Enhanced Manatee Protection Study

Florida Fish & Wildlife Conservation Commission

Final Report
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To report fish and wildlife violations, as well as manatee injuries and mortalities

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Executive Summary

Chapter 2004-343, Laws of Florida (SB540; §370.1202 F.S.), directed the Florida Fish and Wildlife Conservation Commission (FWC) to conduct an "enhanced manatee protection study" that assessed the, "effectiveness of manatee protection signs and sign placement and to evaluate boat speeds". FWC also was directed to evaluate manatee mortality before and after protection zones were established, boater comprehension and compliance of regulatory signs, changes in boating traffic patterns, manatee distribution and behavior, and to evaluate higher speed corridors within protection zones.

Watercraft collision continues to be the primary human-related mortality factor for manatees, averaging about 36% of known-cause mortalities annually since 1975. The principal management strategy to address this mortality factor has been to limit boat speeds in areas where manatees are most likely to occur.

Analyzing manatee mortality before and after implementation of protective zones is a deceptively difficult task to address. Several factors may confound such studies, including zone configuration, carcass drift, changes in boating activity, changes in manatee abundance, changes in carcass discovery rates, climatic factors, and changes in enforcement or boater compliance. Each could induce systematic changes in manatee mortality, making it difficult to estimate the efficacy of a particular zone. Currently, such an analysis is being conducted in Sykes Creek and the Barge Canal on Merritt Island (Brevard County). The area around Sykes Creek and the Barge Canal is unique in configuration and many of the confounding factors can be accounted for or have a measurable influence. Other areas in the state which lend themselves to these analyses also are being investigated. The Sykes Creek/Barge Canal study is expected to be completed in 2007.

Understanding the relationship between boating patterns and manatee distribution and behavior increases the ability to assess the risk of a collision between a boat and a manatee and consequently intervene to reduce such risk. The principle methods being used are mapping of boats during aerial surveys and compiling travel routes reported by boaters during mail surveys. Several boat traffic characterizations that focus on change in traffic before and after posting of new regulations have taken place or are in progress. A study in Lemon Bay (Charlotte County) found little change in boating patterns following posting of slow-speed zones. This is likely due to the observation that many boaters were already using the ICW channel as the primary travel corridor. Other studies currently are in progress.

Manatee distribution is tracked in a variety of ways, most notably aerial surveys, satellite-and/or radio telemetry, and photo identification. Biologists use aerial surveys as a standard technique to assess manatee distributional patterns and estimate relative abundance. Results from these studies provide managers with information on where manatees congregate and which areas manatees may use as travel corridors, facilitating efficient placement of protection zones. However, no studies have been specifically conducted to assess distributional changes of manatees before and after speed zone implementation.

Compliance with speed zones is dependent on a number of variables but typically has ranged from about 50% to 70%, based on previous studies. Variables affecting boater compliance within manatee speed zones include location, type of zone, vessel type, vessel size, season, time (morning/afternoon; weekend/weekday), boating conditions, and port of origin. Although results vary by location, some overall trends have been found. Personal watercraft typically are the least compliant, while sailboats consistently are the most compliant. At many sites, compliance is higher on the weekends; however, because of overall increased traffic, more violations tend to occur at this time.

To assist with boater comprehension and to eliminate confusion, FWC, in conjunction with the U. S. Fish and Wildlife Service, has developed a waterway marker guidance document, "Approved Uniform Waterway Marker Standards for Posting Manatee Protection Zones in Florida's Waterways," which establishes the criteria for the appropriate placement of waterway signs and buoys when posting federal and state manatee protection zones. In combination with the uniform marker plan, FWC has begun to use innovative marker designs that comply with the U.S. Aids to Navigation System. FWC also is researching better ways to post regulatory zone markers within waters of the state to achieve increased boater compliance. Toward that end, FWC has investigated the use of buoys in place of signs affixed to pilings for boating safety purposes, and advantages and disadvantages have been identified. Buoys present less of a hazard to navigation than signs affixed to permanent pilings. However, FWC has determined that in most waterways, buoys used in combination with signs to post a regulatory zone is the most effective marking system. This marker combination appears to adequately post a waterway, minimizing the navigational hazards, and achieve boater understanding of the appropriate vessel operation for the regulated area.

FWRI also investigated higher speed travel corridors in manatee zones to determine the most effective speed to balance safe boating, recreational use, vessel operating characteristics, and manatee protection. Unfortunately, there appears to be no single numeric speed that can optimize manatee protection and vessel performance. A 25 MPH speed limit will allow most vessels to operate on a plane, although it will not allow most of them to operate at their optimum performance speed. Driver reaction times decline as speed increases, and collisions at higher speeds will cause more physical damage to the manatee. Therefore using a higher limit would reduce the negative effects on vessel performance but not without some lessening of manatee protection.

Introduction

The Florida manatee (*Trichechus manatus latirostris*) has been protected in some fashion since the late 19th century, either through state or federal statute. Currently, manatees have protection at the state level under the Florida Manatee Sanctuary Act (FMSA, 370.12(2)) and at the federal level under both the Endangered Species Act (ESA, 16 U.S.C. 1361 et seq.) and Marine Mammal Protection Act (MMPA, 16 U.S.C. 1361 et seq.). These protections are designed to protect manatees and their habitats. Such protections are necessary to ensure the long-term viability of manatees in the wild. Because of their restricted range and unique biology and physiology, manatees are particularly vulnerable to population-level declines. Animals are long-lived and breed once every 3 years at best, producing a single offspring (rarely twins). In addition, manatees are slow moving and frequent areas that often put them in close proximity to traveling watercraft. Such interactions often result in injury or death to manatees (Reep and Bonde 2006).

Since 1975, an average 36% of known-cause manatee deaths (i.e., where a cause of death was determined) have been due to collisions with watercraft (FWC, manatee mortality statistics, http://research.myfwc.com/manatees). Because this is the primary human-related mortality factor, management efforts have focused on reducing this threat. The principal management strategy has been to limit boat speeds in areas where manatees are most likely to occur, with the goal of reducing harmful collisions between manatees and watercraft (U.S. Fish and Wildlife Service, 2001). Since 1979, almost 300,000 acres of Florida's coastal waters have been regulated by the state for manatee protection (FWC, unpublished data). Despite this, watercraft-related manatee deaths continue to be the leading identified human-related mortality factor.

In 2004, the Florida State Legislature enacted and Governor Jeb Bush signed Senate Bill 540 (SB540) amending existing statute 370.12, creating §370.1202 F.S., specifying that, "an enhanced manatee protection study" be conducted by FWC. The statute requested certain aspects of manatee protection be evaluated and reported on by February 1, 2007. The focus of the directive was on assessing the effectiveness of signs and sign placement and to evaluate boat speeds. Other directives included evaluating manatee mortality before and after protection zones were established, boater comprehension and compliance of regulatory signs, changes in boating traffic patterns, and manatee distribution and behavior. No specific funding was appropriated to implement the studies requested within the statute; however, a number of studies have been previously completed, are currently underway, or are planned that address, either directly or indirectly, those aspects called for in SB 540.

Specifically, this reports addresses Section (2), Paragraph (3) of §370.1202 F.S.: Enhanced Manatee Protection Study. The relevant section reads as follows,

> *(3) As part of the enhanced manatee protection study, the Legislature intends that the commission must conduct a signage and boat speed assessment to evaluate the effectiveness of manatee protection signs and sign placement and to assess boat speeds. The commission shall evaluate existing data on manatee mortality before and after existing manatee protection zones were established, boater compliance and comprehension of regulatory signs and buoys, changes in boating traffic*

patterns, and manatee distribution and behavior. The commission shall also provide recommendations on innovative marker designs that are in compliance with the federal aids to navigation system. The signage and boat speed assessment must address:

(a) The effectiveness of signs and buoys to warn boaters of manatee slow-speed zones, with a goal of developing federally approved standards for marking manatee protection zones;

(b) A determination of where buoys may be used in place of pilings for boating safety purposes; and

(c) An evaluation of higher speed travel corridors in manatee zones to determine the most effective speed to balance safe boating, recreational use, vessel operating characteristics, and manatee protection.

The commission shall complete its signage and boat speed assessment by January 1, 2007, and must submit a report of its findings to the Governor, the President of the Senate, and the Speaker of the House of Representatives by February 1, 2007. The report must detail the results of the assessment and identify specific recommendations for developing state and local policies relating to the appropriate placement of signs, including innovative markers, in manatee slow-speed zones.

Based on the language cited above, this report is divided into five sections:

1) Manatee mortality before and after signage
2) Changes in boating traffic patterns
3) Manatee distribution and behavior
4) Manatee protection signs and compliance
5) High speed travel corridors in manatee zones

This report encompasses work performed by FWC's Fish and Wildlife Research Institute (FWRI) and Law Enforcement's Boating and Waterways Section (FWC-LE), and includes work performed by other organizations in conjunction with or under contract by FWC, that address requirements enacted in SB540. Information presented herein is pulled either directly from various reports or summarizes findings from one or more reports. Each section contains a list of "Related Research" that highlights reports or scientific literature cited within the section or that may be of further interest related to the topic. The report also describes research currently in progress or planned in the near future that address either directly or indirectly issues raised by SB540.

References

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USFWS. 2001. Florida manatee recovery plan (*Trichechus manatus latirostris*), Third Revision. U.S. Fish and Wildlife Service, Atlanta, Georgia.

Section 1.

Manatee mortality before and after establishment of manatee protection zones

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Mortality due to boat collisions is a large component of overall manatee mortality throughout the state of Florida (~36% of known-cause mortalities annually; FWC, http://research.myfwc.com/manatees). Like many large-bodied mammals, manatee populations are thought to be sensitive to changes in adult survival rate (Runge et al., 2004). Thus, it has been recognized that this source of mortality may impede the recovery, and subsequent reclassification, of this endangered species. The primary management tool for the mitigation of manatee mortality is the establishment of manatee protection zones in areas where animals are thought to be particularly vulnerable. Such actions are based on the premise that: (1) slower-moving watercraft allow both operators and manatees more reaction time during encounters; and, (2) the force of impact, in the event of a collision, is reduced relative to a faster-moving vessel. However, other factors might reduce the effectiveness of protection zones for reducing mortality risk to manatees; these include (but are not limited to) boater non-compliance to regulations, inadequate zone placement or coverage, and lack of evasive response by manatees.

In spite of this controversy, no studies have been published to estimate the efficacy of protection zones for mitigating manatee mortality risk. Several obstacles impede the design of any such study. First, the appropriate response variable is difficult to measure. Though it is desirable to assess the effectiveness of a particular protection zone based on its effect on manatee mortality, it is difficult to spatially attribute individual manatee deaths at the appropriate scale. Only a proportion of the total number of carcasses is recovered, and recovered carcasses may drift far from the site of death or critically injured animals may travel a long distance before succumbing to their injuries, thus confounding recovery location and location of death or injury. Second, any potential reduction in mortality due to protection zone implementation may be confounded by a suite of other factors, including trends in numbers of active boats, trends in manatee abundance, seasonal or weather-related changes in boater activity, dynamic carcass reporting rates, and changes in enforcement or boater compliance. Each could induce systematic changes in manatee mortality, making it difficult to estimate the efficacy of a particular zone.

Currently, FWRI is examining the association between the implementation of protection areas with the monthly number of manatees recovered in Sykes Creek and the Barge Canal on Merritt Island (Brevard County) from 1986 to 2005. By modeling manatee mortality at this location, we hope to minimize the effects of location error due to carcass drift, yet still provide inference on the implementation of particular protection zones. These are relatively discrete waterways in which protection zones were implemented in 1994 and 2002. Mortality in this area was previously examined by Laist and Shaw (2006). Given the uncertainty about protection zone effectiveness, a scientific course of action is to compare competing models that explain observed patterns in mortality. For example, one could posit four models, each describing different combinations of effects due to regulations: (1) changes in mortality following speed zones implemented in both 1994 and 2002; (2) a 1994 zone effect, but no effect for the 2002 zone; (3) a 2002 effect, but no 1994 effect; and (4) no effect for either zone. These ‘change-point’ models, each representing a different operational hypothesis, fit different expected mean numbers of carcasses before and after years in which zones were implemented, after accounting for some available covariates, boat registrations, and precipitation.

The change-point model expresses the observed number of carcasses killed by watercraft each month as a random draw with a particular expected mean and variance. This mean and variance is thought to be different before and after the implementation of regulations if those regulations are effective, and similar if they are ineffective. Several factors may influence the expected monthly count, including (but not limited to) the number of boats active on the water, the number of manatees in the area, weather conditions, and changes in regulations. The full hierarchical structure of each model incorporates a small set of covariates thought to account for important variation in the number of recovered carcasses attributed to boat collisions.

Using an information-theoretic approach (Anderson et al., 2000; Burnham and Anderson, 2002), it is possible to use the available data to discriminate among the models. This method of model selection compares among candidate models based on information contained in the data used to fit the models. The result is a set of weights that expresses the relative probability that each model is the most appropriate model of the set. An advantage of this approach is that models can be formally re-evaluated over time, as new data are collected. In lieu of a truly experimental study, this may be a fruitful method of evaluating speed zone efficacy. Results from this study are expected in 2007. Other areas in the state that may be amenable to similar analysis (i.e., provide data in which bias variables are minimized) are being investigated.

Related Research

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Section 2.

Changes in boating traffic patterns

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The State of Florida has more registered vessels than any other state in the U.S., currently exceeding 1 million boats. Furthermore, Florida is second in the nation in terms of total coastline (next to Alaska) and leads the nation in the number of mariners visiting its waters annually. Unfortunately, Florida also leads the nation in fatalities from boating accidents (USCG 2006). Boating also can have negative effects on Florida's natural environment. Impacts include sea grass scarring, damage to coral reefs, and collisions with wildlife. Of primary interest to the State of Florida and SB540 are collisions with manatees.

The Florida manatee inhabits freshwater and estuarine habitats of Florida. These near-shore areas also are heavily used by boaters, resulting in frequent encounters between vessels and manatees. On average, 36% of the known-cause annual manatee mortalities result from collisions with watercraft (FWC, http:// research.myfwc.com/manatees). Reducing this type of manatee mortality is a primary goal of state and Federal governments. One attempt at reducing watercraft-related mortality has been the development of comprehensive manatee protection plans by state and local governments. A significant component of manatee-protection planning is regulating boat traffic in areas frequented by manatees. One of the principle ways that governments attempt to reduce collisions between manatees and watercraft is to enact speed zones for boats.

To configure speed zones for an area or evaluate their effectiveness, it is necessary to understand the relationship between boating patterns and manatee distribution and behavior. Understanding this relationship increases the ability to assess the risk of a collision between a boat and a manatee and consequently intervene to reduce such risk. Boating patterns are complex and include spatial and temporal patterns, routes, and speeds. Patterns are influenced by the spatial arrangement of boating sources and destinations, the relationship between vessel draft and bathymetry, regulations and compliance, boater knowledge, attitudes and perceptions, an element of randomness, and global variables such as fuel costs. The first step in understanding and managing boating is to describe the pathways boaters take on the water. The principle methods being used are mapping of boats during aerial surveys and compiling travel routes reported by boaters during mail surveys. One application of these methods is to study changes in boating patterns when regulations are posted (i.e., before and after studies).

Other ongoing work as of this writing is the development of a simulation model that will allow managers and citizens to explore how boating patterns might change with proposed changes in regulations, facility and waterways management, and shoreline development. Of particular interest are comparative boat-traffic studies before and after regulations are posted and/or if higher speed traffic corridors are designated within a manatee slow speed zone.

Boating aerial survey protocols were established in the mid to late 1990s and recently have been refined. In general, surveys are flown along a fixed, pre-determined flight path, encompassing all the waterways in the designated study area. Twenty flights over the course of a year are made. For each quarter, there are three weekend and two weekday flights. Usually two holidays are flown: Memorial Day, Independence Day, and/or Labor Day. Flights alternate between a morning start, around 9:00 AM, and an afternoon start, usually around 1:00 PM. Boats are captured on video and the vessel locations are transferred to Geographic Information

System (GIS) maps using digital orthophotos as the base map for plotting. For each mapped vessel, the following attributes are recorded: boat type, relative size, activity, and if moving, estimated speed and direction. Several covariates of boating also are recorded, including weather and boating conditions. Vessel data are then summarized as GIS maps depending on what patterns are of interest.

Several boat traffic characterizations that focus on change in traffic before and after posting of new regulations have taken place or are in progress. These include studies in Lemon Bay, Terra Ceia Bay, and Anna Maria Sound. The changes taking place in these areas are the addition of higher speed corridors being placed inside manatee slow speed zones. The study in Lemon Bay is complete, while the Terra Ceia Bay and Anna Maria Sound studies are still in progress.

<u>Lemon Bay</u> -- Lemon Bay is located on the Gulf of Mexico on the southwest coast of Florida, near Port Charlotte. It is dominated by shallow seagrass flats and has a middle channel running along the north-south axis. Early in 2004, the Bay was posted as a slow-speed zone except for the channel, which was posted as 25 MPH. Aerial monitoring using the protocols described above revealed that no significant change in boating patterns occurred in Lemon Bay. One change in boating patterns was the increase in reported vessels near Stump Pass. This increase was related to physical changes to the area and not to any affect of the regulations. The creation of the new regulatory zones probably did not impact the majority of boaters using Lemon Bay since many boaters were already using the ICW channel as the primary travel corridor.

<u>Terra Ceia Bay</u> – Terra Ceia Bay is located near the mouth of Tampa Bay on the southern shore. The study in Terra Ceia Bay is completed for Phase One: the before-regulation traffic characterization. The ‘after’ aerial surveys began in September 2006.

<u>Anna Maria Sound</u> – Anna Maria Sound is located along the Gulf of Mexico at the southern tip of Tampa Bay. The study in Anna Maria Sound is completed for Phase One: the before-regulation traffic characterization. Aerial surveys will resume approximately one year after the final sign is posted. The first flight is scheduled for November 2007.

Related Research

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Section 3.

Manatee distribution and behavior

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Manatee Distribution

Manatee distribution is tracked in a variety of ways, most notably aerial surveys, satellite- and/or radio telemetry, and photo identification. Biologists use aerial surveys as a standard technique to assess manatee distributional patterns and estimate relative abundance. Two types of surveys are flown by FWC: synoptic and distribution. Synoptic surveys are flown simultaneously around the state during the winter, at warm-water aggregation sites. These surveys provide a minimum count of the manatee population in the state of Florida. Unfortunately, current aerial survey methodologies for Florida manatees do not provide reliable information about the species actual abundance or changes in abundance over time. This is largely due to the inability to account for visibility and availability biases, and to a poorly-defined sampling frame. Research currently is underway to address these issues and to develop a more robust method for these surveys. Distribution surveys are regional and are conducted twice monthly for about two years in near-shore waters. These studies can convey a broad picture of seasonal manatee locations and identify important habitat features that attract manatees. The flights are designed to maximize manatee counts by concentrating on shallow near-shore waters, where manatees and their primary food source (seagrasses) are located. Flight paths are parallel to the shoreline, and when manatees are sighted, the airplane circles until the researchers onboard are able to count the number of animals in each group. Scientists usually do not survey deeper waters. In urban areas or where waters are particularly opaque, some studies are made using small helicopters.

All aerial survey data are recorded on maps and entered into FWRI's Marine Resources Geographic Information System (MRGIS) for spatial analyses. Survey data in the MRGIS are used as a primary source of data for management planning and decisions. The FWC Atlas of Marine Resources CD-ROM includes 31 data sets of manatee aerial distribution survey sightings, detailed aerial flight paths, and related coverages of bathymetry, shorelines, seagrasses, county boundaries, and aids to navigation.

Distributional surveys have been conducted by FWC since about 1984 and cover a variety of locations around Florida. Additional surveys have been flown in similar and other areas by other agencies (e.g., Florida Power and Light Company, Mote Marine Laboratory, U.S. Fish & Wildlife Service [USFWS]), but these surveys typically are limited geographically (e,g., power plants) or temporally (i.e., seasonal). FWC distribution surveys typically are county-wide and span one to two years in duration. They can provide monthly snapshots of manatee distribution in selected areas from which habitat use and travel corridors are deduced.

In addition to aerial surveys, FWRI uses radio- and satellite-tracking of tagged manatees to monitor movements and distribution of manatees. By tracking the movements of individual manatees in fresh, brackish, and saltwater habitats, FWRI biologists obtain valuable information about manatee seasonal and daily movement patterns, migratory behavior, site fidelity, diving behavior, and habitat requirements. To track manatees, researchers place a padded belt around a manatee's tail and tether a floating radio-tag containing a satellite-linked transmitter to the belt. The satellite-derived locations provide a detailed record of manatee movements over long periods. In the field, biologists locate these study animals by homing in on the tag's unique radio and ultrasonic signals in order to obtain data on behavior, group size, habitat, and movements. Processed data are mapped in a GIS; these data are made available to managers for use in developing regulatory rules, evaluating permits, and devising strategies for manatee conservation and recovery.

Most telemetry work is related to specific projects or areas (e.g., winter movements of animals in and around Tampa Bay Electric Company's Big Bend power plant; see Weigle et al., 2001). This work focuses on obtaining scientific information necessary to develop a meaningful management plan for maintaining a reliable network of warm-water sites and nearby winter feeding grounds for manatees. Mapping manatee movements and delineating travel corridors can help managers determine critical habitat areas (i.e., warm-water sites or feeding grounds) or identify potential problem spots where boats and manatees may frequently co-occur. Most of these studies provide detailed information but may be limited in time and space.

Additionally, FWRI conducts photo-identification of manatees around the state. Manatee photo-identification utilizes the unique pattern of scars and mutilations on a manatee's trunk and tail fluke to identify individual animals over time. The scars are usually a result of encounters with boats, but they can be caused by entanglement in fishing gear, and by infections. This research is accomplished through a partnership between FWC, USGS's Sirenia Project, and Mote Marine Laboratory. Partners work collaboratively to photograph Florida manatees throughout their range, to process images, to identify manatees, and to manage an integrated sightings database, known as the Manatee Individual Photo-identification System (MIPS). Photo-identification data then can provide insights into manatee movements, site fidelity, adult survival rates, and reproductive parameters such as calving intervals and length of calf dependency. Individual animals may be photographed using the same over-wintering site for many years in a row, providing information on site fidelity and survival, or individuals may be identified from photographs from different areas of the state over a period of time, yielding information on range and movement patterns.

FWC recently completed a regional assessment of manatees in the Caloosahatchee River (McDonald and Flamm, 2006). The study utilized data gathered from distribution surveys flown in 1994-1995 and 1997, and compared those data to satellite- and radio-telemetry data and mortality data for the same region. The study was able to characterize manatee seasonal distribution and identify areas of manatee congregation as well as travel corridors frequently used by manatees. Specifically, the study found manatees use the region between Shell Point and the Edison Bridge principally as a travel corridor. Requisites such as warm water are found more abundantly west of Shell Point and east of the Edison Bridge. Manatee travel paths showed restricted, wintertime movements that were concentrated upriver, near Matlacha Isles, and occasionally between the two refugia. During the warm season, manatees used the river extensively, taking advantage of available resources such as seagrasses, fresh water, and resting areas.

Manatee speed zones in the Caloosahatchee River reflect known areas of high manatee use and are designed to protect manatee aggregations sites (e.g., Ft. Myers Power Plant), feeding locations (e.g., seagrass beds), and travel corridors. Various regulations in the Caloosahatchee River have been in place since 1979. Zones specific to the Caloosahatchee River were most recently adopted in 2003 and 2005. FWRI's research into where and when manatees occur in the area has helped determine areas that may benefit from added protections.

Manatee Behavior

A thorough understanding of manatee behavioral and sensory mechanisms underlying manatee-boat collisions is necessary in order to devise effective avoidance approaches, whether they are technological or regulatory. Despite the management emphasis on reducing this source of manatee mortality, there has been relatively little research on the behavioral aspects of the problem. A study by Nowacek et al. (2004) used a tethered aerostat to videotape manatee behavioral responses to passing or approaching watercraft. Regardless of vessel speed, some manatees demonstrated marked responses to vessel approaches (often starting at distances of 25-50 m) while others did not. The typical response was flight toward deeper water (e.g., boat channel), but this was most frequent when the boat approached to within 10 m of the manatee and the manatee was located in shallow seagrass habitat (i.e., when the manatee was most directly threatened and most vulnerable). Speed of the vessel was not a significant factor in affecting manatee response. While this study was an important first step, behavioral observations were sometimes limited by water clarity and by the wake of the passing vessel, and only coarse responses could be reliably scored.

A crucial piece of the manatee-boat interaction puzzle that has been missing is the acoustic environment encountered by the manatee. That is, what does a manatee hear as a motorized vessel approaches and at what distance? This knowledge gap now can be addressed through the application of a state-of-the-art digital acoustic recording tag, known as the dTag, which was developed by the Woods Hole Oceanographic Institution (WHOI) to measure the responses of marine mammals to underwater sound (Johnson and Tyack, 2003). The dTag can be attached to a manatee along with a satellite-linked GPS tag to track its movements. In addition to sound, the dTag also records a suite of behavioral parameters (e.g., pitch, roll, heading, depth, fluke rate, vocalizations), permitting a detailed three-dimensional reconstruction of the manatee's movements, behavior, and orientation underwater. The goal is to create a combined picture of manatee behavior, acoustics, and vessel trajectories so that the responses displayed by manatees when approached by boats and the acoustic cues that may mediate such responses can be elucidated. The dTag will also allow us to quantify the frequency of manatee-boat interactions and disturbance, and how that varies spatially and temporally. FWRI researchers plan to partner with biologists and engineers at Florida State University and WHOI to employ this new technology in a study on manatee-boat interactions. The study is scheduled to begin in 2007.

Related Research

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Section 4.

Evaluation of manatee protections signs and boater compliance:

a. Boater compliance and comprehension
b. Sign effectiveness and placement
c. Recommendations on innovative marker design
d. Standardization of manatee protection signs
e. Use of buoys in place of pilings for boating safety purposes

Evaluation of manatee protections signs and boater compliance:
a. Boater compliance and comprehension of zones

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In 2000, FWC conducted boater compliance studies at a variety of locations around the state to provide managers and law enforcement with information regarding boater compliance, boat traffic, and the effectiveness of law enforcement (Shapiro, 2001). For each location, the study was comprised of two parts: a baseline study of compliance in an area and a study that examined how the presence of law enforcement affected compliance rates.

The sites chosen were: 1. Homosassa River, Citrus County - Year-round idle speed zone at the mouth of the Homosassa River; 2. Biscayne Creek, Dade County - Year-round slow speed zone; 3. Pineda Causeway, Banana River, Brevard County - Slow speed zone for most of the year (except December 1 – February 28); 4. St. Sebastian River, Indian River County - Year-round slow speed zone; 5. Sister's Creek, Duval County - Year-round slow speed zone; 6. Jupiter Sound, Martin County - Year-round slow speed zone.

Baseline Study

The baseline study found a suite of variables affected boater compliance within manatee speed zones. These variables included location, type of zone, vessel type, vessel size, season, time window, weekend or weekday, boating conditions, and port of origin. The complicated interaction among these variables was site-specific. Therefore, when discussing management options or future research, each site should be considered individually. Despite these very site-specific interactions, some statewide trends emerged that closely corresponded with previous compliance studies.

The idle zone was more effective at slowing traffic to either slow (technically non-compliant) or idle speed (compliant). However, if the intent of this designation was to slow traffic to the designated speed, the idle zone was not nearly as effective as the slow zones, with only 26% compliance.

Compliance was highly dependent on both vessel type and vessel size. Over 90% of the possible vessel types were concentrated into seven categories, while 95% of the boats were less than 40 feet. Personal watercraft (i.e., vessels less than 12 feet) were the least compliant, and greatly influenced the compliance-vessel type dependence. Sailboats were consistently the most compliant. Blatant non-compliance decreased with increasing vessel size. The most compliant boats (larger vessels) comprised the smallest proportion of sightings.

Seasonal changes in vessel type and size likely influenced seasonal changes in compliance. Although seasonal variation of compliance was site-specific, during the fall, sites along the ICW experienced higher traffic and lower compliance. While fall is not normally a season with high manatee mortality, manatees utilize the ICW as a travel corridor during their fall migrations. The composition of vessel traffic changed seasonally. Yachts and sailboats exhibited a bimodal distribution, peaking in spring and fall during periods of manatee movements to and from warm-water refuges. Most personal watercraft use peaked in summer, which then caused an increase in blatant noncompliance during this season. The site most heavily influenced by personal watercraft was a shallow area with numerous seagrass beds and the highest number of manatee sightings in the study.

Traffic was consistently higher on the weekends and in the afternoons. At many sites, compliance was higher on the weekends. However, because of overall increased traffic, more violations occurred on the weekends. At some sites, rental and commercial vessels, and boats registered out-of-state comprised a substantive proportion of the total traffic, and were more likely to violate the zone.

A follow-up study in the St. Sebastian River was conducted in June 2005 (Viera-Atwell and McDonald, 2006). Specific objectives for this re-evaluation were to characterize vessel traffic, evaluate compliance rates, and determine what, if any, changes had occurred in either traffic patterns or compliance rates within the last five years. Boater compliance patterns in the St. Sebastian River differ from those seen in other areas of Florida. Peak compliance rates coincided with peak traffic rates in March and April. Manatee sighting frequencies were higher during the cooler months of October through March. Some of the lowest compliance rates also were recorded during this time, posing an increased risk of manatee-vessel collisions. In general, boater compliance with the posted slow speed manatee protection zone has increased approximately 10% over the last five years. Higher compliance rates and increasing trends in compliance rates in the St. Sebastian River may be linked to community environmental stewardship and social pressures.

In the Caloosahatchee River, Gorzelany (1998) found that boater compliance with posted manatee zones was less than 60%. However, he detected a high degree of variability among study sites, ranging from 12%-77%. Tyson and Combs (1999) also found high variability in Brevard County, with compliance ranging from 23% - 98%. Factors affecting compliance levels included sign placement, vessel type, and vessel size typical of the area (Gorzelany, 1998; Tyson and Combs, 1999). Similar to findings by Shapiro (2001), persons operating personal watercraft exhibited the lowest levels of compliance. Gorzelany (1996, 1998) detected neither temporal nor seasonal influences on compliance. However, at one site in Brevard County, Tyson and Combs (1999) detected a peak in compliance during the summer, with significantly lower compliance in the fall. Regardless, the absolute number of speeding vessels may have a greater impact to manatees than the percent compliance. An area with heavy boat traffic and higher compliance may still have a greater total number of noncompliant vessels than a site with a lower compliance rate, but fewer watercraft.

Enforcement Study

Despite the short sampling duration and small sample size, the enforcement portion of the 2000 study (Shapiro, 2001) exhibited trends found in the baseline study and also in the literature.

Traffic was highest on Sundays and in the afternoon. Open fisherman, yachts, and ski boats comprised the majority of sightings. The study took place in fall and early winter and recorded high numbers of yacht and sailboat observations (26-39 feet) along the two ICW sites. The likelihood of encountering a particular vessel type or size depended on the study site.

Compliance rates were similar to previous studies, averaging 54%, with 30% technical and 16% blatant non-compliance. Compliance rates depended on location and zone designation. Compliance and vessel type also were correlated. However, the presence of law enforcement negated any dependence of compliance on any variables. When law enforcement was present, compliance significantly increased, and both forms of non-compliance significantly decreased. Up to 89% compliance was observed when in the presence of law enforcement. Studies of roadway vehicle traffic also have found significant increases in compliance (and decreases in traffic speed) in the presence of law enforcement. These studies determined that stationary, marked patrol vehicles had the greatest effect (Brackett and Edwards, 1977).

No “memory” or “time-halo effect” was detected during this study. The short study duration, small sample size, small number of “repeaters,” and lack of intensive enforcement probably contributed to the lack of effect finding. Gorzelany (2001) conducted a time-halo effect study with a more rigorous sampling schedule and intensive enforcement presence. The study found a time-halo effect lasting up to two weeks following two weeks of intensive enforcement patrols. The study also detected limited numbers of repeat traffic, perhaps due to seasonal changes in user-groups. These seasonal changes combined with the inconsistent schedule of boaters may contribute low numbers of repeaters as a whole. To produce any type of time-halo effect, very labor-intensive enforcement efforts would be required. In roadway studies, Brackett and Edwards (1977) recommended a minimum of six weeks to generate consistent compliance in the absence of a patrol vehicle.

Overall, boaters seem to behave similarly to car drivers. The highway safety literature confirms that, like boaters, motorists respond to the presence of law enforcement with significant increases in compliance and decreases in vehicle (vessel) speed. To reduce boat speeds and increase compliance in manatee speed zones, speed-reducing techniques historically utilized by the police and highway patrol may prove effective. These techniques may provide a cost-effective alternative to the very labor-intensive patrols necessary to produce a time-halo effect. In addition to supporting the presence of a stationary, marked patrol vehicle, the highway safety literature has outlined numerous alternative techniques that have improved speed compliance. These include the use of feedback signs, personalized advisory letters, replica patrol cars, roadside speedometers, and highly integrated education and enforcement programs. Future research may include testing these various methods of traffic calming as applied to waterway vessel traffic.

Boater Comprehension

From 1999-2003, FWC conducted a study that examined boating patterns at two locations in Tampa Bay: Maximo Park and Gandy Beach (Flamm 2005). Maximo Park is located near the north terminus of the Sunshine Skyway Bridge, St. Petersburg, and Gandy Beach is located at the west terminus of the Gandy Bridge, northeast St. Petersburg. Both locations were part of an education program and one site also had regulations posted prior to the third year of study. Education primarily involved ramp intercepts with the distribution of boater kits, but also included on-the-water contacts from a *Manatee Watch* vessel and the distribution of door hangers. Distributed materials contained brochures about the endangered status of the manatee and manatee protection tips, polarized sunglasses, and customized navigational charts. Regulations at Gandy included: 1) year-round slow speed zones inside the channel; 2) a slow speed zone from April through mid-November outside the channel; and 3) a combustion motor exclusion zone from mid-November through March outside the channel. There are no speed regulations at the Maximo Park location.

Neither study area experienced changes in vessel traffic, type, or speeds before or during the education program. After the regulatory signs were posted in the Gandy area, vessel passes decreased by nearly half, non-commercial power vessels and personal watercraft were seen much less frequently, and vessel speeds decreased significantly. Inside the Gandy channel, vessel speeds dropped almost immediately post-regulation and these lower speeds were maintained all year. Outside the channel, vessel speeds declined more during the combustion motor exclusion period than during the slow speed period; however, the majority of speeds still were not fully compliant with the more restrictive regulations. The regulations had a clear influence on boating patterns, while the implemented education program showed no measurable effect.

Results from the surveys suggested that Gandy boaters are a different type of boater than those passing through at Maximo. Gandy boaters knew more about regulations but less about manatees. Also, there were differences in how these boaters obtained information on manatees and regulations. These differences are due, in part, to the observation that the boaters who used each site had different boating goals because the attributes of each site differed. Maximo was primarily used as a transit corridor where boaters were more likely destined to the lower Tampa Bay and the Gulf of Mexico. Gandy was a frequent destination for many and also provided easy access to upper Tampa Bay. The conclusion is that generalized approaches to education may be less effective than more targeted messages. An understanding of the context (e.g., Gulf vs. Tampa Bay as destination, watersports vs. touring vs. sport fishing as primary objective) will help educators construct targeted messages for the different boater types.

Regulation, although effective in modifying boating behavior, may result in some negative consequences, such as creating conflicts between some stakeholders and regulators. Education, although not shown to have any measurable effect in this study, should not be ruled out as a viable contributor toward encouraging desired stewardship behaviors. For education to be effective, the beliefs and attitudes of the boater must be understood so that the most appropriate outreach methods can be applied. Specific desired outcomes of the program should be identified pre-implementation and a method to measure the level of success should be incorporated. Education should be conducted using social marketing principles applied within an adaptive management framework to take advantage of what is already known about encouraging desired behaviors, and so that interventions can be evaluated for their effectiveness and necessary alterations made. Finally, by applying such approaches, data should provide feedback so approaches can be adjusted as necessary, and over time, researchers should be able to apply the most effective education programs for a given situation.

Related Research

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Evaluation of manatee protections signs and boater compliance:

b. Sign effectiveness and placement

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Because watercraft collision is the primary human-related mortality factor for manatees, management efforts have focused on reducing this threat. The principal management strategy has been to limit boat speeds in areas where manatees are most likely to occur, with the goal of reducing harmful collisions between manatees and watercraft (USFWS, 2001). Since 1979, almost 300,000 acres of Florida's coastal waters have been regulated by the state for manatee protection (FWC, unpublished data; Appendix 1). Despite this, watercraft-related manatee deaths continue to be the leading identified human-related mortality factor (USFWS, 2001).

Compliance with speed zones is dependent on a number of variables but ranges from about 50% to 70% in most cases (Gorzelany, 1996, 1998; Tyson and Combs, 1999; Shapiro, 2001; Viera-Atwell and McDonald, 2006). Because of the limited on-water enforcement resources available, wildlife managers are seeking alternative strategies to increase compliance within manatee speed zones. In 2002-2003, FWRI initiated a study in Volusia County to evaluate the effectiveness of an alternative sign and its impacts on compliance with existing regulatory zones (Sorice et al., 2005).

The on-site signs used in this study read "WATCH YOUR SPEED" across the top and "MAX FINE $500" across the bottom (Figure 1). The middle contained an image of a manatee in front of light blue streaks used to indicate that the animal is near the surface of the water. Sign messages were created based on a literature review as well as regulations and guidance provided by USFWS, the U.S. Coast Guard (USCG), and FWC-LE.

Fines for speeding in manatee zones range from approximately $60 in county jurisdictions to a maximum of $25,000 and jail time in federal zones. Therefore, the possible federal fine of $500 was used as a sufficiently "noxious" yet realistic threat in the fear appeal message (see Witte, 1992). "WATCH YOUR SPEED" was used as the recommended coping behavior instead of "SLOW DOWN" because the latter language is reserved solely for regulatory waterway signs (Tara Alford, FWC, pers. comm.). The image of the manatee served as an implied "awareness of consequences" message, providing the vessel operator with a visual illustration of the reason for the regulation: manatees are injured or killed by collisions with fast-moving watercraft. In addition, it increased the on-site sign's attractiveness and thus the probability of its being read.

Regulations governing regulatory waterway signs were followed to create the sign (Florida Administrative Code 68D-23.108 and 68 D-23.109). Sign shape was restricted to a square or rectangle and could not be smaller than three feet by three feet (actual sign dimensions were three feet by four feet). Although light blue was used to indicate water and gray used for the manatee, the sign had to have a predominantly white background with an "international orange" border not less than 2 inches wide. The color of the sign text was limited to black. The on-site signs were posted below regulatory waterway signs.

Sampling took place over 18 weeks between 28 September 2002 and 09 February 2003. Halfway through the study, 08 December 2002, six of the experimental signs were posted immediately below the posted regulatory waterway signs throughout the manatee speed zone so that all boats traveling past the observation point had an opportunity to see at least one sign. Vessel passes were recorded on Saturday and Sunday every week for six hours each day, from 0815h to 1115h and 1215h to 1515h. Compliance was measured qualitatively by comparing the speed of vessels passing through the slow speed zone to the qualitative definitions of speed defined by Gorzelany (2004). A vessel was considered "compliant" if it was operating at slow speed, fully settled in the water with minimum wake; "technically noncompliant" if the vessel was plowing (i.e., the vessel's bow was elevated with significant wake from bow and stern); and "blatantly noncompliant" if the vessel was on plane (i.e., traveling fast enough to raise the boat out of the water). For watercraft with a nonplaning hull, blatant noncompliance was assigned to fast-moving vessels with considerable wake.

This study found that on-site signs incorporating a fear appeal message did not increase compliance, at least not during the nine-week treatment period. It is possible that a longer period of observation may be required (possibly up to a year) to detect evidence of a change in boater compliance as a result of the additional signage. Some of these findings were similar to Shapiro (2001) and Gorzelany (2004). Jon boats, the smallest of the powered vessels, had a low level of compliance, but they represented only a small percentage of vessel passes in the study. Sailboats were the most compliant vessels. This was expected because sailboat hulls are not designed for motorized performance and therefore do not move through the water in the same way that vessels under power do. Results for yachts, cabin cruisers, open fisherman vessels, and runabouts were mixed.

Enhancing compliance in speed zones is largely an issue of persuading boaters to slow down. Persuasion relies mostly on an individual's receiving a message, processing it, and choosing the appropriate behavior. Although extrinsic factors may be related to an individual's proclivity for persuasion, compliance is ultimately a decision made by the boat's operator.

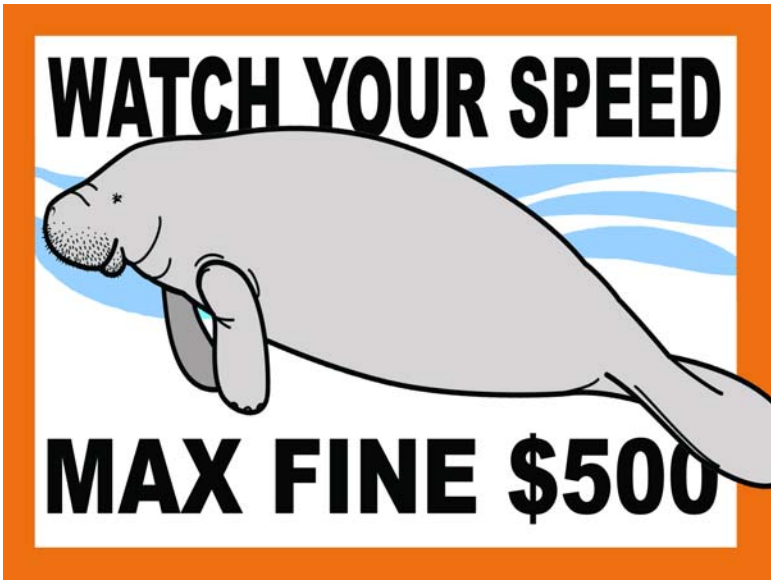

Figure 1. Experimental sign used in the 2002-03 Volusia County study.

Related Research

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Evaluation of manatee protections signs and boater compliance:

c. Standardization of manatee protection signs

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FWC has begun reviewing manatee zones on a county by county basis to ensure they are effectively marked. The Boating and Waterways Section has enlisted the assistance of FWC, federal, and local government law enforcement officers who enforce the zones and the engineering firm PBS&J to assist in this task. Brevard County and the St. Johns River system were chosen as the first areas of review due to significant storm-related damage that needed to be repaired. Complete review of the existing and damaged markers resulted in significant changes to ensure that the damaged markers are repaired and existing markers correctly post the state regulations. Efforts have been made to alleviate confusion of the regulatory wording on the markers so the average boater understands the appropriate vessel operation for the area being regulated. Examples of improved signage within the two areas include: larger size shallow draft buoys, larger font letter size on sign boards, simpler more concise wording, and small informational signs installed below the regulatory marker to help clarify regulation and spacing markers apart in such a manner to clearly identify the zone boundary.

In conjunction with U. S. Fish and Wildlife Service, FWC has developed a waterway marker guidance document, "Approved Uniform Waterway Marker Standards for Posting Manatee Protection Zones in Florida's Waterways," which establishes the criteria for the appropriate placement of waterway signs and buoys when posting federal and state manatee protection zones. This document was prepared in an effort to best achieve the objectives of the specific regulations that have been adopted for each waterway, to ensure compliance with federal standards, and for the safety of all waterway users. This document lays the foundation for what will evolve into a standard manual as a reference tool for all levels of government involved in posting waterway markers (i.e., boating safety, manatee protection, or informational markers) and will be modified as new technology and techniques are introduced in consultation with USCG uniform marking system. The finalized document is reproduced in its entirety in Appendix B.

Evaluation of manatee protections signs and boater compliance:
d. Recommendations on innovative marker design

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FWC has begun to use innovative marker designs that comply with the U.S. Aids to Navigation System. Some examples include utilizing already established infrastructure (e.g., bridges) to post large regulatory notices and developing signs that automatically notice boaters of certain operating requirements during flood conditions. One of the concepts being researched for signage for flood conditions is the development of signage that would raise and lower with the flood waters. This signage would automatically notify boaters of the operational requirements for existing conditions.

FWC is researching better ways to post regulatory zone markers within waters of the state to achieve increased boater compliance. For example, markers that are constructed with LED-type flashing lights may be utilized. These flashing lights would only be used when notifying vessel operators of seasonal regulatory zones. Other concepts might be the actual painting and/or application of the regulatory message on the physical bridge structure (with signage larger than the standard 4’ x 6’ or 5’ x 7’ sized marker), or development of actual changes in the sign shape (e.g., circular vs. rectangular signage). This change might be used to differentiate between boating and manatee protection areas. If developed and deployed, these concepts will be evaluated to determine boater compliance and understanding.

The concepts that conform to existing federal and state laws will be incorporated into the standard manual (Appendix B) that is being developed as a reference tool for all levels of government involved in posting waterway markers.

Evaluation of manatee protections signs and boater compliance:

e. Use of buoys in place of pilings for boating safety purposes

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FWC has investigated the use of buoys in place of signs affixed to pilings for boating safety purposes, and advantages and disadvantages have been identified. Buoys are an alternative method to signs used for marking manatee zones in some settings and present less of a hazard to navigation by decreasing the forces experienced in a vessel strike. However, FWC has determined that in most waterways, buoys used in combination with signs to post a regulatory zone is the most effective marking system. This marker combination appears to adequately post a waterway, minimizing the navigational hazards, and achieve boater understanding of the appropriate vessel operation for the regulated area.

Buoys appear to work very well when installed within confined waterways with little exposure to tide fluctuation, wind, and boat wake. Buoys are more aesthetically appealing over signs when marking boundary areas within small bays or safe harbor areas. In the short term, buoys are initially more economical to install than pilings and signs but do require periodic maintenance and replacement within a relatively short period of time under normal environmental conditions. In spite of the limited amount of message display area, the installation of buoys to mark a buffer zone along the shoreline or at a bridge can work very well.

Some identified disadvantages of buoys are as follows: 1) more expensive to maintain in the long term; 2) less amenable to displaying print messages or regulations; 3) have been known to go off station under certain environmental conditions; 4) inadequate surface area to display some regulatory messages; 5) marine growth can result in sinking or listing; 6) increased chance of loss (especially during storm conditions); and, 7) reduced probability for boater recognition. If installed within an exposed highly fluctuating, tidally influenced waterway, such as within Tampa Bay, buoys generally require replacement more often, even under normal conditions.

FWC currently is utilizing buoys in combination with signs to post state manatee protection zones in Pinellas and Manatee counties. During the first year of installation within Safety Harbor (Pinellas County), a tropical storm removed most of the 22 buoys installed regardless of the helical embedment system (and upward pressure tests to insure stability), yet only caused a few pilings with signs to lean. Though most buoys were retrieved, reinstalled, and the signs righted, it became apparent that buoys could not hold up in such volatile conditions. In addition, recently installed buoys within the Manatee River (Manatee County) have already been lost to normal tidal action. This experience has provided FWC with enough data to determine that buoys as a marking design should be limited to calmer waters.

FWC also has determined that the larger shallow draft buoys (14" diameter) are preferred over the standard size 9"- or 12"–diameter buoys for greater visibility and reduction in surface area exposed below the water. A test was conducted within Terra Ceia Bay (Manatee County) to see whether 9" buoys placed approximately 0.25 miles apart could be observed when marking a 500' shoreline buffer. The test resulted in the recommendation of the use of the larger shallow draft buoys over the smaller buoys to mark the shoreline buffer zone, with spacing no more than 0.25 miles apart. Within Terra Ceia Bay, there is a combination of buoys and signs to mark the regulatory zones, with signs used at major access points, canal entrances, or when the zone is larger in size.

To address short term maintenance, buoys purchased by FWC now will be manufactured with eye hooks at the top of the buoy as well as a "bird-be-gone" cone. The cone should reduce bird droppings that tend to cover the marker message and the eye hook will aid in hoisting the buoy from the water for periodic cleaning and maintenance (e.g., scraping off marine life). These additions should increase both visibility and extend the life of the buoy marker under normal conditions.

FWC will continue to assess the practicality of using buoys over signs in all marker assessments. It must be recognized however, that at this time, signs may be the only option based on the particular zone configuration, regulation and water body. FWC and its consultant PBS&J are researching alternative, innovative marker concepts and reflective materials to increase visibility for day- and night-time conditions.

Section 5.

High speed travel corridors in manatee zones

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The State of Florida uses speed regulations on inland and coastal waterways to increase boater safety and protect natural resources and wildlife. These speeds may be relative (e.g., idle or slow) or numeric. Idle speed is defined as the minimum speed necessary to make headway and be able to maintain control of the vessel (See 68C-22.002(1), F.A.C.), whereas slow speed is defined as the speed at which a vessel is fully off plane, completely settled in the water, and not creating an excessive wake or other hazardous condition (See 68C-22.002(4), F.A.C.). The 25 MPH numeric limit that is commonly used in manatee protection rules is based on data on minimum vessel planing speeds that were compiled from manufacturers in the early 1990s. The highest minimum planing speed reported was 25 MPH, with most falling between 15 and 20 MPH. Based on this information, a speed of 25 MPH was believed to allow most vessels to maintain a plane while operating safely.

A recent study was conducted to provide state managers and law enforcement with vessel speed information so that they could assess the extent of impacts on vessel performance caused by different numeric speed limits. The objectives of the study were to compile planing and performance speeds for vessels that operate in Florida, analyze the results of this work in terms of current numeric speed regulations, and evaluate the extent of negative impacts that current numeric speed zones – especially 25 MPH speed zones – have on the operation of vessels registered in Florida.

Vessel data were compiled from a list of vessel manufacturers acquired from the recreational boat building industry, with the list reduced to include only those powerboat manufacturers whose vessels were more commonly observed in Florida. Specification data, including length overall (LOA), beam, hull type, draft, weight, engine type, horsepower, propeller size, passenger capacity, and load capacity were collected.

Vessel operating speeds were collected from manufacturer or performance testing websites, mostly from performance tables and graphs. Performance tables and graphs illustrate the relationship between revolutions per minute (RPM), miles per hour (MPH), and miles per gallon (MPG). A typical performance curve is shaped similar to a sine wave. First, the MPG drop while the RPM rise as the vessel performance descends toward the minimum fuel efficiency speed. Then, there is an increase in fuel efficiency with an increase in the RPM as the vessel approaches the optimum fuel efficiency speed. Subsequently, there is a decline in fuel efficiency as the vessel approaches its maximum speed. In some instances, a vessel's performance curve deviated from this shape. In other cases, no performance tables or graphs were available or the websites listed only a vessel's minimum, optimum, and/or maximum speed.

Minimum performance speed was defined as the first minimum MPG value in the performance curve (i.e., lowest fuel efficiency). This speed was used as an indicator of minimum planing speed for planing-hull vessels, although it was recognized that this was likely an underestimate of true minimum planing speed. The optimum performance speed was the velocity at the maximum MPG rating (i.e., maximum fuel efficiency). When performance curves deviated from the sine-wave-like pattern, we extracted what speed data we could based on the speed definitions.

Vessel types were categorized in two ways using images on the manufacturers' websites. The first was based on the vessel types used by Gorzelany (1996, 1998) and the second was based on the State of Florida's Vessel Title Registration System (VTRS; Swett et al. 2004). The Gorzelany (1996) vessel types were yacht, cruiser, high performance, small flats, and open fisherman. Yachts were defined as any boat with windows in the hull. Cruisers included deck boats, ski boats, small runabouts, and any other vessel with a windshield present in front of the cockpit. High performance vessels were defined as relatively long vessels with hull designs built for speed and the cockpit close to the stern. Small flats boats were defined as small boats that used a tiller for steerage. Open fishermen included all center console vessels that did not have characteristics that would define them as any other vessel type. In some instances, larger open fishermen and cruisers did have cabin space in the hull, and so were placed into the yacht category. The VTRS vessel types relevant for this study were open motorboat and cabin motorboat. Open motorboats were defined as vessels having no cabin features and included all open fisherman, cruiser, small flats, and some high performance vessels. Cabin motorboats were defined as vessels having cabin features which included all yachts as well as some high performance vessels. Models with no image available were classified as vessel type unknown. Each vessel was assigned to one of three size classes based on length (LOA): 16 (16 feet to < 26 feet), 26 (26 feet to < 40 feet) and 40 (≥ 40 feet).

Mean minimum and optimum performance speeds were calculated for each vessel type, size class, and vessel type of each size class. A total of 6,669 records were compiled, representing 68 manufacturers and 1,561 models. Of these, 377 had information on both minimum and optimum performance speeds, 22 had minimum only, and 33 had optimum only.

We compiled 398 minimum performance speeds. The majority of these were open motorboats (59.1%), most commonly open fishermen of size class 16 (26.1%). No minimum performance speed data were available for small flats boats nor open fishermen and cruisers of size class 40. Cabin motorboats comprised 38.9% of the records with minimum performance speeds, of which yachts of size class 26 were the most common (25.1%).

The mean minimum performance speed for all vessels was 10.2 $\pm$ 2.9 MPH. Performance test websites reported both a minimum planing speed and a performance curve on only three vessels. These included two cruisers, one of size class 16 and one of size class 26, and one yacht of size class 26. The posted minimum planing speeds for these three vessels were, on average, 43.7% higher than the corresponding speeds estimated from the performance curves. Mean minimum performance speeds after adjusting records by 43.7% and 87.4% were 15 MPH and 19.2 MPH respectively. One hundred percent of unadjusted minimum performance speeds were below 25 MPH, followed by 99.5% of the records after adjusting by 43.7%, and 91% after adjusting by 87.4%. The mean (unadjusted) minimum performance speeds by vessel type and size class are shown in Table 1.

Table 1-. Mean and standard deviations (SD) of minimum performance speeds for vessel types by size class. OF = Open Fisherman, CR = Cruiser, HP = High Performance, Y = Yacht. Open Motorboat (OM) and Cabin Motorboat (CB) represent the Florida Vessel Title Registration System vessel types. 16 = vessels 16 to < 26 feet in length, 26 = vessels 26 to < 40 feet in length; 40 = vessels ≥ 40 feet in length; (—) = no vessels in that category. The size class mean is for the combined OF, CR, HP, and Y boat types or the combined OM and CB boat types.

	Size Class 16		Size Class 26		Size Class 40		Type	
Type	Mean	SD	Mean	SD	Mean	SD	Mean	SD
OF	9.7	2.5	10.7	1.6	—	—	10.0	2.3
CR	11.0	3.9	11.2	4.4	—	—	11.0	3.9
HP	9.2	0	12.7	2.9	13.3	0	12.1	2.7
Y	10.0	1.5	11.9	2.6	13.0	2.3	11.4	2.5
OM	10.2	3.2	10.8	2.3	—	—	10.3	3.0
CB	10.0	1.5	11.9	2.6	13.0	2.2	11.4	2.5
Size Class	10.2	2.9	11.5	2.5	13.0	2.2		

We compiled 410 records with optimum performance speeds. Most of these (57%) were open motorboats. Open fishermen were the most common open motorboats and they dominated size class 16. Yachts/closed motorboats were the most common vessel type of size class 26. No optimum performance speed data were available for small flats vessels, open motorboats, cruisers, or open fishermen vessel types of size class 40.

The mean optimum performance speed of all vessels combined was 28.5 ± 4.9 MPH and ranged from 15 to 54 MPH, and except for yachts of size class 40 and high performance vessels, mean optimum performance speeds ranged between 27 and 30 MPH. Again excluding high performance vessels and yachts of size class 40, 19.3%, 63.8%, and 90.5% of the vessels had optimum performance speeds of 25 MPH or less, 30 MPH or less, and 35 MPH or less, respectively. The mean optimum performance speeds by vessel type and size class are shown in Table 2.

The results of this study indicate that almost all vessel operators will be able to exceed the minimum performance speed for their vessel while staying in compliance with a 25 MPH speed limit. Ninety-one percent of the vessels we evaluated had a minimum performance speed below 25 MPH even after increasing our estimated speeds by 87.4%, twice the difference between the reported minimum planing speeds and the minimum performance speeds derived from the performance curves. This adjustment was considered a likely overestimation of minimum planing speeds. An additional study will be conducted to "ground truth" these results by measuring minimum planing speeds for a variety of vessels actually on the water. This information will be used to evaluate the appropriateness and accuracy of using adjusted minimum performance speeds from vessel performance curves as an estimate of minimum planing speeds.

Table 2. Mean and standard deviations (SD) of optimum performance speeds for vessel types by size class. OF = Open Fisherman, CR = Cruiser, HP = High Performance, Y = Yacht. Open Motorboat (OM) and Cabin Motorboat (CB) represent the Florida Vessel Title Registration System vessel types. 16 = vessels 16 to < 26 feet in length; 26 = vessels 26 to < 40 feet in length; 40 = vessels ≥ 40 feet in length; (─) = no vessels in that category. The size class mean is for the combined OF, CR, HP, and Y boat types or the OM and CB boat types.

	Size Class 16		Size Class 26		Size Class 40		Type	
Type	Mean	SD	Mean	SD	Mean	SD	Mean	SD
OF	27.4	4.8	29.7	3.7	─	─	28.0	4.7
CR	28.7	4.8	27.6	4.2	─	─	28.5	4.7
HP	41.1	0	42.7	11.4	43.0	0	42.5	8.1
Y	29.1	3.1	28.0	4.5	25.5	3.8	25.5	3.8
OM	27.9	4.8	29.3	3.8	─	─	28.2	4.7
CB	29.3	4.3	28.4	5.3	27.2	6.6	26.6	5.1
Size Class	28.2	4.7	29.0	4.9	28.0	6.2		

Mean optimum performance speeds were between 25 and 30 MPH with the exception of high performance vessels whose mean exceeded 40 MPH. These results suggest that some vessels may experience negative effects on vessel performance (i.e., lower fuel efficiency) when their operators comply with 25 MPH speed regulations. Our research suggests that most vessels with planing hulls should be able to maintain a plane within a 25 MPH speed zone. Some vessels, however, especially larger open motorboats, may have difficulty maintaining a plane under certain conditions (e.g., heavier loads, rough weather conditions).

Based on this study, there appears to be no single numeric speed that can optimize manatee protection and vessel performance. Our results suggest that a 25 MPH speed limit will allow most vessels to operate on a plane, although it will not allow most of them to operate at their optimum performance speed. Driver reaction times decline as speed increases, and collisions at higher speeds will cause more physical damage to the manatee. Posted speed limits do tend to slow down the fastest boaters, although the average speed for an area may not change significantly from when it was unregulated. A 25 MPH limit provides at least nominally more protection than higher speed limits or no limit at all, although it does negatively affect the ability of some boaters to operate their vessels at their optimum performance speeds. Using a higher limit would reduce the negative effects on vessel performance but not without some lessening of protection. Besides choosing which speed to use for numeric limits in the future, another issue that may be just as important is standardizing existing numeric limits. Currently, there are 20, 25, and 30 MPH zones that were all designed to accomplish the same basic purpose (i.e., to limit top-end speed while still allowing most boats to be operated on plane), and this variability increases rule complexity and likely results in unnecessary confusion for the boating public. A standardized limit would allow for consistency throughout the state and likely reduce confusion over why some areas have different numeric limits.

Related Research

Gorzelany, J. F. 1996. Evaluation of boater compliance with speed regulations in Sarasota County, Florida. Final Report submitted to the Florida Department of Environmental Protection, Tallahassee, Florida. 106 pp.

Gorzelany, J. F. 1998. Evaluation of boat traffic patterns and boater compliance in Lee County, Florida. Final Report submitted to the Florida Department of Environmental Protection, Tallahassee, Florida. 109 pp.

Powerboat Manufacturers. Recreational Boat Building Industry. January 2005. http://www.rbbi.com/links/pbl.htm

Swett, R., C. Sidman, T. Fik, and B. Sargent. 2004. Florida's vessel title registration system as a source of boat locations and characteristics: A case study in Lee and Manatee counties. Florida Sea Grant Report, TP-138. 146pp.

Viera-Atwell, J. and R. O. Flamm. In Review. An overview of minimum and optimum vessel performance speeds as they relate to 25 MPH speed zones. Final Report to FWC Division of Law Enforcement.

APPENDICES

Appendix 1

Posted Speed Zones by County, as of December 2006

County	Location	Month	Year	Type
Brevard	Indian River	Nov.	1979	seasonal zone
	Turkey Creek	Nov.	1984	zone
	Manatee Cove	Nov.	1986	zone
	Indian River	July	1991	amended zone
	Indian River	July	1991	zone
	Banana River	July	1991	zone
	Mosquito Lagoon	Jan.	1992	zone
	South Indian River	July	1993	amended zone
	Canaveral Barge Canal	Oct.	1995	zone
	Sykes Creek	Oct.	1995	amended zone
	Reliant Plant	Jan.	1999	seasonal haven
	FPL Plant	Jan.	1999	seasonal haven
	County	Feb.	2003	amended zone
Broward	Power plants	Nov.	1979	seasonal zone
	Power plants	Nov.	1990	amended zone
	County	Oct.	1994	seasonal zone
Charlotte	Lemon Bay	Apr.	2004	zone
	Turtle Bay	Feb.	2004	zone
	Peace River	Feb.	2004	zone
Citrus	King's Bay	Nov.	1979	zone
	Homosassa River	Nov.	1979	zone
	King's Bay	Nov.	1981	amended zone
	Homosassa River	Nov.	1981	amended zone
	King's Bay	Nov.	1986	amended zone
	Homosassa River	Nov.	1986	amended zone
	Withlacoochee River	Nov.	1986	seasonal zone
	County	12	1992	zone
	Homosassa River	Nov.	2002	no entry zone
Clay	North County	Apr.	2001	zone
Collier	Faka Union Canal	Nov.	1984	zone
	Faka Union Canal	Nov.	1984	amended zone
	County	Feb.	1991	zone
	County	Oct.	1998	amended zone
DeSoto	Peace River	Feb.	2004	zone
Duval	County	9	1993	zone
	County	6	2001	amended zone
Flagler	County	Jan.	1992	zone
Hernando	County	12	1992	zone
Hillsborough	Alafia River	Nov.	1979	zone
	TECO	Nov.	1987	zone
	Alafia River	5	2003	amended zone
	TECO	9	2005	amended zone
	Old Tampa Bay	9	2005	zone
	Little Manatee River	9	2005	zone

County	Location	Month	Year	Type
Indian River	Vero Beach	Nov.	1979	seasonal zone
	Sebastian River	July	1991	zone
	Sebastian River	Oct.	1992	amended zone
	County	July	1993	zone
	Jungle Trail Narrows	6	2003	amended zone
	Vero Beach	6	2003	seasonal haven
Lake	St. Johns River	Jan.	1992	zone
Lee	Power plant	Nov.	1979	zone
	Caloosahatchee River	3	1991	zone
	County	12	2000	zone
	Mullock Creek	Nov.	2002	amended zone
Levy	County	12	1992	zone
Manatee	County	9	2005	zone
	Terra Ceia Bay	Apr.	2005	zone
Martin	St. Lucie Inlet	Nov.	1979	seasonal zone
	Loxahatchee River	Nov.	1984	seasonal zone
	County	July	1991	zone
Miami-Dade	Black Creek	Nov.	1984	zone
	County	Apr.	1993	zone
Palm Beach	Power plant	Nov.	1979	seasonal zone
	Jupiter Inlet	Nov.	1979	seasonal zone
	Loxahatchee River	Nov.	1984	seasonal zone
	Power plant	Nov.	1990	amended zone
	Lake Worth Creek	Nov.	1991	amended zone
	County	Nov.	1991	zone
	Jupiter Sound	Nov.	1991	amended zone
	Lake Worth Creek	6	1994	amended zone
Pinellas	Old Tampa Bay	Apr.	2005	zone
Putnam	Lake George	Jan.	1992	zone
Sarasota	Venice Inlet	Nov.	1984	caution zone
	County	6	1993	zone
	City Island	9	2003	amended zone
	Warm Mineral Springs	Oct.	2003	no entry zone
Seminole	Lake Monroe	Jan.	1992	zone
St. Johns	St. Johns River	6	2001	zone
	Power plant	Nov.	1979	seasonal zone
	County	9	1995	zone
Volusia	Blue Spring	Nov.	1979	seasonal zone
	Tomoka River	Nov.	1990	zone
	St. Johns River	6	1991	zone
	County	Jan.	1992	zone

Appendix 2.

Approved Uniform Waterway Marker Standards for
Posting Manatee Protection Zones
in Florida's Waterways