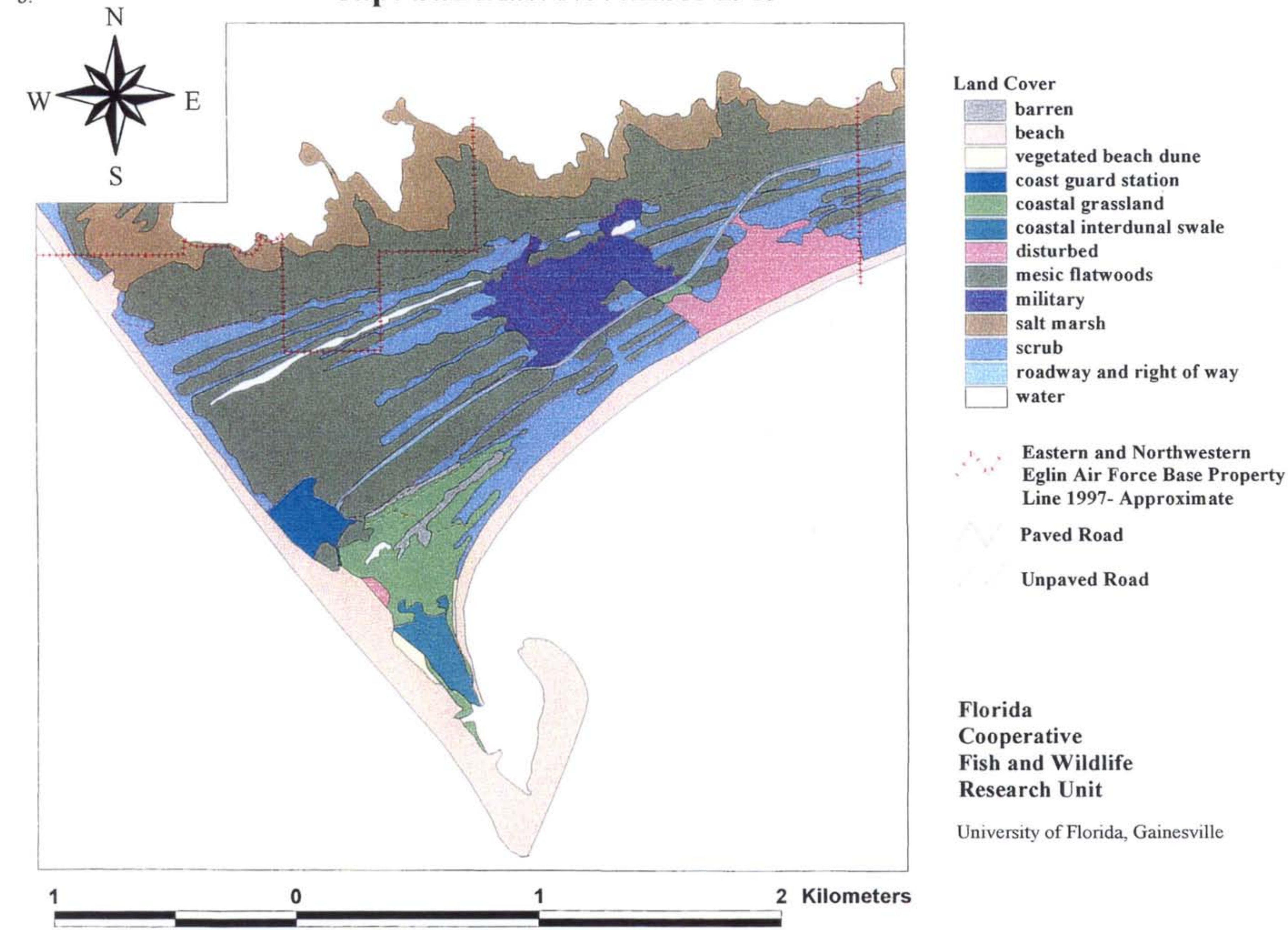


Figure 2-1, a-h. Landform and land cover change on Eglin Air Force Base property along Cape San Blas, Florida during 1942, 1959, 1967, 1971, 1977, 1981, 1990, and 1994. Aerial photos were incorporated into the GIS system to create a visual display of the dynamics of this area over a 50 year time span.

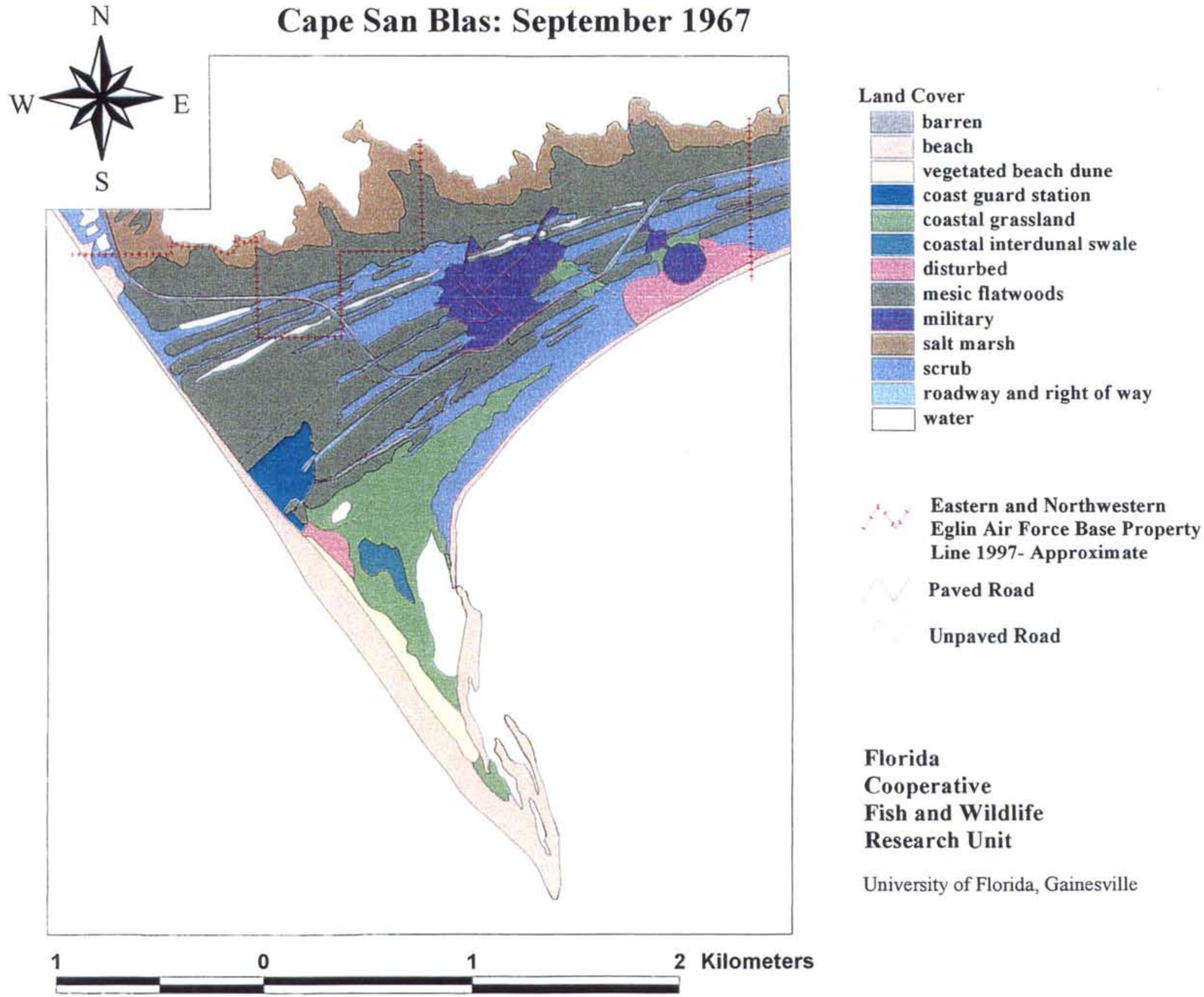
b.

Cape San Blas: November 1959



CSB94 Produced 1\12\97. Compiled using 1:40000 scale aerial photography flown on 11/13/59.

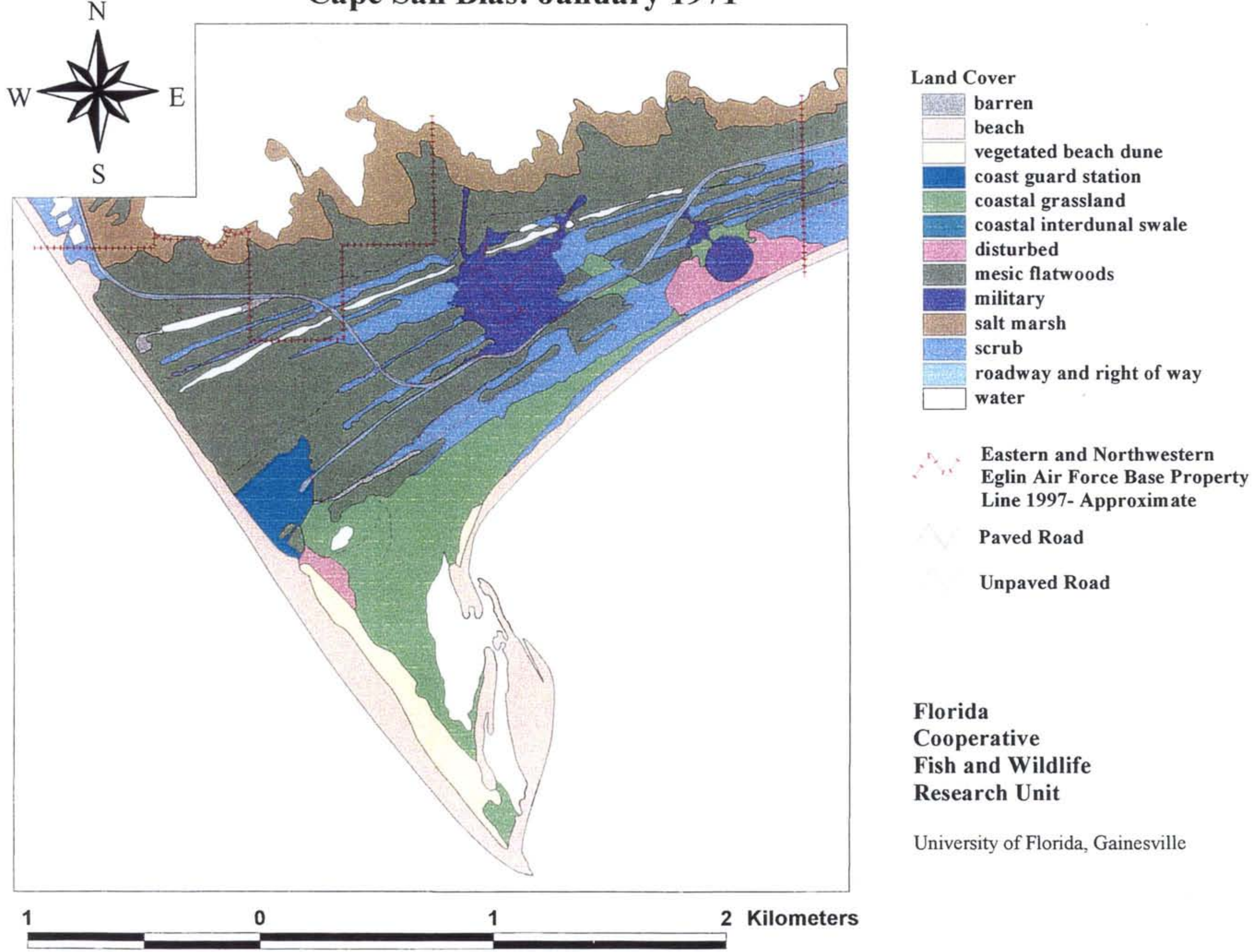
c.



CSB67 Produced 1\12\97. Compiled using 1:40000 scale aerial photography flown on 9/29/67.

d.

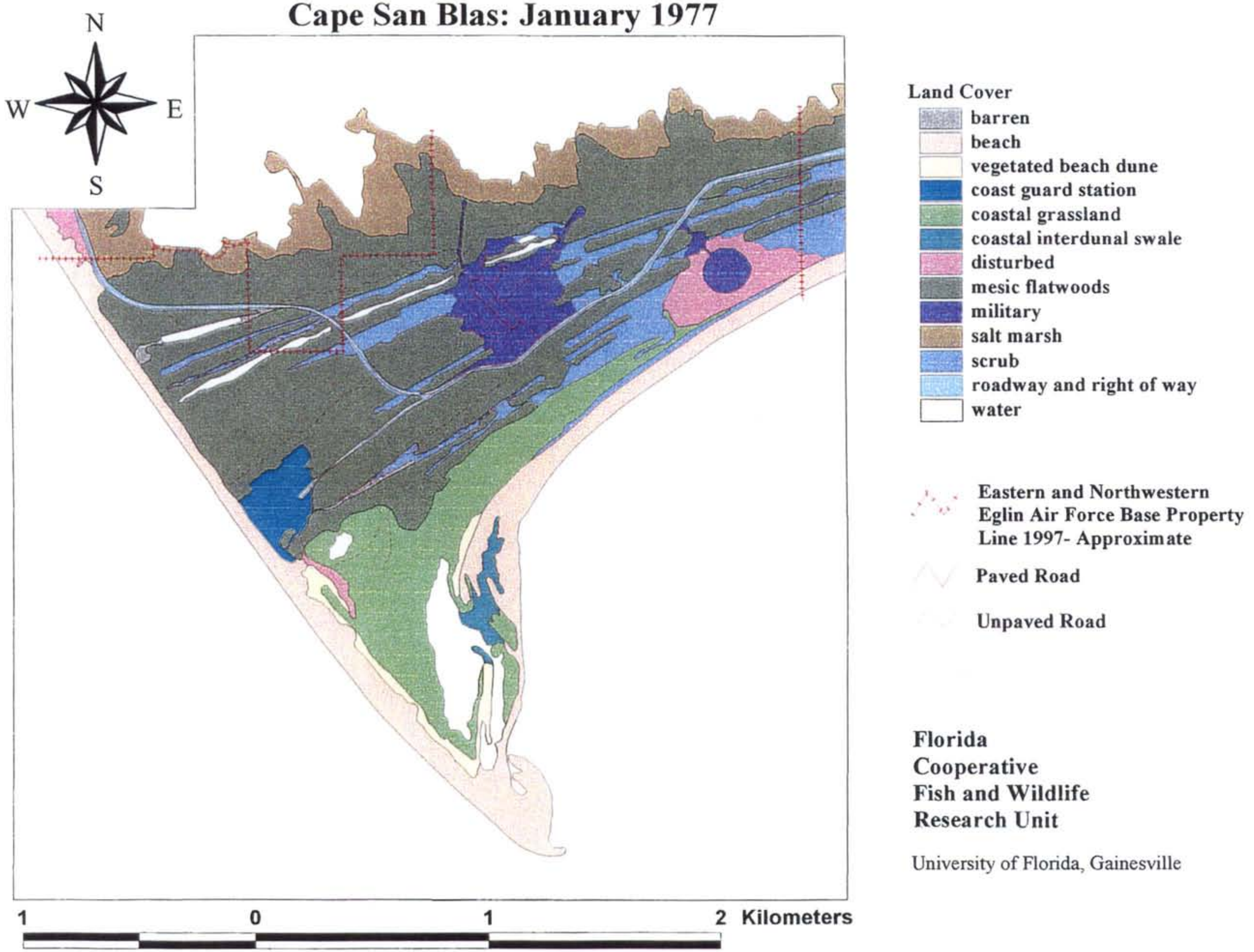
Cape San Blas: January 1971



CSB71 Produced 1\12\97. Compiled using 1:40000 scale aerial photography flown on 1/26/71.

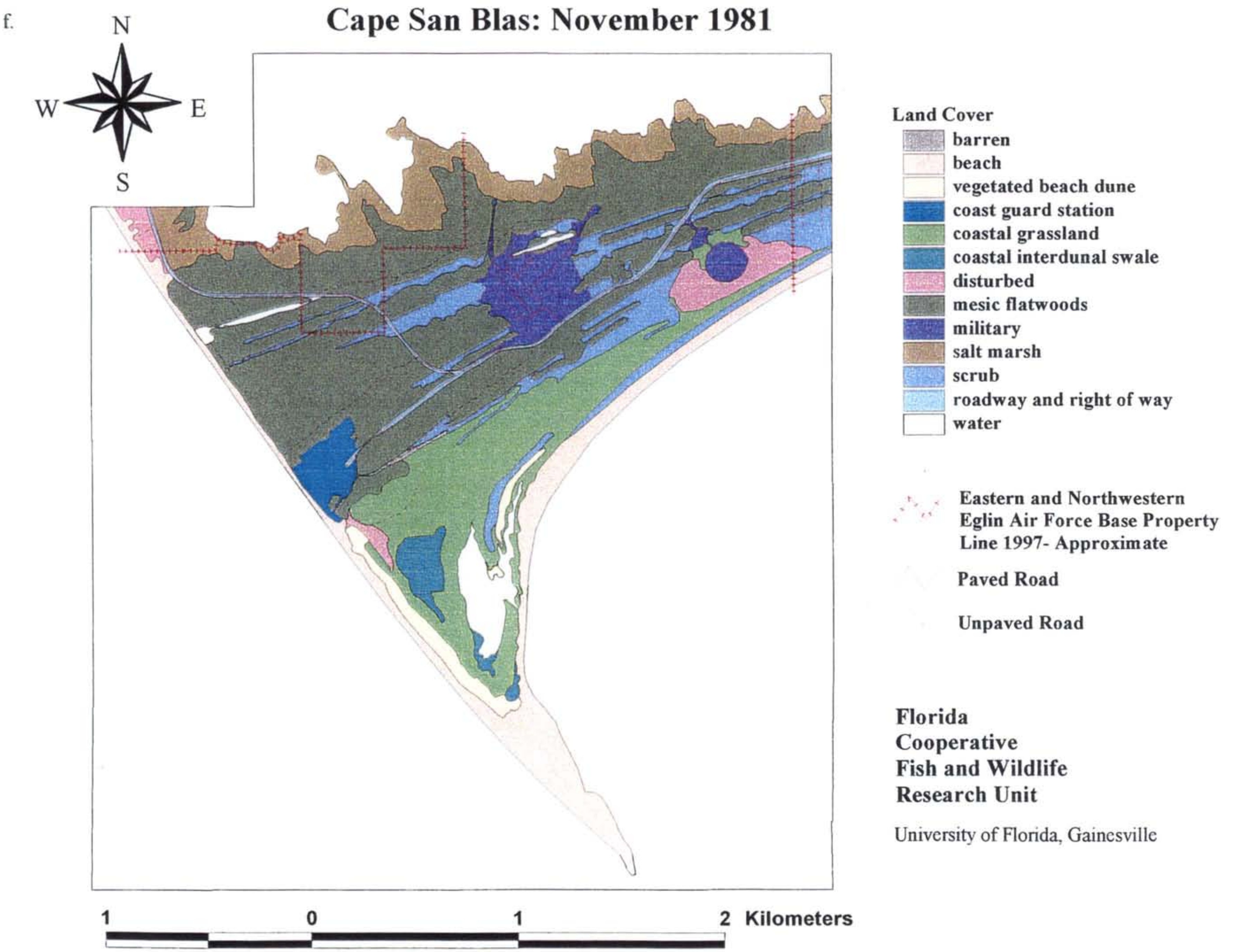
e.

Cape San Blas: January 1977



CSB94 Produced 1\12\97. Compiled using 1:40000 scale aerial photography flown on 1\27\77.

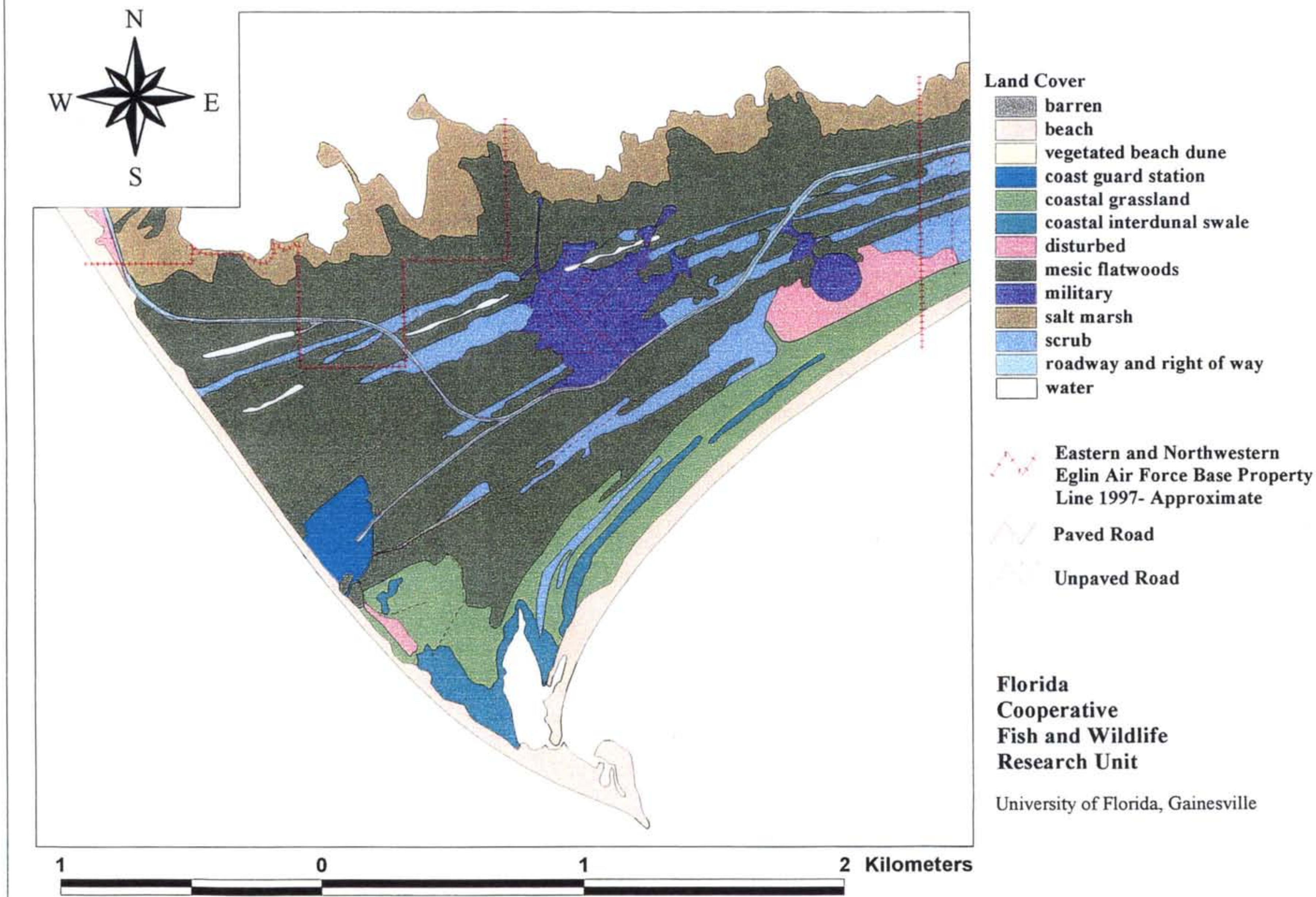
f.



CSB81 Produced 1\12\97. Compiled using 1:20000 scale aerial photography flown on 11/12/81.

g.

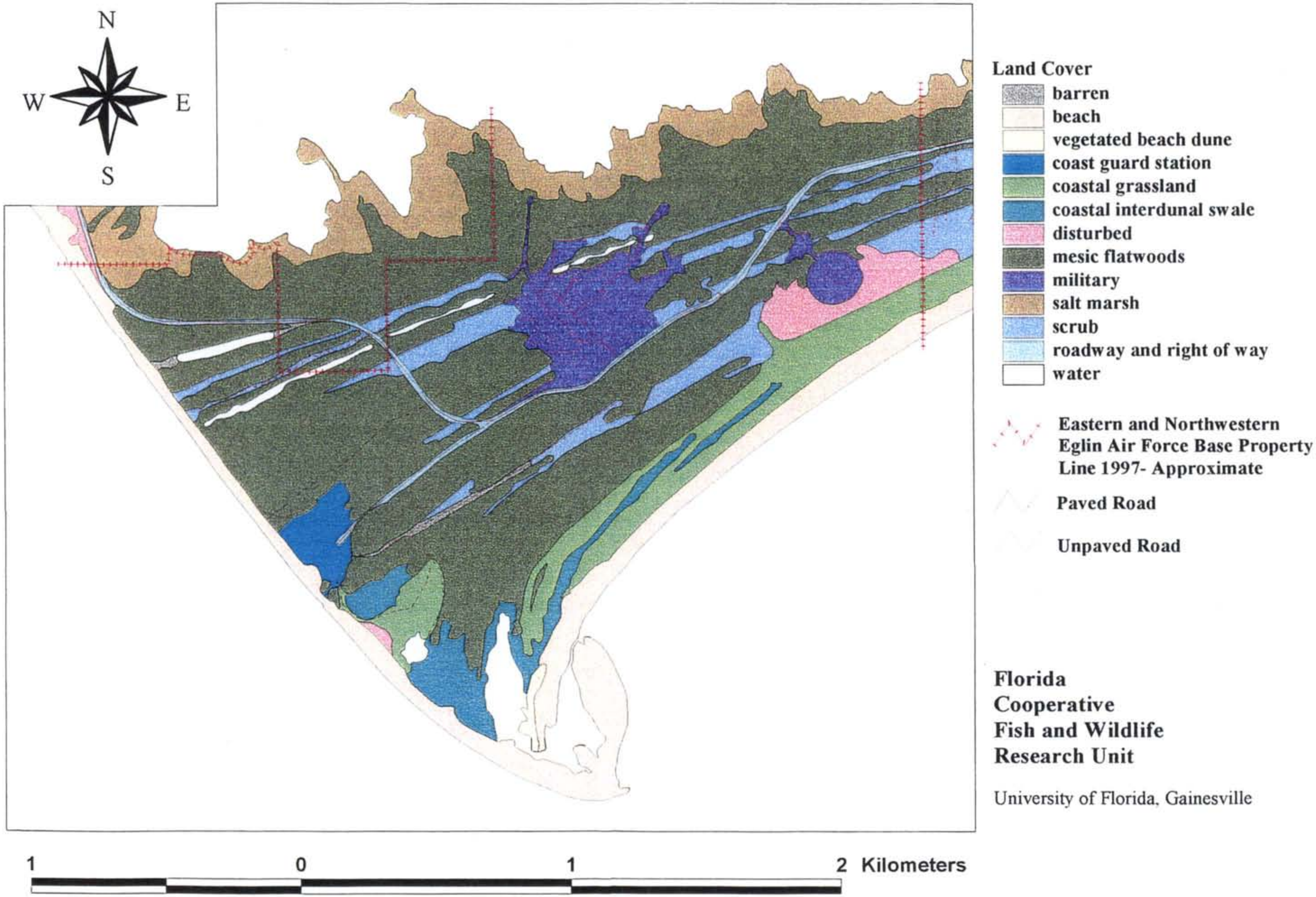
Cape San Blas: January 1990



CSB94 Produced 1\12\97. Compiled using 1:40000 scale aerial photography flown on 1\11\90.

h.

Cape San Blas: January 1994



Florida Cooperative Fish and Wildlife Research Unit

University of Florida, Gainesville

CSB94 Produced 1\12\97. Compiled using 1:40000 scale aerial photography flown on 1\15\94.

CHAPTER 3

HYDROLOGY

Introduction

Characterization of water table regimes is a primary consideration when assessing landscapes, soils, or ecosystems. The normal ranges of water levels may be limited and controlled, as in tidal marshes or systems adjacent to large lakes, or they can be subject to wide fluctuations in relation to cumulative rainfall, as in swamps and marshes (Brown et al. 1990). Soil water levels influence the surrounding habitat by causing growth of drought-tolerant species, flood-tolerant species, or species tolerant of variable conditions.

There is little specific information about the adaptations of most plant species to high or variable water tables, although much can be inferred from their distribution and root anatomy. Cypress (*Taxodium*), slash pine (*Pinus elliottii*), and gums (*Nyssa* sp.) have an internal porosity that allows ventilation of portions of their root systems below the water table (Brown et al. 1990). Roots of saw palmetto (*Sereona repens*) have continuous open cavities that allow growth a meter or more below groundwater levels and in dry sands far from any water table. Sedges, rushes, and wet-site grasses have gas transport structures, and many herbaceous and shrubby dicotyledons that flourish in soil with shallow water tables also have effective air-conducting tissues (Brown et al. 1990).

Soil water levels also influence the distribution of soil-dwelling animals. The gopher tortoise (*Gopherus polyphemus*), pocket gopher (*Geomys pinetis*), harvest mouse (*Peromyscus polionotus*), and harvest ant (*Pogonomyrmex badius*) all confine their burrowing to well-drained soils. The scarab beetle (*Peltotrupes youngi*) is found in areas of low water tables, and several species of crayfish burrow to depths equal to the surrounding water table (Brown et al. 1990).

The water table level, therefore, plays a large part in defining the habitat type. Wet prairies and grassy lakes contain water tables that vary with rainfall, and swamps and marshes have water tables that are at or near the surface throughout much of year

(Brown et al. 1990). Wooded swamps and cypress ponds are saturated or flooded in most years, but are also often subject to drying and fire during occasional droughts. In some of these habitats, the water surfaces are continuous with those of nearby lakes and swamps, and although they fluctuate with rainfall, they are usually present at some depth. In others, however, water tables are located above clay layers and last only as long as rainfall exceeds losses. Losses are most often due to evapotranspiration, therefore destruction of the green canopy by fire, wind, or logging often temporarily increases the height and duration of both types of water tables (Brown et al. 1990). Therefore, habitat type is determined in part by the depth and stability of the water table.

The purpose of this study was to assess the relationship between the water table and the Gulf of Mexico among habitat types along Cape San Blas, Florida. Assessing the source of the water table within these habitats would permit better classification of habitat type therefore allowing proper management of the area.

Methods

Tides

A data logger (Data Sonde3) was placed offshore of the Coast Guard Station on Cape San Blas to continuously record tidal levels. A section of PVC pipe was attached to the old Cape San Blas lighthouse base located approximately 50 feet (ft) offshore in water depths ranging from two to five ft. Information was gathered from the monitor during 6 periods throughout summer and fall 1995. These periods included: July 20-25, September 26-30, October 17-20, October 20-27, October 29-November 2, November 6-14, and November 16-27. Data logged within the monitor was downloaded into a laptop computer as a Microsoft Excel spreadsheet.

These data were compared with tidal levels off Port St. Joe on the north side of Cape San Blas, and Apalachicola on the east side of Cape San Blas, to determine which tidal cycle waters off Cape San Blas follow. Tidal levels from the Tidemaster program were used to determine Port St. Joe and Apalachicola tides. Tidal levels for all three areas were graphed in Microsoft Excel for visual comparisons.

Wells

Wells were constructed of two and one-half inch, and one and one-half inch PVC pipes. A screen was inserted at the bottom of the one and one-half inch PVC pipe and the entire well was capped. Wells were placed along a transect that originated on the Florida Department of Natural Resources benchmark R-121 and continued from the beach through the interdunal swale and into the flatwoods (Fig. 3-1). Two wells were placed in each habitat. Wells 1 and 2 were placed in beach habitat, 3 and 4 in swale, and 5 and 6 in flatwood habitat. Wells were dug by hand with a post-hole digger, deep enough to allow seepage from the groundwater, therefore depths of wells differed. Depth of well 1 was 116 cm, well 2 - 125 cm, well 3 - 52 cm, well 4 - 62 cm, well 5 - 71 cm, and well 6 - 48 cm (see Fig. 3-1).

Wells were monitored once every hour throughout an entire tidal cycle during three days in November 1995 (18-20) and two days in February 1996 (16-17). Water depth and salinity were recorded. Changes in depth and salinity were computed to assess salt water influence on the water table.

Results

Tides

We recorded 923 hours of tidal level activity off the northern coast of Cape San Blas between July and November 1995. Graphs from all sessions indicated Cape San Blas tides follow the cycle of those off Port St. Joe, with one high and one low per day (Fig. 3-2). Those off Apalachicola consist of two highs and two lows per day (Fig.3-3).

Although the tidal cycle followed that off Port St. Joe, tidal ranges off Cape San Blas were smaller than those off Port St. Joe. During our study period, the greatest tidal range off Port St. Joe was approximately 0.7 meters (m), whereas the greatest tidal range off Cape San Blas throughout that time was about 0.3 m.

Wells

Negligible differences in water table depths and salinities were observed among all wells throughout both monitoring periods (Table 3-1). The greatest range in depth was 1.5 cm within well 1 on November 18, 1995 and February 17, 1996, and well 3 on November 18, 1995. Wells 1 and 2 experienced two days each of no change in depth, and well 3 underwent no fluctuation in depth during one sampling day. Throughout the rest of the sampling period, changes in all wells were either 0.5 cm or one cm.

The greatest range in salinity was 1 ppt recorded on three days in wells 1, 3, and 4, and one day in wells 5 and 6. Throughout the remaining sampling days, those wells experienced no change in salinity. Well 2 experienced no change in salinity throughout all five days of monitoring.

Discussion

Gulf County lies within the Gulf Coastal Lowlands geomorphic province that extends from the coast inland to middle Calhoun County and is characterized by generally flat, sandy terrain (Fig. 3-4; Puri and Vernon 1964). Superimposed on this terrain are a series of relict marine beach ridges, bars, spits, dune fields, and low marine terraces (Rupert 1991). Cape San Blas occupies the portion of the Gulf Coast Lowlands termed the Silver Bluff Terrace that extends to the modern Gulf coast and lies below approximately 8 ft mean sea level (MSL). This terrace is characterized by dune systems and relict beach ridges and swales (Rupert 1991). The geology of Gulf County assists in defining the ground water aquifer and it's characteristics. Results of this study are typical of the ground water characteristics of Gulf County and are supported by the geological and topographical features along the Florida panhandle.

Ground water fills the pores and interstitial spaces in the rocks and sediments beneath the surface of the earth. Most of Gulf County's ground water is derived from precipitation within the county and from neighboring counties to the north (Rupert 1991). A portion of the precipitation leaves the area as runoff in stream flow or by evapotransipiration. The remainder soaks into the ground, where some moves downward into the porous zone of saturation (Rupert 1991). The top of this zone is known as the water table.

Once in the water table, water moves under the influence of gravity towards discharge points such as wells, seeps, springs, or eventually the Gulf of Mexico. Some of the water seeps downward into the deeper aquifer units, providing recharge to them. In Gulf County, there are three primary ground water aquifer systems: 1) the surficial aquifer system, 2) the intermediate confining unit, and 3) the Floridan aquifer system (Rupert 1991).

The surficial aquifer system consists of shallow undifferentiated Plio-Pleistocene sand and clay sediments where water is not confined, therefore the water level is free to rise and fall. This aquifer is recharged through direct infiltration of rain water. It is generally a thin unit, varying proportionally with the thickness of the undifferentiated sands and clays. The thickness ranges from about four ft in eastern Gulf County to as much as 90 ft in the northwestern part of the county. The surficial aquifer follows the surface topography and fluctuates in elevation due to droughts or seasonal rainfall differences. Water movement within the surficial aquifer system is generally downhill, therefore it discharges into streams, bays and the Gulf of Mexico.

The intermediate confining unit in Gulf County lies below the surficial aquifer system and is contained within the sediments. This confining unit ranges from about 150 ft thick in northeastern Gulf County to nearly 500 ft near Cape San Blas. The top of the unit varies from about 10 ft MSL in northern Gulf County to approximately 50 ft along the southern edge of the county. Aquifers within the confining unit are recharged primarily from lateral water influx and from seepage from the overlying and underlying aquifers.

The Florida Aquifer is the most important freshwater aquifer in Florida, underlying much of the central and eastern panhandle, and most of the peninsula of Florida. This is the thickest and most productive unit in the central panhandle, supplying the bulk of the domestic, urban and agricultural water used in Gulf County (Rupert 1991). The top of the aquifer varies in depth from approximately 150 MSL at the northern edge of the county to 500 ft MSL under the St. Joseph Peninsula, including Cape San Blas. The Floridan aquifer system is confined in all areas of Gulf County. Minor recharge may occur through downward seepage from the surficial and intermediate aquifers, however most recharge occurs from water inflow from adjacent counties. Most water flowing through the Floridan aquifer system is discharged into the Gulf of Mexico (Rupert 1991).

During this project, water sampled in wells throughout all habitats on Cape San Blas was taken from the surficial aquifer system. Changes in depths and salinities were consistent with the characteristics of this aquifer. Water table depths varied among habitats, most likely due to differences in the surface topography. Along the dune/beach habitat, wells were deepest, whereas wells placed within the interdunal swale were shallowest. Typically, water levels in the surficial aquifer fluctuate due to droughts or seasonal rainfall differences. During our sampling period, rainfall was slight or did not occur, therefore water table depths remained consistent. This indicates that throughout all habitats along Cape San Blas, the surficial water table is freshwater and not influenced by salt water inundation.

Salt water intrusion into the surficial water table may alter the habitats dependent on the water table for survival. South Florida has the shallowest water table in the United States because the topography in this region is low (approximately 18 ft above sea level). The shallow water table makes this area susceptible to salt water intrusion caused by several factors, such as an increase in ocean level due to global climatic changes, fluctuations in the freshwater table level caused by variation in the distribution and intensity of rainfall, or anthropogenic depletion of the freshwater table by well pumping and canal building (Sternberg and Swart 1987). Several plant species, particularly those comprising mangrove habitats, are able to survive saltwater intrusion by excluding or excreting salt. Hardwood hammocks, however, are less able to survive salt water inundation, therefore these species are restricted to freshwater uptake. Changes in the salinity of the surficial water table may, therefore, greatly influence the plant species inhabiting the area (Sternberg and Swart 1987).

Although saltwater tidal cycles may not influence the surficial water table along Cape San Blas, greatly influence coastal habitats. Tides may contribute to the amount of damage afflicted by a tropical storm, depending on tidal range and water depth (Johnson and Barbour 1990). Tidal ranges vary throughout Florida (Livingston 1990). Along the east coast, tides increase northward from about 0.6 m to 2.4 m. Around the tip of the peninsula, tides range from 0.9 m to 1.2 m, whereas along the northern Gulf of Mexico coast, tides average 0.6 m to 1.0 m. Because the northern Gulf of Mexico is shallow and relatively flat, wave action is slight (see erosion chapter; Johnson and Barbour 1990). This allows for smaller tidal ranges observed along the Gulf of Mexico coast. Therefore, the 0.7 m tidal range that occurred along Port St. Joe during our study is typical of the panhandle coast, whereas the tidal range off Cape San Blas (0.3 m) was smaller than the average ranges along the northwest Florida coast. Small tidal ranges may increase risk for severe damage during storms because they do not provide buffers for storm surges. The small tidal range along Cape San Blas may not provide a sufficient buffer during tropical storms, therefore, this area may experience severe damage during storm events.

The shallow waters and small tidal ranges characterizing the northern Gulf of Mexico also make the Florida panhandle coast more susceptible to exceptionally high wind-generated tides (Livingston 1990). Wind-generated tides are generally higher along the Gulf coast than along the rest of Florida's coastline (Livingston 1990). Storm tides along some areas of the Florida panhandle were approximately 7.0 ft above normal during Hurricane Elena (1975), 8.5 ft during Hurricane Kate (1985), and nearly 20 ft during Hurricane Opal (see storm history chapter). These surges caused extensive environmental and personal damage. Therefore, wind-generated tides may also cause extensive damage to structures and habitats along Cape San Blas because of the shallow waters and small tidal range along this coast.

Similar to tidal ranges throughout the state, the tidal cycles along the Florida coast also vary. Along most of the east coast of Florida, semidiurnal tides predominate, whereas around the southern tip of the peninsula and north along the eastern panhandle coast to Apalachicola, mixed tides prevail (two unequal highs and two unequal lows each day). Across the northwest panhandle coast, diurnal tides occur (Livingston 1990). The tidal cycle off Cape San Blas throughout our study period was diurnal, typical of the cycle along the western panhandle coast.

Management Recommendations

Tides

Damage occurring to structures and habitats along Cape San Blas during tropical storms is exacerbated by the small tidal ranges and shallow waters along the northern Gulf of Mexico. These natural features cannot be altered, therefore little can be done to prevent this damage. Damage may be minimized, however, by protection of habitats, particularly the dune system, and by proper construction of coastal buildings.

Dunes help protect landward habitats from destruction due to water or wind. Because the northern Gulf of Mexico is shallow and the panhandle coast experiences small tidal ranges, storms striking the panhandle often have severe effects on coastal habitats. Dunes provide a barricade for landward habitats that are less adapted to saltwater intrusion than dune vegetation, such as interdunal swale, rosemary scrub, or pine flatwoods. Large, stable dunes may provide more protection than small, loose dunes, therefore, conservation of the dune habitat along Cape San Blas may assist in reducing effects of tropical storms on landward habitats. As suggested in the erosion chapter, transplanting smooth cordgrass along the north beach of Cape San Blas may assist in maintaining the dune system, or even promoting increased growth of dunes.

Another factor that may increase erosion during storms are coastal structures. Buildings placed along the beach may exacerbate erosion by destroying dunes when built and freeing sand for erosional transport. Construction within the dune habitat may destroy dune building vegetation, such as cordgrass and sea oats. Dunes are built as stems of dune grasses increase the surface roughness, causing wind to slow and drop sand grains being carried across the beach (Johnson and Barbour 1990). Therefore, dunes may not begin to build nor continue growing if dune vegetation is destroyed.

Coastal structures may also contribute to dune erosion by collapsing during storms, thus freeing sand for transport. When structures collapse, they loosen sand that then becomes available for removal by wind and water (see erosion chapter). Because Cape San Blas beaches experience severe erosion, structures built directly landward of dunes are quickly eroded shoreward, therefore intruding on the dune system. To minimize effects to dunes, air force structures along Cape San Blas should be built a great distance landward of the dune system. Along the north beach of Cape San Blas, approximately 10 meters of beach were lost in one year. This beach loss should be taken into account when structures are built along the Cape San Blas coast. Protection of the dune habitat may assist in reducing erosion caused by tropical storms.

1. Protection of the dune system and building of coastal structures as far inland from the beach as possible are recommended for protection of habitats from

damaging high tides. If possible, building of new structures should be limited to those sites not influenced by erosion, which include site D-3 and D-3A. When building new structures, the erosional pattern occurring along that stretch of beach should be considered (see erosion chapter).

<u>Water table</u>

The primary threat to any fresh water aquifer is salt-water intrusion. Presently, fresh water availability within the Florida aquifer system is good for all of Gulf County. This was supported by our findings of consistently low salinities within wells placed throughout the habitats along Cape San Blas. In coastal areas, however, the fresh water layer within the aquifer thins in a seaward direction, gradually pinching out as it laps over the wedge of saltwater that fills the aquifer rocks under the Gulf of Mexico (Rupert 1991). Less fresh water is available to pump in coastal areas, and over-pumping may cause landward migration of the fresh-saltwater interface (Rupert 1991). As long as population growth and water withdrawal rates in the coastal areas are low, saltwater contamination of the aquifer system wells near the coast should not occur (Rupert 1991). Currently, a civilian support staff of approximately 75 people use the air force buildings on Cape San Blas five days a week, however, there are no military personnel permanently stationed on air force property along Cape San Blas. Therefore, Eglin Air Force Base on Cape San Blas is presently imposing no serious threat to Gulf County's aquifer system. If eventually there are increased personnel housed on Cape San Blas, water should be conserved to prevent saltwater intrusion into the freshwater aquifer.

Effects of saltwater intrusion are not limited to human interests, however. Habitats along Cape San Blas may also be altered if the surficial water table were flooded by saltwater. Cores taken along the south Florida coast often indicate mangrove habitat, followed by sawgrass habitat, followed again by mangrove peat. These vegetation changes are predominantly due to changes in the boundary between the freshwater table and ocean water in this area (Sternberg and Swart 1987). Plant species respond differently to salt water intrusion also. Some species, such as red mangrove (*Rhizophora mangle*) are able to exclude saltwater, and others such as black mangrove (*Avicennia germinans*) can excrete saltwater through its leaf glands (Sternberg and Swart 1987). Various other species, though, such as Coastalplain willow (*Salix caroliniana*), pond cypress (*Taxodium ascendens*), and waxmyrtle (*Myrica cerifera*) suffer greatly if inundated by saltwater (J. Stenberg, University of Florida, pers. comm.). Little can be done to protect habitats from saltwater inundation due to oceanographic changes or variations in the amount of rainfall, however, limiting pumping of the fresh water aquifer may be successful in preventing saltwater intrusion (Sternberg and Swart 1987).

2. Limiting pumping of the surficial water table during times of increased human use of air force property along Cape San Blas is recommended for protection of the water table from salt-water intrusion.

Literature Cited

Brown, R. B., E. L. Stone, and V. W. Carlisle. 1990. Soils *in* Ecosystems of Florida, R. L. Myers and J. J. Ewel, eds. University of Central Florida Press, Orlando, Florida. 765 pp.

Johnson, A. F. and M. G. Barbour. 1990. Dunes and Maritime Forests *in* Ecosystems of Florida, R. L. Myers and J. J. Ewel, eds. 765 pp.

Livingston, R. J. 1990. Inshore Marine Habitats *in* Ecosystems of Florida, R. L. Myers and J. J. Ewel, eds. 765 pp.

Puri, H. S. and R. O. Vernon. 1964. Summary of the geology of Florida and a guidebook to the classic exposures: Florida Geological Survey Special Publication 5 (revised), 312 pp.

Rupert, F. R. 1991. Geology of Gulf County, Florida. Florida Geological Survey Bulletin No. 63, Tallahassee, Florida. 51 pp.

Sternberg, L. S. L. and P. K. Swart. 1987. Utilization of freshwater and ocean water by coastal plants of southern Florida. Ecology 68(6): 1898-1905.

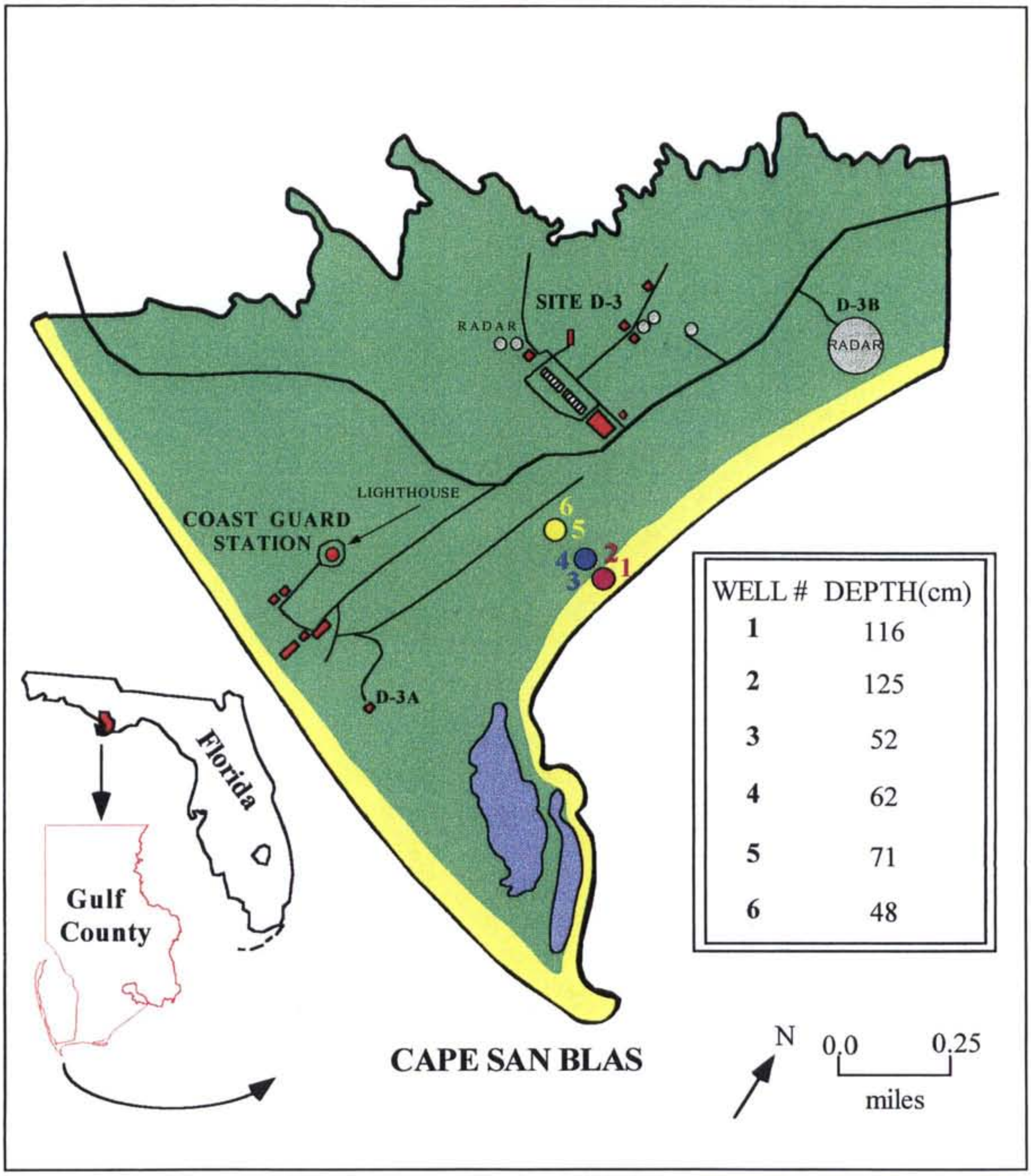
Table 3-1. Depth in centimeters (a) and salinities in parts per thousand (b) of freshwater wells placed within the surficial water table through three habitats along Eglin air Force Base on Cape San Blas, Florida from November 18-20, 1994 and February 16-17, 1996. Well numbers 1 and 2 were placed in dune habitat, 3 and 4 in swale habitat, and 5 and 6 in flatwoods.

a.

	WELL DEPTHS					
	1	2	3	4	5	6
18-Nov	1.5	0.0	1.5	1.0	1.0	1.0
19-Nov	1.0	0.5	0.5	1.0	1.0	1.0
20-Nov	0.0	0.0	0.0	0.5	0.5	1.0
16-Feb	0.5	0.5	1.0	1.0	0.5	0.5
17-Feb	1.5	1.0	0.5	0.5	0.5	0.5

b.

	WELL SALINITIES					
	1	2	3	4	5	6
18-Nov	1.0	0.0	0.0	1.0	1.0	0.0
19-Nov	0.0	0.0	1.0	1.0	0.0	0.0
20-Nov	1.0	0.0	1.0	0.0	0.0	1.0
16-Feb	1.0	0.0	1.0	1.0	0.0	0.0
17-Feb	0.0	0.0	0.0	0.0	0.0	0.0



WELL #	DEPTH(cm)
1	116
2	125
3	52
4	62
5	71
6	48

Figure 3-1. Locations and depths of freshwater wells (numbers 1-6) placed along a transect through flatwoods ( ),swale ( ), and dunes ( ) on Eglin Air Force Base along Cape San Blas, Florida. Water depths and salinities in wells sampled in November 1995 and February 1996 indicated the surficial water table along Cape San Blas was not influenced by salt water intrusion.

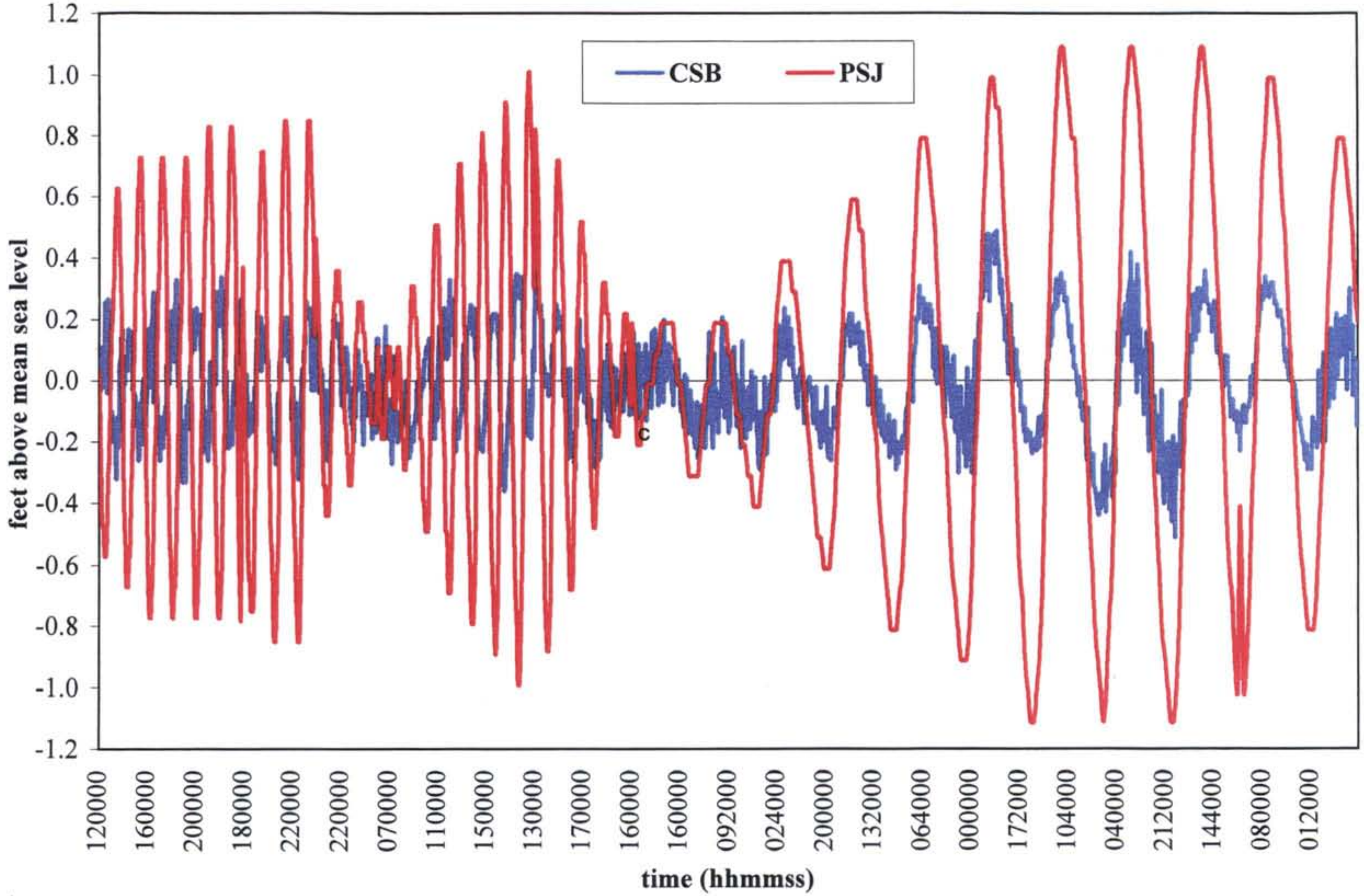


Figure 3-2a. Tidal ranges off Port St. Joe, Florida versus those off Cape San Blas, Florida from July 26 to November 27, 1995.

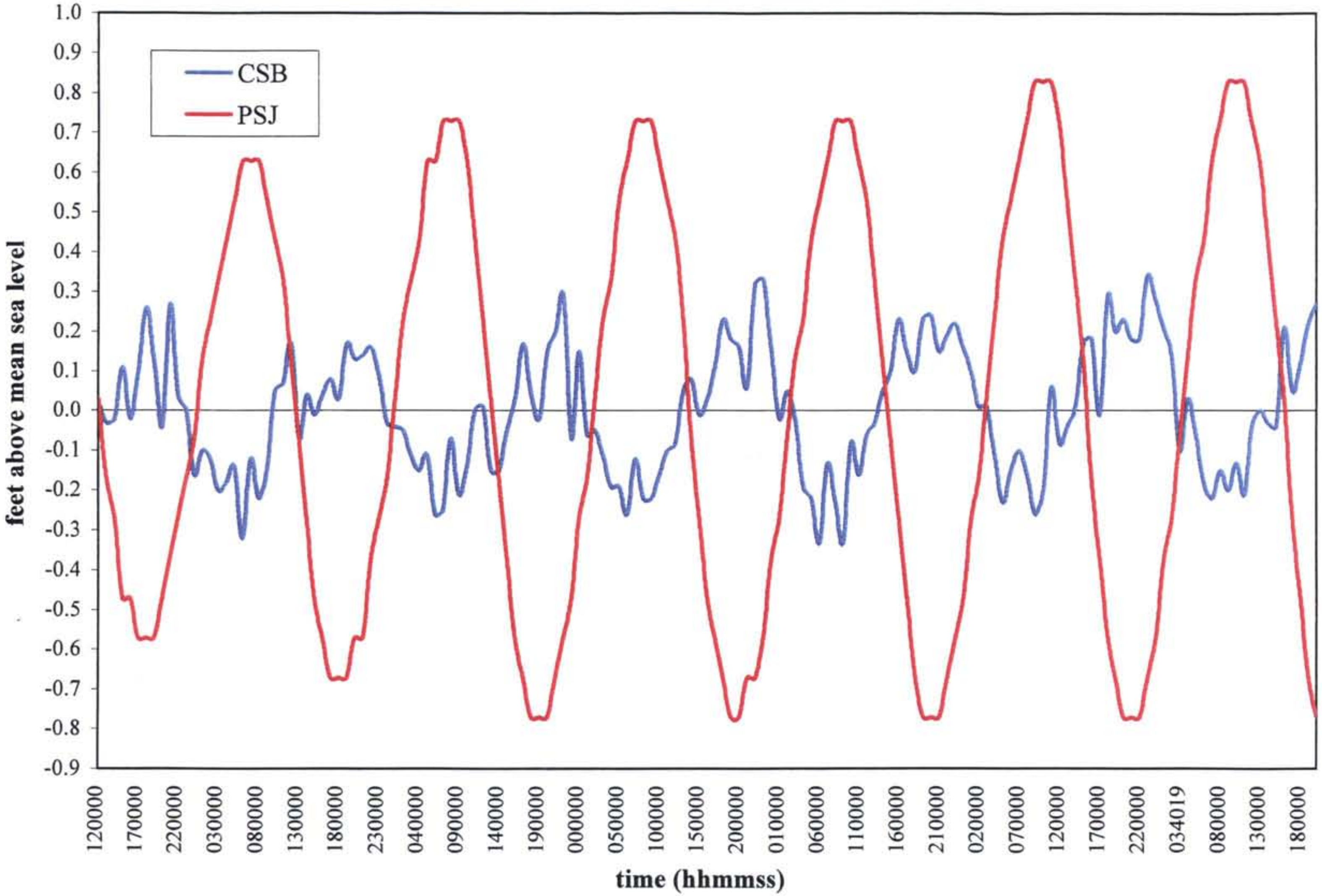


Figure 2b. Tidal ranges off Port St. Joe, Florida versus those off Cape San Blas, Florida from July 20 - 26, 1995.

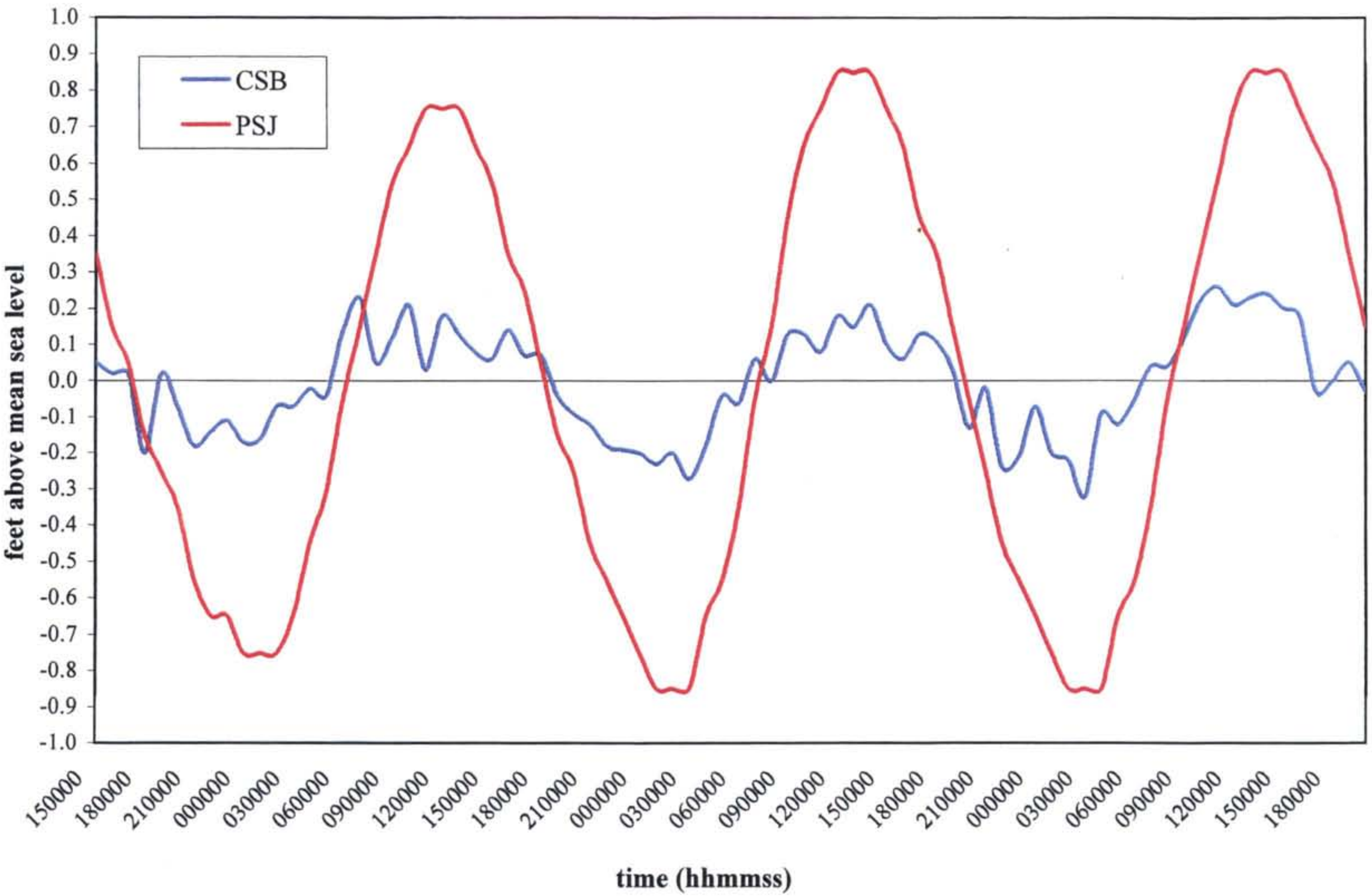


Figure 2c. Tidal ranges off Port St. Joe, Florida versus those off Cape San Blas, Florida from September 27 - 30, 1995.

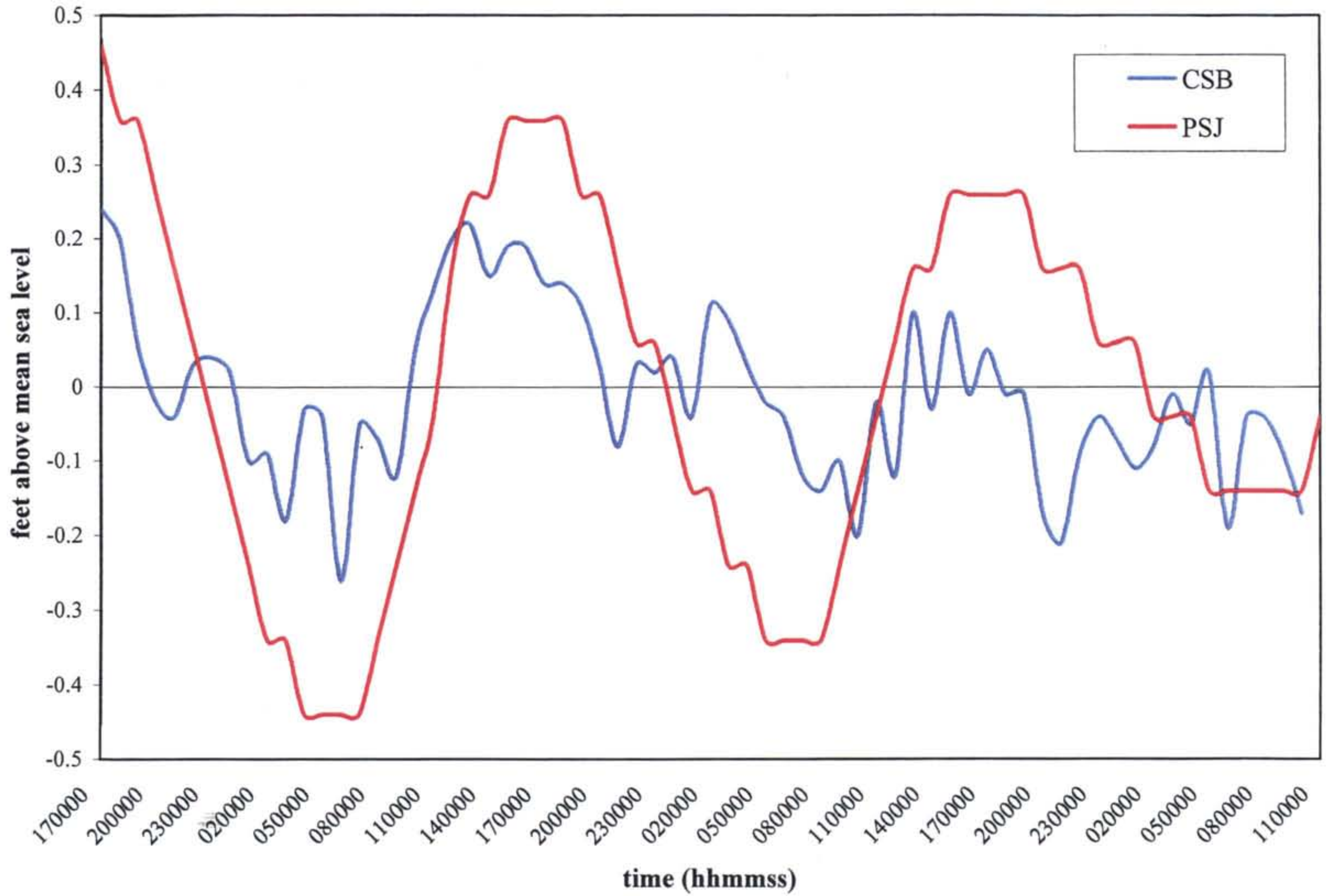


Figure 2d. Tidal ranges off Port St. Joe, Florida versus those off Cape San Blas, Florida from October 17 - 20, 1995.

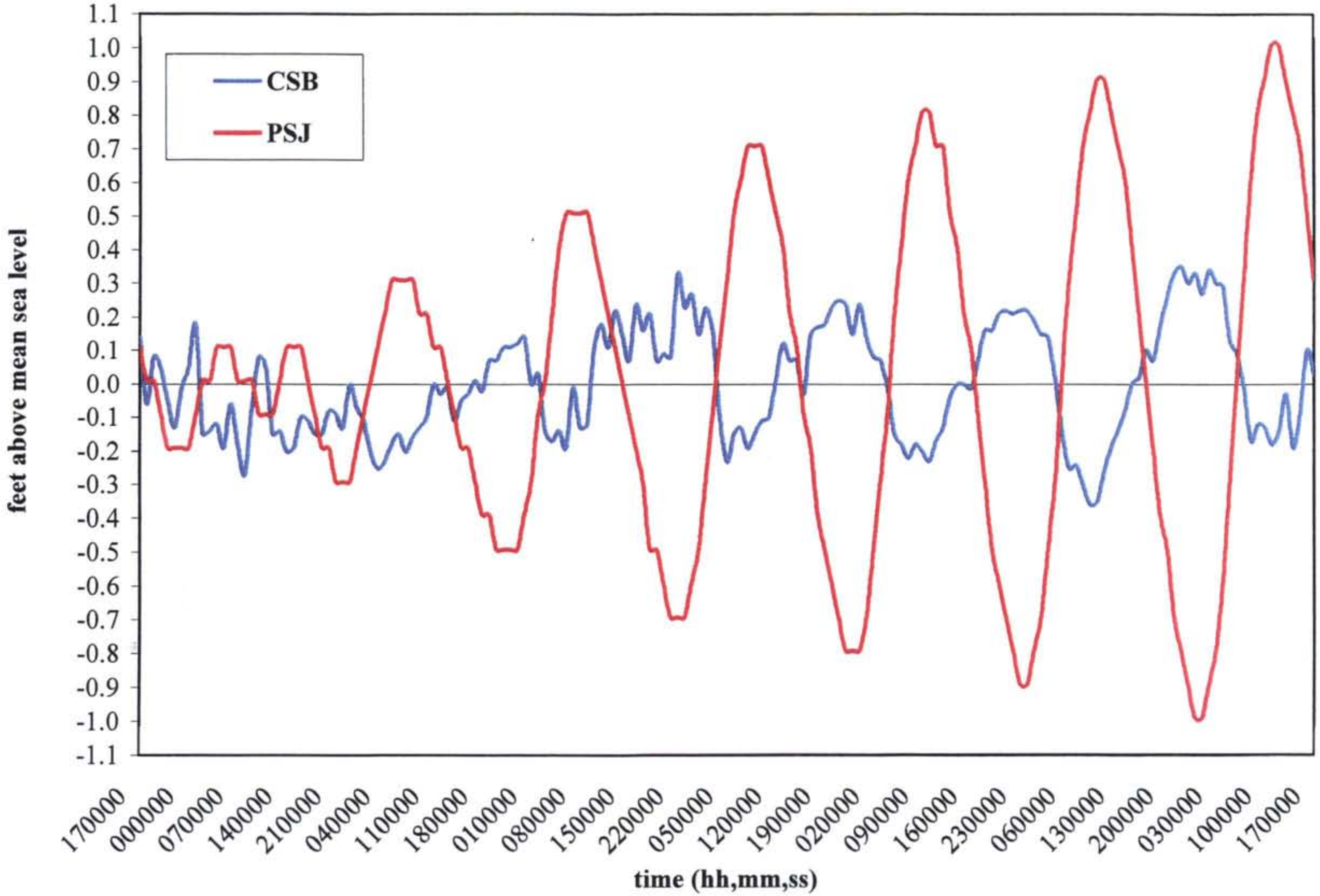


Figure 2e. Tidal ranges off Port St. Joe, Florida versus those off Cape San Blas, Florida from October 20 - 27, 1995.

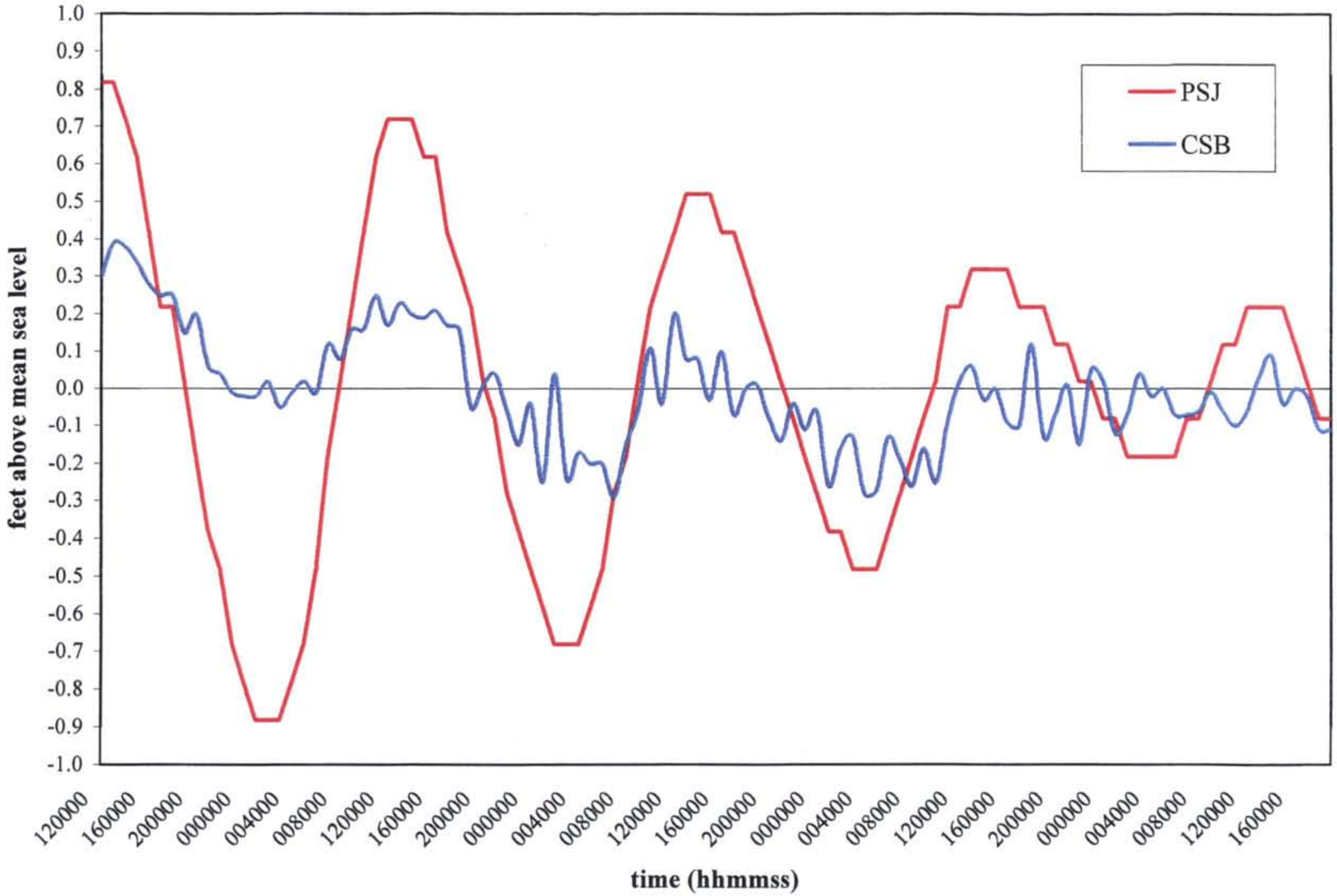


Figure 2f. Tidal ranges off Port St. Joe, Florida versus those off Cape San Blas, Florida from October 29 - November 2, 1997.

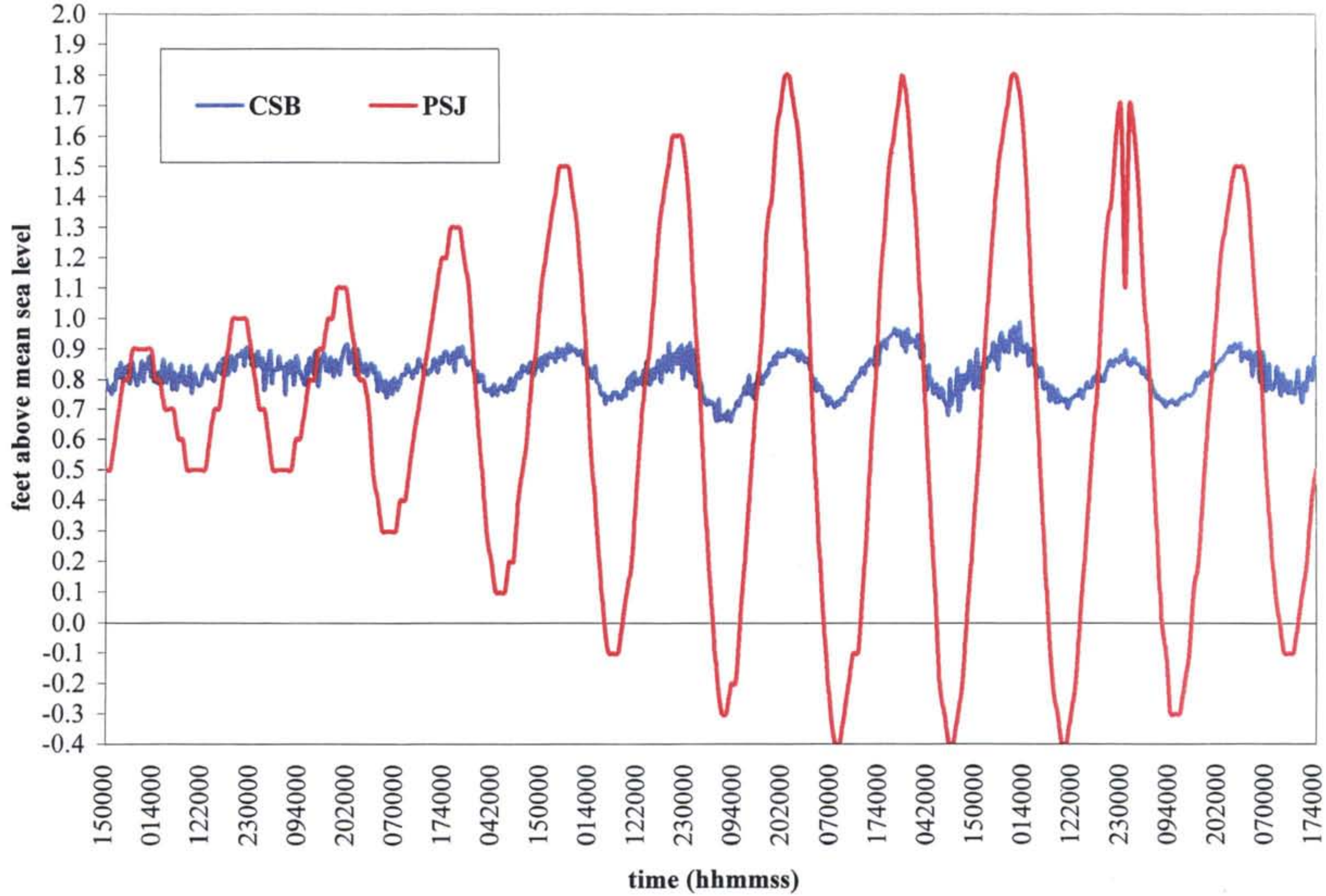


Figure 2g. Tidal ranges off Port St. Joe, Florida versus those off Cape San Blas , Florida from November 16 -27, 1995.

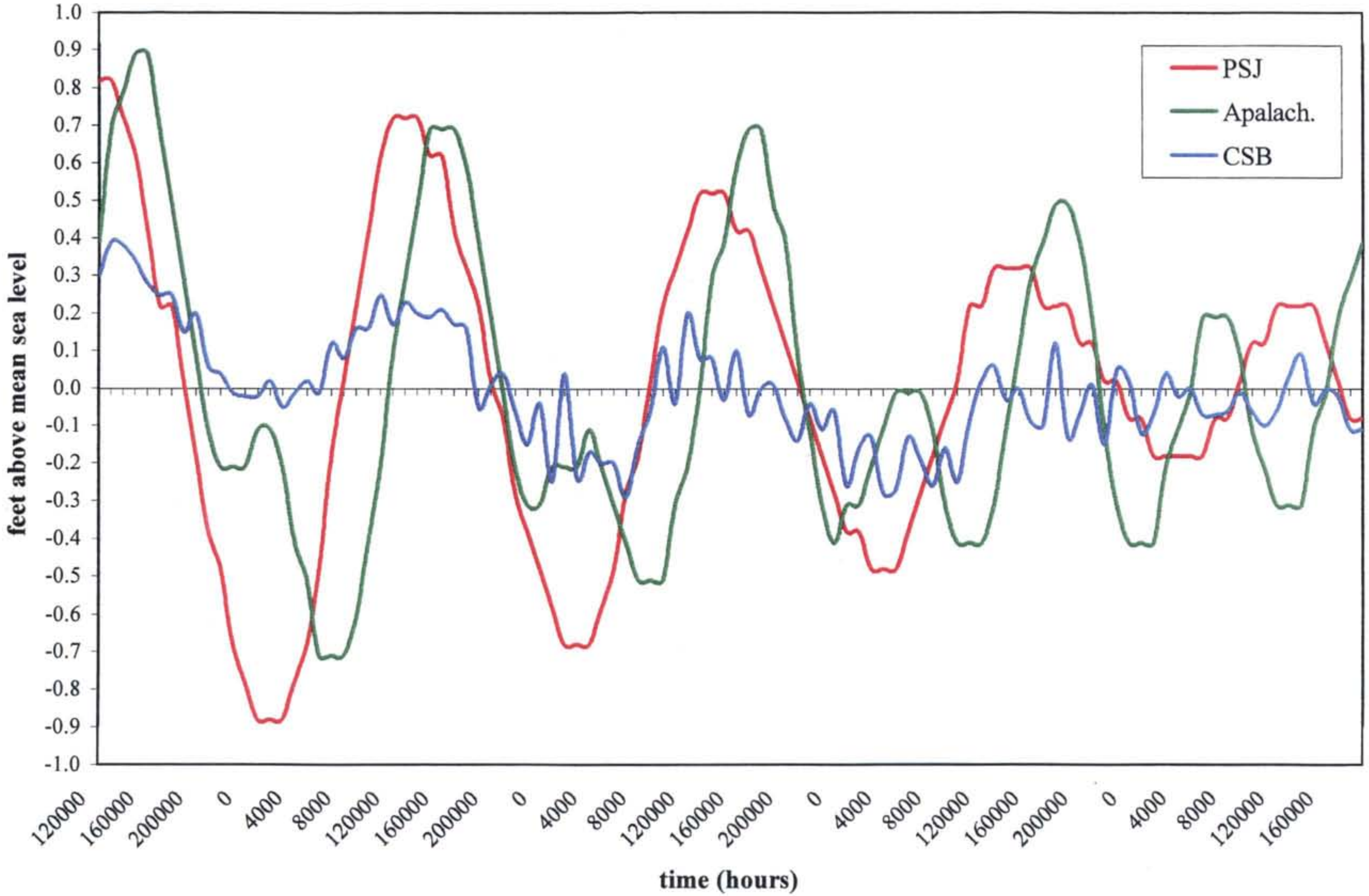


Figure 3-3. Tidal ranges off Cape San Blas, Florida versus those off Apalachicola and Port St. Joe, Florida from October 29 to November 2, 1995.

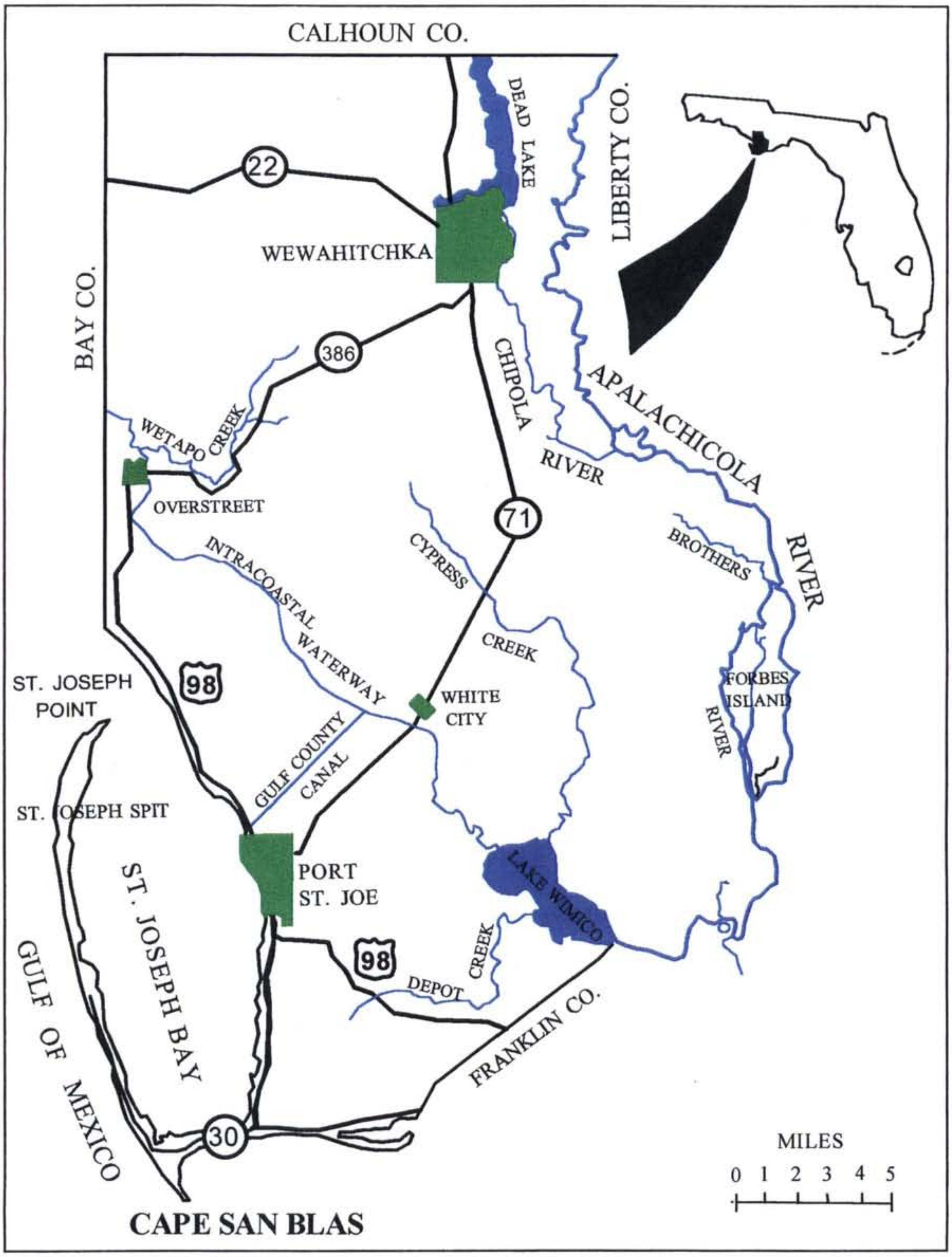


Figure 3-4. Gulf County, Florida, located along the Florida panhandle, is where the Cape San Blas Ecological Study was conducted from April 1994 to April 1996.

CHAPTER 4

SOILS

Introduction

The following is a report on the major characteristics of the soils located along Eglin Air Force Base property on Cape San Blas. Often, changes in vegetation types occur across major soil boundaries, therefore identifying soils types may aid in understanding the various vegetative habitats located in an area (Brown et al. 1990). The soil types located along Cape San Blas are most likely influenced by the source material of this barrier island (see erosion chapter) and the water table (see hydrology chapter) supplying the soils with nutrients. Soils were collected throughout the various habitats on Cape San Blas to accomplish the following objectives:

1) provide a more detailed soil map of the area
2) conduct chemical and physical analyses of the soils, and
3) describe morphological characteristics of the soils.

Methods

Soil samples were collected by personnel in the Soil and Water Science Department at the University of Florida during 1995 and 1996. Soils were collected from the surface to maximum depths that ranged from 60 to 180 cm. The sampling of the very wet soils at greater depths was limited by the high water table and saturated conditions. Samples were collected from each major horizon and subhorizon and subsamples were taken within horizons that were more than 50 cm thick.

Laboratory analyses were completed on soils sampled in the following soil map units:

2 – Bayvi fine sand, tidal

3 – Beaches

6A – Corolla sand, 0-1% slopes, frequently flooded

6B – Corolla fine sand, 1-5% slopes (soils were sampled from three map unit sites).

8 – Duckston fine sand, frequently flooded

9 – Kureb fine sand, high dunes

11 – Pickney and Rutlege soils

12 – Resota fine sand, 0 – 5% slopes

Laboratory Analyses

Laboratory analyses included:

Physical properties (Table 4-1): % Very Coarse (VC), Coarse (C), Medium (M), Fine (F), and Very Fine (VF) sand; % Total Sand; and %Silt and Clay.

Chemical properties (Table 4-2): pH, % Organic Carbon (OC), and meq/100 g of soil of Calcium (Ca), Potassium (K), Phosphorus (P), and Sodium (Na).

Mapping

Mapping of soil units was completed by Dr. Mary E. Collins, Professor of Environmental Pedology in the Soil and Water Science Department, Institute of Food and Agricultural Sciences, University of Florida, and the following graduate students in the Soil and Water Science Department: David C. Heuberger, J. Reid Hardman, and Laura Anderson. Hand augers were used to sample, describe, and map the soils.

Blue-line copies of the Florida Department of Transportation maps were used as the base map for the soil mapping. The soil delineations were completed on the maps which have a scale of one inch = 400 feet. One copy of the soil maps that were produced are being provided as a separate document from this report (Fig. 4-2). The symbol (i.e. 6A) in each delineation refers to a specific soil mapping unit identified in that area.

Results

The results of the particle size analyses indicates all the soils sampled along Cape San Blas were high in sand content with just a very small amount of silt and clay (generally <1%). The fine sand size fraction dominated the sands as all the soils sampled contained >50% fine sand with the exception of map unit 6A: Corolla sand, frequently flooded. This map unit contained >50% medium sand in most of the horizons. In addition, the frequently flooded unit contained a higher percentage of coarse sand than the other soils sampled. These differences in sand sizes may reflect the effects of the frequent flooding and rapid water movement. The other soils sampled generally had a very low content of coarse sand as well as a very low content of very coarse sand and very fine sand. The dominance of the fine and medium sand sizes may indicate a uniform rate of depositions of the sandy sediments.

The following are the soil map units that were identified and shown on the blue-line copies of the Florida Department of Transportation maps. The numbers that identify the map units are shown on the maps.

1 – Arents

2 – Bayvi fine sand, tidal

3 – Beaches

4 – Beach wash

5 – Borrow area

6A – Corolla sand, 0 to 1% slopes, frequently flooded

6B – Corolla fine sand, 1 to 5% slopes

7 – Corolla and Resota sands, dune sequence

8 – Duckston fine sand, frequently flooded

8B – Duckston muck, buried surface layer

9 – Kureb fine sand, high dunes

10 – Kureb and Corolla fine sands, high dunes

11 – Pickney and Rutlege soils

12 – Resota fine sand, 0 to 5% slopes

13 – Rutlege fine sand, depressional

Discussion

Descriptions of soil map units

1 – Arents

This map unit consists of soils that contain a heterogeneous mixture of material that were removed from other areas and used in land leveling or a fill material to elevate building sites. The soils in this map unit are variable, and have not developed an orderly sequence of horizons.

2 – Bayvi fine sand, tidal

The Bayvi soils are very poorly drained and occur in low-lying depressional areas that are subject to tidal flooding by normal high tides. Bayvi soils have a thicker surface layer and higher organic matter content in the surface layer than most other soils mapped. The low-lying landscape position and poor drainage with anaerobic conditions allows for the accumulation of organic matter and the resulting thicker surface layer. The effect of the tidal flooding is evident in the chemical analyses of the pedon that is shown in Table 4-2. The Bayvi soils have a moderately high content of calcium and very high levels of sodium, especially in the surface layers (0-45 cm). The pH of the soils is neutral or slightly acid in the supper surface layers, but becomes very strongly acid immediately below the surface layer. The lower pH is likely a reflection of a high content of sulfates that are accumulating under these very wet conditions.

3 – Beaches

The beaches map unit consists of narrow strips of sandy materials immediately adjacent to the waters of the Gulf of Mexico. Beaches are covered daily with saltwater at high tides. Because beaches received daily flooding, these soils have not had an opportunity to develop diagnostic soil horizons. some areas of beaches may appear to be fairly uniform throughout with the other areas lack any consistent pattern of development of soils horizons with depth. For this reason, a soil series name (such as Bayvi, Corolla, etc) was not assigned to this map unit. Beaches have a very high content of calcium and sodium in the surface layer, as shown in Table 4-2. The calcium and sodium content decreases irregularly with depth. In the soil sampled, the content of calcium and sodium remained quite high to a depth of about 97 cm. The pH in the soils sampled was consistently slightly to medium acid throughout. Beaches are sand textures throughout, but contain a slightly higher content of medium sand and less fine sand than may of the higher-lying soils.

4 – Beach wash

Beach wash consists of low-lying areas below and behind the beaches in which sands from the beaches have been washed into the area and accumulated. This map unit only occurs in very small areas.

5 – Borrow area

This map unit consists of areas in which soil materials have been excavated for other use such as fill material around buildings, roads, etc.

6A – Corolla sand, 0 to 1% slopes, frequently flooded

The Corolla soils in this map unit formed in sandy alluvial deposits overlying marine sediments on low-lying swales behind the beaches. Because the areas in which these occur are so low-lying, the soils in this map unit are subject to frequent flooding during the periods of high tides. The flooding is probably the reason that these soils have a sand fractions that is dominated by medium sands rather than the fine sands typical of the marine sediments. The soils in this map unit also have a higher percentage of coarse and very coarse sands than the soils in other map units. Corolla soils typically have light-colored layers (C horizons) overlying a slightly darker-colored layer which is considered a buried A horizon (original surface layer). The Corolla soils in this map unit are poorly drained and have a high water table near the surface. The chemical analyses in Table 4-2 show the Corolla soils in this map unit have a very high content of calcium and sodium. The calcium content is the highest of any of the soils sampled. The surface layer of the Corolla soils has a very high calcium content, the calcium decreases with depth, but then increases greatly to levels similar to the surface layer in the buried A horizons at a depth of about 55 cm. The sodium content as well as the content of potassium also increases substantially in the buried A horizons at a depth of 55 cm. The pH levels reflect the high calcium content s with pH levels ranging to moderately alkaline (pH 8.2). It can be seen that when the sodium content increased in the buried A horizon, the pH of the soil decreased.

6B – Corolla fine sand, 1 to 5% slopes

The Corolla soils in this map unit occur on gently sloping coastal dunes. These soils are moderately well and somewhat poorly drained and have a water table at depths of about 20 to 60 cm below the surface. The Corolla soils typically have a very thin light gray or gray A horizon underlain by thick, white fine sands in the C horizons. The Corolla soils in this map unit were sampled for chemical and physical analyses at three different locations. The chemical analyses generally showed very low levels of calcium, potassium, phosphorus,, and sodium. The levels of these elements were very much lower than the poorly drained and frequently flooded soils, and were similar to the levels in the better drained Kureb and Resota soils. The pH levels of the Corolla soils in this map unit were mostly medium acid, with a few layers ranging to strongly acid. In contrast, the pH levels of the Corolla soils in the frequently flooded map unit ranged from neutral to moderately alkaline (pH of 8.2)

7 – Corolla and Resota fine sand, dune sequence

This map unit consists of a regular sequence of higher-lying dunes that are separated by the lower-lying swales. The Corolla and Resota soils are so closely associated in this map unit that it was not possible to separate them at the scale of mapping. Corolla soils are on the lower-lying portions of the dunes, and are somewhat poorly drained. The Corolla soils have a seasonal high water table at depths of about

20 to 60 cm. Resota soils are on the more sloping, higher-lying parts of the dunes and are moderately well drained. The Resota soils have a seasonal high water table at depths of about 100 to 150 cm for portions of the year. The water table will be below a depth of 180 cm during the dry times of the year.

8 – Duckston fine sand, frequently flooded

The Duckston soils in this map unit are poorly to very poorly drained and occur in low-lying swales between dunes. These low-lying areas are subject to frequent flooding and ponding, and the soils have a water table at or near the soil surface for much of the year. The organic carbon content of the surface layer (0-15 cm) of the soil sampled was 4.6%. This is quite high for a sandy soil, and is a reflection of the wet conditions under which these soils formed. The calcium content of the surface layer was also high. The calcium levels decreased substantially in the 15-34 cm depth, and then increased in the underlying layers. This variability with depth is not surprising in a soil that is subject to frequent flooding. The sodium and potassium levels were not as high, but followed a similar trend with the surface layer having the highest amount, a substantial decrease in the 15-34 cm depth, and an increase in the lower depths sampled. Phosphorus levels were not high, but were considerably higher than in the better drained Corolla, Resota, and Kureb soils, and were similar to the frequently flooded, poorly drained Corolla soils. The pH of the Duckston soil sampled was neutral throughout. This is in contrast to the better drained soils which generally had a pH of medium acid, and sharply contrasting with the tidal Bayvi soils which had a pH that ranged to strongly and very strongly acid (pH of 4.7)

8B – Duckston muck, buried surface layer

The Duckston soils in this map unit are in low-lying depressional areas that re subject to ponding of water most of the year. These soils are very poorly drained and have a water table above the surface for much of the eyar. The soils in this map unit have a black muck (organic material) surface layer, about 10 to 15 cm thick. The development of muck on the surface is a good indication of the very wet conditions under which this soil has formed. Underlying the muck are black and dark gray fine sands, similar to the sand in Duckston map unit 8.

9 – Kureb fine sands, high dunes

The Kureb soils in this map unit are excessively drained sands with a water table that remains below a depth of 180 cm throughout the year. Particle size data on the soil sampled in this map unit shows the soils contains about 80% fine sand or greater in all layers, except for the 0-3 and 3-10 cm depths. The two upper layers contain a much higher percentage of medium sand. Chemical analyses also show the upper two layers contain a considerably higher content of calcium and potassium, . Except for the higher levels of calcium and potassium in the surface layers, the levels of calcium, potassium, phosphorus, and sodium are generally quite low throughout. This is as expected as the elements leach through this excessively drained soil very easily. The sodium level of the soil sampled did increase considerably at a depth of 61071 cm, and sodium may be accumulating above this layer. The pH of the Kureb soil was medium acid throughout.

10 – Kureb and Corolla fine sands, high dunes

This map unit is similar to map unit 9, except the dunes are more undulating with the resulting lower-lying areas that are not as well drained. Most areas of this map unit are associated with the very poorly drained Duckston soils. The lower-lying areas in this map unit consist mainly of Corolla soils which have a seasonal high water table at depths of about 45 to 90 cm. The depth to the seasonal high water table in the Kureb soils is >180 cm. The higher-lying and lower-lying areas are so closely associated on these dunes that is was not possible to separate the two soils on the maps.

11 – Pickney and Rutlege soils

These very poorly drained soils are in poorly-defined drainage-ways. Often this unit occurs within areas of the poorly drained, frequently flooded Corolla soils (map unit 6A) or the very poorly drained frequently flooded Duckston soils (map unit 8). The Pickney and Rutlege soils are very similar. The major difference in the soils is that Pickney soils have a very thick, dark-colored surface layer 60 cm or more thick. The surface layer in the Rutlege soils is thinner. The thick, dark-colored surface layer in the Pickney soils is an indication of the very wet conditions in which organic matter is accumulating. Because the Pickney soils were so wet, only the Rutlege soils were sampled and described.

In the Rutlege soils mapped at Cape San Blas, the upper part of the surface layer consisted of organic materials (muck). The muck was 9 cm thick in the soils that was sampled and described. The organic carbon content of that layer was 21%. The organic carbon content of many of the other soils mapped was not analyzed as it was apparent the content of organic matter was less than 1%. Only the very poorly drained Bayvi and Duckston soils had significant levels of organic carbon, but the organic carbon content of the Rutlege soils was much higher than any of the other soils The accumulation of the organic matter in the Rutlege oils is another indication of the very wet conditions under which these soils are also forming Chemical analyses of the Rutlege soils sampled shows that the organic surface layer contains very high levels of calcium, potassium, and sodium,. The organic layer of the Rutlege soils had the highest levels of these level of these elements of all the soils sampled.

12 – Resota fine sand, 0 to 5% slopes

Resota soils are on the nearly level to gently sloping areas o the dunes and are moderately well drained. The Resota soils have a seasonal high water table at depths of about 100 to 150 cm for portions of the year. The water table will be below a depth of 180 cm during the dry times of the year. Resota soils are sandy to depths of more than 180 cm, are very low in organic matter, and are low in fertility, similar to the Corolla soils.

13 – Rutlege fine sand, depressional

The Rutlege soils in this map unit are very poorly drained, and are sandy throughout. The Rutlege soils can be expected to have a water table at or near the surface for much of the year, and will experience ponding of water above the surface after heavy rainfall or tidal flooding.

Acknowledgements

The Soil and Water Science Department would like to thank Ronald Kuehl, David Heuberger, J. Reid Hardman, Jared Brown, Laura Anderson, and Lucy Zamorano for their assistance with the field mapping, collection of samples, analysis of samples, and writing of the report. This investigation could not have been completed without them.

Literature Cited

Brown, R. B., E. L. Stone, and V. W. Carlisle. 1990. Soils *in* Ecosystems of Florida, R. L. Myers and J. J. Ewel, eds., Central Florida Press, Orlando, FL.765 pp.

DESCRIPTIONS OF SOILS SAMPLED AT CAPE SAN BLAS

Soil Map Unit #2 - Bayvi fine sand, tidal

Drainage: very poorly drained.
Depth to Water Table at the time of sampling: at the surface.
Depth to Seasonal High Water Table: above the surface (soil is inundated at high tide).
Soil Series Sampled: Bayvi
Soil described by: Mary E. Collins, David C. Heuberger, J.Reid Hardman, and Jared Brown.
Date described: January 18, 1995

Horizon	Depth (cm)	Description
A1	0 - 34	black (10YR 2/1) fine sand; weak fine granular structure; friable; slightly sticky; common fine and medium roots; neutral to slightly acid; clear smooth boundary.
A2	34 - 60	very dark grayish brown (10YR 3/2) fine sand; common splotches or streaks of dark gray (10YR 4/1); loose; single grained; few fine and medium roots; strongly to very strongly acid.
Cg	60 - 110	dark gray (10YR 4/1) fine sand; loose; single grained; very strongly to slightly acid.

Soil Map Unit #3 - Beaches

Drainage: moderately well to poorly drained.
Depth to Water Table at the time of sampling: 81 cm.
Depth to Seasonal High Water Table: at the surface.
Soil Series Sampled: No named series. Soil has not developed any diagnostic horizons.
Soil described by: David C. Heuberger, J.Reid Hardman, and Laura Anderson.
Date described: June 28, 1995

Horizon	Depth (cm)	Description
C1	0 - 10	white (10YR 8/1) fine sand; loose; single grained; slightly acid; clear smooth boundary.
C2	10 - 22	gray (10YR 6/1) fine sand; loose; single grained; slightly acid; clear smooth boundary.
C3	22 - 40	white (10YR 8/1) fine sand; loose; single grained; common fine faint very pale brown (10YR 7/3) mottles; slightly acid; diffuse smooth boundary.
C4	40 - 81	white (10YR 8/1) fine sand; loose; single grained; slightly acid; clear smooth boundary.
C5	81 - 97	light brownish gray (10YR 6/2) fine sand; loose; single grained; slightly acid; clear smooth boundary.
C6	97 - 104	dark brown (7.5YR 3/3) fine sand; loose; single grained; medium acid; clear smooth boundary.
C7	104 +	light gray (10YR 7/1) fine sand; loose; single grained; medium acid.

Soil Map Unit #6A - Corolla sand, frequently flooded

Drainage: poorly drained.
Depth to Water Table at the time of sampling: 5 cm.
Depth to Seasonal High Water Table: 0 to 5 cm.
Soil Series Sampled: Corolla Variant (wet phase).
Soil described by: Mary E. Collins, David Heuberger, J. Reid Hardman, and Jared Brown.
Date described: January 18, 1995

Horizon	Depth (cm)	Description
A	0 - 4	dark grayish brown (10YR 4/2) and grayish brown (10YR 5/2) sand; loose; single grained; few fine prominent reddish yellow (5YR 6/6) redox concentrations; mildly alkaline; clear smooth boundary.
Cg1	4 - 10	light brownish gray (10YR 6/2) sand; loose; single grained; common medium distinct dark grayish brown (10YR 4/2) organic accumulations; many medium distinct reddish yellow (7.5YR 6/6) and common fine prominent yellowish red (5YR 5/6) redox accumulations (oxidized rhizospheres); common fine roots; moderately alkaline; gradual smooth boundary.
Cg2	10 - 27	light brownish gray (10YR 6/2) sand; loose; single grained; many very fine shell fragments; common medium distinct dark grayish brown (10YR 4/2) and very dark grayish brown (10YR 3/2) organic stains; very few fine roots; moderately alkaline; gradual smooth boundary.
Cg3	27 - 55	gray (10YR 6/1) sand; loose; single grained; few very fine shell fragments; common medium distinct very dark grayish brown (10YR 3/2) organic stains; very few fine roots; mildly to moderately alkaline; abrupt smooth boundary.
Ab1	55 - 85	black (N 2/0) fine sand; loose; single grained; neutral; gradual smooth boundary.
Ab2	85 - 96	dark gray (N 4/0) sand; loose; single grained; common very fine shell fragments; neutral; clear smooth boundary.
Cg	96 - 106	greenish gray (5GY 6/1) sand; loose; single grained; few medium intact shells; common fine and very fine shell fragments; neutral.

Soil Map Unit #6B - Corolla fine sand, 1 to 5% slopes

Drainage: moderately well to somewhat poorly drained.
Depth to Water Table at the time of sampling: 87 cm.
Depth to Seasonal High Water Table: 45 cm.
Soil Series Sampled: Corolla.
Soil described by: Laura Anderson.
Date described: June 28, 1995

Horizon	Depth (cm)	Description
A	0 - 3	gray (10YR 6/1) fine sand; loose; single grained; strongly acid; clear smooth boundary.
C1	3 - 67	light gray (10YR 7/1) fine sand; loose; single grained; medium to strongly acid; clear smooth boundary.
C2	67 - 87	light brownish gray (10YR 6/2) fine sand; loose; single grained; medium acid; clear smooth boundary.

Soil Map Unit #6B - Corolla fine sand, 1 to 5% slopes

Drainage: moderately well drained.
Depth to Water Table at the time of sampling: 105 cm.
Depth to Seasonal High Water Table: 45 cm.
Soil Series Sampled: Corolla.
Soil described by: J. Reid Hardman and David C. Heuberger
Date described: June 29, 1995

Horizon	Depth (cm)	Description
A	0 - 8	light gray (10YR 7/1) fine sand; loose; single grained; few fine roots; strongly acid; clear wavy boundary.
C1	8 - 105	white (10YR 8/1) fine sand; loose; single grained; medium acid; diffuse wavy boundary.
C2	105 +	white (10YR 8/1) fine sand; loose; single grained; common fine to medium very dark gray (10YR 3/1) organic stains.

Soil Map Unit #6B - Corolla fine sand, 1 to 5% slopes

Drainage: moderately well drained.
Depth to Water Table at the time of sampling: >100 cm.
Depth to Seasonal High Water Table: 45 cm.
Soil Series Sampled: Corolla.
Soil described by: Laura Anderson
Date described: June 28, 1995

Horizon	Depth (cm)	Description
A	0 - 10	gray (10YR 5/1) fine sand; loose; single grained; few fine roots; strongly acid; gradual wavy boundary.
C1	10 - 80	pale brown (10YR 6/3) fine sand; loose; single grained; medium acid; clear smooth boundary.
C2	80 - 90	gray (10YR 6/1) fine sand; loose; single grained; common fine faint grayish brown (10YR 5/2) mottles; medium acid; gradual smooth boundary.
C3	90 - 100	light gray (10YR 7/1) fine sand; loose; single grained; medium acid.

Soil Map Unit #8 - Duckston fine sand, frequently flooded

Drainage: poorly to very poorly drained.
Depth to Water Table at the time of sampling: at the surface.
Depth to Seasonal High Water Table: At the surface or above.
Soil Series Sampled: Duckston
Soil described by: Mary E. Collins, David C. Heuberger, J.Reid Hardman, and Jared Brown.
Date described: January 18, 1995.

Horizon	Depth (cm)	Description
A	0 - 15	very dark grayish brown (10YR 3/2) fine sand; weak fine granular structure; very friable; many medium and coarse roots; neutral; clear smooth boundary.
Cg	15 - 61	light gray (10YR 7/2) fine sand (A horizon); common medium distinct very dark grayish brown (10YR 3/2) organic stains; loose; single grained; few fine roots; neutral.

Soil Map Unit #9 - Kureb fine sand, high dunes

Drainage: excessively drained.
Depth to Water Table at the time of sampling: >180 cm.
Depth to Seasonal High Water Table: >180 cm.
Soil Series Sampled: Kureb
Soil described by: Mary E. Collins, David C. Heuberger, J. Reid Hardman, and Jared Brown
Date described: January 18, 1995

Horizon	Depth (cm)	Description
A	0 - 3	gray (10YR 5/1) fine sand; loose; single grained; common fine and medium roots; medium acid; gradual smooth boundary.
E	3 - 71	light gray (10YR 7/1) fine sand; loose; single grained; medium acid; clear wavy boundary.
C/Bh	71 - 120	pale brown (10YR 6/3) fine sand (E horizon) with a few bands and bodies of dark brown (7.5YR 4/4) fine sand (Bh horizon); loose; single grained; medium acid; gradual wavy boundary.
C	120 - 180	light gray (10YR 7/1) fine sand; loose; single grained; medium acid.

Soil Map Unit #11 - Pickney and Rutlege soils

Drainage: very poorly drained.
Depth to Water Table at the time of sampling: 12 cm.
Depth to Seasonal High Water Table: At the surface or above.
Soil Series Sampled: Rutlege Variant, mucky surface phase (Due to the very wet conditions, only the Rutlege part of this complex was sampled. The lab data confirms that this complex is wetter than typical for these soils as the surface layer is a muck texture (organic soil). This confirms that the soil has water ponded on the surface for much of the year.
Soil described by: Mary E. Collins, David C. Heuberger, J.Reid Hardman, and Jared Brown.
Date described: January 18, 1995.

Horizon	Depth (cm)	Description
Oi	0 - 9	muck; an organic mat composed mostly of undecomposed and partially decomposed leaves and roots.
A	9 - 19	very dark gray (5Y 3/1) fine sand; weak fine granular structure; friable; many fine, medium and coarse roots above the water table; medium acid; clear smooth boundary.
A/Cg	19 - 28	gray (10YR 5/1) fine sand (A horizon), and light gray (10YR 7/1) fine sand (Cg horizon); loose; single grained; slightly acid; gradual smooth boundary.
Cg	28 - 60	very pale brown (10YR 7/3) fine sand; loose; single grained; neutral.

Soil Map Unit #12 - Resota fine sand, 0 to 5% slopes

Drainage: moderately well drained.
Depth to Water Table at the time of sampling: 170 cm.
Depth to Seasonal High Water Table: 100 to 150 cm.
Soil Series Sampled: Resota.
Soil described by: J. Reid Hardman and David C. Heuberger
Date described: June 29, 1995

Horizon	Depth (cm)	Description
A/E	0 - 13	dark gray (10YR 4/1) fine sand, (A horizon) and light gray (10YR 7/1) fine sand, (E horizon); soil has salt and pepper appearance when dry; loose; single grained; few fine and medium roots; strongly acid; clear smooth boundary.
Bw1	13 - 50	pale brown (10YR 6/3) fine sand; loose; single grained; medium acid; gradual smooth boundary.
Bw2	50 - 90	dark grayish brown (10YR 4/2) fine sand; loose; single grained; medium acid; gradual smooth boundary.
Bw3	90 - 120	very pale brown (10YR 8/3) fine sand; loose; single grained; medium acid; gradual smooth boundary.
C	120 - 170 +	white (10YR 8/1) fine sand; loose; single grained; sands are uncoated; medium acid; gradual smooth boundary.

	Table 1.	Particle Size Analyses					
DEPTH (Cm)	% VC	% C	% M	% F	% VF	% SAND	% SILT+CLAY
		MAP UNIT	2 - BAYVI	FINE SAND, TIDAL			
0-20	0.3	1.4	27.6	69.7	1.0	100.0	0.0
20-34	0.0	0.1	21.8	77.2	0.9	100.0	0.0
34-45	0.1	0.2	15.5	83.8	0.4	100.0	0.0
45-60	0.0	0.5	12.8	86.4	0.0	99.7	0.3
60-76	0.1	0.7	25.8	71.7	0.7	99.0	1.0
76-91	0.1	0.6	27.9	71.3	0.0	99.9	0.1
91-105	0.0	0.6	31.5	67.4	0.5	100.0	0.0
105-110	0.0	0.6	28.3	70.1	0.8	99.8	0.2
		MAP UNIT 3 - BEACHES					
0-10	0.0	0.6	45.3	53.8	0.1	99.8	0.2
10-22	0.2	1.6	33.2	64.2	0.3	99.5	0.5
22-40	0.1	0.8	30.9	68.1	0.1	100.0	0.0
40-53	0.0	0.1	22.6	77.1	0.1	99.9	0.1
53-63	0.0	0.2	30.6	68.9	0.1	99.8	0.2
63-81	0.0	0.9	41.5	57.5	0.1	100.0	0.0
81-97	0.1	12.0	33.4	54.4	0.1	100.0	0.0
97-104	0.0	0.7	24.0	75.2	0.1	100.0	0.0
		MAP UNIT	6A - COROLLA SAND, FREQ. FLOODED				
0-4	0.7	5.6	52.4	40.1	0.6	99.4	0.6
4-10	0.3	6.2	62.9	30.4	0.1	99.9	0.1
10-27	0.3	4.5	60.4	34.5	0.0	99.7	0.3
27-44	0.2	2.4	56.5	40.1	0.0	99.2	0.8
44-55	0.0	1.0	49.9	48.8	0.3	100.0	0.0
55-65	0.2	1.3	34.2	62.7	0.0	98.4	1.6
65-85	0.3	2.2	43.0	53.3	0.5	99.3	0.7
85-96	1.1	5.4	46.0	47.1	0.0	99.6	0.4
96-106	0.3	3.5	55.7	39.0	0.1	98.6	1.4

DEPTH (Cm)	% VC	% C	% M	% F	% VF	% SAND	% SILT+CLAY
		MAP UNIT 6B - COROLLA FINE SAND, 1 TO 5% SLOPES					
0-10	0.0	0.3	30.2	68.9	0.2	99.6	0.4
10-27	0.0	0.2	28.4	70.1	0.2	98.9	1.1
27-47	0.0	0.2	31.7	67.9	0.2	100.0	0.0
47-67	0.0	0.4	36.4	63.0	0.1	99.9	0.1
67-87	0.0	0.3	33.6	66.0	0.1	100.0	0.0
		MAP UNIT 6B - COROLLA FINE SAND, 1 TO 5% SLOPES					
0-8	0.0	0.1	20.2	79.2	0.2	99.7	0.3
8-20	0.0	0.1	19.2	80.5	0.2	100.0	0.0
20-36	0.0	0.0	19.3	80.5	0.1	99.9	0.1
36-50	0.0	0.2	21.9	77.5	0.2	99.8	0.2
50-60	0.0	0.1	24.6	75.0	0.1	99.8	0.2
60-75	0.0	0.1	13.1	86.7	0.1	100.0	0.0
75-90	0.0	0.2	18.6	81.1	0.1	100.0	0.0
90-105	0.0	0.2	26.4	73.2	0.1	99.9	0.1
		MAP UNIT 6B - COROLLA FINE SAND, 1 TO 5% SLOPES					
0-10	0.0	0.3	30.0	69.4	0.1	99.8	0.2
10-30	0.0	0.2	30.8	68.9	0.1	100.0	0.0
30-50	0.0	0.2	30.0	69.6	0.2	100.0	0.0
50-70	0.0	0.2	32.5	67.1	0.1	99.9	0.1
70-80	0.0	0.2	32.6	67.1	0.1	100.0	0.0
80-90	0.0	0.1	21.3	78.2	0.3	99.9	0.1
90-100	0.0	0.2	20.6	78.9	0.2	99.9	0.1
		MAP UNIT 8 - DUCKSTON FINE SAND, FREQ. FLOODED					
0-15	0.5	1.8	36.8	60.9	0.0	100.0	0.0
15-34	0.0	0.5	32.1	67.0	0.3	99.9	0.1
34-46	0.0	0.5	28.4	70.7	0.3	99.9	0.1
46-55	0.0	0.4	22.0	77.0	0.6	100.0	0.0
55-61	0.0	1.4	30.8	67.8	0.0	100.0	0.0

DEPTH (Cm)	% VC	% C	% M	% F	% VF	% SAND	% SILT+CLAY
		MAP UNIT 9 - KUREB FINE SAND, HIGH DUNES					
0-3	0.0	0.5	42.6	55.9	0.0	99.0	1.0
3-10	0.0	1.0	60.0	37.4	0.0	98.4	1.6
10-25	0.1	0.3	16.5	81.2	0.3	98.4	1.6
25-33	0.1	0.1	12.8	86.1	0.2	99.3	0.7
33-45	0.0	0.1	19.0	80.2	0.1	99.4	0.6
45-61	0.0	0.3	13.2	85.9	0.2	99.6	0.4
61-71	0.0	0.1	10.1	89.0	0.4	99.6	0.4
71-82	0.0	0.0	6.8	92.4	0.4	99.6	0.4
82-96	0.0	0.2	17.0	82.0	0.2	99.4	0.6
96-110	0.0	0.3	22.3	76.8	0.2	99.6	0.4
110-120	0.0	0.2	14.7	84.3	0.3	99.5	0.5
120-133	0.0	0.2	23.1	75.9	0.2	99.4	0.6
133-147	0.0	0.2	20.0	78.0	0.2	98.4	1.6
147-157	0.0	0.1	18.3	81.0	0.2	99.6	0.4
157-168	0.0	0.2	17.6	81.6	0.2	99.6	0.4
168-180	0.0	0.1	15.1	82.1	0.2	98.5	1.5
		MAP UNIT 11 - PICKNEY AND RUTLEGE SOILS					
0-9							
9-19	0.5	3.0	29.9	66.0	0.6	100.0	0.0
19-28	0.0	0.1	30.2	69.1	0.4	99.8	0.2
28-60	0.0	0.0	31.3	68.0	0.3	99.6	0.4

DEPTH (Cm)	% VC	% C	% M	% F	% VF	% SAND	% SILT+CLAY
		MAP UNIT 12 - RESOTA FINE SAND, 0 TO 5% SLOPES					
0-13	0.1	0.5	33.6	65.0	0.3	99.5	0.5
13-30	0.0	0.2	23.8	75.8	0.1	99.9	0.1
30-50	0.0	0.2	29.6	69.8	0.1	99.7	0.3
50-63	0.1	0.2	25.3	74.2	0.2	100.0	0.0
63-75	0.0	0.0	12.5	87.3	0.2	100.0	0.0
75-90	0.0	0.0	7.6	92.1	0.3	100.0	0.0
90-105	0.0	0.0	22.3	77.4	0.2	99.9	0.1
105-120	0.1	0.1	21.2	78.4	0.1	99.9	0.1
120-133	0.0	0.0	17.7	82.1	0.1	99.9	0.1
133-146	0.0	0.5	58.8	40.5	0.0	99.8	0.2
146-154	0.0	0.0	16.0	83.8	0.1	99.9	0.1
154-170	0.0	0.0	47.4	52.4	0.0	99.8	0.2
170+	0.0	0.0	13.5	86.4	0.0	99.9	0.1

Table2. Chemical Analyses

DEPTH (Cm)	% O.C.	pH	Ca	K	P	Na
		MAP UNIT 2 - BAYVI FINE SAND, TIDAL				
0-20	2.0	6.9	473.0	81.6	3.9	940.0
20-34	1.0	6.3	204.0	40.4	1.8	691.0
34-45	0.8	5.2	184.0	42.0	1.0	798.0
45-60	0.9	4.7	95.2	18.4	1.2	424.0
60-76		4.9	85.2	8.4	0.8	517.0
76-91		5.0	78.5	19.2	0.9	459.0
91-105		5.1	63.2	20.0	1.1	360.0
105-110		6.3	59.6	16.0	0.6	301.0
		MAP UNIT 3 - BEACHES				
0-10		6.1	586.0	14.8	1.4	346.0
10-22		6.1	78.8	27.6	2.9	279.0
22-40		6.2	19.8	8.4	1.3	127.0
40-53		6.1	16.8	9.2	0.8	218.0
53-63		6.0	15.7	8.4	0.6	196.0
63-81		6.3	25.9	6.4	0.4	240.0
81-97		6.2	55.4	13.6	14.5	172.0
97-104		6.0	12.5	0.4	1.7	53.1
		MAP UNIT 6A - COROLLA SAND, FREQ. FLOODED				
0-4		7.7	5570.0	31.6	1.2	77.9
4-10		7.9	4140.0	8.4	1.9	60.4
10-27		8.2	3440.0	5.2	3.7	50.3
27-44		8.1	3150.0	5.6	2.2	78.3
44-55		7.8	3600.0	12.8	6.0	154.0
55-65		7.3	5600.0	40.0	0.1	405.0
65-85		7.1	5410.0	45.6	6.2	412.0
85-96		7.1	5450.0	32.8	1.8	292.0
96-106		7.2	4640.0	8.4	5.6	96.4

DEPTH (Cm)	% O.C.	pH	Ca	K	P	Na		
		MAP UNIT 6B - COROLLA FINE SAND, 1 TO 5% SLOPES						
0-10		5.4	9.8	3.2	0.7	4.8		
10-27		5.4	5.9	2.0	0.7	4.7		
27-47		5.5	5.0	1.2	0.6	6.0		
47-67		5.6	3.3	2.8	0.7	8.2		
67-87		5.7	4.6	3.2	0.8	9.3		
		MAP UNIT 6B - COROLLA FINE SAND, 1 TO 5% SLOPES						
0-8		5.4	6.4	5.6	0.4	3.7		
8-20		5.6	8.6	2.4	0.8	3.8		
20-36		5.6	5.2	1.6	0.6	4.2		
36-50		6.0	5.6	4.4	0.7	6.2		
50-60		5.7	4.5	1.6	0.7	6.4		
60-75		5.7	4.0	2.0	0.4	7.6		
75-90		5.7	3.9	2.0	0.6	12.2		
90-105		5.9	3.6	0.8	0.5	8.3		
		MAP UNIT 6B - COROLLA FINE SAND, 1 TO 5% SLOPES						
0-10		5.4	30.5	4.0	1.4	7.6		
10-30		5.6	7.2	2.0	0.7	5.9		
30-50		5.7	10.4	1.2	0.5	3.5		
50-70		5.7	14.1	0.8	0.6	2.9		
70-80		5.8	6.2	1.6	0.4	3.4		
80-90		5.7	7.1	1.6	0.5	6.2		
90-100		5.7	6.4	1.2	0.8	7.5		
		MAP UNIT 8 - DUCKSTON FINE SAND, FREQ. FLOODED						
0-15	4.6	6.7	2400.0	36.8	3.8	307.0		
15-34		6.6	176.0	2.4	3.4	31.6		
34-46		7.0	918.0	3.2	4.6	63.7		
46-55		7.3	968.0	6.0	6.8	42.6		
55-61		7.3	1810.0	11.6	6.0	96.1		

DEPTH (Cm)	% O.C.	pH	Ca	K	P	Na		
		MAP UNIT 9 - KUREB FINE SAND, HIGH DUNES						
0-3		5.9	83.5	12.0	2.6	7.2		
3-10		5.1	21.0	10.0	1.1	6.0		
10-25		5.5	6.6	3.2	0.7	6.0		
25-33		5.5	5.1	3.2	0.6	4.9		
33-45		5.5	3.9	3.2	0.6	4.2		
45-61		5.6	9.4	2.4	1.0	4.8		
61-71		5.7	7.0	2.4	1.3	28.9		
71-82		5.7	5.6	1.6	0.6	7.7		
82-96		5.5	3.1	1.2	0.3	5.2		
96-110		5.6	5.3	1.2	0.7	4.2		
110-120		5.7	5.1	3.6	1.1	7.2		
120-133		5.7	4.0	1.6	1.1	4.7		
133-147		5.7	5.4	0.8	0.6	4.2		
147-157		5.7	4.8	0.8	0.3	5.2		
157-168		5.7	6.4	0.8	0.6	4.4		
168-180		5.7	5.3	0.8	0.6	3.6		
		MAP UNIT 11 - PICKNEY AND RUTLEGE SOILS						
0-9	21.2	6.0	2840.0	119.0	4.3	1270.0		
9-19	2.8	6.1	1030.0	48.0	4.4	307.0		
19-28		6.4	255.0	13.2	2.2	182.0		
28-60		6.7	80.6	4.4	0.8	61.8		

DEPTH (Cm)	% O.C.	pH	Ca	K	P	Na		
		MAP UNIT 12 - RESOTA FINE SAND, 0 TO 5% SLOPES						
0-13		5.3	22.5	4.0	1.3	9.0		
13-30		5.6	5.3	2.4	0.6	5.0		
30-50		5.6	3.6	1.2	0.5	3.4		
50-63		5.8	7.4	0.8	0.7	6.8		
63-75		5.7	5.7	0.8	0.7	4.1		
75-90		5.8	9.9	0.8	0.6	6.1		
90-105		5.9	3.8	1.2	0.7	10.0		
105-120		5.8	4.8	1.6	0.6	4.3		
120-133		5.9	4.7	0.8	0.7	4.8		
133-146		5.9	4.4	0.4	1.0	13.6		
146-154		5.7	6.3	2.8	0.9	7.2		
154-170		5.8	5.3	0.8	0.7	4.3		
170+		6.0	8.3	2.0	1.0	9.7		

NOTE: The values shown for Calcium (Ca), Potassium (K), Phosphorus (P), and Sodium (Na) are mg/kg of soil.

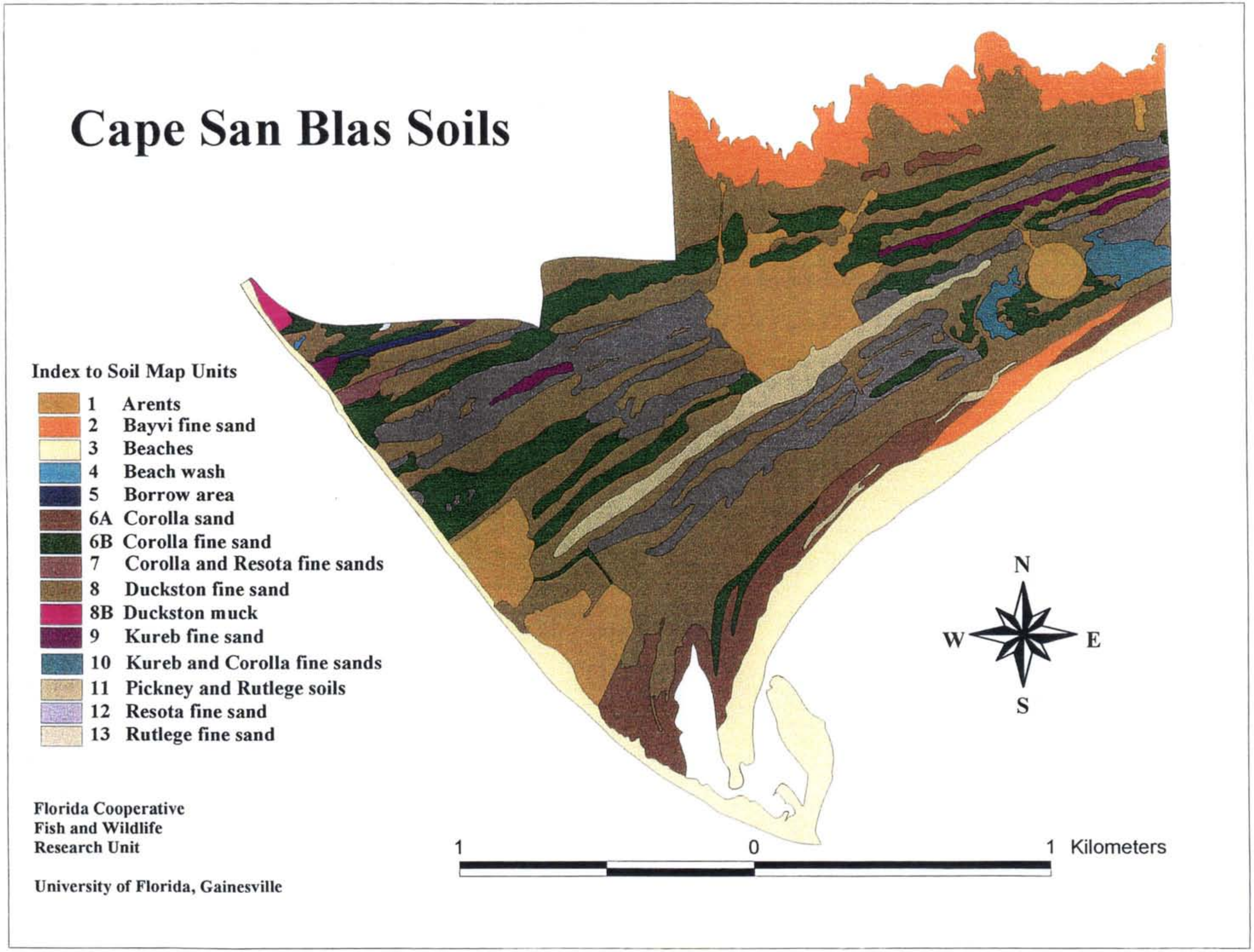

Cape San Blas Soils
Index to Soil Map Units
1 Arents
2 Bayvi fine sand
3 Beaches
4 Beach wash
5 Borrow area
6A Corolla sand
6B Corolla fine sand
7 Corolla and Resota fine sands
8 Duckston fine sand
8B Duckston muck
9 Kureb fine sand
10 Kureb and Corolla fine sands
11 Pickney and Rutlege soils
12 Resota fine sand
13 Rutlege fine sand
N
W
E
S
1
0
1 Kilometers
Florida Cooperative
Fish and Wildlife
Research Unit
University of Florida, Gainesville

Figure 4-2 (see attached map). The soil types sampled from 1994 through 1996 along Eglin Air Force Base on Cape San Blas, Florida plotted against a Florida Department of Transportation map which has a scale of 1 inch = 400 feet. Symbols indicate the specific soil mapping unit identified in that area (see Description of soil mapping units section of chapter 4).

CHAPTER 5

Shorebirds, seabirds, and wading birds

Introduction

The Gulf of Mexico coast provides important habitat for migrating and wintering shorebirds, breeding seabirds, and breeding and resident wading birds. Texas is often considered one of the primary flyways for migrating shorebirds, and several researchers have reported the importance of the Louisiana coast to nesting seabirds (Cooke 1910, Myers et al. 1990, Withers and Chapman 1993, Visser and Peterson 1994). In addition, studies conducted along the Mississippi coast have documented large numbers of wading birds utilizing Mississippi's gulf coast (Werschkul 1977). Although, the Gulf of Mexico coast from Mississippi to Texas has been shown to provide important habitat for shorebirds, seabirds, and wading birds, few researchers have investigated the importance of the Gulf coast of Florida to these species.

The Gulf coast of Florida appears to provide suitable habitat for shorebirds, seabirds, and wading birds, although most research in Florida has been conducted along the Atlantic coast and in southern Florida. Approximately 100 threatened Piping Plovers (*Charadrius melodus*) winter along Honeymoon Island State Recreation Area along the southern gulf coast of Florida (Pranty 1996), and Spendlow and Patton (1988) reported 97% of the United States breeding population of Sandwich Terns nests along the Gulf of Mexico coast, including Florida. Along Tampa Bay, Reddish Egrets (*Egretta rufescens*), Snowy Egrets (*Egretta thula*), Tricolored Herons (*Egretta tricolor*), and Yellow-crowned Night Herons (*Nycticorax violaceus*) breed (Rodgers 1980, Rodgers 1980, Toland 1991). These studies indicate the Florida coast provides appropriate habitat for several species of shorebirds, seabirds, and wading birds, however it is unknown, whether the northern gulf coast of Florida is also used by numerous species of shorebirds, seabirds, and wading birds, as are the neighboring Gulf coasts of Texas, Louisiana, and Mississippi.

Although few studies have been conducted along the Florida panhandle, those that have indicate this area provides important habitat for shorebirds, seabirds, and wading birds (Nicholls and Baldassarre 1990, Gore 1990, and Rodgers 1980). Nicholls and Baldassarre (1990) surveyed the gulf coast of Florida for the threatened Piping Plover from 1986 to 1988 and found 8.4% of the Piping Plover population in the United States wintered along the gulf coast of Florida. Gore (1991) surveyed the western panhandle of Florida for nesting seabirds and reported greater than 2,000 Least Tern nests and 350 Black Skimmer nests, and Pranty (1996) reported observations of Reddish Egrets and American Bitterns (*Botaurus lentiginosus*) along the coast of Gulf County in the Florida panhandle (Pranty 1996). Therefore, the Florida panhandle coast may be similar to the coasts of Texas, Louisiana, and Mississippi, and provide important habitat for shorebirds, seabirds, and wading birds.

Much of the Florida panhandle has been developed for tourism and recreation, thereby limiting habitat for shorebirds, seabirds, and wading birds. State parks, refuges, or wildlife areas located throughout the region provide protected areas for these species. One such area owned by Eglin Air Force Base is located on Cape San Blas in Gulf County, Florida. The five kilometers of beach along Cape San Blas encompass a variety of habitats, including beach front, lagoon, sand flat, mud flat, and vegetation, all in close proximity to the Gulf of Mexico. These habitats, concentrated in one area appear to provide suitable resources for foraging and nesting shorebirds, seabirds, and wading birds, however, few researchers have documented use of Cape San Blas by these species.

Preliminary studies indicated Cape San Blas provides important habitat for many shorebirds, seabirds, and wading birds, including the federally-threatened Piping Plover and state-threatened Least Tern, however few researchers had investigated shorebird, seabird, and wading bird use of this region. The objectives of this study were to census shorebirds, seabirds, and wading birds along Cape San Blas to determine numbers and seasonal use, and to assess their use of this area as a breeding site.

Methods

Shorebird, seabird, and wading bird censuses were conducted along lagoon shores (lagoon #1 and #2) and the gulf side of the Cape spit (Fig. 5-1). From April 1994 to April 1996, shorebird, seabird, and wading bird surveys were conducted weekly by technicians at the University of Florida. Surveys occurred at various times of day and tidal stage in an attempt to encompass all daylight hours and tidal stages. The area was surveyed on foot following the same general path that allowed full coverage of both lagoons and the beach. Environmental conditions, number and activity of birds, number of disturbances throughout the survey, and counting method (whether exact or an estimate) were recorded. Western, Semipalmated, and White-rumped Sandpipers were difficult to distinguish in the field, therefore they were combined into one category termed "peep".

Between the Gulf and the southeastern side of lagoon #2 is an area of sand and crushed shell of approximately 150 x 75 meters, used frequently by nesting Least Terns (see Fig. 5-1). During

May and June, this area was surveyed weekly for Least Tern nests. The area was scanned visually using binoculars to locate birds on nests. Nests were then approached to confirm the presence or absence of eggs. The location of the nest was marked using a tongue depressor placed in the sand approximately 0.5 to 1 meter away from the nest. Marked nests were checked weekly to assess hatching success.

The area of sand and vegetation between the lagoons and the eastern shore of lagoon #2 were surveyed for nesting plovers from April 1994 through August 1996 (see Fig. 5-1). The area was walked and scanned visually for nesting birds or nests. When observed, nests were approached to confirm the presence and number of eggs. Nests were monitored weekly to assess hatching success.

A one-way ANOVA was conducted to evaluate seasonal variation in shorebird, seabird, and wading bird numbers along Cape San Blas.

Results

Shorebirds

During 67 surveys throughout three years (April 1994 - April 1996), 7,979 shorebirds were counted along Cape San Blas beaches.

Per Month

Throughout the 24 months of the study, 332.5 shorebirds per month were recorded along Cape San Blas (Table 5-1). The greatest number of shorebirds per month and greatest average number per survey per month were observed in February 1996 (1,007/month;

335.7/survey/month) and the second greatest in May 1995 (1003/month; 334.3/survey/month). In May 1995, the greatest number of shorebird species per month were observed (20), with the second greatest number recorded in April 1995 (17). The greatest average number of shorebird species per survey per month was observed in January 1994 (11), and the second greatest in April 1995 (8.5).

Per Season

From April 1994 to April 1996, significantly more shorebirds were recorded along Cape San Blas in spring than in any other season ($p > 0.05$). This was observed throughout the entire study period, with the greatest number of shorebirds per season and the greatest average number per survey per season recorded in spring 1995 (1,785/season; 595/survey/season). The second greatest number was counted in winter 1996 (1,429/season), whereas the second greatest average per survey per season was observed in spring 1994 (485). The greatest number of shorebird species per season was counted in spring 1995 (22), and the second greatest number observed in summer 1995 (21). The greatest average number of species per survey per season occurred in spring 1994 (4.0) and the second greatest in spring 1995 (3.1)

Species Counts

Throughout the entire study period, 26 shorebird species were recorded along Cape San Blas (Table 5-2). More species were observed from April 1995 to April 1996 (25), than from April 1994 to April 1995 (22). The most common species observed was the Sanderling, which was recorded in 58 of 67 (86.6%) surveys. The Willet (*Catoptrophorus semipalmatus*) was the second most common species (57; 85.1%), and the Black-bellied Plover (*Pluvialis squatarola*) was third (82.1%). The Piping Plover (45, 67.2%) and the Semipalmated Plover (45, 67.2%) were the fourth most common species on Cape San Blas.

The most abundant species on Cape San Blas was the Dunlin (*Calidris alpina*), with 2,505 (31.4%) observations recorded throughout the 2 year surveying period. Peep were the second most abundant species (1729, 21.7%), the Sanderling was third (806, 10.1%), the Willet (490, 6.14%) was fourth, and the Semipalmated Plover (488, 6.11%) was the fifth most abundant species.

Piping Plover

From April 1994 through April 1996, the Piping Plover was the fourth most common species on Cape San Blas, observed during 45 of 67 (67.2%) surveys, and the seventh most abundant species (318, 4.0%). The greatest number of Piping Plovers observed per month were recorded in October 1994 (50) and the second greatest in November 1994 (34). In October 1994 the greatest average number of Piping Plovers per survey per month was recorded (13). The second greatest average per survey per month occurred in March 1995 (12).

Piping Plovers were most abundant on Cape San Blas in fall 1994 (104) and second most abundant in winter 1995 (43). The greatest average number of Piping Plovers per survey per season was recorded in fall 1994 (33.8), with the second greatest recorded in winter 1995 (15.7)

Breeding Shorebirds

Throughout the spring/summer of 1994, 1995, and 1996, four Wilson's Plover nests and one Snowy Plover nest were located. In 1994, two Wilson's Plover nests were observed, one incubating three eggs and one with two eggs. One Snowy Plover nest was located, incubating three eggs. It is unknown whether these nests hatched, although chicks of both species were observed along the Cape in 1994. In 1995, one Wilson's Plover nest was observed, with two eggs. Again, the fate of this nest was unknown. One Wilson's Plover nest was observed in 1996, incubating three eggs. This nest was destroyed by a four-wheel drive vehicle before hatching.

Although formal surveys for additional nesting shorebird species were not conducted, two Willet nests were located in 1994. Hatching success of these nests was unknown. In addition, adult Willets were observed defending territories in 1994 and 1996.

Seabirds

During 67 surveys throughout two years (April 1994 - April 1996), 31, 069 seabirds were counted along Cape San Blas beaches.

Per Month

An average 1,305 seabirds per month were recorded along Cape San Blas throughout the study period (see Table 5-1). The greatest number of seabirds per month and greatest average number per survey per month were observed in May 1995 (4,613/month; 1,538/survey/month), and the second greatest in September 1995 (2,898/month; 1,449/survey/month). In April and July 1995, the greatest number of seabird species were observed (12). The second greatest number occurred in May, June, August, and September 1995 (11). The greatest average number of seabird species per survey per month was recorded in April 1995 (6.0), and the second greatest in June and September 1995 (5.5).

Per Season

In summer 1995, the greatest number of seabirds per season and the greatest average per survey per season were observed (6,229/season; 2,076/survey/season), with the second greatest occurring in spring 1995 (5,748/season; 1,916/survey/season). The greatest number of seabird species per season and the greatest average per survey per season was recorded in summer 1995 (34/season; 11.33/survey/season). The second greatest was observed in spring 1995 (33/season; 11.00/survey/season). There were no significant differences in seabird numbers among seasons ($p < 0.05$).

Species Counts

Throughout the study period, 17 seabird species were recorded along Cape San Blas (Table 5-3). The most common species on Cape San Blas from April 1994 to April 1996 was the Royal Tern, observed 63 of 67 (94.0%) surveys. The Laughing Gull (*Larus atricilla*; 58, 86.6%) was second most common, the Brown Pelican (53, 79.1%) third, the Herring Gull (*Larus argentatus*; 51, 76.1%) fourth, and the Forster's Tern (*Sterna forsteri*; 43, 64.2%) fifth.

Laughing Gulls were the most abundant species on Cape San Blas throughout the study period with 6,540 (21.0%) individuals. The second most abundant species was the Sandwich Tern (5,640, 18.2%), the third was the Common Tern (*Sterna hirundo*; 5,073, 16.3%) the fourth was the Royal Tern (4,285, 13.8%), and the fifth was the Brown Pelican (3,214, 10.3%).

Least Terns

From April 1994 through April 1996, 840 (2.7%) Least Terns were recorded along Cape San Blas beaches. The greatest number of Least Terns per month were observed during July 1995

(207), and the second greatest during June 1994 (162). The greatest average number of Least Terns per survey per month were recorded in July 1994 (78.5) and the second greatest occurred in May 1994 (55.0).

In summer 1994, the greatest number of Least Terns per season and the greatest average number per survey per season was recorded (381/season; 153.2/survey/season) with the second greatest occurring in summer 1995 (268/season; 80.3/survey/season).

Throughout May and June 1994, 74 Least Tern nests were recorded along Cape San Blas. During May and June 1995, 8 Least Tern nests with eggs were located. None of the nests hatched. Eleven adults were observed sitting on nests in May and June 1996, but only 8 nests were confirmed to have eggs. Hatching success of 1996 nests was also 0%.

Wading birds

From April 1994 through April 1996, 406 observations of wading birds were recorded during 67 surveys along Cape San Blas.

Per Month

Seventeen wading birds per month were recorded along Cape San Blas throughout the study period (see Table 5-1). The greatest number of wading birds per month and greatest average number per survey per month were recorded in July 1995 (90.0/month, 22.5/survey/month). The second greatest number per month occurred in August 1995 (32.0), whereas the second greatest average number per survey per month was recorded in June 1995 (13.0).

In July 1995, the greatest number of wading bird species per month was recorded (8.0), and the second greatest occurred in May 1994, June 1994, September 1994, and August 1995 (6.0). The greatest average number of species per survey per month was documented during May and September 1994 (3.0), and the second greatest in April, June, and September 1995 (2.5).

Per Season

In summer 1995, the greatest number of wading birds and the greatest average number per survey per season was recorded along Cape San Blas (148.0/season, 49.3/survey/season). The second greatest occurred during fall 1994 (54.0/season; 18.0/survey/season). Significantly more wading birds were observed during summer than during winter along Cape San Blas ($p > 0.05$). All other seasonal comparisons were not significant ($p < 0.05$).

The greatest number of wading bird species and greatest average number per survey per season was recorded in summer 1995 (19/season; 6.3/survey/season). The second greatest number per season documented in fall 1994 (15.0), and the greatest average number per survey per season occurred in spring 1994 and fall 1994 (5.0).

Species Counts

From April 1994 to April 1996, 9 wading bird species were observed along Cape San Blas (Table 5-4). The most common wading bird species recorded on Cape San Blas throughout the study period was the Great Egret (*Casmerodius albus*), observed 56 of 67 surveys (83.6%). The second most common was the Snowy Egret (50, 74.6%), the third was the Great Blue Heron (39, 58.2%), the fourth was the Reddish Egret (17, 25.4%), and the fifth was the Tricolored Heron (16, 23.9%).

The Snowy Egret was the most abundant wading bird species along Cape San Blas with 127 (31.3%) observations throughout the study period. The Great Egret was second most abundant (108, 26.6%), the Great Blue Heron was third (56, 13.8%), the Tricolored Heron was fourth (24, 5.9%) and the Reddish Egret was fifth (18, 4.4%).

Discussion

Shorebirds

Shorebirds were most abundant and most diverse along Cape San Blas beaches during spring migration (February-April), however this area did not appear to be an important stopover for large numbers of shorebirds or for a variety of shorebird species during fall migration. Myers et al. (1990) suggested shorebirds migrate in elliptical routes, therefore, shorebirds would not be in the same geographic region during spring and fall migrations. Most Sanderlings migrate north over the Gulf of Mexico coast during spring and move south along the Atlantic coast during fall migration, thus avoiding the Gulf in fall (Myers et al. 1990). This general migration route may also be followed by additional species such as Lesser Golden-Plovers (*Pluvialis dominica dominica*) and White-rumped Sandpipers (*Calidris fuscicollis*; Cooke 1910). Perhaps, the shorebird species using Cape San Blas beaches during spring migration are following elliptical routes and migrating over the Atlantic coast during fall.

In addition, shorebirds may not be as abundant along Cape San Blas in fall because their prey may not be as available in fall as they are in spring. Along the coast, Sanderlings probe for marine invertebrates within 10 mm of the surface (Ehrlich et al. 1988). Diets of Black-bellied Plovers, Willets, Piping Plovers, and Semipalmated Plovers all include mollusks, crustaceans, and marine worms (Ehrlich et al. 1988). Invertebrate sampling on Cape San Blas has not occurred, but possibly, marine invertebrates are more available to shorebirds during spring than during fall. Shorebird densities in the Mad River estuary, California and the Bay of Fundy, Canada were found to correlate positively with prey abundance (Hicklin and Smith 1984, Colwell and Landrum 1993). In 1986 along Oso Bay, Texas, Withers and Chapman (1993) found greater shorebird density in spring and early winter corresponded with greater prey abundance in spring and early winter. Shorebirds may be stopping at Cape San Blas beaches during spring migration to feed on available prey, such as mollusks, crustaceans, and worms.

Finally, competition for prey and space in primary foraging areas may force shorebirds into peripheral feeding areas. Myers et al. (1993) suggested Sanderlings use the Gulf coast of Texas as a migration pathway, and Cooke (1910) indicated Lesser Golden-Plovers and White-rumped Sandpipers, among others, migrate north through coastal Texas. Possibly, competition for space and food along the main migration route through Texas forces shorebirds to the periphery of the migration path, which may include the gulf coast of Florida.

Species Diversity

The Texas coast is often considered one of the primary flyways for migrating shorebirds (Cooke 1910, Myers et al. 1990, Withers and Chapman 1993). Although fewer numbers of shorebirds used Cape San Blas beaches from 1994 to 1996 (119.1/survey) than used Oso Bay, Texas beaches in 1985 (269.9/survey), similar numbers of shorebird species used Cape San Blas as used Oso Bay throughout these times. The number of shorebird species using Cape San Blas beaches in 1994 (21) and 1995 (25) are comparable to the number observed along Oso Bay, Texas in 1985 (26; Withers and Chapman 1993). Although sample sizes are small, this indicates habitat along Cape San Blas may provide important resources for a variety of shorebird species.

The most common shorebird species observed along Cape San Blas beaches throughout the study period was the Sanderling. The Willet and Black-bellied Plover were the second and third most common species. Of these three species, only the Willet is considered a year-round resident of the Gulf of Mexico coast (Peterson 1980). Although considered only a winter resident along the Gulf coast (Peterson 1980), the Sanderling is a widely distributed species and was observed throughout the year along Oso Bay, Texas (Withers and Chapman 1993). Black-bellied Plovers are also considered winter residents of the Gulf of Mexico coast (Peterson 1980), but Withers and Chapman (1993) found Black-bellied Plovers and Willets were the most frequently observed species along Oso Bay, and were present in small numbers throughout the year. Perhaps, individual Sanderlings or Black-bellied Plovers, not strong enough to continue in spring migration, remain and forage at stopover areas, such as Oso Bay and Cape San Blas, until their return trip during fall migration.

The three most abundant species on Cape San Blas (Dunlin, peep, and Sanderlings) form large concentrations at specific staging areas during migration (Ehrlich et al. 1988). An interim stopover area for these species during migration may be the Gulf coast of Texas (Myers et al. 1993, Withers and Chapman 1993). The most abundant of the 26 shorebird species recorded along Oso Bay, Texas during spring 1985 migration were peep, which included Semipalmated Sandpipers (*Calidris pusilla*) and Western Sandpipers (*Calidris mauri*; Withers and Chapman

1993). In addition, Withers and Chapman (1993) recorded Dunlin as the fourth and Sanderlings as ninth most abundant species. Possibly, due to prey availability along Cape San Blas or competition in Texas, large numbers of Sandpipers, Dunlin, and Sanderlings that migrate towards the Texas coast, stop instead at adjacent areas, such as Cape San Blas.

Piping Plovers

The Piping Plover was most abundant along Cape San Blas in winter and fall, which is consistent with Haig and Oring's (1985) definition of the Piping Plover's winter range. Nicholls and Baldassarre (1990) surveyed for wintering Piping Plovers along the Gulf of Mexico coast and found that, although the Gulf coast of Florida contained a large percentage of the survey total, Piping Plovers occurred less frequently along the coast of Florida than other Gulf coast states. They suggested this was due to reduced suitable habitat along the Florida coast, which would force Piping Plovers to gather in small, isolated patches. During one survey along the Cape San Blas coast between December 1987 and March 1988, Nicholls and Baldassarre (1990) counted 16 Piping Plovers. During one survey in October 1994, we counted 23 Piping Plovers along the Cape San Blas coast. In 4 of the 67 surveys we counted at least 16 Piping Plovers (6.0%), and in 12 of the 67 surveys (17.9%) we counted at least 10 Piping Plovers.

Possibly, numbers of Piping Plovers wintering along Cape San Blas have increased since Nicholls' and Baldassarre's (1990) survey. If preferred wintering grounds are altered, plovers may move to secondary foraging grounds. When Piping Plover's primary foraging grounds on Dauphin Island, Alabama were destroyed by Hurricane Elena in 1985, plovers foraged primarily on Sand Island, Alabama (Johnson and Baldassarre 1988). Johnson and Baldassarre (1988) reported great sight fidelity in Piping Plovers, therefore, once plovers begin using a secondary foraging area, they may remain there in future winters. Nicholls and Baldassarre (1990) reported that along the Gulf of Mexico coast, Texas and Louisiana had the greatest number of Piping Plovers per kilometer surveyed, therefore habitat loss along the Texas and Louisiana coast may have forced Piping Plovers into secondary foraging sites, such as Cape San Blas, Florida, where they may return in following winters.

Breeding Plovers

Wilson's Plovers and the state-threatened Snowy Plover are rare to uncommon residents of less-disturbed sandy beaches in Florida (Johnson and Barbour 1990, Pranty 1996). Both species nest on the ground between April and August. Wilson's Plovers nest on beachs with sparse vegetation, often concealing their nest within a clump of plants, whereas Snowy Plovers typically nest on bare sand beaches with no vegetation (Johnson and Barbour 1990). Wilson's Plovers nest throughout the Gulf coast of Florida, including St. George Island, St. Andrews State Recreation Area, Honeymoon Island State Recreation Area, and Bradenton (Pranty 1996). In Florida, nesting Snowy Plovers are limited to the Gulf of Mexico coast and are located mostly along the Florida Panhandle (Johnson and Barbour 1990). The Snowy Plover was listed as a state-threatened species in the 1970's, and presently there are approximately 200 breeding pairs of Snowy Plover's in Florida (Pranty 1996). Cape San Blas provides suitable nesting habitat for Wilson's and Snowy Plovers, although predation and human disturbance may limit successful hatching. Further research is needed, however, to assess the nesting status of Wilson's and Snowy Plovers along Cape San Blas, as well as nesting status of additional shorebird species, such as Willets.

Seabirds

Large numbers of seabirds were consistently observed throughout the two years of the study along Cape San Blas, with slight peaks during spring and fall migration. Many seabirds, such as Sandwich and Forster's Terns, breed along the Gulf of Mexico coast, and although these species are often present throughout the year, their numbers may peak as they migrate south from additional northern breeding grounds (Visser and Peterson 1994). Spendelow and Patton (1988) reported that of the total United States breeding populations, 97 % of Sandwich Terns, 72% of Black Skimmers, and 62% of Forster's Terns breed along the Gulf of Mexico coast. Royal Terns are also common on both coasts of Florida throughout the year, but numbers greatly increase in fall as terns migrate south (Smith et al. 1994). Visser and Peterson (1994) reported greater than 9,000 Sandwich Tern, 1,500 Royal Tern, and 6,000 Laughing Gull breeding adults along the Gulf coast of Louisiana in 1993. Observations of approximately 5,000 Sandwich Terns, 2,500 Royal Terns, and 1,000 Laughing Gulls were recorded along Cape San Blas in 1994. Thus, Cape San Blas appears to be an important area for seabirds along the Gulf of Mexico coast. Extent of breeding by seabirds along Cape San Blas beaches must be further investigated, however, before its importance as a breeding site can be assessed.

Along the Gulf of Mexico coast, seabirds use a variety of habitats. Many gull and tern species nest on sandy beaches or marshes, placing their eggs in a shallow scrape on the ground (Ehrlich et al. 1988). Along the Louisiana coast, Forster's Terns were observed mainly in marsh sites, Laughing Gulls in both marsh and beach sites, and Sandwich and Royal Terns only on beach sites.

Brown Pelicans use sand spits for roosting and foraging, and juvenile pelicans rely greatly on sand spits during fledging because they are not yet coordinated enough to land in trees (Schreiber and Schreiber 1982). Cape San Blas provides both marsh and sandy beach habitat, with direct access to the Gulf of Mexico for foraging. The Cape spit is available at high and low tide, and provides resting areas for all seabirds, especially Brown Pelicans. Storms severely impact the spit however, causing erosion and loss of habitat. Marsh and sand beaches also are influenced greatly by human disturbance. Visser and Peterson (1994) reported Sandwich and Royal Terns nested together along beaches where human disturbance was minimal, and in New Jersey, Burger (1984) found human disturbance accounted for over half of the reproductive failures of Least Tern colonies. Along the Louisiana coast, numbers of breeding Royal, Sandwich, Forster's and Least Terns had great annual variation, possibly due to loss of preferred habitat to storms (Visser and Peterson 1994). Visser and Peterson (1994) surveyed East Timbalier Island before and after Hurricane Chantal passed through the area and estimated a 50% reduction in numbers of breeding adults at that site. Therefore, although Cape San Blas may provide suitable habitat for seabirds, severe erosion and human disturbance may reduce the numbers of seabirds using the area and may prevent seabirds from breeding along the Cape San Blas coast.

Species Diversity

The three most common species along Cape San Blas, the Royal Tern, Laughing Gull, and Brown Pelican, are common residents of the Gulf of Mexico coast (Pranty 1996). All three species nest in large numbers along the Gulf coast of Louisiana and breed commonly throughout Florida (Visser and Peterson 1994, Pranty 1996). They are colonial nesters, with Royal Tern and

Laughing Gull colonies often containing thousands of birds (Ehrlich et al. 1988). In addition, Royal Terns and Laughing Gulls typically associate together throughout the year (Ehrlich et al. 1988). Laughing Gulls, Sandwich Terns, and Common Terns were the three most abundant species along Cape San Blas, possibly due to their year-round colonial associations. Sandwich Tern colonies are often associated with Royal Terns, which were the most common species along Cape San Blas throughout the study period (Ehrlich et al. 1988). Common Terns are not typically associated with other gull or tern species, but form congregations often numbering 10,000 birds. Therefore, along Cape San Blas, Sandwich and Common Terns were observed less frequently than Royal Terns and Laughing Gulls, but when present, formed large congregations.

Least Terns

Least Terns have been observed breeding on Cape San Blas beaches, although hatching success of their nests is not well known. Along the east coast of the United States, Least Terns nest on sandy beaches that often face the oceanfront, which makes the nests highly susceptible to predation, erosion, and human disturbance (Burger 1984). Predators of Least Tern nests included Red Foxes (*Vulpes fulva*), Raccoons (*Procyon lotor*), American Kestrels (*Falco sparverius*), American Crows (*Corvus brachyrhynchos*), and Herring Gulls (Burger 1984, Massey and Fancher 1989, Rimmer and Deblinger 1992). Although Cape San Blas beaches provide appropriate habitat for nesting Least Terns, presence of predators such as Raccoons, Gulls, and Crows may prevent hatching of nests.

A decline in the number of Least Tern nests along Cape San Blas was observed from 1994 to 1996. Visser and Peterson (1994) reported great annual variation in the number of Least Tern nests along coastal Louisiana, and suggested this was due to human disturbance in Least Tern nesting areas. Possibly, human presence along Cape San Blas was less in 1994 than in 1995 or 1996, causing less disturbance to Least Terns. From April to June 1994 we recorded 2.5 people per survey within the entire survey area. During April through June 1995 we recorded 14.1 people per survey within the entire area. These numbers include the entire study area, therefore they may not represent the amount of disturbance within only the Least Tern nesting area. If, however, this trend occurred in the Least Tern nesting area, the increase in human disturbance in 1995 may have contributed to the fewer Least Tern nests in 1995.

More likely though, the intense hurricane season of 1995 resulted in Least Tern nest destruction and loss of habitat. Cape San Blas was strongly influenced by 5 tropical storms in 1995. Hurricane Alison, a category 1 storm, struck the Cape on June 4 at the peak of Least Tern nesting. In New Jersey, Burger (1984) reported that, instead of lowering Least Tern reproductive success, habitat loss resulted in abandonment of colony sites. Possibly, Hurricane Alison destroyed Least Tern nests during peak laying, and subsequent storms destroyed efforts to re-nest. Also, these storms may have altered nesting habitat and forced terns to other areas. Not much can be done though, to protect Least Tern nesting habitat along Cape San Blas from storms. Better protection from predators, however, such as electric fencing or predator exclosures (Rimmer and Deblinger 1992), and from human disturbance, including roping off nesting areas, posting signs, or closing beaches, may be necessary to increase successful nesting by Least Terns along the Cape San Blas coast.

Wading Birds

Wading birds were observed in small but consistent numbers from April 1994 through April 1996 along Cape San Blas. It appears that Cape San Blas does not support a large group of wading birds relative to other areas along the Gulf of Mexico. On Riomar Island, Florida, during the 1971-1972 breeding season there were approximately 2,000 Cattle Egrets (*Bubulcus ibis*), 1,000 Snowy Egrets, and 300 Tricolored Herons (Maxwell and Kale 1974), and at Cliftonville, Mississippi approximately 1,500 Cattle Egrets and 1,750 Little Blue Herons nested during the 1975 breeding season (Werschkul 1977). Although throughout the study period, Cape San Blas consistently supported an average 17 wading birds per month, relatively large numbers of wading birds were not using this area.

Large numbers of wading birds may not be found on Cape San Blas because of lack of suitable nesting habitat. During the 1973 breeding season on Riomar Island, Florida, Tricolored Herons built 65%, Snowy Egrets 78%, Great Egrets 77%, and Little Blue Herons 100% of their nests in black mangrove (Maxwell and Kale 1977). Wading birds, such as Great Blue Herons, Great Egrets, Tricolored Herons, and Little Blue Herons, nested primarily in white mangrove during 1974-75 along Merritt Island National Wildlife Refuge, Florida (Girard and Taylor 1979). Although wading birds in south Florida often nest in mangrove, wading birds in Cliftonville, Mississippi typically nest in deciduous trees, such as oaks (*Quercus* spp.), hickories (*Carya* spp.), elms (*Ulms* spp.), and ash (*Fraxinus* spp.; Werschkul 1977). Also, Ehrlich et al. (1988) reported most wading bird species nest primarily in deciduous trees. Cape San Blas habitat consists primarily of conifer species, such as slash pine (*Pinus elliotti*) and sand pine (*Pinus clausa var* *imuginata*), and palms, including cabbage palm (*Sabal palmetto*) and saw palmetto (*Serenoa repens*). Therefore, the small numbers of wading birds along Cape San Blas may be attributed to lack of suitable nesting habitat.

Peaks in numbers of wading birds along Cape San Blas were observed in spring and fall, possibly correlating with migration. A large flock of Great Egrets (22) on July 19, 1995 resulted in an unusually large peak in numbers for the summer of 1995 (90). Many wading bird species, including the Great Egret, Yellow-crowned Night Heron, Tricolored Heron, Great Egret, and Great Blue Heron winter in Central or South America. In summer, post-breeding wandering of species such as the Snowy Egret, Great Egret, and Great Blue Heron takes birds into the northern United States (Peterson 1980, Pranty 1996). Peaks in numbers of wading birds along Cape San Blas most likely occur during southbound winter migration or northbound post-breeding dispersal.

Peaks in number of wading birds may also correlate with rainfall. In the Corkscrew Swamp area of southwest Florida, Bancroft et al. (1988) found fewer wading birds nested in dry years than in relatively wet years, and in 1988, large numbers of wading birds appeared in the Bird Drive Everglade Basin, Florida after the onset of the rainy season in June (Richter and Myers 1993). Variation in wading bird numbers along Cape San Blas throughout the year may correlate with variations in amount of rainfall. Along Cape San Blas, peaks in wading bird numbers during summer may be related to increased rainfall in summer, and a decrease in numbers throughout winter may reflect drier conditions during winter.

Species Diversity

The most common and abundant wading bird species on Cape San Blas were the Great Egret, Snowy Egret, and Great Blue Heron. All three species are permanent residents of Florida (Pranty 1996). Great Egrets are the most cosmopolitan of all heron species, and their range is still expanding following severe depletion by plume hunters at the beginning of the century (Ehrlich et al. 1988). The Snowy Egret's range also continues to expand (National Geographic Society 1987). This species is highly colonial, found often in mixed flocks, and is a common resident throughout Florida (Ehrlich et al. 1988, Pranty 1996). The Great Blue Heron is also a common species, not only in Florida, but throughout the contiguous United States (National Geographic Society 1987), and numbers of Great Blue Herons are increasing throughout most of their range (Ehrlich et al. 1988). All three species are reported to nest along Merritt Island National Wildlife Refuge, Florida and along the Indian River, Florida. Great Egrets and Snowy Egrets nest along Riomar Island, Florida, and Cliftonville, Mississippi (Maxwell and Kale 1977, Werschkul 1977, Girard and Taylor 1979, Rodgers 1980). The most common and abundant wading bird species found along Cape San Blas are also found in large numbers throughout the southeast United States.

An exception to this is the Reddish Egret, the fourth most abundant wading bird species found on Cape San Blas throughout the study period. The Reddish Egret was hunted extensively in the early 1900's and disappeared from Florida from 1927 to 1937 (Ehrlich et al. 1988). The population increased to approximately 50 pairs in 1944 and grew to 150 pairs by 1954 (Powell et al. 1989). Presently, there are approximately 2,000 breeding pairs throughout the United States

(Ehrlich et al. 1988), and about 400 breeding pairs in Florida (Pranty 1996). Along Cape San Blas, Reddish Egrets were observed in small numbers during every season throughout the study period. Although in winter most Reddish Egrets migrate to South America, some wander throughout the United States (Ehrlich et al. 1988). Also, during post-breeding dispersal Reddish Egrets, especially immatures, move north of their breeding range into the Florida Panhandle (Pranty 1996). The consistent sightings of Reddish Egrets along Cape San Blas throughout the year indicate the numbers and range of Reddish Egrets in Florida may be increasing. Although many of the Reddish Egrets observed on Cape San Blas may be immatures wandering during post-breeding dispersal, egrets were seen consistently throughout the year on Cape San Blas. According to Powell et al. (1989), there have been no attempts to survey the Reddish Egret population in Florida since 1980. Possibly, numbers of Reddish Egrets are increasing throughout Florida and are occurring in areas not previously considered part of their residential range. Also, their permanent range may be expanding along the Gulf coast which may increase sightings in areas previously considered only summer range, such as Cape San Blas.

Finally, because wading birds occupy a high trophic level in the aquatic food chain, they have been proposed for use as ecological indicators (Powell and Powell 1986). A major change in water quality, nutrient levels or other environmental factors may be reflected in population changes of wading birds. Therefore, an increase in the number of Reddish Egrets in Florida may be a reflection of increased productivity of south Florida wetlands, where most breeding habitat for Reddish Egrets in Florida is located. Wading birds forage and breed in areas with complex food webs, such as wetlands, estuaries, and bays. Therefore, protection of areas used by wading birds is essential in protecting, not only the wading birds, but the entire habitat.

Conclusions

Shorebirds

Although Cape San Blas does not appear to be an important stopover for shorebirds during fall migration, large numbers and many species of shorebirds use Cape San Blas beaches during spring migration. The Gulf coast of Texas appears to be an important foraging site for shorebirds during spring migration (Myers et al. 1990, Withers and Chapman 1993). Groups of shorebirds following the migration path through Texas, may move to areas on the periphery of the migration route such as Cape San Blas, to escape competition or loss of habitat along the Texas coast. Also, prey availability along Cape San Blas beaches during spring may attract migrating shorebirds.

Cape San Blas beaches also support significant numbers of threatened Piping Plovers. Although past surveys have indicated the Florida coast is not a primary wintering area for Piping Plovers, it appears Cape San Blas supports a consistent number of Piping Plovers. Loss of habitat in preferred areas, such as Texas and Louisiana, may result in Plovers relocating to new wintering grounds, including Cape San Blas. Because substantial mortality can occur during this period, protection of wintering grounds, such as Cape San Blas, are essential for recovery of this species (Baker and Baker 1973, Evans 1976, Nicholls and Baldassarre 1990).

In addition to wintering Piping Plovers, nesting plovers, such as Wilson's and Snowy Plovers, also use the habitat available on Cape San Blas. These species nest along the beaches, either around sparse vegetation or on bare sandy areas (Johnson and Barbour 1990). It is apparent that Cape San Blas provides nesting habitat for these plover species, however, more research is needed to assess the extent of nesting by plovers, and other shorebird species, along Cape San Blas.

Seabirds

Large numbers of seabirds used Cape San Blas beaches, especially during spring and fall migration, however, more research is needed to assess the extent of seabird breeding along Cape San Blas. The Cape provides important habitat for seabirds, such as marsh areas for Laughing Gulls, beach front for Royal and Sandwich Terns, and sand spits for Brown Pelicans. These areas, though are severely impacted by erosion and human disturbance that may prevent seabirds from breeding along Cape San Blas.

The only seabird species observed nesting along Cape San Blas was the Least Tern, although hatching success was nearly zero. Although suitable nesting habitat for Least Terns is available along the eastern side of the Cape, factors preventing hatching or fledging are present, such as consistent human disturbance and predation. Also, a decline in numbers of nesting Least Terns since 1994 may be due to increased disturbance in 1995, or a severe tropical storm season in 1995, in which several storms occurred during peak nesting of Least Terns. Although nothing can prevent storm activity, better protection from predators and human disturbance, such as fencing, roping off areas, or closing beaches, may be necessary to increase successful nesting of Least Terns along Cape San Blas. Thus, increased protection of Least Tern nesting habitat on Cape San Blas may improve nesting success.

Wading Birds

Although wading birds occur consistently throughout the year on Cape San Blas, large numbers of wading birds are not using the area, and wading birds are most likely not breeding along Cape San Blas. Fewer birds and lack of breeding may be due to lack of suitable nesting habitat, such as mangrove and deciduous trees, on Cape San Blas.

Peaks in wading bird numbers in the spring and fall on Cape San Blas may be attributed to spring and fall migration, in which wading birds are moving south during fall and then dispersing in spring after breeding. Also, peaks in numbers may correlate with environmental conditions, such as rainfall. Increased rainfall may allow for larger numbers of wading birds, and drier conditions may result in fewer birds.

The most common and abundant species recorded on Cape San Blas, the Great Egret, Snowy Egret, and Great Blue Heron are common residents along the Gulf of Mexico coast, and throughout much of the United States. The fourth most common species on Cape San Blas, however was the Reddish Egret, a species nearly extirpated from Florida in the 1920's due to hunting. This species, considered a resident of south Florida, occurred consistently throughout the year along Cape San Blas, therefore Reddish Egrets may be increasing in numbers or range.

Management Recommendations

Shorebirds

Protection of shorebird staging areas is essential for migrating shorebirds. Many shorebird species stop along their migration route to accumulate energy reserves for the remainder of the flight. Migrating shorebirds deplete much of their energy reserves during flight, therefore the ability to accumulate additional reserves may be crucial if birds are impeded by bad weather or poor feeding conditions at staging areas (Meyers et al. 1987). Areas such as Oso Bay, Texas and Cape San Blas may provide these small reserves for shorebirds migrating through the central flyway. Myers et al. (1987) suggested management of staging areas should begin with halting or reversing destruction of habitat used by migrating shorebirds and restoring what has been damaged. Along Cape San Blas, primary sources of habitat destruction are erosion and human disturbance. It may be impossible to eliminate erosion, however erosion may be reduced by limiting vehicular traffic to more robust habitats, such as the outer ocean beach seaward of the drift line (Godfrey et al. (1980). Beach re-nourishment has been attempted in several areas to restore sand lost to erosion. This process is expensive and often futile, however. Miami Beach replaced 11 miles of eroded beach at $6 million per mile, and Delray, Hobe Sound, and Cocoa Beach have repeatedly lost their newly re-nourished beaches to erosion, often within five years (Johnson and Barbour 1990).

1. Beach re-nourishment along Cape San Blas is not recommended due to expense, lack of previous success, and interference with nesting sea turtles.

It may be more feasible to protect shorebird habitat by limiting human disturbance rather than attempting to stop erosion. Vehicular traffic is permitted on Cape San Blas beaches, which poses a serious potential threat to shorebird habitat. Along Cape San Blas, shorebirds often feed on exposed salt marsh and sand flats. These habitats are severely impacted by off-road vehicles (ORV; Godfrey et al. (1980). Godfrey et al. (1980) suggested that of all the ecosystems studied along Cape Cod National Seashore, Massachusetts, salt marsh and sand flats were most severely impacted by ORV's. They also found ORV traffic on open sand and mud flats affected the survival of marine organisms often fed upon by migrating shorebirds, such as worms, clams and other mollusks. During a 20 day test along a sand flat on Cape Cod National Seashore, 50 passes of an ORV per day resulted in decimation of the polychaete worm populations. Besides direct destruction of organisms, vehicular traffic may also compact the sand, which would interfere with normal exchange of sea water within sediments and create anaerobic conditions in the substrate (Godfrey et al. (1980). Also, compacted sand may prevent clams from extending their siphons to the surface for food and water, which would result in death (Godfrey et al. (1980). Therefore, to protect shorebird habitat, driving should be limited to areas below the drift line, and should be prohibited in sensitive ecosystems such as salt marshes, sand flats, and mud flats.

Shorebird nesting areas should also be restricted to vehicular traffic during nesting season. Along Cape San Blas, shorebirds nest primarily in the vegetated area between the two lagoons and along the dunes. Both of these habitats are sensitive to disturbance. Godfrey et al. (1980) suggested ORV's have substantial effects on dune vegetation. They found maximum damage to vegetation occurred during the first few passes of a vehicle, therefore even minimal traffic through vegetation may destroy the habitat. Also, shorebird nests and eggs are highly camouflaged, therefore they are difficult for drivers to locate and avoid. Thus, along Cape San Blas, shorebird nesting areas should be marked clearly and restricted to human activity during the nesting season.

2. Limit vehicular traffic to below the drift line and restrict traffic in sensitive areas such as salt marshes, sand flats, and mud flats.

Vehicular traffic is not the only potential disturbance to nesting shorebirds on Cape San Blas. In New Jersey, shorebirds were disturbed most by children, joggers, and unleashed dogs (Burger 1986). Burger (1986) suggested dogs posed a direct threat to shorebirds because they may catch and kill them. She recommended restricting beaches to dogs, unattended children, and joggers, at least during peak shorebird use (May through June) and near shorebird nesting areas. On Cape San Blas, unleashed dogs are common. Peak use of the lagoons occurs during the nesting season (spring/summer), as people often fish for bait and crab along the lagoons' banks. Shorebird nesting areas, at least along the west side of lagoon #2, should be restricted to human activities during peak shorebird nesting. The area should be posted with interpretative signs and roped to ensure protection. During the non-nesting season, these areas may be open to human activity, although to protect habitat, vehicles should be remain restricted.

3. Close the area north of lagoon #2 (between lagoon #1 and #2) to human activity during shorebird nesting season (spring and early summer).

Protection of shorebird habitat may also increase use of Cape San Blas by wintering Piping Plovers. Haig and Plissner (1993) found 51% of wintering Piping Plovers on ocean beaches, and 43% on sand or algal flats, and Nicholls and Baldassarre (1990) found more wintering Piping Plovers on barrier beaches washed by tides or along mud flats. These data indicate protection of beaches, sand flats, and mud flats is essential in management of threatened Piping Plovers. Piping Plovers spend much of their time foraging within these habitats during the winter, possibly because sand and mud flats provide preferred prey or because the substrate coloration provide ample camouflage from aerial predators (Nicholls and Baldassarre 1990). As stated above, vehicular traffic along sand and mud flats may compact the substrate and kill marine invertebrates found there (Godfrey et al. (1980). Restriction of vehicular traffic in sand and mud flats along Cape San Blas may permit growth of a larger prey base for Piping Plovers, thus allowing larger numbers of Piping Plovers use of Cape San Blas habitats throughout the winter.

4. Restrict vehicular traffic within sand and mud flats for protection of Piping Plover habitat along Cape San Blas.

More research is needed, however, to better understand shorebird use of Cape San Blas habitats. Invertebrate sampling along Cape San Blas would provide information regarding prey availability for shorebirds, which would help identify and protect important foraging areas. This may also help in understanding how migrating shorebirds are using Cape San Blas. Also, additional research of shorebird nesting along Cape San Blas would assist in locating primary nesting habitats. Protection of nesting areas would be most effective if all nesting areas were identified and restricted. These measures may aid in improving shorebird habitat along Cape San Blas, thus maintaining, or possibly increasing, shorebird use of these habitats.

5. Conduct further research, including invertebrate sampling and more detailed nesting surveys, for better understanding of shorebird use of Cape San Blas.

Seabirds

Seabird habitat must be maintained along Cape San Blas to protect the large numbers of seabirds using this area. As with shorebirds, seabird nesting habitats appear to be most significantly affected by erosion and human disturbance. East Timbalier Island, Louisiana supported a large colony of breeding Brown Pelicans in the early 1900's (Visser and Peterson 1994). Recently, Brown Pelicans have attempted to nest there again, however, severe erosion has destroyed all suitable habitat and pelicans have been unsuccessful (Visser and Peterson 1994). Nesting terns are also greatly influenced by loss of habitat. Visser and Peterson (1994) surveyed five species of breeding terns (Sandwich, Royal, Least, Forster's and Caspian) along East Timbalier Island, Louisiana before and after Hurricane Chantal hit the area in August 1989. They estimated a 50% reduction in numbers of breeding adults along the island after the hurricane, and attributed this to loss of habitat. Although nothing could be done to protect seabird nesting habitat in Louisiana from storm damage, Visser and Peterson (1994) found that habitat restoration along several barrier islands (e.g., Wine Island and Queen Bess Island) helped maintain active seabird colonies in those habitats. Cape San Blas beaches are greatly influenced by erosion, which may limit seabird nesting. Prohibiting vehicular traffic in sensitive habitats, may benefit seabirds by slowing erosional rates. Additional seabird nesting habitat along Cape San Blas may be provided by restoring severely eroded areas. Restorative efforts are typically expensive and often fail, however. Also, erosion is so severe along Cape San Blas (30 meters lost in one month) that restoration may not be practical.

1. Limit vehicular traffic to below the drift line along the beaches of Cape San Blas.

Human disturbance is possible to control, however. Bird Key, Florida was an important roosting area for Brown Pelican, but since 1976 when human activity increased in the area, the site has been abandoned by pelicans (Schreiber and Schreiber 1982). Also, along the Louisiana coast, Royal and Sandwich Terns nest together on beaches where human disturbance is minimal (Visser and Peterson 1994). As with shorebirds, restricting vehicular traffic and unleashed dogs around seabird colonies may increase seabird nesting along Cape San Blas.

2. Restrict human activity within seabird nesting areas by posting signs and rope nesting areas.

Protection of nesting seabird habitat is essential in protection of all seabirds, but especially for endangered species such as Least Terns. Least Tern colonies are greatly affected by human disturbance and predation. In Louisiana, disturbed Least Tern colonies contained no nests, whereas all undisturbed colonies had nests with eggs (Visser and Peterson 1994), and in New Jersey, among small Least Tern colonies (less than 80 birds), 58% of colony failure was the result of human disturbance. Least Terns place their buff colored eggs in a scrape on the ground, which makes them difficult to avoid (Ehrlich et al. 1988). Placing interpretive signs at beach entrances and roping nesting areas would aid in protection of Least Tern nesting colonies. Godfrey et al. (1980) suggested posting signs at least 100 feet on either side of the colony, urging visitors not to approach any closer. They've found that vehicles may pass the colony closer if they do not stop, but people getting out of their vehicles will flush nesting birds. Along Cape San Blas, Least Terns nest in a localized area between the Gulf of Mexico and lagoon #2. To protect nesting Least Terns, this area should be roped or fenced throughout nesting season. Interpretive signs around the nesting area and along the beach leading to the nesting area may elicit greater cooperation from the public. Dogs must be kept away from nesting areas because birds are more alarmed by dogs than humans (Godfrey et al. 1980). At least during nesting season, dogs should be required to be on leashes. Protection of Least Tern nesting areas may help maintain a breeding population of Least Terns along Cape San Blas, and may possibly increase Least Tern hatching success at this site.

Least Terns have adapted to increased human presence in nesting areas by nesting on gravel-covered roofs. Least Terns were first reported nesting on roofs in Florida more than 30 years ago, and the number of roof-nesting colonies has steadily increased since then (Goodnight 1957, Fisk 1975, Fisk 1978, Jackson and Jackson 1985). Gore and Kinnison reported successful nesting by four roof-nesting colonies of Least Terns in northwest Florida in 1989. Possibly, artificial roofs may be built on which Least Terns may nest. Artificial roofs may allow protection from several forces threatening Least Tern nests along Cape San Blas, including ground predators and overwash by storms. This may increase reproductive success of Least Terns along Cape San Blas.

3. Place interpretive signs at beach entrances and approximately 100 feet from nesting areas, rope or fence nesting areas, and require leashes on dogs for protection of Least Tern nesting areas along Cape San Blas. In addition, research the use of artificial roofs for Least Tern nesting as a possible method of improving nesting success of Least Terns along Cape San Blas.

Also, predation causes great losses in Least Tern colonies. In New Jersey, predation accounted for 29% of Least Tern colony failures, and in Los Angeles, California predation on eggs and chicks was the major cause of nest failure from 1980 to 1987 (Burger 1984, Massey and Fancher 1989). Many of the frequent predators of Least Tern nests are common species along Cape San Blas. Fencing has been used successfully in Massachusetts to limit predation of Least Tern nests (Rimmer and Deblinger 1992), and Ehrlich et al. (1988) suggested snow fencing effectively provided shade for chicks and protection from predation.

4. Along Cape San Blas, Least Tern nesting areas should be fenced, preferably with snow fencing, to provide not only for protection from vehicular traffic, but also from predation.

Further investigation into seabird breeding along Cape San Blas would aid in protection of seabird populations and habitat. Banding Least Terns may provide information on site fidelity of this species, and allow assessment of whether Least Terns breeding along the Cape are new recruits or are birds returning from previous years. Also, surveys for breeding seabirds, such as Royal and Sandwich Terns, along with more detailed surveys of Least Tern nesting would allow better definition of essential seabird nesting habitat along Cape San Blas.

5. Conduct more detailed investigations of seabird nesting along Cape San Blas for better understanding of breeding seabirds use of this area.

Wading Birds

As with shorebirds and seabirds, to protect wading bird groups their habitat must be preserved. Wading birds typically inhabit productive ecosystems with complex food webs (Powell and Powell 1986). Therefore, destruction of these habitats may not only influence wading birds, but may affect other trophic levels. Along Cape San Blas, wading birds primarily forage along the vegetated edges of the lagoons. These salt marsh areas are extremely sensitive to disturbances, such as vehicular traffic. Along Cape Cod National Seashore, Massachusetts, less than 200 passes in a four-wheel drive vehicle killed the standing biomass, and required three years for recovery (Godfrey et al. (1980). Fortunately, the majority of this habitat along Cape San Blas is not used for driving, therefore maintaining protection of these areas, specifically by posting signs, may assist in preservation of these wading bird groups and the surrounding food web.

1. Maintain protection of primary wading bird habitat for protection of the species that use Cape San Blas, including Reddish Egrets.

Further research into breeding behavior and food availability is needed to better understand wading bird use of Cape San Blas. Research on wading birds nesting in this area has not occurred, but would assist in understanding wading bird use of the habitats along Cape San Blas and would allow better protection of prime wading bird habitats. Also, additional wading bird species, such as American and Least Bitterns (*Ixobrychus exilis*) and Green-backed Herons have been observed along Cape San Blas in areas not included in this study. Surveys for these wading bird species may also assist in defining essential habitat. Finally, further research of food availability within wading bird foraging habitat along Cape San Blas is needed to better understand the entire ecosystem in which they feed. This would also allow definition of the most important foraging areas, which would assist in protection of wading birds and the complex ecosystem they support.

2. Conduct further investigations of wading bird breeding behavior and food availability, and survey for additional wading bird species, such as Green Herons and Least Bitterns, to allow for protection of wading birds and their habitat along Cape San Blas.

Although Cape San Blas may not be a primary migration or breeding site for shorebirds, seabirds and wading birds, this area may provide valuable resources as a secondary or peripheral site for a variety of species. Protection of these resources may be accomplished primarily through limiting human disturbances in primary bird habitats, such as mud and sand flats, and near nesting areas. Public education, posted restrictions, and continued monitoring may best accomplish these goals.

Literature Cited

Baker, M. C. and A. E. M. Baker. 1973. Niche relationships among six species of shorebirds on their wintering and breeding ranges. Ecological Monographs 43:193-212.

Bancroft, G. T., J. C. Ogden, and B. W. Patty. 1988. Wading bird colony formation and turnover relative to rainfall in the corkscrew swamp area of Florida during 1982 through 1985. Wilson Bulletin 100(1):50-59.

Burger, J. 1984. Colony stability in Least Terns. The Condor 86:61-67.

Burger, J. 1986. The effect of human activity on shorebirds in two coastal bays in Northeastern United States. Environmental Conservation. 13(2):123-130.

Colwell, M. A. and S. L. Landrum. 1993. Nonrandom shorebird distribution and fine-scale variation in prey abundance. The Condor 95:94-103.

Cooke, W. W. 1910. Distribution and migration of North American shorebirds. U.S. Department of Agriculture Biological Survey Bulletin #35.

Cox, J. H., H. F. Percival, and S. V. Colwell. 1994. Impact of vehicular traffic on beach habitat and wildlife at Cape San Blas, Florida. Technical Report #50. Florida Cooperative Fish and Wildlife Research Unit, University of Florida, Gainesville, FL. 44 pp.

Ehrlich, P. R., D. S. Dobkin and D. Wheye. 1988. The Birder's Handbook. Simon and Schuster Inc., New York, New York. 785 pp.

Evans, P. R. 1976. Energy balance and optimal foraging strategies in shorebirds: some implications for their distributions and movements in the non-breeding season. Ardea 64:117-139.

Girard, G. R. and W. K. Taylor. 1979. Reproductive parameters for nine avian species at Moore Creek, Merritt Island National Wildlife Refuge, Florida. Florida Scientist 42(2):94-102.

Godfrey, P. J., S. P. Leatherman, and P. A. Buckley. 1980. ORV's and Barrier Beach Degradation. Parks 5:2,5-11

Gore, J. A. 1991. Distribution and abundancd of nesting Least Terns and Black Skimmers in Northwest Florida. Florida Field Naturalist 19(3):65-72.

Haig, S. M. and J. H. Plissner. 1993. Distribution and abuncance of Piping Plovers: results and implications of the 1991 international census. The Condor 95:145-156.

Haig, S. M. and L. W. Oring. 1988. Distribution and dispersal in the Piping Plover. The Auk 105:630-938.

Hicklin, P. W. and P. C. Smith. 1984. Selection of foraging sites and invertebrate prey b migrant Semipalmated Sandpipers, *Calidris pusilla* (Pallas). in Minas Basin, Bay of Fundy. Canadian Journal of Zoology 62:2201-2209.

Johnson, A. F. and M. G. Barbour. 1990. Dunes and Maritime Forests *in* Ecosystems of Florida. Ronald L. Myers and John J. Ewel, eds. University of Central Florida Press, Orlando, Florida. 765 pp.

Johnson, C. M. and G. A. Baldassarre. 1988. Aspects of the wintering ecology of Piping Plovers in coastal Alabama. Wilson's Bulletin 100(2):214-223.

Massey, B. W. and J. M. Fancher. 1989. Renesting by California Least Terns. Journal of Field Ornithology 60(3):350-357.

Maxwell, G. R. II and H. W. Kale II. 1974. Population estimate of breeding birds on a spoil island in the Indian River, Indian River County, Florida. Florida Field Naturalist 2:32-39.

Myers, J. P., M. Sallaberry A., E. Ortiz, G. Castro, L. M. Gordon, J. L Maron, C. T. Schick, E. Tabilo, P. Antas, and T. Below. 1990. Migration routes of New World Sanderlings. The Auk 197:172-180.

National Geographic Society. 1987. Birds of North America. National Geographic Society, Washington, D.C. 464 pp.

Nicholls, J. L. and G. A. Baldassarre. 1990. Habitat associations of Piping Plovers wintering in the United States. Wilson's Bulletin 102(4):581-590.

Peterson, R. T. 1980. A Field Guide to the Birds of Eastern and Central North America. Houghton Mifflin Co., Boston, Massachussetts. 384 pp.

Powell, G. V. N. and A. H. Powell. 1986. Reproduction by Great White Herons *Aredea herodias* in Florida Bay as an indicator of habitat quality. Biological Conservation 36:101-113.

Powell, G. V. N., R. D. Bjork, J. C. Odgen, R. T. Paul, A. H Powell, and W. B. Robertson, Jr. 1989. Populatio trends in some Florida Bay wading birds. Wilson Bulletin 101(3):436-457.

Pranty, B. 1996. A Birder's Guide to Florida. American Birding Association, Inc., Colorado Springs, Colorado. 388 pp.

Richter, W. and E. Myers. 1993. The birds of a short-hydroperiod, *Muhlenbergia*-dominated wetland prairie in southern Florida. Florida Field Naturalist 21(1):1-28.

Rimmer, D. W. and R. D. Deblinger. 1992. Use of fencing to limit terrestrial predator movements into Least Tern colonies. Colonial Waterbirds 15(2):226-229.

Rodgers, J. A., Jr. 1980. Breeding ecology of the Little Blue Heron on the west coast of Florida. The Condor 82:164-169.

Rodgers, J. A., Jr. 1980. Reproductive success of three heron species on the west coast of Florida. Florida Field Naturalist 8(2):37-56.

Schreiber, R. W. and E. A. Schreiber. 1982. Essential habitat of the Brown Pelican in Florida. Florida Field Naturalist 10(1):9-17.

Smith, H. T., W. J. B. Miller, R. E. Roberts, C. V. Tamborski, W. W. Timmerman, and J. S. Weske. 1994. Banded Royal terns recovered at Sebastial Inlet, Florida. Florida Field Naturalist 22(3):81-83.

Spendelow, J. A. and S. R. Patton. 1988. National atlas of coastal waterbird colonies in the contiguous United States: 1976-82. U.S. Fish and Wildlife Service Biological Report 88(5).

Stevenson, H. 1960. A key to Florida Birds. Peninsular Publishing Co., Tallahassee, Florida.

Toland, B. 1991. Successful nesting by Reddish Egrets at Oslo Island, Indian River County, Florida. Florida Field Naturalist 19(2):51-53.

Visser, J. M. and G. W. Peterson. 1994. Breeding populations and colony site dynamics of seabirds nesting in Louisiana. Colonial Waterbirds 17(2):146-152.

Werschkul, D. F. 1977. Changes in a Southeastern Heronry. The Oriole. ?:5-9.

Withers, K. and B. R. Chapman. 1993. Seasonal abundance and habitat use of shorebirds on an Oso Bay Mudflat, Corpus Christi, Texas. Journal of Field Ornithology 64(3):382-392.

Table 5-1. Average numbers of shorebirds, seabirds, and wading birds observed per survey per month along Cape San Blas, Florida from April 1994 to March 1996.

Months	Shorebirds		Seabirds		Wading birds	
	1994/95	1995/96	1994/95	1995/96	1994/95	1995/96
April	165.0	151.5	513.5	341.5	4.0	5.0
May	320.0	334.3	201.0	1,537.7	12.0	4.3
June	26.3	35.5	291.3	1,164.0	5.7	13.0
July	39.0	127.8	497.0	592.0	6.5	22.5
August	93.5	85.7	578.5	511.0	7.0	10.7
September	101.0	93.0	1,115.5	1,449.0	7.0	6.5
October	83.0	40.7	237.3	213.5	6.5	9.0
November	119.0	93.3	185.3	338.7	3.5	2.0
December	45.0	70.8	463.0	477.0	2.3	3.0
January	21.0	34.8	324.0	323.5	3.0	2.8
February	57.5	335.7	480.5	125.7	3.5	1.7
March	239.5	180.5	226.0	128.0	1.0	3.7

Table 5-2. Average numbers of shorebird species observed per survey per season along Cape San Blas, Florida from April 1994 to March 1996.

Species	Winter	Spring	Summer	Fall	TOTAL
Dunlin	56.39	81.27	0.00	15.06	38.18
Peep	5.72	59.53	21.25	21.83	27.08
Sanderling	6.39	21.40	6.56	14.72	12.27
Semipalmated Plover	3.22	10.60	6.19	9.56	7.39
Short-billed Dowitcher	5.00	9.33	4.31	0.17	4.70
Willet	3.17	7.80	14.69	4.50	7.54
Piping Plover	4.39	4.27	2.94	7.11	4.68
Red Knot	4.22	1.40	0.06	2.56	2.06
Black-bellied Plover	4.83	4.47	1.31	3.89	3.63
Ruddy Turnstone	0.56	8.33	2.88	4.39	4.04
Wilson's Plover	0.00	7.87	8.13	0.44	4.11
Least Sandpiper	0.33	5.40	2.81	2.50	2.76
Greater Yellowlegs	0.28	0.07	0.38	0.72	0.36
Snowy Plover	0.83	1.00	1.00	1.00	0.96
American Oystercatcher	0.00	0.27	0.69	0.00	0.24
Marbled Godwit	0.00	0.87	0.19	0.00	0.27
American Avocet	0.00	0.93	0.00	0.00	0.23
Lesser Yellowlegs	0.00	0.40	0.06	0.06	0.13
Killdeer	0.28	0.07	0.13	0.17	0.16
Black-necked Stilt	0.00	0.27	0.00	0.00	0.07
Solitary Sandpiper	0.00	0.00	0.00	0.11	0.03
Spotted Sandpiper	0.00	0.00	0.06	0.00	0.02
Stilt Sandpiper	0.00	0.00	0.06	0.00	0.02
Whimbrel	0.00	0.07	0.00	0.00	0.02
TOTAL	95.61	225.62	73.70	88.79	

Table 5-3. Average numbers of seabird species observed per survey per season along Cape San Blas, Florida from April 1994 to March 1996.

Species	Winter	Spring	Summer	Fall	TOTAL
Laughing Gull	150.12	65.60	119.81	65.71	100.31
Sandwich Tern	5.24	193.93	69.50	90.00	89.67
Common Tern	0.00	87.60	132.81	95.18	78.90
Royal Tern	38.47	52.67	96.13	76.65	65.98
Brown Pelican	10.06	19.93	90.69	76.06	49.19
Forster's Tern	55.00	37.60	0.06	18.18	27.71
Herring Gull	34.65	13.73	0.94	14.06	15.85
Least Tern	0.00	11.33	40.56	0.41	13.08
Black Tern	0.00	0.13	0.13	0.00	0.07
Ring-billed Gull	27.82	1.20	0.19	7.76	9.24
Bonaparte's Gull	27.00	7.60	0.00	0.12	8.68
Double-crested Cormorant	11.47	13.60	0.00	0.82	6.47
Caspian Tern	0.18	0.13	2.25	1.18	0.94
Black Skimmer	0.00	0.27	1.13	0.41	0.45
American White Pelican	0.22	0.00	0.00	0.00	0.06
Common Loon	0.00	0.00	1.87	0.00	0.47
Northern Gannet	0.00	0.00	21.47	31.53	13.25
TOTAL	283.29	505.32	577.54	478.07	

Table 5-4. Average numbers of wading birds observed per survey per season along Cape San Blas, Florida from April 1994 to March 1996.

Species	Winter	Spring	Summer	Fall	TOTAL
Great Egret	1.00	1.07	3.19	1.28	1.64
Great Blue Heron	0.89	0.13	1.13	1.06	0.80
Snowy Egret	0.56	2.07	3.25	1.89	1.94
Little Blue Heron	0.06	0.27	0.44	0.11	0.22
Reddish Egret	0.17	0.33	0.31	0.28	0.27
Tricolored Heron	0.00	0.20	0.94	0.33	0.37
Yellow-crowned Night-Heron	0.00	0.00	2.50	0.00	0.63
Cattle Egret	0.00	0.40	0.19	0.50	0.27
Green-backed Heron	0.00	0.07	0.00	0.00	0.02
TOTAL	2.68	4.54	11.95	5.45	0.00

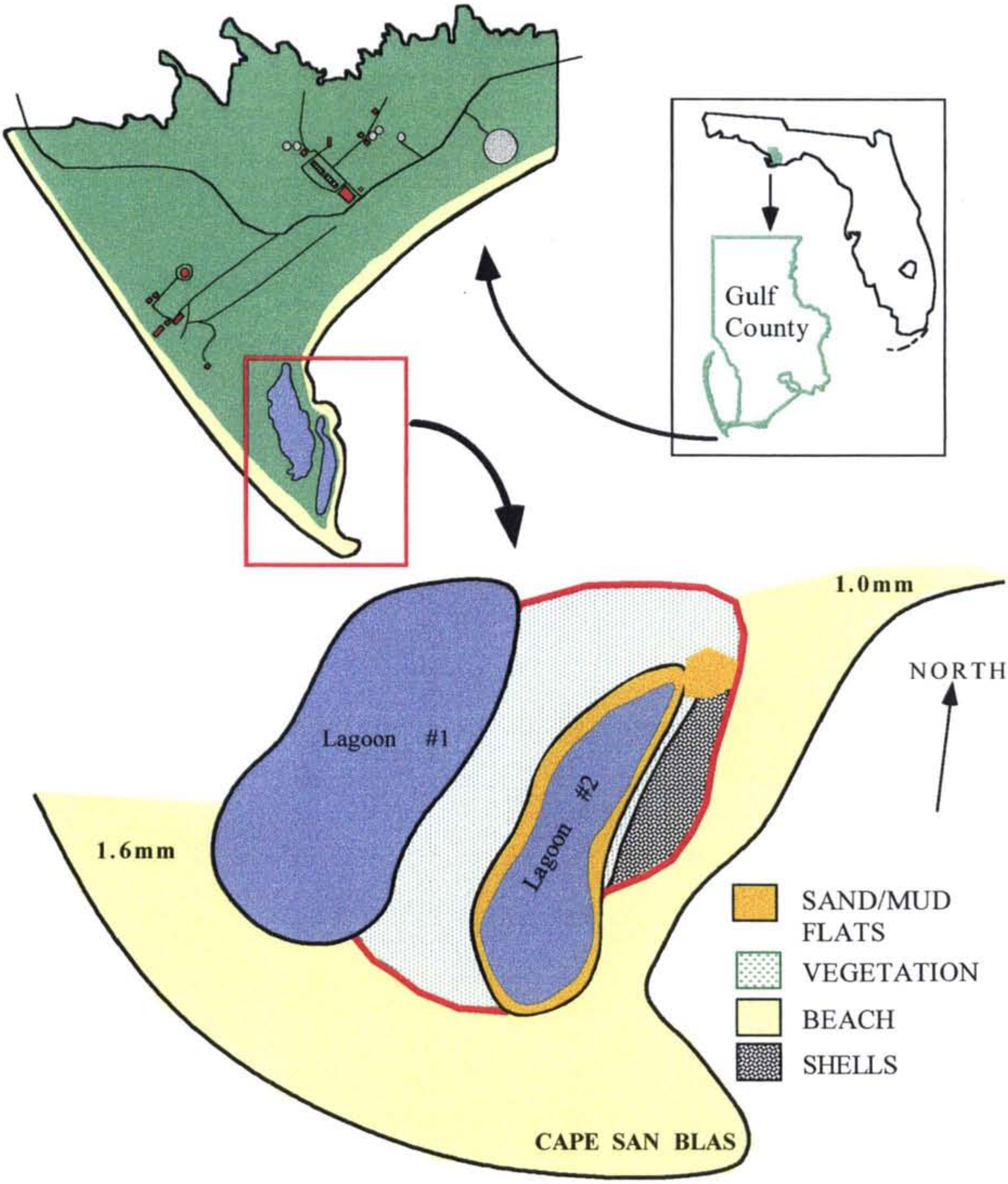


Figure 5-1. An area of sensitive habitat along Eglin Air Force Base on Cape San Blas between mile markers 1.6 and 1.0. This area encompasses sand flats, mud flats, and marsh vegetation that are used frequently by nesting shorebirds and seabirds, and by feeding shorebirds, seabirds, and wading birds. The red circle indicates the section that should be restricted to human activity, especially vehicular traffic.

CHAPTER 6

BEACH MICE

Introduction

The oldfield mouse (*Peromyscus polionotus*) is common and abundant throughout the southeastern United States. Along the Atlantic Ocean and Gulf of Mexico coasts, local populations of the oldfield mouse, known as beach mice, have been isolated by formation of islands and rising sea levels. Due to isolation, these populations have diverged into separate subspecies. Formerly, these subspecies occupied substantial stretches of coastal dunes in northwest Florida and southern Alabama, however destruction of the dune system by natural forces and human disturbance has resulted in a severe decline in numbers of beach mice (U.S. Fish and Wildlife Service 1986). One species of beach mouse currently protected by Florida as an endangered species and under consideration for federal listing is the St. Andrews beach mouse, *P. p. peninsularis*.

Few studies have been conducted on the St. Andrews beach mouse, therefore little is known of the numbers and range of this subspecies. The historic range of the St. Andrews beach mouse was Crooked Island, Bay County, south and east to the St. Joseph peninsula, Gulf County (James 1992). Along the western portion of their range on Crooked Island, however, no mice have been caught since 1992 (Jeff Gore, FL Game and Freshwater Fish Commission, pers. comm.). Within the eastern portion of their range along the St. Joseph peninsula, trapping in St. Joseph State Park has revealed a substantial population of beach mice (J. Moyers, Auburn University, pers. comm.). It is unknown, however, if beach mice still inhabit the remaining portions of the St. Joseph peninsula, including Cape San Blas.

Throughout their range, St. Andrews beach mice occur in well-developed dunes where the major vegetation is sea oats (*Uniola paniculata*). They also inhabit older and higher back dunes that support live oaks (*Quercus genimata*) and rosemary (*Ceratiola ericoides*; James 1992). The east beach of Cape San Blas typically consists of a set of low dunes (approximately 1-3 m) vegetated primarily by beach grass (*Spartina* *alterniflora*) and sea oats. Possibly, this dune system supported a population of beach mice in the past, however natural and human disturbances have damaged the habitat making it uninhabitable by beach mice. Additionally, in October 1995 Hurricane Opal struck the Florida panhandle and destroyed most of the dunes along Cape San Blas. It is unknown if Cape San Blas supported a population of St. Andrews beach mice prior to Hurricane Opal and if so, how this natural disturbance affected the beach mice in this area. The objectives of this study were to assess the status and range of the St. Andrews beach mouse along Eglin Air Force Base property on Cape San Blas, Florida.

Methods

Sherman live-traps were used to assess the numbers of beach mice present along Eglin Air Force Base property on Cape San Blas, Florida. We set 172 traps each night from December 8 through December 13, 1994 for a total 860 trap nights. Traps were set along four transect lines on the east beach of Cape San Blas, from the cape point to the eastern boundary of Eglin Air Force property (approximately 1.0 mile). Traps were baited with oatmeal and lined with cotton-poly fill to provide warmth for trapped animals.

Results

No beach mice were caught throughout all 860 trap nights along Eglin Air Force Base property on Cape San Blas. The only animal caught in traps was one cotton rat (*Sigmodon hispidus*) trapped on December 10.

Discussion

These data indicated there were no St. Andrews beach mice inhabiting Cape San Blas in winter 1994, therefore the St. Andrews beach mouse is most likely restricted to the northern portion of the St. Joseph peninsula. It appears the southernmost range of the St. Andrews beach mouse is private land just south of Billy Joe Rish State Park on St. Joseph peninsula, approximately 3 km south of the entrance to the St. Joseph State Park and 7 km north of the entrance to Eglin Air Force Base property on Cape San Blas. In July 1996, 9 mice were captured during 500 trap nights in Billy Joe Rish State Park and one mouse was caught in 250 trap nights along the private property (J. Moyers, Alabama Coop. Unit, pers. comm.). Possibly, due to habitat destruction or increased numbers of predators, the range of this beach mouse has decreased, limiting the population to the northernmost portion of the St. Joseph peninsula.

Destruction of beach mouse habitat has occurred due to natural forces and human disturbance. Perdido Key, Florida was flooded to a depth of 2.4 m during Hurricane Fredrick in 1979 and much of the foredune habitat was destroyed by overwash (Johnson and Barbour 1990). Trapping data after the hurricane indicated the Perdido Key beach mouse, *P. p. trisyllepsis*, was on the verge of extinction, and this decrease in numbers was attributed to loss of habitat from the storm (Holliman 1983). Shell Island in Bay County, Florida supported a population of 800 to 1,200 Choctawhatchee beach mice (*P. p. allophrys*) prior to Hurricane Opal in October 1995. Shell Island was completely overwashed during the hurricane and nearly all the dune habitat was destroyed. Trapping conducted after the storm revealed beach mice in two small areas with remaining scrub dunes (Moyers et al. 1996). Cape San Blas has been severely impacted by several storms, including Hurricane Agnes in 1972 that had sustained winds of 86 mph and a 7 ft tidal surge, Hurricane Elena in 1985 during which 1,500 ft were lost from the cape point along Cape San Blas, and Hurricane Kate in 1985 that had sustained winds of 135 mph and a tidal surge of 8 ft. Possibly, St. Andrews beach mice do not inhabit Cape San Blas because these storms have severely altered the dune system along Cape San Blas and destroyed suitable habitat for beach mice.

Lack of secondary dunes may also contribute to loss of beach mice during storms. Although frontal dunes along Grayton Beach and Topsail Hill, Florida were destroyed by Hurricane Opal, secondary and scrub dunes were only temporarily flooded with sea water. Possibly, Choctawhatchee beach mice were able to survive the hurricane along these beaches because they were able to find refuge in the secondary dunes (Moyers et al. 1996). Because primary dunes along Cape San Blas are small, secondary dunes are often severely impacted during storms. Therefore, beach mice may have no available refuges during hurricanes, which may also contribute to the lack of beach mice along Cape San Blas.

Foredunes and secondary dunes are also impacted by human disturbance. Trapping data from the east coast of Florida indicated populations of *P. p. niveiventris* and *P. p. phasma* have been severely constricted due to development of their habitat (Humphrey et al. 1987). Along the Gulf of Mexico coast in 1950, the Choctawhatchee beach mouse was widespread and abundant, but by 1962 two-thirds of the dune habitat had been lost to development and in 1974 only sparse, intermittent beach mouse populations were observed (Bowen 1968, Smith 1978). In 1979, Humphrey and Barbour (1981) found that throughout their ranges, Choctawhatchee, Perdido Key (*P. p. trissyllepsis*), and pallid beach mice (*P. p. decoloratus*) were absent from areas altered by human development. Our study sites were located on Eglin Air Force Base where commercial and residential development are not permitted. Therefore, human development of beach mouse habitat along Cape San Blas may not be restricting mice from inhabiting this area. Development of areas between St. Joseph State Park and Cape San Blas may, however, be restricting movement of mice between the state park and Cape San Blas. This may contribute to reduced number of mice along Cape San Blas by limiting colonization of mice into areas outside of the state park.

Although development is not permitted along Cape San Blas beaches, vehicular and foot traffic are allowed. Godfrey et al. (1980) suggested continuous vehicle impact along a foredune could induce or accelerate dune erosion. They reported as few as 100 passes by an off-road vehicle are sufficient to create maximum damage to dune vegetation, such as American beach grass (*Ammophila breviligulata*), and this disturbance may also interfere with the invasion and colonization of *Ammophila breviligulata* (Godfrey et al. 1980). Additional species of dune vegetation, such as sea oats, are also influenced by vehicular traffic. Sea oats colonize through seeds that wash onshore and settle along the beach in the drift line. Once settled on the beach, seeds propagate through spreading of rhizomes (see erosion chapter). Vehicles may not only destroy adult plants but also seeds, rhizomes, and tillers, thus preventing colonization and growth of sea oats. Therefore, even if vehicles on Cape San Blas are not driving directly over dunes, they may be limiting colonization of dune vegetation, thereby preventing formation and growth of dunes. Lack of dunes along Cape San Blas would most likely result in poor habitat for St. Andrews beach mice.

Beach mice rely on dunes for burrows, food, and protection from predators. Throughout their range, beach mice are typically widespread within the dune system. The Anastasia Island beach mouse (*P. p. phasma*) was found to burrow along bottoms of bare, wind-swept hollows, on high grassy plateaus along back dunes, in perpendicular banks, and on moderate slopes below growths of sea oats (Ivey 1949). Along the Canaveral Peninsula, Merritt Island, Florida, Extine and Stout (1987) found *P. p. niveiventris* throughout the most seaward zone of sea oats, the intermediate zone consisting of bare sand with clumps of palmetto (*Serenoa repens*), and the most landward zone located at the top of the major dune line. The St. Andrews beach mouse has also been reported in several regions of the dune system along St. Joseph State Park. They occur in the front dunes that support sea oats, and along the higher, back dunes consisting of live oak (*Quercus geminata*), sea oats, and rosemary (*Ceratiola ericoides*; James 1992). Therefore, beach mice are able to colonize and survive throughout the entire dune system and in various types of dune vegetation.

Dune vegetation encourages beach mice colonization by aiding in growth and formation of dunes. It also provides beach mice with nutrition. Moyers (1996) found Alabama, Perdido Key, and Santa Rosa beach mice fed primarily on insects and plant products. Typically, seeds and fruits consumed by these subspecies had become available as fallen seeds or were produced by low-growing, prostrate plants (Moyers 1996). Plants that produced light weight, wind dispersed seeds were not consumed by beach mice. Seeds and fruits of vegetation with supple stems, such as dune toadflax (*Linaria floridana*) or joint weed (*Polygonella gracilis*) may also be preyed upon because beach mice may be able to bend stems making seeds and fruits easier to reach (Moyers 1996). The primary food items of beach mice varied seasonally. Along Perdido Key in fall and winter, sea oats dominated the diets, with evening primrose (*Oenothera humifusa*), bluestem (*Schizachyrium maritimum*), and insects also being fed upon (Moyers 1996). In spring, dune toadflax, yaupon holly (*Ilex vomitoria*), and seashore elder (*Iva imbricata*) were common, whereas in summer, primrose and insects were again typically fed upon. Diets of Santa Rosa and Alabama beach mice were similar although winter diets of both subspecies differed. Santa Rosa mice fed more frequently on beach pea (*Galactia sp.*) whereas Alabama mice preyed upon jointweed (*Polygonella gracilis*) more often than Santa Rosa or Perdido Key beach mice (Moyers 1996).

The dune habitat surrounding Cape San Blas supports a variety of vegetation. On St. Vincent Island dunes are inhabited by vegetation typically fed upon by beach mice such as sea oats, woody goldenrod, bluestem, primrose, ground cherry, and rosemary (Johnson and Barbour 1990). The beach/dune community along Dog Island is characterized by sea oats, beach morning glory, sea rocket, woody goldenrod, evening primrose, and bluestem (Anderson and Alexander 1985). Along Cape San Blas, vegetation often fed upon by beach mice, such as sea oats, are common (pers. obs.).

This indicates dune habitat along Cape San Blas may provide appropriate food sources for beach mice.

Studies have indicated consumption of food items by beach mice is most likely determined by availability and quality of foods (Phelan and Baker 1992, Moyers 1996). In times of poor seed production by sea oats along Perdido Key, mice were found to consume other items, such as evening primrose, insects, and yaupon holly (Moyers 1996). Seed production in sea oats declined dramatically along Perdido Key in 1992, and great diversity indices of beach mouse diets in autumn 1992 indicated increased foraging by beach mice for foods other than sea oats (Moyers 1996). Therefore, beach mice appear to have flexible diets within their habitat allowing a change in diet in response to changes in the environment. Cape San Blas habitat provides not only primary food items, such as sea oats and bluestem, but also secondary items, such as rosemary and live oaks.

Beach mice also benefit from camouflage with the dune habitat. These mice have white underparts and sides, and their backs are pale and buffy (James 1992), which allows them camouflage against the white sand beaches. This aids in protection from predators, such as house cats (*Felis domesticus*). Because Cape San Blas is owned by Eglin Air Force Base, it is not commercially or residentially developed, therefore there are few house cats in the area (pers. obs.) reducing the threat of predation.

Another threat to beach mice is competition with other species, especially house mice (*Mus musculus*; Humphrey and Barbour 1981). Humphrey and Barbour (1981) found that although beach mice previously inhabited the mainland portion of St. Andrews State Park, adjacent dunes were developed and house mice invaded much of the undeveloped dune grassland. No beach mice remain in the area (Humphrey and Barbour 1981). Shell Island, separated from the St. Andrews mainland by a ship channel, is not inhabited by house mice, however, and beach mice are still present on the island (Humphrey and Barbour 1981). We caught no house mice throughout all trap nights during our study, therefore house mice may not limit beach mice from inhabiting the dunes along Cape San Blas.

Management Recommendations

Lack of beach mice within the dune habitat along Cape San Blas is most likely a result of severe storm damage and erosion that has destroyed much of the primary beach mouse habitat. Storms such as Agnes (1972), Elena (1985), Kate (1985), and Opal (1995) have often been accompanied by extremely high storm surges that have completely washed over dunes along Cape San Blas and adjacent beaches. This natural removal of sand, accompanied by consistent human disturbance (vehicular traffic), may limit growth of dunes and dune vegetation thereby preventing beach mice from inhabiting the area. Better protection of the dune habitat and possibly dune revegetation efforts may create appropriate habitat for the St. Andrews beach mouse.

Protection of dune habitat along Cape San Blas involves limiting traffic, especially vehicular traffic, within and above the drift line. This will allow recruitment, propagation, and growth of dune building vegetation, such as sea oats, that also provide food for beach mice. Revegetation efforts may also assist in creating appropriate habitat for beach mice along Cape San Blas. Sand fence at a height of 50 cm and placed 10-15 m seaward of the old high tide line was installed along 8 km of nourished beach at Johnson Beach, Perdido Key, Alabama (Gibson and Looney 1994). Within one year of installment, the fencing was buried and the deposited sand supported several sea rocket, evening primrose, and sea oats. Vegetative development of these dunes was so rapid that beach mice began using the eastern portions of the dunes within three years of placement (Moyers 1996). Sand fencing may interfere with sea turtle nesting activity, however.

Revegetation may be best accomplished through planting of sea oat seeds or seedlings along the east beach of Cape San Blas. The east beach experiences net accretion throughout the year (see beach erosion chapter), therefore sand trapping devices, such as fencing, may not be necessary. Possibly, assisting with sea oat colonization and propagation through planting of seeds and seedlings would increase the number of sea oats inhabiting the dune system along Cape San Blas, thereby protecting dunes from erosion and providing more food for beach mice. Additional food items, such as bluestem or primrose, may also be considered for planting.

1. Restrict vehicular traffic to below the drift line and assess the food supply within the dune system to protect and possibly increase the amount of St. Andrews beach mouse habitat along Cape San Blas.

Another factor limiting beach mice along Cape San Blas may be increased human development between St. Joseph State Park and Cape San Blas. Possibly, this development prevented mice from moving between the St. Joseph State Park and Cape San Blas, thereby isolating beach mice along the northern tip of the peninsula. Re-introduction of beach mice to the Cape San Blas may allow for re-establishment of a population of St. Andrews beach mice outside of St. Joseph State Park. Because the number of beach mice within the state park appears to be stable or growing (J. Moyers pers. com.), removal of individuals from this group will most likely not threaten the population.

2. Transplant beach mice from St. Joseph State Park to the east beach of Cape San Blas, provided the population within the state park remains stable and habitat along Cape San Blas is not adversely affected by a tropical storm before the transplant.

Effective management of the dune habitat along Cape San Blas area may allow for establishment of a successful population of St. Andrews beach mice along Cape San Blas. This may be accomplished through revegetation efforts, limitation of vehicular traffic, and continued protection from commercial and residential development. Additional factors, such as absence of beach mouse predators and competitors, may also contribute to appropriate beach mouse habitat along Cape San Blas. Removal of individual mice from the healthy population within St. Joseph State Park would provide necessary mice to transplant to Cape San Blas. Continued monitoring of the state park population would assist in these efforts.

Literature Cited

Anderson, L. C. and L. L. Alexander. 1985. The vegetation of Dog Island, Florida. Florida Scientist 48(4): 232-243.

Bowen, W. W. 1968. Variation and evolution of Gulf Coast populations of beach mice, *Peromyscus polionotus*. Bulletin of the Florida State Museum 12: 1-91.

Extine, D. D. and I. J. Stout. 1987. Dispersion and habitat occupancy of the beach mouse, *Peromyscus polionotus niveiventris*. Journal of Mammalogy 68(2): 297-304.

Gibson, D. J. and P. B. Looney. 1994. Vegetation colonization of dredge spoil on Perdido Key, Florida. Journal of Coastal Restoration 10: 133-134.

Godfrey, P. J., S. P. Leatherman, and P. A. Buckley. 1980. ORV's and barrier beach degradation. Parks 15: 2, 5-11.

Holliman, D. C. 1983. Status and habitat of Alabama Gulf coast beach mice, *Peromyscus polionotus ammobates* and *P. p. trisyllepsis*. Northeast Gulf Scientist 6: 121-129.

Humphrey, S. R. and D. B. Barbour. 1981. Status and habitat of three subspecies of *Peromyscus polionotus* in Florida. Journal of Mammalogy 62(4): 840-844.

Humphrey, S. R., W. H. Kern, Jr., and Ludlow, M. W. 1987. Status survey of seven Florida mammals. Cooperative Fish and Wildlife Research Unit Technical Report No. 25, School of Forest Resources and Conservation, Institute of Food and Agricultural Science, University of Florida, Gainesville, Florida.

Ivey, R. D. 1949. Life history notes on three mice from the Florida east coast. Journal of Mammalogy 30(2): 157-162.

James, F. C. 1992. St Andrew Beach Mouse. Pages 87-93 *in* S. R. Humphrey, Ed., Rare and Endangered Biota of Florida, Volume 1. Mammals. University Press of Florida, Tallahassee. 392 pp.

Johnson, A. F. and M. G. Barbour. 1990. Dunes and Maritime Forests. Pages 429-480 *in* R. L. Myers and J. J. Ewel, eds. Ecosystems of Florida, University of Central Florida Press, Orlando, FL. 765 pp.

Moyers, J. E. 1996. Food habits of Gulf Coast subspecies of beach mice (*Peromyscus polionotus* spp.). Master's thesis, Auburn University. 84 pp.

Moyers, J. E., H. G. Mitchell, and N. R. Holler. 1996. Status and distribution of Gulf coast subspecies of beach mouse. Annual report submitted to The U. S. Fish and Wildlife Service. 19 pp.

Phelan, J. P. and R. H. Baker. 1992. Optimal foraging in *Peromyscus polionotus*: the influence of item-size and predation risk. Behavior 121: 95-109.

Smith, M. H. 1978. Choctawhatchee beach mouse. Pages 18-19 *in* J. N. Layne, ed. Rare and endangered biota of Florida. Volume 1. Mammals. University of Florida Presses, Gainesville, FL. 52 pp.

United States Fish and Wildlife Service. 1986. Hurricanes damage southeastern beach mouse habitat. Endangered Species Technical Bulletin. 11(1): 14.

CHAPTER 7

NEOTROPICAL MIGRANTS

Introduction

Migrating birds are often exhausted and energy-depleted after crossing large barriers, such as the Gulf of Mexico, therefore peninsulas and barrier islands become natural funnels for migrating birds (Proctor and Lynch 1993). Woodlands and wooded barrier islands along the northern Gulf of Mexico coast provide the last foraging opportunity for fall migrants crossing the Gulf of Mexico and the first potential landfall for spring migrants (Moore et al. 1990). Cape San Blas, a barrier island strategically located in the southernmost extremity of the Florida panhandle, may provide suitable habitat for neotropical migrants, therefore this area may be an important stopover site for neotropical bird species migrating over the Gulf of Mexico.

Peninsulas and barrier islands throughout North America attract neotropical migrants. Many avian species are found along Point Pelee in Ontario, Canada during spring migration because it is often the first land birds encounter after crossing Lake Erie (Proctor and Lynch 1993). The Isthmus of Tehuantepec in southern Mexico is the northernmost severe narrowing in North America, and this area also attracts many neotropical migrants during migration (Winker 1995). This funneling of migrating birds also occurs on peninsulas and barrier islands along the Gulf of Mexico. On East Ship Island, Texas, one of 50 barrier islands along the northern Gulf of Mexico, 874 birds of 49 species were captured in mist nets during spring migration from 1987 to 1989. Along Horn Island, Mississippi, 1,499 birds of 46 species were captured in mist nets from April 10 to May 13, 1987 (Moore et al. 1990, Kuenzi et al. 1991). This indicates barrier islands, including those along the northern Gulf of Mexico, may be important stopover areas for neotropical migrants.

Although these barrier islands may be essential to successful migration by neotropical birds, no research has been conducted on use of Cape San Blas by migrating bird species. West of Cape San Blas, along Tyndall and Eglin Air Force Bases, neotropical migrants were primarily found in riparian corridors, hammocks, barrier island scrub, and flatwood habitats (Hill et al. 1994). Cape San Blas provides a variety of these habitats, including ridges of rosemary scrub and swales of slash pine. Of the approximately 300 hectares owned by Eglin Air Force Base along Cape San Blas, only 60 hectares are occupied and the remaining are undeveloped. Therefore, due to its location as a barrier island along the northern Gulf of Mexico and because of the variety of habitats it encompasses, Cape San Blas may provide necessary resources for migrating avian species. The purpose of this study was to assess neotropical migrant use of Cape San Blas during the 1994 fall and 1995 spring migration. Basic data on the species that use Cape San Blas, their densities and habitat associations were collected to assist in development of conservation strategies for Cape San Blas and associated areas, such as St. Joseph State Park.

Methods

Point counts were conducted once a week during Fall (September - November) 1994 and Spring (March - May) 1995, by a knowledgeable observer who recorded species and number of birds during a five minute period. Thirty 50-m radius point counts were established in the flatwoods and scrub habitat throughout Eglin Air Force Base on Cape San Blas (Fig. 7-1). Stations were located at least 150 m apart. Point counts were conducted between approximately 700 am and noon, and all species heard or seen within the plot were recorded. Birds were identified to species when possible. For analysis, data were separated into migratory categories, including transient neotropical migrant, breeding neotropical migrant, or resident.

Results

Fall 1994

During 330 point counts in fall 1994, 1,817 birds of 57 species were recorded (Table 7-1a). Of all birds recorded, 1,109 (61.0%) were residents, 391 (21.5%) were neotropical breeders, 280 (15.4%) were wintering species, 22 (1.21%) were unidentified, and 15 (0.83%) were transient neotropical migrants of 7 species. The most abundant of all species recorded along Cape San Blas throughout the point counts was the Gray Catbird (*Dumetella carolinensis*; 316, 17.3%), and the second most abundant was the Rufous-sided Towhee (*Pipilo erythrophthalmus*; 273, 15.0%). The Gray Catbird was also the most abundant neotropical migrant recorded along Cape San Blas, and the White-eyed Vireo (*Vireo griseus*; 39, 2.14%) was second. The most abundant transient neotropical migrant was the American Redstart (*Stenophaga ruticilla*) with 9 individuals (0.49%). The remaining six transient neotropical migrants recorded within the study area were individual birds (0.06%).

Of all species recorded along Cape San Blas in fall 1994, the most frequently encountered throughout the 330 point counts was the Rufous-sided Towhee (150; 45.5%), and the second most common was the Gray Catbird (146, 44.2%; Table 7-2). The most common neotropical migrant species was the Gray Catbird (146; 44.2%). The second most common was the White-eyed Vireo (30;9.10%). The American Redstart was the most common transient neotropical migrant observed 8 of 330 point counts (2.40%). All six remaining transient neotropical migrant species were observed in individual point counts (0.30%).

Spring 1995

In Spring 1995, 2,038 birds of 69 species were recorded during 330 point counts (Table 7-1b). Of all birds recorded, 1,484 (72.8%) were residents, 401 (19.7%) were neotropical breeders, 143 (7.02%) were winter species, and 10 (0.49%) were transient neotropical migrants comprising 4 species. Of all species recorded throughout the point counts, the Rufous-sided Towhee was most abundant (347, 17.0%), and the Northern Cardinal (*Cardinalis cardinalis*) was second most abundant (305, 15.0%). The most abundant neotropical migrant recorded was the Gray Catbird (125, 6.13%), and the second most abundant was the White-eyed Vireo (120, 5.89%). The most abundant transient neotropical migrant was the Rose-breasted Grosbeak (*Pheucticus ludovicianus*; 4, 0.20%). The remaining four transient neotropical migrant species recorded during Spring 1995 were of two birds each (0.10%).

Of 330 point counts that occurred in spring 1995, the Rufous-sided Towhee was recorded in 189 (57.3%), making it the most common species recorded throughout the study area. The Northern Cardinal was second, having been recorded in 177 point counts (53.6%). The most common neotropical migrant was the White-eyed Vireo (75, 22.7%), and the Gray Catbird was second most common (68, 20.6%). The Rose-breasted Grosbeak was the most common transient neotropical migrant, recorded two of 330 point counts (0.60%). The remaining four transient neotropical migrant species were observed in only one of the 330 point counts (0.30%).

Discussion

Numbers of neotropical migrants

It is apparent Cape San Blas is not an important stopover for transient neotropical migrant species. Although a large number of birds were recorded throughout all 660 point counts (3,855), the majority of birds recorded in fall (61%) and spring (72.8%) were residents. Numbers of transient neotropical migrants recorded along Cape San Blas were comparable to those observed along Tyndall and Eglin Air Force Bases, Florida (Hill et al. 1994). Along both bases in spring 1994, Hill et al. (1994) reported 8 neotropical migrants of five species during 630 point counts. They suggested Eglin and Tyndall Air Force Bases lie in a "migrant shadow", which they define as a portion of the Gulf coast where trans-Gulf migrants rarely make landfall (Hill et al. 1994). Cape San Blas may also be part of this "migrant shadow". Areas with larger numbers of migrants, such as Horn Island, Mississippi, averaged an equal number of neotropical migrant species per day (25) during one month of spring migration, as were recorded throughout the entire spring migration along Cape San Blas (Moore et al. 1990). Moore et al. (1990) recorded 1,499 individuals of 46 species in one month (10 April to 13 May 1987) of mist-netting along Horn Island. They suggested birds were stopping on Horn Island because of suitable habitat, which included abundant food resources, protection from predators, and favorable weather over the Gulf of Mexico during spring and fall migration.

Few transient neotropical migrants along Cape San Blas may therefore be due to lack of suitable habitat in the area. In spring and fall, 1993 and 1994 along Eglin Air Force Base, Florida, neotropical migrants were located most often in riparian, hammock, and barrier island scrub habitats (Hill et al. 1994). Approximately 30 to 40 miles west of Cape San Blas, along Tyndall Air Force Base, the greatest number of neotropical migrants during spring and fall 1993 and 1994 were located in hammocks, mature flatwoods, and coastal scrub (Hill et al. 1994). Therefore, Cape San Blas appears to provide suitable habitat for neotropical migrants including, barrier island scrub, coastal scrub, and mature flatwoods. Moore et al. (1990), however, found that, based on availability of habitats along Horn Island, Mississippi, the distribution of migrants among habitats deviated from the expected. Along Horn Island, the Scrub-Shrub habitat, which consisted of groundsel-tree (*Baccharis halimifolia*), southern bayberry (*Myrica cerifera*), yaupon holly (*Ilex vomitoria*), dwarf live oak (*Quercus geminata*), and saw palmetto (*Serenoa repens),* comprised only 14% of available habitat, however the greatest number of individuals, greatest number of species, and greatest species diversity were observed within that habitat. They suggested migrants selected suitable habitat based on factors such as food availability, habitat fragmentation, and protection from predators (Moore et al. 1990). Therefore, although it appears Cape San Blas may provide habitat for neotropical migrants such as scrub and flatwoods, this habitat may not be suitable because of few available resources.

One reason habitat along Cape San Blas may not be suitable is due to lack of abundant food resources. To ensure successful breeding, migrants must be able to replenish energy reserves during migration (Moore and Simons 1989). Most of the birds that stopped along East Ship Island, Mississippi during spring migration arrived near or below fat-free mass (Kuenzi et al. 1991). Birds must replenish this loss to complete their migration and arrive at their breeding grounds with enough energy to defend a territory, find a mate, and reproduce. Bibby et al. (1976) found Sedge Warblers (*Acrocephalus schoenobaenus*) stayed longer on migration grounds in Southern England longer and gained weight faster in years when plum-reed aphids

(*Hyalopterus pruni*) were abundant. In southern Illinois, the spring arrival of wood-warblers (*Parulinae*) coincided with irruptions of lepidopteran larvae in 1979-81, with peak numbers of birds present at or near the peak larvae population, and Hutto (1985) found seasonal changes in bird density over different habitat types in Arizona closely matched changes in food availability (Graber and Graber 1983). Most neotropical migrants feed on insects, although they also eat nectar, berries, and seeds (Ehrlich et al. 1988). Insect sampling has not occurred along Cape San Blas, but possibly, abundant food resources were not available on Cape San Blas during fall 1994 and spring 1995, therefore neotropical migrants were not able to replenish low energy reserves and did not stop on Cape San Blas during migration.

A few species, such as the American Redstart, however did stop along Cape San Blas during migration. The American Redstart's diet is similar to many other neotropical migrant's diets (insects, berries, seeds), therefore it appears appropriate food resources may have been available along Cape San Blas, at least during fall migration when American Redstarts were prevalent (Ehrlich et al. 1988). Possibly, neotropical migrants did not stop along Cape San Blas in fall 1994 and spring 1995 for other reasons, such as habitat fragmentation. Bird species require different threshold levels of habitat area, below which they find habitat unsuitable (Robbins et al. 1989). Often, habitat is unsuitable if tracts of land are fragmented creating large areas of edge. Larger amounts of edge tend to increase the diversity of the community, however those species attracted to edge habitat are typically resident species, not migrants (Anderson 1981). Potential habitat for neotropical migrants along Cape San Blas consists of approximately 150 hectares, which may not be large enough to support great numbers of transient neotropical migrants.

Another reason habitat may be unsuitable along Cape San Blas, is that it does not provide protection from predators. Lindstrom (1989) reported that approximately 10% of the mortality of finches migrating through southern Sweden in fall was due to predation. Along Horn Island, Mississippi, Moore et al. (1990) found 12 neotropical migrants of at least five species had been preyed upon by raptors. A primary area for fall hawk migration is the St. Joseph

Peninsula, on which Cape San Blas is located. Occasionally, as many as 1,500 Sharp-shinned Hawks (*Accipiter striatus*) and 200 American Kestrels (*Falco sparverius*) have been observed migrating over the peninsula (Pranty 1996). The primary prey of many raptors, including Sharp-shinned Hawks, is small birds, such as neotropical migrants (Ehrlich et al. 1988). Possibly, neotropical migrants did not stop on Cape San Blas because of large numbers of predators.

Adverse weather also effects migration of neotropical bird species. The peak of trans-Gulf migration occurs from late-April through early May and coincides with a period of predictable southerly airflow and infrequent frontal activity in the Gulf of Mexico (Moore and Simons 1989). The timing of birds entering the southern United States in spring is related to the stable, favorable weather characterized by the tropical regions from which the migrations originate, and the decreasing number of powerful cold fronts that move over the Gulf of Mexico after the first week in April (Gauthreaux 1971). Gauthreaux (1971) reported that from March 14 to April 7, 1962, trans-Gulf migrants did not arrive on the northern Gulf coast when winds over the southern Gulf were strong and blowing from northerly or easterly directions. After the first week in April, when winds over the Gulf became favorable, the day-to-day constancy of flights across the Gulf were interrupted on only three dates during the study, when strong cold fronts were positioned over the southern Gulf (Gauthreaux 1971). Therefore, weather conditions over the Gulf of Mexico can cause considerable year-to-year variation in the amount of trans-Gulf migration of birds (Gauthreaux 1989). Neotropical migrants may have been prevented from migrating towards the Florida panhandle in fall 1994 and spring 1995 by northerly winds and strong cold fronts over the southern Gulf.

Possibly, Cape San Blas does provide suitable habitat for transient neotropical migrants but birds were missed during point counts. Biases encountered when using point counts to census birds include time of day, number of point counts, capture-probability, and weather conditions (Ekman 1981, Robbins and Stallcup 1981, Fuller and Langslow 1984). Researchers conducting point counts record presence of birds by their song, therefore birds present but not singing during censuring would be missed. Most species that are detected primarily by song are recorded in largest numbers in the hour of sunrise or the hour following sunrise (Robbins 1981a). Many neotropical migrant species, such as the Scarlet Tanager (*Piranga olivacea*) and Indigo Bunting (*Passerina cyanea*) show a strong activity peak in the sunrise hour (Robbins 1981a). At Estacion Biologica La Selva, Costa Rica, total number of individual birds and total number of bird species recorded during point counts declined significantly from early to late morning (Blake 1992). Along Cape San Blas, the earliest point count during fall migration began at 7:29 am and during spring migration began at 7:12 am. During fall 1994, 47.3% of point counts began between 7:00 and 7:59 am, 40.7% began between 8:00 and 8:59 am, and 12% began between 9:00 and 9:59 am. Throughout spring 1995 point counts, 49.9% began between 7:00 and 7:59 am, and 50.1% began between 8:00 and 8:59 am. Larger numbers of transient neotropical migrant species may have been present along Cape San Blas, but not singing during the point counts, therefore they may not have been recorded.

Point counts were conducted once a week throughout the study period along Cape San Blas. Often neotropical migrants arrive at a stopover site during the day and initiate another migration that same night, therefore birds may be present in an area but uncounted unless censuring occurred daily (Gauthreaux 1971). To avoid missing migrants, Moore et al. (1990) conducted daily point counts along Horn Island, Mississippi during spring migration 1987. Possibly, migrants did not remain on Cape San Blas for more than 24 hours, thus the weekly point counts conducted during fall 1994 and spring 1995 may have underestimated the number of neotropical migrants stopping along Cape San Blas.

Capture probability and observability of birds are influenced by the observer's ability to identify bird songs and the observer's hearing capacity. Misidentification of similar bird species, such as Fish Crows and American Crows, and American Redstarts and Cape May, Blackburnian or Bay-breasted Warblers is a common bias during point counts (Robbins and Stallcup 1981). Also, the ability of the observer to distinguish a range of frequencies and pitches influences their ability to hear various bird songs, and may bias their counts (Cyr

1981). One method of reducing biases when conducting point counts is to use multiple observers. Verner and Milne (1989) suggested point counts associated with monitoring should be conducted by multiple observers so that individual biases will average out within a year. Individual observers experience biases also, such as misidentification of species they may not be familiar with or they are not expecting to see or hear (Robbins and Stallcup 1981). Observers may be expecting to hear certain species, therefore they may be biased towards those species. These problems may be reduced through use of multiple observers.

Birds also tend to sing less often in rain, wind, and extreme temperatures, therefore censuring birds during these weather conditions may bias results (Robbins 1981b). Although precautions were taken throughout this project to prevent biases during censuring, many of these variables may have influenced our point counts, therefore they must be considered when examining results.

Species Composition

The most abundant and most common avian species along Cape San Blas during fall 1994 and spring 1995 were common year-round or winter residents of the southeastern United States (Table 7-2). Throughout fall 1994 point counts, the most abundant species was the Gray Catbird, a common winter species along the Gulf of Mexico coast (Peterson 1980). Gray Catbirds are winter residents of several habitats in Florida, including pine-wood, oak forest, scrub, and swamp (Pranty 1996). The Rufous-sided Towhee, the second most abundant species along Cape San Blas in fall 1994, is a permanent resident of the southeastern United States (Peterson 1980). It is a common to abundant resident throughout most of Florida, and found mostly in pine-wood, oak forest, and scrub habitats (Pranty 1996).

In fall 1994, the most common and abundant neotropical migrant species along Cape San Blas were the Gray Catbird and White-eyed Vireo. Both species are common throughout Florida, and although the Gray Catbird is a winter resident, the White-eyed Vireo is a common year-round resident of the Florida panhandle (Pranty 1996). The White-eyed Vireo is prevalent in a variety of habitats in Florida, including pine-wood, oak forest, scrub, hammock, and swamp (Pranty 1996). The American Restart was the most abundant and common transient neotropical migrant along Cape San Blas in fall 1994. This species summers in the southeastern United States and winters in central and southern Florida, therefore it travels through the Florida panhandle during fall migration to its wintering grounds. Thus, the most abundant bird species found along Cape San Blas during fall 1994 migration are typical year-round or winter residents of Florida, except the American Redstart, which migrates along the Florida panhandle in fall.

Several of the most common and abundant species along Cape San Blas in spring 1995 were also abundant in fall 1994, including the Rufous-sided Towhee and Gray Catbird. The abundances of two species, the Northern Cardinal and American Redstart, differed between seasons, however. There was an increase in the number of Northern Cardinals and a decrease in the number of American Redstarts during spring 1995 migration. The Northern Cardinal was the second most abundant species during spring (15.0%), but third most abundant in fall (11.4%). Although the Northern Cardinal is considered a common year-round resident of Florida, many Cardinals move north or northeast during late summer and early fall, therefore they may not be as abundant along Cape San Blas during fall as in spring (Ehrlich et al. 1988). Also, the abundance of the American Redstart differed between fall and spring migrations. Although the American Redstart was the most abundant transient neotropical migrant recorded during fall 1994 migration, it was not recorded at all during spring migration. This may be because in spring, Redstarts often migrate north along the Atlantic coast of Florida, therefore avoiding the Gulf of Mexico coast (Pranty 1996). The bird species found along Cape San Blas during spring 1995 migration were similar to those recorded during fall 1994 migration, except for an increase in Northern Cardinals and a decrease in American Redstarts.

Management Recommendations

A better assessment of neotropical migrant use of Cape San Blas may be possible if additional sampling occurred. Increased sample size may reduce within year variations, such as weather and predator densities, therefore allowing a better understanding of the reasons transient neotropical migrants did not stopover along Cape San Blas during fall 1994 and spring 1995 migrations. During future point counts, biases such as time of day, number of point counts, and observer bias, may be reduced by alteration of censuring methods. Point counts should begin earlier in the morning (at least an hour before sunrise), and possibly be conducted twice a day to include dawn and dusk (Moore et al. 1990). Point counts should also be conducted daily rather than weekly to avoid missing migrants (Moore et al. 1990). Finally, to reduce observer bias, multiple observers may be used, however to reduce variability among observers, all observers should be equally trained (Kepler and Scott 1981, Manley et al. 1993).

1. Continue point counts throughout several additional seasons to increase sample size and reduce biases. This may allow for a better understanding of neotropical use of Cape San Blas habitat.

There are several possibilities why transient neotropical migrants were not present in large numbers along Cape San Blas during fall 1994 and spring 1995 migrations, such as lack of food and increased predator density. Future research into these possibilities may allow better identification of limiting factors. Surveys for available prey, such as insect sampling, would help identify whether migrants were not stopping along Cape San Blas due to lack of food. Predator surveys, such as hawk censuring, would assist in determining the affect of predator density on transient neotropical migrants along Cape San Blas. Little can be done to change poor weather conditions, but censuring neotropical migrants throughout several years, during various weather conditions, may allow better understanding of this affect on migrating neotropical species. Therefore, censuring for at least one more year, insect sampling, and predator surveying may allow identification of factors limiting the numbers of transient neotropical migrants along Cape San Blas.

2. Survey for available prey and predator density during future surveys which may allow for identification of factors limiting transient neotropical migrant use of Cape San Blas habitat.

Forest management, such as prescribed burning, is often suggested if habitat is unsuitable for certain avian species. Prescribed burns effect bird species differently, however, within and among various habitats. In the coastal sage scrub of Los Angeles County, California, species commonly associated with thick, brushy areas generally avoided the open areas characteristic of a recently burned site, whereas those associated with open areas or species that ground-forage for seeds had greater densities in the recently burned habitat (Moriarty et al. 1985). In conifer forests of the Sierra Nevada Mountains, species that forage among needles and twigs of conifers were most common on the burned plots, whereas in sagebrush-grass communities, species that nest in trees were found to be especially vulnerable to prescribed burning. Therefore, the type of habitat being investigated, the species of birds using the habitat, and the objectives of management of that habitat must be considered before burns are prescribed for certain habitats.

The habitat utilized by most neotropical migrants on Cape San Blas are the sand/slash pine scrub and flatwoods. Breininger and Smith (1992) found that within the coastal scrub and slash pine flatwoods of the Kennedy Space Center, Florida, the Carolina wren (*Thryothorus ludovicianus*) and white-eyed vireo had significantly greater densities in areas that had not burned for more than 10 years. Densities of the common yellowthroat (*Geothlypis trichas*) and the rufous-sided towhee, however, were greatest in stations burned four years previously. No shrub species had its greatest density within the one-year-since-fire class. Recently burned areas within the Kennedy Space Center habitat tended to favor some species, such as woodpeckers and ground-dwelling birds, as long as burns are relatively infrequent (Breininger and Smith 1992). Therefore, Breininger and Smith (1992) suggested burning extensive areas of scrub and slash pine flatwoods as frequently as every 7 years would have a negative influence on several shrub-dwelling birds, although small patchy burns may have little affect on those species.

The type and timing of a prescribed burn may also greatly influence its affects on avian species. Along the Piedmont region of Alabama, Stribling and Barron (1995) recorded greater numbers of birds and bird species on areas receiving cool burns than on those receiving hot burns. They found canopy, shrub, and cavity nesters, and shrub and bark gleaners were more abundant in areas burned by cool fires than those burned in hot fires. Hot fires favored ground nesters and ground feeders by opening more areas for nesting and feeding (Stribling and Barron 1995). A cooler fire results in patchy vegetation both horizontally and vertically which is attractive for a lager number of birds and bird species (Stribling and Barron 1995). Therefore, if producing the maximum number of birds and bird species is one objective of management, then Stribling and Barron (1995) recommend a cool burn.

In some areas that do not burn regularly a different method of habitat maintenance develops. Scrub, such as that found along Cape San Blas, does not burn easily and can be relatively difficult to ignite therefore making natural fires difficult to start and burn (Johnson 1982, Myers 1990). Another habitat found along Cape San Blas, sand pine forest, burns and then regenerates itself through fire-induced seed release from closed cones. Sand pines, however, may become at least partially self-perpetuating without fire if the habitat is composed primarily of open-coned trees. A large number of open-coned sand pines are found along the Florida panhandle and tropical storms are frequent in the area, therefore, Myers (1990) suggested fire may be less important along the panhandle than elsewhere in Florida. Possibly, along the Florida panhandle, wind during storms may be as important in maintaining coastal sand pine scrub habitat as fire (Myers 1990). It appears that fire may not have been the primary force maintaining the scrub habitat along Cape San Blas, therefore prescribed burning of Cape San Blas would not increase the number of neotropical migrants using the area.

This theory is also supported by data collected along Tyndall (TAFB) and Eglin Air Force Bases (EAFB) during spring and fall migration 1994. The greatest number of neotropical migrants along EAFB during spring and fall migration were recorded in several habitats, including riparian habitat (Hill et al. 1994). The lowest number of individuals were found in three habitats, including burned flatwoods. Along TAFB during fall migration, the greatest number of individuals were found in coastal scrub, and least number in burned flatwoods. During their study, Hill et al. (1994) classified unburned flatwoods as similar to riparian habitats, therefore, it appears unburned flatwoods may provide more suitable habitat for neotropical migrants than burned flatwoods, however the sample size during Hill et al.'s (1994) study was small because very few transient neotropical migrants were recorded along Eglin Air Force Base during spring 1994 migration.

3. Because there is little history of fire along EAFB on Cape San Blas it appears fire has not been the force maintaining the habitat in this area. Therefore, prescribed burns would most likely not increase the number of birds or bird species using Cape San Blas during migration and are not recommended for this area.

Further research of neotropical migrant use of Cape San Blas is recommended to identify limiting factors. Prescribed burns are not recommended because the habitat along Cape San Blas is most likely maintained by storms rather than fire. It may be this area lies within a "migrant shadow" as defined by Hill et al. (1994), therefore little can be done to increase the numbers of transient neotropical migrants using Cape San Blas. Increased knowledge will allow better assessment of the habitat limitations for transient neotropical migrants along Cape San Blas.

Literature Cited

Anderson, S. H. 1981. Correlating habitat variables and birds. Estimating Numbers of Terrestrial Birds *in* Studies in Avian Biology No. 6. C. John Ralph and J. Michael Scott, eds. Proceedings of an International Symposium. Asilomar, California, October 26-31, 1980. The Cooper Ornithological Society. pp. 538-542.

Bibby, C. J., R. E. Green, R., Pepler and P. A. Pepler. 1976. Sedge Warbler migration and reed aphids. British Birds 69: 384-399.

Blake, J. G. 1992. Temporal variation in point counts of birds in a lowland wet forest in Costa Rica. The Condor 94: 265-275.

Breininger, D. R. and R. B. Smith. 1992. Relationships between fire and bird density in coastal scrub and slash pine flatwoods in Florida. American Midland Naturalist 127: 233-240.

Ehrlich, P. R., David S. Dobkin and Darryl Wheye. 1988. The Birder's Handbook: a Field Guide to the Natural History of North American Birds. Simon and Schuster, Inc., New York, New York. 785 pp.

Ekman, J. 1981. Problems of unequal observability. Estimating Numbers of Terrestrial Birds *in* Studies in Avian Biology No. 6. C. John Ralph and J. Michael Scott, eds. Proceedings of an International Symposium. Asilomar, California, October 26-31, 1980. The Cooper Ornithological Society. pp. 230-234.

Fuller, R. J. and D. R. Langslow. 1984. Estimating numbers of birds by point counts: how long should counts last? Bird Study 31:195-202.

Gauthreaux, S. A., Jr. 1971. A radar and direct visual study of passerine spring migration in southern Louisiana. The Auk 88: 343-365.

Gauthreaux, S. A., Jr. 1989. The use of weather radar to monitor long-term patterns of trans-Gulf migration in spring. *in* Ecology and Conservation of Neotropical Migrant Landbirds John M. Hagan and David W. Johnston., eds. Manomet Bird Observatory, Woods Hole, Massachussetts. pp. 96-100.

Graber, J. W. and R. R. Graber. 1983. Feeding rates of warblers in spring. The Condor 85: 139-150.

Hill, G. E., N. R. Holler, J. W. Tucker, Jr. 1994. Habitat use by Neotropical migrants on Eglin and Tyndall Air Force Bases, Florida. Preliminary report to Eglin Air Force Base. 15 December 1994. 39 pp.

Hutto, R. L. 1985. Seasonal changes in the habitat distribution of transient insectivorous birds in southeastern Arizona: competition mediated? Auk 102: 120-132.

Johnson, A. F. 1982. Some demographic characteristics of the Florida rosemary *Ceratiola ericoides* Michx. The American Midland Naturalist 108(1): 170-174.

Kepler, C. B. and J. M. Scott. 1981. Reducing bird count variability by training observers. *in* Studies in Avian Biology No. 6. C. John Ralph and J. Michael Scott, eds. Proceedings of an International Symposium. Asilomar, California, October 26-31, 1980. The Cooper Ornithological Society. pp. 301-310.

Kuenzi, A. J., F. R. Moore, and T. R. Simons. 1991. Stopover of Neotropical landbird migrants on East Ship Island following trans-Gulf migration. The Condor 93: 869-883.

Lindstrom, A. 1989. Finch flock size and risk of hawk predation at a migratory stopover site. The Auk 106: 225-232.

Manley, P. N., W. M. Block, F. R Thompson, G. S Butcher, C. Paige, L. H. Suring, D. S. Winn, D. Roth, C. J. Ralph, E. Morris, C. H. Flather, and K. Byford. 1993. Guidelines for monitoring populations of Neotropical migratory birds on national forest system lands. Monitoring Task Group Report. United States Department of Agriculture, Forest Service. Washington, D.C. 35 pp.

Moore, F. R. and T. R. Simons. 1989. Habitat suitability and stopover ecology of Neotropical landbird migrants. *in* Ecology and Conservation of Neotropical Migrant Landbirds John M. Hagan and David W. Johnston., eds. Manomet Bird Observatory, Woods Hole, Massachussetts. pp. 345-355.

Moore, F. R., P. Kerlinger and T. R. Simons. 1990. Stopover on a gulf coast barrier island by spring trans-Gulf migrants. The Wilson Bulletin 102(3): 487-500.

Moriarty, D. J., R. E. Farris, D. K. Noda, and P. A. Stanton. 1985. Effects of fire on a coastal sage scrub bird community. The Southwestern Naturalist 30(3): 452-453.

Myers, R. L. 1990. Scrub and High Pine. *in* Ecosystems of Florida R. L. Myers and J. J. Ewel, eds. University of Central Florida Press, Orlando, Florida. 765 pp.

Peterson, R. T. 1980. A Field Guide to the Birds of Eastern and Central North America. Houghton Mifflin Company, Boston, Massachusetts. 384 pp.

Pranty, B. 1996. A Birder's Guide to Florida. American Birding Association, Colorado Springs, Colorado. 388 pp.

Proctor, N. S. and P. J. Lynch. 1993. Manual of Ornithology, Avian Structure and Function. Yale University Press, New Haven, Connecticut. 340 pp.

Robbins, C. S. 1981a. Effect of time of day on bird activity. Estimating Numbers of Terrestrial Birds *in* Studies in Avian Biology No. 6. C. John Ralph and J. Michael Scott, eds. Proceedings of an International Symposium. Asilomar, California, October 26-31, 1980. The Cooper Ornithological Society. pp. 275-286.

Robbins, C. S. 1981b. Bird activity levels related to weather. Estimating Numbers of Terrestrial Birds *in* Studies in Avian Biology No. 6. C. John Ralph and J. Michael Scott, eds. Proceedings of an International Symposium. Asilomar, California, October 26-31, 1980. The Cooper Ornithological Society. pp. 301-310.

Robbins, C. S. and R. W. Stallcup. 1981. Problems in separating species with similar habits and vocalizations. Estimating Numbers of Terrestrial Birds *in* Studies in Avian Biology No. 6. C. John Ralph and J. Michael Scott, eds. Proceedings of an International Symposium. Asilomar, California, October 26-31, 1980. The Cooper Ornithological Society. pp. 360-365.

Robbins, C. S., J. R. Sauer, R. S. Greenberg, and S. Droege. 1989. Population decline in North American birds that migrate to the neotropics. Proceedings of the National Academy of Sciences, USA. 86: 7658-7662.

Stribling, H. L. and M. G. Barron. 1995. Short-term effects of cool and hot prescribed burning on breeding songbird populations in the Alabama Piedmont. Southern Journal of Applied Forestry 19(1): 18-22.

Verner, J. and K. A. Milne. 1989. Coping with sources of variability when monitoring population trends. Ann. Zool. Fennici 23: 191-199.

Winker, K. 1995. Autumn stopover on the Isthmus of Tehuantepec by woodland Nearctic-Neotropic migrants. The Auk 112(3): 690-700.

Table 1a. Numbers of avian species and their abundance recorded during 330 point counts along Eglin Air Force Base on Cape San Blas, Florida during fall 1994 migration.

FALL 1994

Species	#	Species	#
American Redstart	9	HOFI	1
American Robin	4	Hooded Warbler	1
Bald Eagle	2	Wouse Wren	51
Barn Swallow	2	Indigo Bunting	3
Black-and-white Warbler	1	Mourning Warbler	1
Belted Kingfisher	1	Northern Cardinal	207
Blue-gray Gnatcatcher	23	NOFL	4
Brown-headed Nuthatch	7	Northern Mockingbird	25
Blue Jay	92	Osprey	2
BLTH	1	PAWA	12
BRTH	113	Peregrine Falcon	1
BTNW	1	Pine Warbler	34
Carolina Chickadee	33	Prarie Warbler	1
CARW	112	Red-bellied Woodpecker	28
Chipping Sparrow	1	RCKI	6
Common Yellow-throat	61	Red-eyed Vireo	6
Downy Woodpecker	18	Red-shouldered Hawk	5
Eastern Bluebird	3	Rufous-sided Towhee	273
Eastern Phoebe	12	Red-winged Blackbird	94
Eastern Wood Peewee	1	Sharp-shinned Hawk	2
Fish Crow	5	Summer Tanager	4
Great Crested Flycatcher	1	Tree Swallow	39
GCKI	8	Turkey Vulture	5
Grey Catbird	316	White-eyed Vireo	39
Great Egret	2	White-throated Sparrow	5
Green-backed Heron	1	Yellow-bellied Sapsucker	1
Great Blue Heron	2	Yellow-rumped Warbler	128
Hermit Thrush	1	Yellow-throated Warbler	1

Table 7-1b. Number and abundance of avian species recorded during 330 point counts along Eglin Air Force Base on Cape San Blas, Florida during spring 1995 migration.

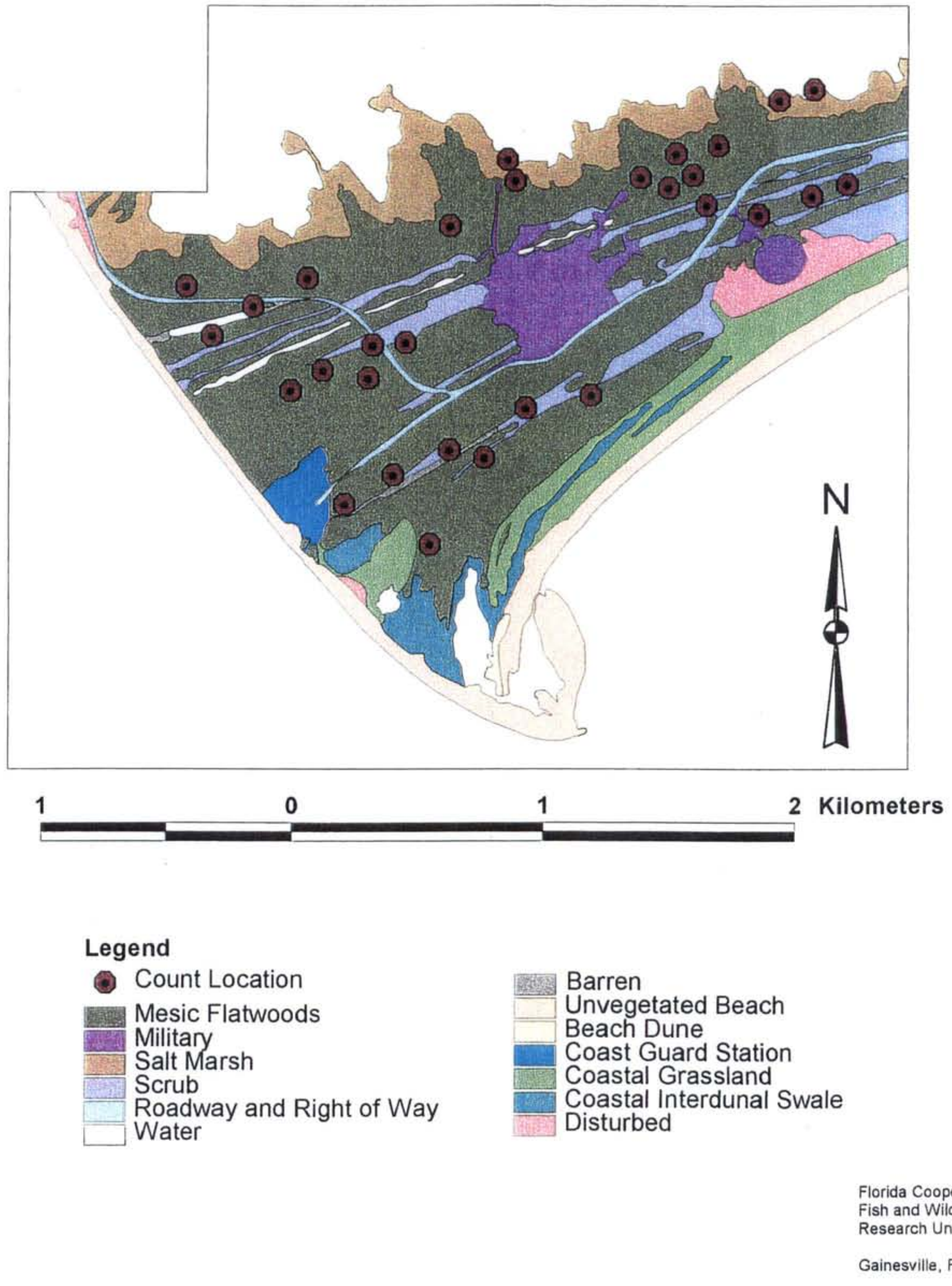
SPRING 1995

Species	#	Species	#
American Robin	2	Northern Cardinal	305
Bald Eagle	1	Northern Mockingbird	3
Barn Swallow	7	Northern Parula	15
Blue-gray Gnatcatcher	51	Northern Rough-winged Swallow	2
Brown-headed Cowbird	46	Orchard Oriole	1
Brown-headed Nuthatch	21	Osprey	1
Blue Grosbeak	5	Palm Warbler	1
Blue Jay	68	Pine Warbler	74
Bobolink	1	Prothonotary Warbler	7
Brown Pelican	5	Purple Martin	7
Brown Thrasher	18	Rose-breasted Grosbeak	2
Black-throated Green Warbler	1	Red-bellied Woodpecker	19
Carolina Chickadee	30	Ruby-crowned Kinglet	16
Carolina Wren	137	Red-eyed Vireo	5
Cedar Waxwing	114	Royal Tern	2
Chipping Sparrow	18	Rufous-sided Towhee	347
Common Ground-Dove	3	Ruby-throated Hummingbird	3
Common Nighthawk	10	Red-winged Blackbird	13
Common Yellowthroat	1	Scarlet Tanager	1
Double-crested Cormorant	67	Snowy Egret	1
Downy Woodpecker	4	Spotted Sandpiper	1
Eastern Bluebird	8	Solitary Vireo	1
Eastern Screech-Owl	3	Summer Tanager	5
Fish Crow	1	Swamp Sparrow	4
Field Sparrow	19	Tree Swallow	7
Great Crested Flycatcher	4	Tufted Titmouse	1
Green-backed Heron	29	Turkey Vulture	2
Gray Catbird	1	White-eyed Vireo	120
Hooded Warbler	125	Wood Thrush	3
House Wren	16	White-throated Sparrow	8
Indigo Bunting	16	Yellow-rumped Warbler	214
Killdeer	1	Yellow-throated Vireo	5
Louisiana Waterthrush	2	Yellow-throated Warbler	1
Northern Bobwhite	1	Unidentified Flycatcher	1

Table 7-2. The first and second most common and most abundant of all avian species, of neotropical migrants, and of transient neotropical migrants, recorded during 330 point counts in fall 1994 and 330 point counts in spring 1995 along Eglin Air Force Base on Cape San Blas, Florida.

MOST COMMON	FALL 1994	STATUS	SPRING 1995	STATUS
All Avian Species	Gray Catbird	winter resident	Rufous-sided Towhee	resident
2	Rufous-sided Towhee	resident	Northern Cardinal	resident
Neotropical Migrants	Gray Catbird	winter resident	Gray Catbird	winter resident
2	White-eyed Vireo	resident	White-eyed Vireo	resident
Transient Neotrops.	American Redstart	migrates S. through FL	Rose-breasted Grosbeak	migrating
MOST ABUNDANT	**Fall 1994**	**Status**	**Spring 1995**	**Status**
All Avian Species	Rufous-sided Towhee	resident	Rufous-sided Towhee	resident
2	Gray Catbird	winter resident	Northern Cardinal	resident
Neotropical Migrants	Gray Catbird	winter resident	White-eyed Vireo	resident
2	White-eyed Vireo	resident	Gray Catbird	winter resident
Transient Neotrops.	American Restart	migrates S. through FL	Rose-breasted Grosbeak	migrating

1994 Neotropical Bird Count Locations at Cape San Blas



CHAPTER 8

STORMS

Introduction

Climate directly effects an area by influencing the weather and environmental conditions, either through persistent, long-term weather patterns or by occasional, short-term events. Indirectly, climate influences the type of habitat and fauna that inhabit an area and may often have a severe effect on those inhabitants. Typical climate patterns help maintain habitat by providing sun, rain, high or low temperatures, and humidity. In some areas, however, such as Florida, climate may cause extreme damage in the form of tropical storms.

One of the most severe climactic events that influences the southeastern United States are tropical storms. Tropical storms that effect this area typically originate in the Atlantic tropical cyclone basin, which includes the North Atlantic Ocean, the Caribbean Sea, and the Gulf of Mexico (Simpson and Riehl 1981, Nieuwolt 1977). During the past 122 years, from 1971 to 1992, nearly 1,000 tropical storms have occurred in the tropical north Atlantic Ocean. Of those, about 180 have struck or passed immediately offshore or adjacent to the Florida coastline (Williams et al. 1993).

Major damage caused by hurricanes occurs primarily due to wind and flooding (Chen and Gerber 1990). Winds loosen sands making them more susceptible to erosion. Along Shackleford Bank, North Carolina, winds from an 1899 hurricane displaced sand that caused a slow burying of the inland forest. By 1969, only 4% of the island's original forest was left unburied (Johnson and Barbour 1990). In 1985, Hurricane Kate's 46 mph winds, with peaks of 68 mph, contributed to major damage of 31 buildings in Gulf county, Florida. Winds of up to 125 mph associated with Hurricane Elena, also in 1985, contributed to four deaths and an estimated $1 billion in damage along the Florida panhandle (Clark 1986).

Another primary cause of damage during a hurricane is flooding. Flooding results both from rainfall associated with the storm, from wind-generated waves and tides, and by the rise in water level, known as storm surge. Tropical Storm Alberto produced great amounts of rainfall over northwest Florida, southeast Alabama, and southwest Georgia between July 4-7, 1994. The resulting floods claimed 29 lives and caused substantial damage to property and agriculture (NOAA 1995). In 1995, Hurricane Opal's storm surge caused severe structural damage along the coastline, such as crumbled piers, demolished homes and eroded or submerged highways. During Hurricane Opal, the tide gage at the Panama City Beach pier recorded 8.3 feet above mean sea level, indicative of storm surge. These severe high water levels often result in extensive damage to affected areas.

Damage from tropical storms typically varies along the Florida coast. The coast from Florida Bay to Melbourne and from Pensacola to Panama City has the highest risk of hurricanes, with an expected return rate of one hurricane every six to eight years (Simpson and Riehl 1981). The risk drops to one hurricane per twelve to seventeen years from Apalachicola to Tampa Bay along the Gulf coast, and for the Atlantic coast from Fort Pierce to Cape Canaveral (Chen and Gerber 1990). Of the worst 11 hurricanes to hit Florida from 1885 to 1971, south Florida experienced the top 6, whereas the remaining five struck the panhandle (Johnson and Barbour 1990). Because south Florida is more developed than the panhandle, severe storms in south Florida typically cause more economic damage (Johnson and Barbour 1990).

Although south Florida may experience greater economic damage during a hurricane than the panhandle, northwest Florida experiences greater storm surges due to the shallow waters along this coast. The average minimum pressure in Florida's hurricanes is 50 mm less than the average atmospheric pressure (Simpson and Riehl 1981). This amounts to a lifting of approximately 0.5 m of water, but near shore, in shoal water, this may result in a mound of water as high as 4 m. Because of the action of waves, the surge of water may even be greater if the hurricane approaches shore rapidly than if it approaches slowly. Furthermore, coastal areas with a greater extent of shoal water will generally experience a higher storm surge. Therefore, in hurricanes of equal size and strength, the Gulf coast of Florida typically experiences greater storm surges than the Atlantic coast (Chen and Gerber 1990). This results in extreme alterations to the coastline and habitat along the Florida panhandle coast. Because waters off Cape San Blas, Florida are shallow and shoal extensively, storm surges caused by tropical storms are often large and cause extensive damage to structures and habitats. To review effects of tropical storms on the Cape San Blas area, a literature search was conducted. The earliest report of a tropical storm affecting the Cape San Blas area was 1837, and the most recent was tropical storm Josephine in the fall of 1996.

Storm Report

1837 Storm #6 - The Apalachee Bay Storm: August 30-31, 1837. On August 30, a hurricane hit Cape St. George. It was reported by the editor of the Apalachicola Gazette that the storm nearly destroyed the entire city of Apalachicola un-roofing almost every house and destroying many buildings. He also noted tides six feet above normal which washed over wharves. The storm caused an estimated $200,000 in damages. According to the Sept 6, 1837 edition of the St. Joseph Times, it was the severest storm its residents had ever known. A three-story building was destroyed along with several smaller buildings. (Early Am. Hurr. 1492-1870, Ludlum)

The Late Gale at St. Joseph: According to the October 9, 1841 edition of the St. Joseph Gazette, an "equinoctial" storm caused higher than normal tides which destroyed a large part of the wharf on September 14, 1841. In Apalachicola, the storm destroyed several buildings and wharves, and flooded many boats in the harbor. (Early Am. Hurr. 1492-1870, Ludlum)

Apalachicola 1844: On September 8, 1844, a storm landed in Apalachicola. Although the intensity of the storm is unknown, documentation indicates it was a hurricane, and the storm's eye passed through Apalachicola. Damages to buildings and wharves were great, although there were no deaths documented. Damages were estimated at $18,000-$20,000 according to the Tuesday, September 9, 19844 edition of the Commercial Advertiser of Apalachicola. (Early American Hurricanes 1492-1870, David M. Ludlum, American Meteorological Society (published by,), Boston, MA, 1963, 198 pp.). Effects to the St. Joe area are unknown.

Storm at Apalachicola 1850: A severe storm of unknown intensity raked the Apalachicola area in 1850. As reported in N.Y. Daily Tribune, Sept 12, 1850, the storm blew off the roofs of two buildings and the flooded Water, Commerce, and Market Streets in Apalachicola. Landfall was estimated to have occurred between Pensacola and Panama City, although its effects on the St. Joe area are unknown. (Early Am. Hurr. 1492-1870, Ludlum)

The Great Middle Florida Hurricane of August 1851: On August 23, 1851, a hurricane hit just to the west of Apalachicola destroying many homes, businesses, and wharves. According to the local paper, all three lighthouses were destroyed, five lives lost on Dog Island, and at Cape San Blas, a Spanish brig-of-war was beached and several lives lost. It was said to be the most destructive storm ever to have hit the city up to that time.(Early Am. Hurr. 1492-1870, Ludlum)

The Southeastern States Hurricane of 1856: On August 30, 1856, a hurricane made landfall west of Cape San Blas near Panama City. Apalachicola was hit hard with strong winds and extensive flooding. A depth of three to four feet of water lay over Commerce Street, and waters flooded many homes and businesses.(Early Am. Hurr. 1492-1870, Ludlum)

1924: Category 1 hurricane hits St. Joe in September.

1929 Category 3 hurricane

This storm struck Panama City in September with 150 mph winds and a minimum barometric pressure of 27.99. The storm caused tidal surge of 9 feet, $821,000 in damages, and 3 deaths.

1953: Hurricane Alice (June)

On September 26, 1953, **Hurricane Florence** made landfall about 40 miles north of Highland View. Although at landfall, winds up to 95 mph were recorded, wind damage was limited to a one hour power failure and a few fallen trees in the Port St. Joe area. High tides and about seven inches of rain, were more serious causing storm sewers to back-up and flood streets. (PSJ Star Vol. XVII. Oct. 1, 1953)

1956: Hurricane Flossy struck Pensacola in September

1959: TS Irene

1960: TS Brenda

1966: Hurricane Alama

This category 2 storm struck in June with 125 mph winds.

1972: Hurricane Agnes

Barely a category 1, this storm made landfall in the Apalachicola/Port St. Joe area.

1969 Season

Hurricane Camille was a deadly storm that caused devastation in Louisiana and Mississippi in August 1969. This storm affected the Port St. Joe area in minor ways. The shoulder of U.S. Highway 98 was washed away at Highland View due to high storm tides and wave action. Damages due to winds were also minor limited to a few fallen tree limbs, lost shingles, and several broken windows in the beach areas. (PSJ Star, 32 year no.50, Aug. 21, 1969, p 1 & 7).

1975 Season

On September 23, 1975, **Hurricane Eloise** made landfall between Destin and Panama City, Florida. That morning a storm tide caused St. Joseph Bay waters to flood portions of U.S. Highway 98 in Highland View and Port St. Joe. Due to flooding of U.S. Highway 98 and Monument Ave, by 10:00 am the only north-south street open for traffic was Garrison Ave. Apart from the flooding of streets, very little property damage was reported. Winds brought down a few trees and powerlines causing a power outage that lasted less than an hour. (PSJ Star 49 year no. 4, Sept 25, 1975, p 1 and 8).

1979 Season

Hurricane David affected the Port St. Joe area with high tides on September 12, 1979. The storm tides washed over County Road C30-E at the Stump Hole. (PSJ Star 43 yr, no 2, Sept 12 p1)

Hurricane Frederick made landfall on September 15, 1979 and caused higher than usual tides and slightly rough seas. The Port St. Joe area received a moderate rainfall of 5 inches between 9:00 am on September 16 and 9:00 am on September 17. U.S. Highway 98 flooded just south of the Apalachicola Northern Railroad overpass, but was passable by mid-morning on September 17. A few homes also experienced minor flooding, but no damage was reported on the beaches. (PSJ Star, 43 year, no.3, Sept. 20, 1979, p1)

1985 Season

The 1985 storm season produced 11 tropical storms in the North Atlantic Ocean, the Caribbean Sea, and the Gulf of Mexico with 7 storms reaching hurricane strength (Case and Gerrish 1986).

On August 29, **Hurricane Elena** passed within 66 miles of the Gulf County coastline causing heavy rainfall with about 7 inches recorded between 29-30th August in the Port St. Joe area. She made another pass along the Gulf County coast on September 1. Between 30 August and 1 September, 13.58 inches of rainfall was recorded at the Port St. Joe wastewater treatment plant. According to Wayne Snyder, meteorologist of the National Weather Service center at Apalachicola, sustained winds reached 66 mph with gusts to 90 mph during her second pass. In the city of Port St. Joe, winds destroyed the roofs of two buildings, blew out windows of eight businesses, and destroyed the St. Joe Hardware lumber warehouse. Winds also caused trees to fall on several houses causing some moderate damage to those dwellings, and minor wind damage to roofs was widespread. Elena also caused two fires which destroyed one home and the Long Avenue Baptist Church Pastorium. (PSJ Star, 48:1).

Along the St. Joseph Peninsula and Cape San Blas, **Hurricane Elena** caused moderate to heavy beach and dune erosion. As Elena passed offshore, an estimated 1,500 feet of the southern tip of the cape disappeared. The storm tide elevation was reported to be +7.0 feet NGVD, however, there was likely a substantial storm tide difference across the cape and the outer shoals as indicated by scour channels and flattened dune and wetland vegetation (Balsillie 1985). The lighthouse beach access was inundated by flooding and several tidal channels were formed across the cape (Ralph 1986). On Cape San Blas, 1 dwelling and 1 home in progress were destroyed (PSJ Star, 48:1). Just east of Cape San Blas, the Indian Pass fishing pier was damaged and minor wind damage to roofing was reported throughout the Indian Peninsula area. (Clark 1986).

On October 31, **Tropical Storm Juan** landed at Gulf Shores Alabama (Clark 1986). Although high winds were not reported in the Port St. Joe area, rainfall from the storm system affected the area. Port St. Joe received approximately five inches of rain between 8:00 am on 29 October to 9:00 am on 30 October causing flooding of U.S. Highway 98 from the railroad crossing to Avenue A. The storm also caused a 45-minute power failure when a tree limb fell on a powerline in town.

On November 21, **Hurricane Kate** made landfall on Crooked Island near Mexico Beach approximately 25 miles west of Cape San Blas. Although Kate had attained the intensity of a category 3 hurricane in the southeastern Gulf of Mexico on November 20, she had weakened to a category 1 before making landfall. In Panama City, the weather station reported maximum sustained winds of 40 mph, gusts to 85 mph, and minimum barometric pressure of 973.1 millibars. Apalachicola, located within the maximum wind field of Kate, reported sustained winds of 62 mph, gusts of 85 mph, and a minimum barometric pressure of 985.3 millibars. Approximately 1 ½ hours before the storm's eye made landfall, wind gusts to 115 mph were reported in the Port St. Joe area (PSJ Star, 48 year, no. 13, p. 1). As Kate moved inland through Georgia and South Carolina, she weakened to tropical storm strength on November 22. Rainfall totals averaged between 4-6 inches with north Florida and southwest Georgia reporting the highest rainfall.

Gulf County was severely impacted by Hurricane Kate, third only to Franklin and Wakulla Counties to the east. In all, more than 31 major structures (excluding roads) were destroyed or sustained major structural damage along coastal Gulf County. In Highland View, just west of Port St. Joe, a high water mark of +6.8 feet NGVD was recorded by the Coastal and Oceanographic Engineering Department of University of Florida. Minor wind damage, downed powerlines, and roofing damage was widespread in Port St. Joe. Six buildings of the St. Joe Paper Company and a Gulf County school bus maintenance building sustained major wind damage. At the local airport, a hanger building containing one single engine airplane was destroyed (Clark 1986). The St. Joe Hardware lumber shed and Butler's restaurant were also completely destroyed. Winds blew off the Port St. Joe Elementary School's roof and part of the Port St. Joe High School roof. At least 70 trees fell along Florida State Hwy. 71, and trees fell on 12 homes in Port St. Joe (PSJ Star, Nov. 28, 48 year, no. 13, p. 1). Several roads including portions of U.S. Highway 98 and Constitution Drive were flooded and damaged (Clark 1986 and PSJ Star 48:13). Long Ave was also flooded with several inches of water, the 1st United Methodist Church had 8 inches of water inside, and at least one home experienced flooding.

Along the entire gulf side of St. Joseph Peninsula, moderate to severe beach and dune erosion was reported. At T.H. Stone Memorial State Park, located on the north end of the Peninsula, the hurricane caused heavy beach and dune erosion and destroyed beach access walkways. A topographic survey conducted two weeks after Kate by the Bureau of Coastal Data Acquisition, Division of Beaches and Shores, showed a horizontal dune recession of almost 50 feet since a survey conducted in July 1984. The dune's recession was first impacted by Hurricane Elena in September when a barrier dune of +22 feet NGVD was substantially eroded by Elena, then completely destroyed Kate. The University of Florida measured a storm surge of +5.6 feet NGVD near the entrance of the park. Nearly all beach walkways were damaged along the peninsula's gulf side between the state park and Cape San Blas. This area was only sparsely developed in 1985, but two single-family dwellings and a swimming pool were destroyed by erosion, flooding and wave loads. Several other dwellings sustained major damage. Aerial photography taken in November 1983 showed the two dwellings and the swimming pool to be about 40 feet and 70 feet landward from the beach respectively. Profile data gathered by the Bureau of Coastal Data Acquisition adjacent to the destroyed dwellings approximated horizontal dune recession at 35 feet due to Kate and a total of 80 feet since November 1983. This area south to Cape San Blas experiences historically high rates of erosion. Kate's storm surge of 12-14 feet caused flooding in almost every home not elevated on stilts (PSJ Star 1985, 48 year no. 13, p 1). The storm surge also washed over County Road C30-E where it curves toward the gulf, an area known locally as the stump hole.

On Cape San Blas, erosion and damage due to Kate was severe. In addition to the approximately 1,500 feet of the cape's tip lost to Hurricane Elena, about 1,000 feet of the cape was washed away by Kate, totaling nearly a half mile lost to the two hurricanes combined. About 200 feet of the beach access road was destroyed. Profile data indicate the barrier dune adjacent to this road had an elevation of +13.5 feet NGVD prior to Elena and Kate, but after Kate the elevation was +3 feet NGVD. According to Clark (1986), the entire barrier dune from south of the beach access road to the south tip of the cape was completely destroyed. Several buildings owned by Eglin Air Force Base sustained major roofing damage, many equipment structures were damaged, and a radio antennae was destroyed. One dwelling was also destroyed by winds.

Along the mainland from Money Bayou to the eastern boundary of Gulf Coast, minor beach and dune erosion was sustained. In this area, University of Florida measured a high water mark of +8.4 feet NGVD. Two mobile homes and at least two other dwellings were destroyed. In addition, one mobile home and 7 other dwellings sustained major damage from winds, flooding, and or waves. Wind induced damage to roofing and screens was also widespread in this area. Along Indian Peninsula, which extends two and a half miles between Money Bayou and Indian Pass, many of the dwellings and businesses on the peninsula sustained roofing damage. The fishing pier at Indian Pass was also destroyed. (Clark 1986). As a result of Hurricane Kate, Gulf County was declared a disaster area with an estimated $5 million in damages to the Port St. Joe area (PSJ Star, 48 yr no. 14, Dec 5, 1985 p1).

1992 Season:

Late Friday, October 2, 1992, an **unnamed**, large low pressure system in the southern Gulf of Mexico tracked northeastward spreading gusty winds up to gale force and rain showers north and east across the eastern Florida panhandle and Big Bend. The area of low pressure interacted with an old frontal boundary which extended westward across southern Florida into the Gulf. Late Friday evening and early Saturday morning, October 3, the area of low pressure moved through the northeastern Gulf of Mexico and onshore producing rain and near gale force winds from the southeast and south along with high tides. The National Weather Service Office in Apalachicola reported winds of 21 to 23 miles per hour for a 12 hour duration and a maximum sustained wind of 45 miles per hour.

Tides of one to three feet above normal added to the high tide Saturday morning causing coastal flooding around the Big Bend and eastern Florida panhandle. The storm tides and storm wave activity associated with this storm caused the worst beach erosion throughout Gulf, Franklin and Wakulla Counties since hurricane Kate in November 1985. Among the hardest hit areas were the southwestern St. Joseph Peninsula, including the Stump Hole and Cape San Blas.

The shore between the south tip of Cape San Blas and the historic public access ramp had already lost nearly all of the barrier dunes during hurricane Kate. The granite revetment built after Kate across the historic public beach access ramp was overtopped by the storm tide, and 400 to 500 feet of the chain link fence at the Air Force installation was destroyed. A large lagoonal beach that formed during the storm and new downed trees north of Air Force Property, basically cut off public beach access to Cape San Blas. Between the Air Force installation at the lighthouse and Stump Hole, beach driving conditions were rendered virtually impassable by exposed stumps and fallen trees. Further north along the peninsula, many houses were damaged, particularly decks and seaward sides of houses.

1994 Season:

The 1994 storm season produced seven named storms in the Atlantic, including three hurricanes (Sun-Sentinel, Fort Lauderdale, Nov.30). Two tropical storms, Alberto and Beryl, and one no name storm directly affected Northwest Florida.

On July 3, **Tropical Storm Alberto** made landfall near Destin sustaining winds over 55 kt and a minimum pressure of 993 mb as measured at Eglin Air Force Base when the storm passed within 20 NM of Eglin AFB's WSR-88D radar system. By the early morning of July 4, Alberto had weakened to a depression as it moved north into Georgia and Alabama. Heavy rainfall produced by the storm between July 4-7 caused record floods with the heaviest rainfall reported in Alabama and Georgia. In Americus, Georgia reported the greatest rainfall at 21 inches. Damages in northern Florida were estimated at more than $35 billion (Sun-Sentinel Nov. 30, 1994).

During the storm, winds of 40 mph were recorded at Beacon Hill just east of Port St. Joe. The Wewahitchka and Howard Creek areas were severely flooded by local rivers and creeks breaching their banks. The Apalachicola River in Blountstown crested at 27.4 feet, 12.4 feet above flood stage. Flooding affected nearly 300 homes in Gulf County with the majority in the northern portion of the county (PSJ Star, 56 year no. 45, July 7, 1994). The worst coastal erosion from the storm centered on Cape San Blas where approximately 14 feet of shoreline washed away in the Stump Hole area (PSJ Star, 56 year no. 45, July 7, 1994).

On August 15, **Tropical Storm Beryl** made landfall near Cape San Blas, sustaining winds of 50 mph. The Tallahassee airport reported wind gusts up to 64 mph in the early morning of August 16 (Kleindienst, Orlando Sentinel, Aug. 17, 1994). Maximum sustained winds of 50 kts and a minimum pressure of 999 mb were recorded at Eglin AFB. By August 16, Beryl was downgraded to a tropical depression, and had lost it's tropical characteristics by August 17. The storm brought heavy rain to the Big Bend and Tallahassee areas of Florida with some locations reporting 10 to 15 inches of rain. (Shaw, The Tampa Tribune, Nov. 29, 1994 and Kleindienst, The Orlando Sentinel, Aug. 17, 1994). The Wastewater Treatment Plant in Port St. Joe recorded 7.8 inches of rain in less than 48 hours (PSJ Star 56 year no. 51, Aug 18, 1994). Damages reached $ 8 million in Florida mainly due to flooding (Sun-Sentinel, November 30, 1994).

In Port St. Joe, one house sustained damage from winds, and road damage was reported at the intersections of Monument Avenue and 10th Street and U.S. Highway 98 andMonument Avenue (PSJ Star, 56 year, no.51, Aug 18, 1994).

On October 2-3, an **unnamed tropical storm** struck the Florida panhandle causing heavy rainfall with some areas reporting up to 10 inches in a 48-hour period. Port St. Joe received 4.88 inches causing some flooding in the city of Port St. Joe. Several utility poles were down due to winds. On Cape San Blas 12 of 53 (23%) sea turtle nests were washed away.

1995 Season:

On June 3, a tropical depression named **Allison** formed 230 n miles east of Belize City. On June 4, as Allison moved northward she strengthened to a 65-knot hurricane in the southeast Gulf of Mexico, at which time she was centered 240 n mi west of Key West, Florida. As she turned toward the Florida panhandle, Allison maintained minimal hurricane force winds, but just before making landfall at Alligator Point on June 5, she weakened to below hurricane intensity with winds at 55-60 knots. Allison made a second landfall at St. Marks about one hour later. As the storm moved inland, it weakened to a tropical depression by the early morning of June 6 while it passed through southern Georgia. On June 7, the system emerged into the Atlantic just north of Cape Hatteras.

Rainfall totals between 4 and 6 inches were reported due to the storm from Florida to North Carolina. Storm surge heights of at least 6.8 feet above National Geodetic Vertical Datum were measured in Apalachee Bay (Turkey Point). Maximum storm surge heights were estimated at 6 to 8 ft in Wakulla and Dixie counties, and 4 to 6 ft in Franklin County. Sustained wind speeds of 34 knots with gusts to 39 knots was reported in Apalachicola. Several tornadoes were also reported in northeast Florida and southeast Georgia on 5 June, but none were reported in Gulf or surrounding counties.

According to the National Hurricane Center, an active tropical wave strengthened into Tropical Storm Erin, early on July 31, and became a hurricane by August 1 near Rum Cay in the Bahamas Islands. On August 2, **Hurricane Erin** moved northwest to make landfall, sustaining winds of 75 knots, near Vero Beach as a Category 1. Erin weakened to a tropical storm as she moved across the Florida peninsula, but later began to re-intensify. On August 3, once over the Gulf again, Erin strengthened to a Category 2 hurricane and made a second landfall near Fort Walton Beach, Florida. Erin sustained winds of 85 knots during her second landfall, but weakened to a tropical storm by August 4. Several tornadoes were reported in Florida including one near Hurlburt Air Field near Ft. Walton Beach. Storm tides of 6-7 feet were recorded at Navarre Beach and 3-4 feet at Pensacola Beach. Areas of the panhandle reported up to 5 inches of rain.

The worst damage during the final landfall occurred on Pensacola Beach, Navarre Beach, Mary Esther, and in northeast Pensacola where more than 2,000 homes were damaged. Beach erosion was reported along the panhandle coast near Navarre Beach. Farther inland, about 100 homes were damaged in Alabama. Widespread tree, power line and crop damage extended inland.

Hurricane Opal made landfall just east of Pensacola on October 4 sustaining winds of 125 mph and gusts to 144 mph. Tides were 20 feet above normal in some areas due to storm surges. The hurricane spawned several tornadoes in the western panhandle, including one in Crestview that killed one women. At the waste water treatment plant in Port St. Joe, winds were recorded at 80 mph. In addition, the highest tides in more than 50 years were recorded. At the height of the storm, water washed completely over the St. Joseph Peninsula. County road 30-E, that runs along the St. Joseph Peninsula, was washed out at the stump hole, just north of Eglin Air Force Base property, taking water and power lines with it. Most homes on the water's edge were damaged or destroyed. The storm left more than 357,000 homes and businesses without electricity (Clary and Katz, Los Angeles Times, October 1995). In Gulf County, 233 houses were damaged, 145 with major damage, and 33 were destroyed. Along Highland View, the entire neighborhood of Bay View was flooded. Three homes in this area floated off their foundations. In addition, Highland View elementary school was four feet under water. In neighboring Mexico Beach, thirty-five to 50 homes were destroyed (PSJ Star 58 yr, no6).

1996 Season:

On October 7, **tropical storm Josephine** made landfall along Florida's Big Bend region. Although the storm caused moderate rainfalls, winds of approximately 70 mph just before landfall caused only minor damage in most areas.

LITERATURE CITED

The Port St Joe Star:

Vol XVII. No. 4. Oct. 1, 1953. "Florence takes to land about 40 miles north of Highland View." p1 (C-D).

32nd year, no. 50. Aug. 21, 1969 "Camille spares Gulf County after threatening gestures". P1 (col.B-D), p7 (col. A,B).

43th year, no. 3. Sept. 13, 1979. "Residents ready to flee from Fred." p1(A-H)

43th year, no.2. Sept. 20, 1979. "Heavy rains flood city." p1 (D)

48th year, no. 1. Sept. 5, 1985. "Elena make like a tourist: leaves resident of Gulf County with a big clean-up job." p1 (A-D).

48th year: no. 9. Oct. 31, 1985. "Rains cause flooding: power failure darkens most of the city." p1 (D-H), p3 (D-H).

48th year, no. 13. Nov. 28, 1985. "Kate no lady while visiting Gulf County. She hit a solid lick on area "between Apalach and Panama City". " p1 (A-F), p5 (A-C), p6-7, 3B, 6B.

48th year, no.14. Dec. 5, 1985. "Gulf named disaster area by President Reagan. Storm Damage tops 5 million." p1 (A-F).

49th year, no. 4. Sept. 23, 1975. "Eloise feints, then punches St. Joe". P1 (A-C), p8 (A)

56th year, no. 45. July 7, 1994

56th year, no.46. July 14, 1994.

56th year, no. 51. Aug. 18, 1994

57th year, no. 6. Oct. 6, 1994.

57th year, no. 43. June 8, 1995.

57th year, no. 50. Aug. 1995.

58th year, no. 6. Oct 12, 1995. "Opal brings heavy destruction to Gulf County." p1 (A-D), p3 (B-C).

Balsillie, J. H. 1985. Long-term shoreline change rates for Gulf County, Florida - A First Appraisal. Florida Department of Natural Resources, Division of Beaches and Shores. Special Report No. 85-3. pp. 24.

Case, Robert A. and H. P. Gerrish. 1986. North Atlantic Tropical Cyclones, 1985, National Hurricane Center, NOAA, Miami, Florida.

Chen, E. and J. F. Gerber. 1990. Climate, *in* Ecosystems of Florida, R. L. Myers and J. J. Ewel eds. University of Central Florida Press, Orlando, FL.

Clary, M. and J. Katz. 1995. Los Angeles Times, October 5, Headline: Hurricane Opal hits Florida; 100,000 Flee.

Clark, R. 1986. The impact of Hurricane Elena and Tropical Storm Juan on coastal construction in Florida. Florida Department of Beaches and Shores Post-Storm Report no. 85-3. pp 6.

Clark, R. 1986. Hurricane Kate, November 15-23, 1985. Department of Natural Resources, Division of Beaches and Shores. Post Storm Report No. 86-1. September.

Clark, R. and S. West. 1996. Tropical Storm Josephine storm damage summary - October 7, 1996. Florida Department of Beaches and Shores.

Garcia, A. W. and W. S. Hegge. 1987. Hurricane Elena Storm Surge Data. Report 3. Department of the Army, Coastal Engineering Research Center, Waterways Experiment Station, Corps of Engineers, Vicksburg, Mississippi. July.

Johnson, A. F. and M. G. Barbour. 1990. Dunes and Maritime Forests, *in* Ecosystems of Florida, R. L. Myers and J. J. Ewel eds. University of Central Florida Press, Orlando, FL.

Ludlum, D.W. 1963. Early American Hurricanes 1492-1870. American Meteorological Society, Boston, Massachusetts. 198 pp.

National Oceanic and Atmospheric Administration. 1995. Tropical Storm Alberto - Heavy rains and flooding, Georgia, Alabama, and Florida, July 1994. Natural Disaster Survey Report.

Nieuwolt, S. 1977. Tropical Climatology. Wiley, New York, New York.

Simpson, R. H. and H. Riehl. 1981. The hurricane and its impact. Louisiana State University Press, Baton Rouge, Louisiana.

Williams, J. M., F. Doehring, and I. W. Duedall. 1993. Heavy Weather in Florida. Oceanus, Spring: 19-26.

APPENDIX

Bald Eagle (*Haliaeetus leucocephalus*)

A pair of bald eagles has nested along EAFB on Cape San Blas since 1994. Adults were observed working on the nest in 1994/95, however no chicks were observed. The nest appeared to be inactive in 1995/96, although adult birds were observed in the area. The adults may not have nested due to the severe storm season that occurred in 1995, with major hurricanes striking the Cape San Blas coast in June, August, and October 1995. The eagles left the Cape San Blas area in spring 1996 and returned to the nesting area in November 1996. The eagle pair was again observed building and sitting on the nest in 1996/1997. Although eggs were present in the nest in 1996/97, it appears the eggs did not hatch. The eagles left the Cape San Blas area in May 1997 and returned in late-August 1997. Since their return, they have been observed placing nesting material on the nest and feeding offshore. It is presently unknown if the birds have or will lay eggs again this season, however it is apparent the eagle pair is actively using this nest (J. Gore, pers. comm.). Primary threats to the eagles along Cape San Blas include erosion and human disturbance (see Executive Summary).

Black Bear (*Ursus americanus*)

Significant black bear populations occur within the Apalachicola National Forest and on Eglin Air Force Base. Typical home ranges span approximately 40 miles, however during breeding and dispersal, bears will travel outside of their home range looking for mates or food. During movements between these two populations, Black bears have occasionally been reported in the Cape San Blas area by Vitro guards and local residents. In spring 1997, an adult female black bear with three cubs was observed along EAFB property on Cape San Blas by a University of Florida biologist. Approximately one week before the sighting, a dead and highly decomposed sea turtle washed up approximately 0.2 miles north of the Coast Guard Station barracks on EAFB property. About two days after the turtle was observed washed up, it was apparently dragged off the beach and into the flatwoods. Tracks around the drag marks appeared to be small bear tracks. Several days later, the female and her cubs were observed walking along the edge of the flatwoods, from the old lighthouse keepers houses to the CGS access road. They entered the woods on the north side of the CGS access road and stayed in the wooded area for several hours, presumably foraging. After observing their tracks, it became apparent that the animals that took the decomposing sea turtle were bears. Sightings within that month were also reported by Vitro guards.

Bobcat (*Felis rufus*)

Bobcats have sporadically been observed along EAFB property and adjacent areas along Cape San Blas. Because of the occasional sighting of kittens, it appears bobcats are breeding within this area. Primary observation locations include the access road to the CGS and the dirt road leading to D-3A. Bobcats are typically found in scrubby country and broken forests, and occasionally inhabit swamps, farmlands, and rocky or brushy arid lands. Prey include rabbits, mice, squirrels, and bats. Bobcats breed in spring and young are born in April and May in dens built of leaves or other dry vegetation in a hollow log, rock shelter, under a fallen tree, or any other protected place. The flatwoods surrounding Cape San Blas appear to provide appropriate habitat for resident and breeding bobcats, which would indicate at least one pair of bobcats reside in this area and produce kittens.

Eastern Diamondback Rattlesnake (*Crotalus adamanteus*)

One of the largest and most dangerous snakes in North America has been observed on EAFB at Cape San Blas. The diamondback rattlesnake inhabits palmetto pine flatwoods at the edges of wet savannas and feeds primarily on small mammals. Diamondbacks breed in late fall and spring and young are born in late summer or early fall. At birth, young diamondbacks are approximately 12 inches long. On two separate occasions, diamondback rattlesnakes were observed on EAFB property. In September 1996, a diamonback appeared from under the barracks at the CGS on EAFB. The snake was approximately 14 inches long, therefore it was most likely newborn. The snake was moving north. It crossed the CGS access road just inside the compound and moved towards the flatwoods behind the lighthouse. In July 1997 a diamondback was observed crossing the CGS access road, just north of the CGS entry gate. The snake was approximately 18 inches long and was most likely a first year juvenile. This snake was heading east towards the flatwoods. Large diamondbacks have been observed crossing Cape San Blas road on EAFB property, therefore it appears diamondbacks are residents of and most likely breed along Cape San Blas.

Manatee (*Trichechus manatus*)

The Florida manatee, an endangered species, typically ranges along the east and west coast of the Florida peninsula, although movements into neighboring states occur during summer. Accounts of manatees north of the Suwannee River, however, occur infrequently. One such observation occurred in August 1997, when a pod of approximately 10 manatees was observed travelling west off the Cape San Blas coast. In the past, numbers of manatees declined dramatically due primarily to collisions with boats and additional human disturbances. A comprehensive survey conducted in 1991 resulted in a count of 1,465 manatees throughout Florida (O'Shea and Ludlow 1992). Populations may now be increasing, however. More than 60 manatees now winter at Blue Springs compared with 11 in 1971. In addition, nearly 300 manatees have been observed in the Crystal River areas, in comparison with 45 in 1968 (O'Shea and Ludlow 1992). Possibly, increased numbers of manatees in Florida result in greater dispersions, therefore manatees are now being observed in areas where they previously were not seen, such as Cape San Blas.

River Otter (*Lutra canadensis*)

River otters occur typically along rivers, ponds, and lakes in wooded areas. They feed primarily on fish, but also eat small mammals such as mice and terrestrial invertebrates. In February 1996, a river otter was observed running south along the beach in front of the Coast

Guard Station on EAFB at Cape San Blas. Previously, dead otters had been observed along Cape San Blas road on EAFB property and reports of sightings on EAFB had occurred. River otters are fairly abundant in the southeast and are common in areas adjacent to Cape San Blas, such as St. Marks National Wildlife Refuge. Most likely, river otters are not residents of Cape San Blas, but may occasionally roam into the area in search of food or mates.

Red Imported Fire Ant (*Solenopsis invicta*)

The red imported fire ant is a relatively new, non-indigenous addition to the invertebrate fauna of the United States. They are opportunistic generalist foragers feeding primarily on other invertebrates (Allen et al. 1997). They have been known to kill birds, reptiles, and mammals, including humans. *Solenopsis* was observed in one sea turtle nest along EAFB on Cape San Blas in 1995. Ants were observed again in 1996. In fall of 1996, baits (meatballs) were placed along four transects on the East beach of Cape San Blas. After two hours, baits and the attached ants were placed in plastic film canisters and frozen. Numbers and species of ants on each bait were identified. Results of these transects indicated red imported fire ants were frequent along east beach of Cape San Blas. Transects were then placed along the north beach to assess the presence of ants in this location. Again, ants were observed among the transects, indicating presence of red imported fire ants along the entire beachfront of EAFB on Cape San Blas. During the 1997 sea turtle nesting season, several turtle nests were inundated with fire ants. At least two sea turtle hatchlings were killed by ants while the turtles were pipping. Increased presence of fire ants within sea turtle nests on Cape San Blas indicates this species may become a primary threat to sea turtle nesting on EAFB.

Literature Cited

Ashton, R. E. Jr. and P. S. Ashton. 1981. Handbook of Reptiles and Amphibians of Florida. Part One. The Snakes. Windward Publishing, Inc. Miami, FL. 176 pp.

Allen, C. R., K. G. Rice, D. P. Wojcik, and H. F. Percival. 1997. Effect of red imported fire ant envenomization on neonatal American alligators. Journal of Herpetology 31(2): 318-321.

O'Shea, T. J. and M. E. Ludlow. 1992. Florida manatee *Trichechus manatus latirostris*, pgs. 190-200 *in* S. R. Humphrey ed., Rare and Endangered Biota of Florida. Volume one. Mammals. 392 pgs.

Whitaker, J. O., Jr. 1980. The Audubon Society Field Guide to North American Mammals. Alfred A. Knopf, Inc. New York, New York. 745 pgs.