DISCUSSION

Channel margin erosion in the southern half of the GTMNERR from 1970/1971 to 2002 was severe and has most likely caused significant changes in the estuarine ecosystem. Lateral erosion was found to be significantly related to exposure to boat wakes generated in the AICW channel. Erosion was also found to be significantly related to exposure to wind waves generated by predominant winds; however, the increase in erosion related to exposure to wind waves was significantly less than that associated with exposure to boat wakes.

The relatively low levels of correlation between the causal factors and erosion rates detected using linear regression and Kendall's Tau-b should not be viewed as an indication that boat wakes are not a primary cause of erosion. As stated, the reliance on binary variables and bluntness of measurement are two possible causes of the low R^2 of the regression model and these factors may also explain the relatively low Kendall's Tau-b coefficients.

A process of elimination of the likely causal factors also implicates boat wakes as the most significant cause of erosion. Because more erosion was estimated to have occurred in areas not exposed to waves generated by the predominant wind than in areas exposed to these wind waves, wind waves cannot be assumed to be the main cause of erosion. Since curvature was not significantly correlated with erosion rates and visual analysis of erosion patterns and bathymetric cross-sections did not reveal significant evidence of meander migration, currents can be rejected as a cause of erosion. The slightly lower rate of erosion in dredged areas south of the State Road 206 Bridge, suggests that dredging, too, does not exacerbated erosive processes.

Variation in sediment type, as indicated by channel margin classification, significantly influences erosion rates, but is not, in itself, a cause of erosion. Finally, biological change does not appear to be a major factor in high erosion rates because erosion was found to have occurred in all channel margin classification categories. This leaves boat wakes as the primary causal factor of erosion in the reserve. As displayed in Figure 14, above, the widespread susceptibility to boat wakes, alone, demonstrates the potential for vessel traffic to contribute significantly to erosion. In light of this conclusion it is useful to examine the options for managing erosion in the reserve as well as the public policy governing implementation of management strategies.

Erosion management alternatives

With implementation in mind, methods of inshore erosion management are best grouped into two classes: (1) regulation-based alternatives, which address the cause of erosive forces and (2) stabilization-based alternatives, which address the effect of erosive forces. Along inland waterways the main controllable causes of channel margin erosion are wake-producing vessel traffic and dredging activity. Dredging does not presently appear to be a major cause of erosion in the GTMNERR, thus regulatory options for erosion control in the GTMNERR must involve the regulation of navigational activities. Stabilization options include structural measures and non-structural measures such as moving sediment or increasing natural stabilization. The selection of erosion control strategies depends mainly on the goal of erosion management.

The goals of inshore erosion management

Inshore erosion in the GTMNERR is an issue of concern because erosive processes are altering ecosystems of economic and environmental importance. The goal of erosion

management activities depends to some degree on what interests are being represented. Pleasure boaters, fishermen, and waterfront homeowners may each have different visions of what constitutes "good" management strategy. In order to develop a strong erosion management plan it is important to involve all concerned parties. Not only is this type of planning process essential to ensure public acceptance of a management plan, it will also help to gain the cooperation of owners of submerged land in any stabilization efforts and will ease the enforcement of any regulation of boating activity. A management goal broad enough to accommodate all interests might be to "minimize channel margin erosion to the extent necessary to allow the recovery of altered shoreline and nearshore ecosystems, while accommodating the needs of diverse local interests to the extent possible." As evidence suggests, increased channel margin wave energy levels are the main cause of erosion in the GTMNERR; the key to limiting erosion is decreasing these energy levels. Achieving such a decrease on a scale as large as the entire GTMNERR is likely to involve the incorporation of both stabilization and regulation.

Stabilization based alternatives

Stabilization based options include structural and non-structural measures. Non-structural strategies include less permanent structures which commonly make use of vegetation and other naturally occurring material. Structural measures involve the construction of permanent stabilization works. Both types of stabilization have advantages and disadvantages.

Non-structural, or soft, stabilization options are probably the most widely promoted and possibly the most widely used means of controlling inshore erosion for ecosystem preservation. They are intended to physically resist erosive forces by stabilizing shoreline sediments. In estuaries, some of the first tools of those planning soft stabilization efforts are the organisms which naturally provide stabilization— the marsh grass, *Spartina alterniflora* (Knutson and Woodhouse, 1983), and oyster shells (Meyer, Townsend, and Thayer, 1997). The most obvious shortcoming of these strategies is the fact that they rely on the same biota that are being impacted by erosion to provide stability. If well-established marsh grasses and oyster bars are being eroded, then it is unlikely that new plantings of either will establish themselves before they, too, are eroded away. Stabilizing only the shoreline also fails to protect nearshore habitat, such as oyster bars, from increased wave energy.

Two studies which recognize the impermanence of vegetative plantings in areas of elevated wave energy are the works of Broome, Rogers and Seneca (1992) and Rogers (1994). Both of these reports provide extensive discussions of the combined use of vegetation and low cost, wooden breakwaters in controlling erosion in a North Carolina estuary. Breakwaters are structures built in the water, parallel to an eroding shoreline for the purpose of reducing wave energy. They present the main structural option for controlling erosion in the GTMNERR. Erosion control structures, such as groins and jetties, which are built perpendicular to the shoreline, are of little use in the inshore environment because these structures are designed to reduce longshore transport of sediment rather than to reduce wave energy.

With a few exceptions, breakwaters are a type of permanent stabilization, usually built from wood or stone. They extend from the bottom of a body of water to just below or well above the surface of the water. In addition to protecting shorelines, breakwaters also provide a hard substrate for the attachment of oysters and a refuge and foraging ground for fish. However, they have the potential to have unintended adverse effects on sedimentation or other ecological processes, and so they should be pilot tested before construction and used with caution.

According to Dale Campbell, of the USCOE Panama City office, stone breakwaters are often opposed by boaters because of the potential hazards they pose to those who inadvertently leave the marked navigation channel (personal communication, September 10, 2004).

One example of a nonpermanent breakwater is the new product called WhisprWave®, developed by Wave Dispersion Technologies, Inc.. This structure is a floating plastic breakwater, which serves the same purpose as a permanent breakwater but has the advantages of being quicker to install and easier to relocate. Such a structure would also have the advantage of being less damaging in case of a vessel impact.

An example of a large, traditional, inshore breakwater project is offered by the 11,700 foot long stone breakwater constructed in Louisiana to protect eroding marshes bordering the Gulf Intracoastal Waterway from wake damage (Louisiana Coastal Wetlands Conservation and Restoration Task Force, 2001). An example from Florida, involving the same regulatory agencies which would be involved in a stabilization project in the GTMNERR, is Project Green Shores in Pensacola (Florida Department of Environmental Protection, 2005) (Fig. 15).

Fig. 15: Project Greenshores in Pensacola, Florida

While these projects are expected to significantly decrease marsh loss to erosion, they are costly. The Louisiana project cost about $137 per linear foot of breakwater. Although this cost also includes construction of stone terraces, to reduce available fetch in a portion of the protected

marsh, building a similar protective structure for only half of the study area would cost about $15 million. Breakwater construction at lower cost has been shown to be possible.

In both coastal Louisiana (Steller, 1991) and Italy's Venice Lagoon (Scarton, Cecconi, Are, Day, and Rismondo, 2000), an innovative technique has been used to construct fence-type breakwaters from wood and brush. Both of these projects involved the construction of a wooden bin between posts set into the bottom. In Italy, the fences were filled with willow and poplar bundles. In Louisiana, the fences were filled with discarded Christmas trees. This innovative reuse effort won a participating parish a national award for environmental sustainability (Kratch, 1996). High levels of volunteer participation resulted in the construction of 7,000 meters of fence for only $190,000 in 1991. The obvious drawback of these less costly fences is their durability. The breakwater in Italy received severe damage during a storm and a large portion of the sediment which had accumulated behind it was lost. Before construction of this type of breakwater, careful study should be undertaken to determine if the low cost is worth the lower durability and resulting higher maintenance costs. It is possible that a breakwater of this design could be an excellent pilot project to study the effects of breakwaters on local erosion rates before construction of a more permanent structure.

The high cost and possible adverse ecological impacts associated with stabilization, such as breakwaters, makes it unlikely that a significant portion of the GTMNERR channel margin environment will ever be protected by structures. This emphasizes the need for regulatory protective strategies.

Regulation based strategies

Regulation-based erosion management strategies address the cause of erosion without permanent physical alteration of the nearshore ecosystem. These strategies focus primarily on the reduction of boat wakes. The role of boat wakes in channel margin erosion rates can be expected to increase as the level of boat traffic in the reserve increases. There has been increase in boat registration in St. Johns and Flagler counties of over 400% since 1977 (Fig. 16).

Boat traffic can be regulated in several ways to reduce margin erosion caused by wakes. As previously stated, factors influencing the erosive impact of boat wakes include the size of the wake, the water depth, the current direction and velocity, the morphology of the impacted bank, the presence of wind waves, and the distance of the vessel from the shore (Macfarlane and Renilson, 1999). Factors which can potentially be regulated include the distance of vessels from shore and factors such as vessel speed, hull form, draft, loading and trim which influence the size of the wake.

Vessel speed and distance from shore are the most obvious opportunities for regulation. Development of precise regulations may need to be supported by additional research linking wakes to habitat degradation in the GTMNERR. Such research would also help to clarify which vessels and what activities should be regulated. For example, is it more important to regulate less common displacement-hulled vessels that produce huge wakes or more common planing vessels that produce smaller wakes? Although such studies have been conducted elsewhere (Wilcox, n.d.), it is important to understand the impacts of the specific distribution of vessel types found in the GTMNERR.

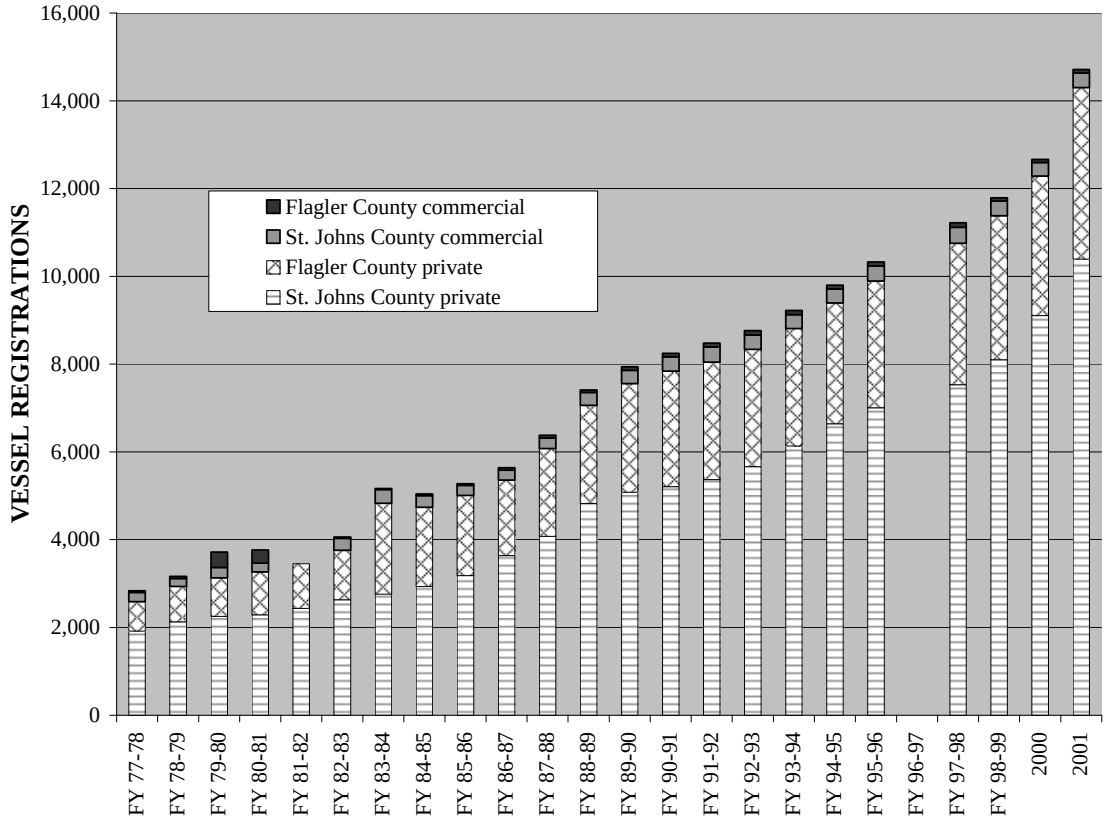

Fig. 16: Boat registrations in Flagler and St. Johns Counties, 1977 to 2001 (Florida Statistical Abstract, 1977-2001)

Implementation of both stabilization-based plans and regulation-based plans will require significant planning. Before such a planning effort is undertaken, an attempt should be made to establish which private and governmental entities will need to be involved in the implementation process.

Policy governing implementation of management alternatives

The options for implementation of stabilization plans and regulation plans differ considerably. Implementation of stabilization plans involves public participation and environmental permitting, while implementation of regulation is mainly a matter of law enforcement.

Implementation of stabilization plans

Implementation of stabilization plans is complicated by the fact that the AICW in the GTMNERR is constructed in waters of the United States within a right-of-way, composed of federally owned easements on state and private land. Although shoreline protection is a

permitted activity for property owners within the right-of-way, a large scale public margin stabilization project, partially on private land, would be an involved process.

First, the project must be permitted under applicable federal and state regulations. Federal permitting authority to regulate construction in waters of the AICW stems from two main sources, Section 404 of the Clean Water Act (2005) and Section 10 of the Rivers and Harbors Act (2005). The Clean Water Act regulates placement of any type of fill, including materials used to build stabilization works, in the navigable waters of the United States. The Rivers and Harbors Act applies to projects which have the potential to obstruct navigation in the navigable waters of the United States. The USCOE is charged with the implementation of both of these statutes. If federal funding is used in the completion of a project or a federal permit is issued, completion of an Environmental Impact Statement, in compliance with the National Environmental Policy Act (2005), may also be required.

The State of Florida maintains an Environmental Resource Permitting (ERP) system, independent of the federal system. The ERP system, which is implemented by the Florida Department of Environmental Protection and the Florida Water Management Districts, regulates most major land alterations within the state including projects involving dredging and filling of waters or wetlands. Statutory authorization of the ERP program to regulate activity in wetlands is contained in Part IV of Chapter 373 of the Florida Statutes (2004). Issuance of an ERP permit from the state certifies not only that a project is compliant with state wetlands regulations, but also that it is consistent with the goals of the Florida Coastal Zone Management Program (Coastal Planning and Management, 2004). Although the USCOE issued a Statewide Programmatic General Permit to the State of Florida to avoid duplication in federal and state permitting procedures, regulation of breakwaters is specifically excluded from the scope of this permit (State of Florida, n.d.). Separate applications to the USCOE and the state are required to ensure compliance with the Clean Water Act (2005) and the Rivers and Harbors Act (2005). As nearshore and shoreline stabilization projects have been constructed in Florida (Florida Department of Environmental Protection, 2005), meeting the federal and state requirements is clearly possible with proper project design.

In addition to regulatory permits, proprietary authorization must also be obtained from involved parties. If the work is to take place within the AICW right-of-way, then the USCOE Real Estate Branch must authorize the use of an easement. If the work is to take place on submerged lands owned by the State of Florida, the state must issue a proprietary authorization for use as required in Chapter 253 of the Florida Statutes (2004). If the work is to take place on privately owned lands, consent must also be obtained from these land owners. According to David Roach, of the Florida Inland Navigation District (personal communication, January, 2005), the owners of the AICW right-of-way retain all rights to the land except those interfering with the navigation project. Once the consent of property owners and the USCOE Real Estate Branch is obtained and all applicable permits are acquired, construction can begin.

Implementation of regulation plans

Implementation of new navigation regulations is mainly a matter of law enforcement, however, such enforcement occurs within a complex regulatory framework which establishes and supports the right to inshore navigation in the AICW.

The right to inshore navigation in Florida

In Florida, and the United States as a whole, the right to navigate is protected by expressions of the Public Trust Doctrine which is rooted in the Roman Code of Justinian (Robert Deyle, personal communication, March, 2005) under which publicly useful bodies of water are preserved as public property. In Florida this authority is defined in a constitutional provision (FL Const. art. X, § 11) which declares that land beneath navigable waters is to be publicly held, and not for sale (Reimer, 2001). Navigable water bodies are defined in case law as any bodies, which in 1845, at the time of statehood, were "capable of being used" for transportation. The ordinary high water line defines the extent of public ownership. In the case of saltwater bodies, this high water line is statutorily defined as the "mean high water line," a location that can be established from local tidal gages (Reimer, 2001). The Atlantic Intracoastal Waterway, is a federal waterway, and so the right to navigation is based on federal navigational servitude as established in the Commerce Clause of the United States Constitution (U.S. Const. art. I, §8).

Support of inshore navigation

Governmental support of navigation mainly consists of developing, marking, and maintaining inshore channels. The 1927 Rivers and Harbors Act (2005) assigned the federal government the role of constructing and maintaining the navigation channel of the Intracoastal Waterway (Florida Inland Navigation District, 1967a). The USCOE is assigned the responsibility for the physical construction work and for cooperating with state and local authorities in planning and project development (Florida Inland Navigation District, 2002).

In Florida, the Florida Inland Navigation District (FIND), established by the state legislature as an independent special district in 1927, helps to provide necessary rights-of-ways and land for channel dredging spoil disposal areas, to the federal government, free of charge (Florida Inland Navigation District, 2002). FIND is composed of eleven Florida east coast counties: Duval, St. Johns, Flagler, Volusia, Brevard, Indian River, St. Lucie, Martin, Palm Beach, Broward, and Miami-Dade. The district is governed by an eleven member Board of Commissioners, one from each county in the district, appointed by the Governor (Florida Inland Navigation District, 2002). According to Franklin Morrison, with the Jacksonville District of the USCOE, the local port authorities cooperate with both the USCOE and FIND in funding local navigational projects and the acquisition of dredge material management sites (personal communication, November 20, 2003).

Regulation of navigational activities

Once the right to navigate is established and the creation and maintenance of a waterway, which can support modern navigation, is ensured, the conditions are such that the environmental conflicts begin to occur. As boat traffic on Florida's waterways continues to increase, the need to regulate boating in order to moderate environmental degradation will increase. Federal, state, and local authorities share an interest in the regulation of marine navigation, but the legal authority of these entities to enact such regulation differs substantially.

Federal regulation

The ability of the federal government to regulate marine navigation is established jointly in the Commerce Clause of the United States Constitution and the Property Clause of the Constitution (U.S. Const. art. IV, §3). The Commerce Clause gives the government the right to regulate maritime activity in waters of the United States based on the "federal navigational servitude" and this basis for regulation has been supported by the courts (Gibbons v. Ogden, 1984). The authority to restrict navigation based on the reasoning that the U.S. has the right to make rules governing conduct on federal property and adjacent non-federal property, as described in the Property Clause, has also been upheld (McGrail v. Babbitt, 1997). The implementation of these constitutional authorities has been delegated to a number of federal agencies.

Brooks (2000) discusses six federal agencies with potential power to regulate navigation in Florida waters, the United States Coast Guard (USCG), the USCOE, the Fish and Wildlife Service (USFWS), the National Marine Fisheries Service (NMFS), the National Park Service (NPS), and NOAA. The powers of NOAA and the NPS are restricted to national marine sanctuaries and national parks, respectively (Brooks, 2000). Although the Fort Matanzas National Monument borders the study area, its small size makes any regulation within its boundaries insignificant in terms of protecting the resources of the GTMNERR as a whole. While the GTMNERR is administered jointly by NOAA and the State of Florida, it is not a marine sanctuary, and thus NOAA is also unlikely to have significant regulatory authority over activities in the reserve. The USFWS and the NMFS derive broad authority from the Endangered Species Act (2005) and the Marine Mammal Protection Act (2005) to regulate activity which may impact endangered species or marine mammals. This authority has been largely delegated to the State of Florida, which makes use of it in regulation of boating activities for the protection of the West Indian Manatee (Florida Manatee Sanctuary Act, 2004). However, regulation related to endangered species does not appear to have immediate application to the current issue of channel margin protection. The power of the USCOE to restrict navigation is generally limited to issues of military operations and national security (Brooks, 2000). The limitations on the previously discussed agencies leave the USCG as the federal body with the most power to affect meaningful regulation within the GTMNERR. The Coast Guard has authority to restrict vessels operating in the navigable waters of the United States for "environmental purposes" (Ports and Waterways Safety Program, 2005) and to restrict vessels from "safety zones" for safety or environmental purposes (Navigation and Navigable Water Rule, 2005).

State regulation

State regulation of inshore navigation in Florida is accomplished through the statutory grant of police powers and the Public Trust Doctrine, as defined in the State Constitution (FL Const. art. X, §11). Such regulation is implemented by the Board of Trustees of the Internal Improvement Trust Fund, the Florida Fish and Wildlife Conservation Commission (FWCC), and the Florida Department of Environmental Protection (FDEP). However, only the FWCC and FDEP have power to restrict navigation for environmental purposes.

The FWCC uses its statutory authority, under the Florida Manatee Sanctuary Act (2004), to restrict and exclude vessels to ensure manatee protection. This authority has been upheld in court (Marine Industries Ass'n of South Florida, Inc. v. FDEP, 1996). Perhaps this power has the potential to be extended to ensure the protection of other environmental entities.

The FDEP has the authority to restrict motorized watercraft within state-defined canoe trails (Recreational Trails System, 2004), but at this time there are no such trails within the study area.

Local regulation

Local governments in Florida, through exercise of their police power, have the authority to restrict the operation of vessels, within water bodies in their jurisdiction, through local law or ordinance. These local regulations cannot conflict directly with state or federal laws and cannot pertain to vessels operating within the AICW (Vessel Safety, 2004). The restriction on local laws regulating activities in the Intracoastal Waterway makes significant local regulation of inshore boating activity along much of Florida's east coast very difficult. Particularly in regions such as northern Flagler County or southern St. Johns County, where practically all inshore navigation takes place in the Waterway, local governments are left with few means to restrict boating activity. In situations such as these, any significant restriction on navigation on the AICW will have to occur on the federal or state level.