Snake Bight Pole and Troll Zone Everglades National Park

Year 1 Monitoring Report

A report for:

Everglades National Park
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Executive Summary

The National Park Service Organic Act was enacted by the U.S. Congress in 1916 to create the National Park Service. The main responsibility of the National Park Service is to promote and regulate the use of Federal lands as national parks, monuments, and reservations and to "conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations" (NPS 2008). Everglades National Park (ENP) was authorized by Congress in 1934 and established "for the benefit and enjoyment of the people. It is set apart as a permanent wilderness preserving essential primitive conditions, including the natural abundance, diversity, behavior, and ecological integrity of the unique flora and fauna" (NPS ENP 2003). ENP is nationally and internationally important for many reasons including providing sanctuary for threatened and endangered species, supporting the largest mangrove ecosystem in the Western Hemisphere, and containing a nationally significant estuarine complex (i.e., Florida Bay) that provides a major nursery ground for sport and commercial fishing (NPS ENP 2003). To help preserve a part of this World Heritage site and Wetland of International Significance, ENP implemented a pole and troll zone (PTZ) in Snake Bight on January 1, 2011, as a management strategy to help "protect sensitive aquatic vegetation and wilderness resources, improve the quality of flats fishing, enhance paddling and wildlife viewing opportunities, and expand education on proper shallow-water boating techniques" (NPS 2011a). Within a PTZ, boaters are required to shut off their internal combustion motors and switch to drifting, poling, paddling and/or the use of electric trolling motors. The objective of the Snake Bight PTZ Monitoring Project was to quantify the amount of propeller scarring (hereafter referred to as "prop scarring") within the Snake Bight PTZ and to compare it to other areas (i.e., Treatment Area 1 and Treatment Area 2) that do not have restrictions to combustion engine use.

A total of 6,040 potential prop scars were identified and mapped in all three, project areas (i.e., Snake Bight PTZ, Treatment Area 1, and Treatment Area 2) during the 2011 aerial image analysis. Individual mapped prop scars ranged in length from ~2 meters (m) to ~4 kilometers (km) and the mean length was ~103 m (S. D. ± 179 m) for all project areas. To determine the accuracy of the aerial image analysis, a field effort was conducted 115 days post flight to validate or invalidate the greatest number of mapped prop scars possible. Results of the field validation effort indicated an overall accuracy of 60% (i.e., 311 prop scars were verified at the 520 field validation sample sites). Several factors may have contributed to the 60% accuracy value for this project, particularly the inability to adequately identify less severe seagrass damage in the field. Observations from the boat may have been too narrow in scope, thereby reducing "low severity" prop scar accuracy relative to what was visible in the aerial image. Nevertheless, the method utilized during the field validation effort produced a serviceably accurate assessment of the distribution of seagrass damage types and was largely successful in identifying the most severe damages.

Geospatial tools and analysis techniques were utilized to spatially describe the magnitude and clustering of prop scar incidence among the three project areas. All digitized prop scar lines were used for these spatial statistical analyses. The prop scar density analysis was performed to quantify the amount of seagrass scarring within the three project areas. The hot spot analysis, using the Getis-Ord Gi* spatial statistics tool, was performed to determine if prop scar patterns were random in nature or if the observed clustering of prop scars indicated a significant issue on the seagrass banks. Results of these analyses indicated high prop scar densities and hot spots along and between marked and unmarked channels, at the boundaries between deep water and seagrass banks, and around areas most heavily used by boats (such as Porpoise Point and near Jimmy's Lake).

To more accurately assess damage to seagrasses, 27 *in situ* monitoring sites were established. Prop scar length, scour depth, damage severity (high vs. low), and surrounding seagrass species were documented at each location. A low severity class was assigned to those prop scars with little to no substrate exposure while a high severity class was assigned to prop scars with extensive substrate exposure. The overall mean length for all *in situ* monitoring scars was ~32 m and mean scour depth was ~6 cm in Treatment Areas 1 and 2 and ~9 cm in the Snake Bight PTZ. These data collected in 2011 will be compared to future monitoring data to qualitatively describe changes in prop scar geometry based on passive restoration.

The baseline data presented in this report represents the state of prop scarring immediately prior to implementation of the PTZ within Snake Bight. These 2011 data will be compared to future monitoring events in order to determine the effectiveness of a PTZ as a management strategy within ENP.

1.0 Introduction

1.1. Everglades National Park

1.1.1. General Description

Everglades National Park (ENP) was authorized by Congress in 1934 and established “for the benefit and enjoyment of the people. It is set apart as a permanent wilderness preserving essential primitive conditions, including the natural abundance, diversity, behavior, and ecological integrity of the unique flora and fauna” (NPS ENP 2003). Encompassing ~1.5 million acres (ac), ENP is the third largest national park in the contiguous United States and is located on the extreme southern portion of the Florida Peninsula (ParkVision 2008; Figure 1). A variety of natural habitats are found within ENP, including freshwater marshes, tree islands, tropical hardwood hammocks, pinelands, mangrove swamps, coastal lowlands, and coastal estuarine and marine environments (Lodge 2005). The coastal receiving waters of the Everglades watershed are Florida Bay to the south and the Gulf of Mexico to the southwest (Lodge 2005).

Florida Bay constitutes one quarter of ENP and is located south of the southern tip of the Florida Peninsula (Figure 2). It encompasses ~385,000 ac of interconnected basins, seagrass beds, and mangrove islands. Seagrass beds provide food and shelter for a variety of recreationally and commercially important fish and invertebrate species such as tarpon, pink shrimp, and spiny lobster (Zieman and Zieman 1989). They are also critical nursery habitat for a number of fish, shrimp, and crab species. Seasonal residents that spend part of their life cycle in seagrass beds, mainly as a nursery area for spawning and/or juvenile development, include the spotted seatrout, silver perch, pigfish, grunts, and tomtate (Florida Museum of Natural History 2010). Coral reef fishes such as ocean surgeonfish, goatfish, gag grouper, gray snapper, and southern flounder also reside in seagrass beds as juveniles and immature adults (Florida Museum of Natural History 2010). Threatened and endangered species including wading birds, manatees, and sea turtles also depend on seagrass communities as foraging grounds. Florida Bay is also listed as critical habitat for manatees and smalltooth sawfish.

Florida Bay’s submerged aquatic vegetation (SAV) and bottom habitat are defined as federally designated wilderness within ENP and are thus protected by law as a significant natural resource. They are also afforded federal protection as natural features that should not be damaged or disturbed. While the primary environmental stressors in Florida Bay are related to watershed management (i.e., overall lack of freshwater delivery), recreational boat use has also contributed to benthic resource damage (NPS SFNRC 2008). Boats equipped with propellers have been shown to cause direct damage to seagrasses. As the boat propeller comes into contact with the seagrass and associated sediment, a propeller scar (hereafter referred to as “prop scar”) forms within the seagrass bed (Figure 3). Prop scars create structural changes in the seagrass community from physical destruction and disruption of the seagrasses, sediment re-suspension, and an increased susceptibility to storm damage (NPS SFNRC 2008). Natural recovery of prop scars varies depending upon the seagrass species affected, sediment type and source, and the severity of damage; however, estimates range from less than one year to more than seven years (NPS SFNRC 2008). Deep prop scars (i.e., 10-20 cm deep) can disrupt the seagrass rhizome (root) structure and biomass, making natural seagrass recovery more difficult and making the scar more susceptible to secondary continued erosion/expansion (NPS SFNRC 2008).

1.1.2. Results from Previous Propeller Scarring Studies in Florida Bay

Since 1995, two prop scarring studies have collected data within Florida Bay. These studies utilized different approaches and methodologies to quantify prop scarring.

Sargent et al. (1995) identified and quantified the extent of scarred seagrasses within Florida's shallow marine and estuarine waters. The study area extended from the Alabama-Florida border, east and south along the Gulf coast to the Florida Keys, and then north along the lagoonal river system of the Atlantic Coast to Volusia County. Thirty-one of the state's 35 coastal counties were included in this survey. Polygons were drawn around groups of prop scars and each polygon was classified according to scarring intensity: light (less than 5% of the seagrasses were scarred), moderate (5-20% scarring), and severe (>20% scarring). This study reported ~30,050 ac of scarred seagrasses within Monroe County. This estimate included seagrasses in both Florida Bay and the Florida Keys. Forty eight percent (48%) of the scarred seagrasses exhibited light scarring, followed by 35% with moderate scarring, and 17% with severe scarring. Based on county-wide rankings, this study found that Monroe County had the most seagrass and the most moderate and severe scarring in comparison to all other counties within the study area.

A second prop scarring study was completed by the National Park Service's South Florida Natural Resource Center (SFNRC) in 2008 to quantify and characterize seagrass scarring entirely within Florida Bay and was used to inform the Park's General Management Plan (GMP) project (NPS SFNRC 2008). Georeferenced digital imagery collected in 2004 was used to digitize individual prop scars (N=12,000) to determine scarring densities. Regression analyses were then performed to examine relationships between scar density and a variety of variables, including water depth, channels, marine facilities, boat use, and shorelines. Prop scarring patterns were noted, with high densities of prop scars in shallow water depths, near navigation channels, and around areas most heavily used by boats. This study concluded that scarring was not improving over time within Florida Bay and that new management strategies were needed in order to protect the seagrass habitat.

1.2. Project Objectives

On January 1, 2011, ENP implemented a pole and troll zone (PTZ) in Snake Bight to help "protect sensitive aquatic vegetation and wilderness resources, improve the quality of flats fishing, enhance paddling and wildlife viewing opportunities, and expand education on proper shallow-water boating techniques" (NPS 2011a). Within a PTZ, boaters are required to shut off their internal combustion motors and switch to either drifting, poling, paddling and/or the use of electric trolling motors (USFWS 2009). Numerous locations around the State of Florida have implemented PTZs, including Merritt Island National Wildlife Refuge and the Pinellas County Shell Key/ Ft. De Soto area.

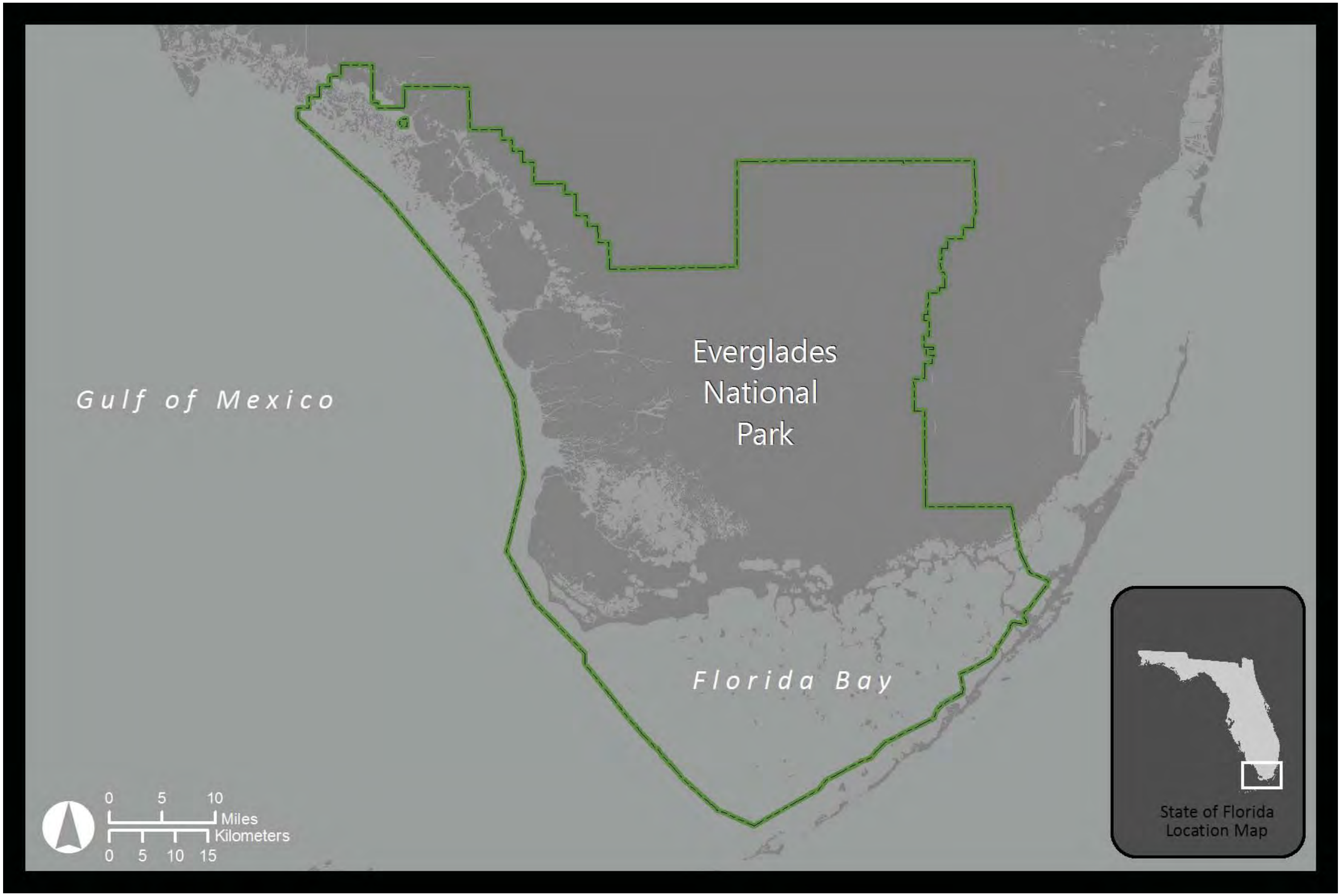

Figure 1. Overview map showing the boundaries of Everglades National Park.

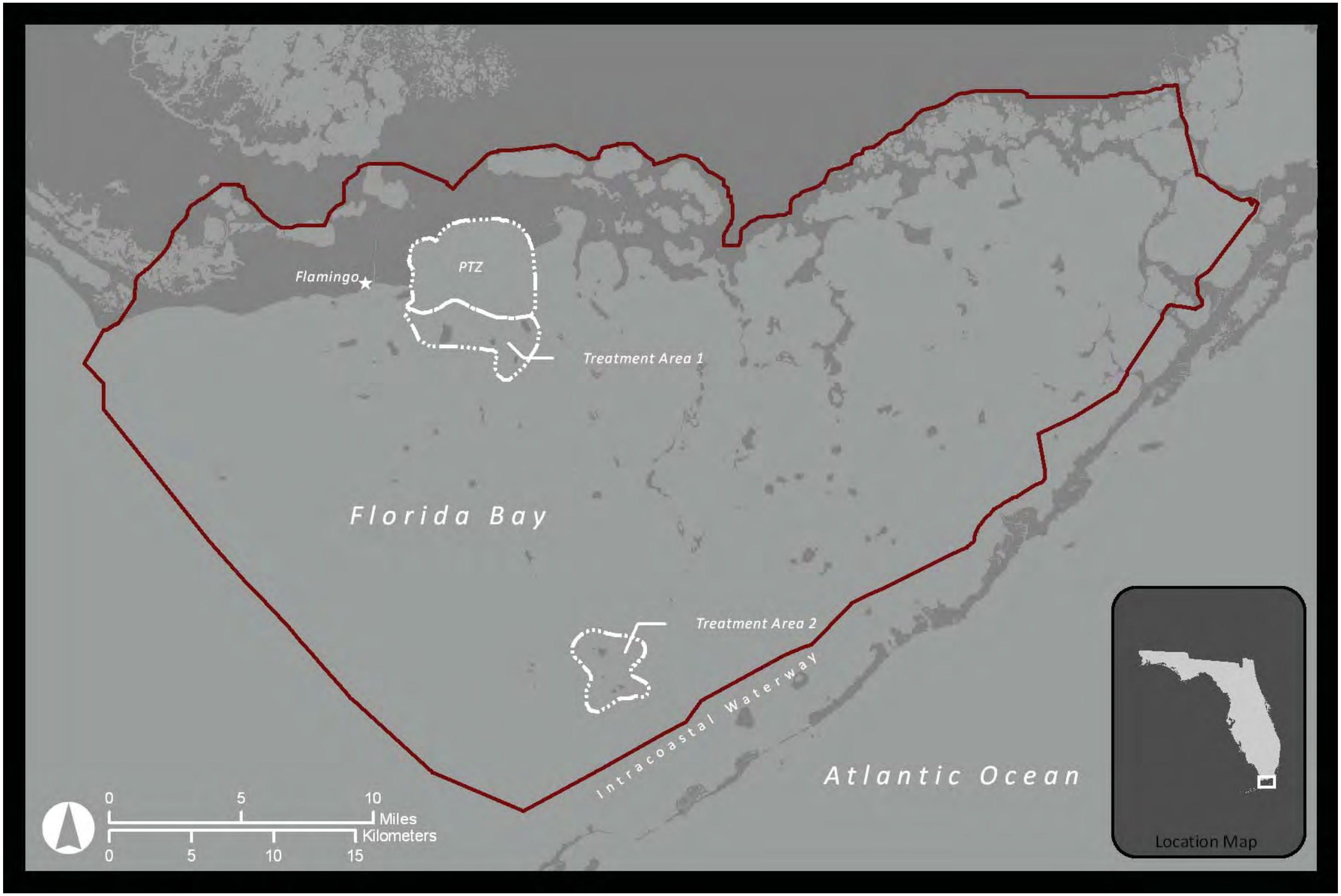

Figure 2. Overview map showing the boundaries of Florida Bay and the three project areas: the Snake Bight PTZ, Treatment Area 1, and Treatment Area 2.

Figure 3. Photograph of prop scar.

The objective of the Snake Bight PTZ Monitoring Project is to quantify the amount of prop scarring within the Snake Bight PTZ and compare it to other areas in Florida Bay that do not have enforceable management (i.e., Treatment Area 1 and Treatment Area 2). Treatment Areas 1 and 2 have similar environmental and physical conditions as the Snake Bight PTZ, such as water depth and SAV coverage, but no management strategies designed to reduce prop scarring have been implemented within these areas. The data from the three project areas will be used to measure the success of the management strategy within the Snake Bight PTZ over time.

1.3. Description of Project Area

The project area includes three areas: the Snake Bight PTZ, Treatment Area 1, and Treatment Area 2. Each area is discussed in more detail below.

1.3.1. Snake Bight Pole and Troll Zone

Extensive public and stakeholder meetings were held in 2009 as part of the GMP to discuss the issue of prop scarring in Florida Bay. After presenting four alternatives for managing Florida

Bay (two of which included the PTZ concept) and reviewing the results of the NPS' 2008 study (NPS SFNRC 2008), stakeholders suggested that ENP should explore the implementation of a PTZ within an area of Florida Bay that is heavily impacted by prop scars (NPS 2011b). To begin the process, ENP researched four different sites (i.e., Snake Bight, Garfield Bight, Shell Key Bank, and Peterson Key Bank) for suitability as a PTZ in Florida Bay (NPS 2011b). Each area was prioritized using the following criteria: accessibility, education impact, enforceability, effective signage potential, area of protection, public support, existing damage, probability of seagrass recovery, and enhanced visitor experience (NPS SFNRC 2009). After ranking the four different sites, the sites and rankings were presented at two public meetings and at a presentation to the Florida Keys National Marine Sanctuary (FKNMS) Advisory Council to gain input on the NPS' proposal and to determine the location, configuration, and parameters of the PTZ. After a 30-day comment period, it was determined that Snake Bight was the area most suitable for the establishment of a PTZ (Figure 4).

Snake Bight is the first bight encountered by boaters while heading east out of Flamingo Marina. Snake Bight extends from Joe Kemp Key (west), south to Tin Can Channel, east to Buoy Key, and north to Porpoise Point (Figure 5). Excluding Jimmy's Lake, the average water depth within Snake Bight is ~1 ft (NOAA 2006). Installation of the PTZ signage began December 16, 2010 and was completed by January 1, 2011, officially marking Snake Bight as a PTZ within ENP (NPS 2011b; Figure 4). The total area of the Snake Bight PTZ measures ~9,400 ac (Figure 5). Within the Snake Bight PTZ, internal combustion motors can only be used in Tin Can and Snake Bight channels and in the Jimmy's Lake idle speed-no wake area. Within all other areas of the Snake Bight PTZ, boats may only be propelled by push poles, paddles or electric trolling motors (NPS 2011c).

1.3.2. Treatment Area 1

Treatment Area 1, immediately south of the Snake Bight PTZ, encompasses ~4,900 ac and includes the seagrass banks adjacent to and between Palm, Buoy, Cormorant, and Curlew Keys (Figure 5). The limits of this area extend from Dave Foy channel (west), north to Tin Can Channel and east to Buoy Key (Figure 5). The average water depth within this area is ~1-2 ft (NOAA 2006).

1.3.3. Treatment Area 2

Treatment Area 2, in southern Florida Bay, includes the seagrass banks adjacent to and between Barnes and Buchanan Keys and covers ~3,700 ac (Figure 6). Several unmarked channels and one marked channel (i.e., Barnes Key Channel) are located between the seagrass banks in this area. The moats (or deepwater trenches surrounding mangrove islands) and internal creek associated with the Buchanan Keys are regulated as "closed areas" by ENP and all public entry is prohibited within these areas to offer additional protection to wildlife habitat. Due to prohibited entry, reduced prop scarring is anticipated within the closed area in Treatment Area 2. Water depths within Treatment Area 2 range from ~1-6 ft; however, depths on the seagrass banks were similar to those observed in the Snake Bight PTZ and Treatment Area 1, ~1-2 ft. Depths in excess of 2 ft were observed south of Buchanan Bank and within the basin between Buchanan and Barnes Keys (NOAA 2006).

Figure 4. Photographs of signage installed for the Snake Bight PTZ. Photos courtesy of Fred Herling, ENP.

Figure 5. Map showing the boundaries of the Snake Bight PTZ, Treatment Area 1, and the Jimmy's Lake idle-speed no wake area. Aerial photography provided by Photo Science.

Figure 6. Map showing the boundaries of Treatment Area 2. Aerial photography provided by Photo Science.

2.0 Aerial Imagery

2.1. Acquisition and Processing

Photo Science was sub-contracted to supply high-resolution, orthorectified imagery for ~385,000 ac of Florida Bay within ENP, including the three areas associated with this project: the Snake Bight PTZ, Treatment Area 1, and Treatment Area 2. The initial aerial flight was performed on December 4, 2010; however, due to poor water quality (i.e., turbid water conditions), not all aerial images were adequate for this project or future data analysis by the NPS. Those areas with turbid water conditions were recaptured on January 8-9, 2011 and April 18, 2011. To collect color imagery with an effective ground pixel resolution of 1-ft, Photo Science deployed an aircraft equipped with a Zeiss DMC sensor. Flights were conducted with a sun angle between 30° and 45°, an end to side overlap of 60%-30%, and flight paths were oriented in a north-south direction to reduce sun glint. Photo Science also integrated Airborne Global Positioning System (ABGPS) and Inertial Navigation Unit (INU) technology with conventional ground control methods to ensure that the spatial accuracy exceeded USGS Map Accuracy Standards for 1:12,000 scale products.

The individual image frames were orthorectified and formatted into a seamless mosaic. To make the file size more manageable, Photo Science cut the mosaic into 5,000-ft by 5,000-ft image tiles. Because a majority of the aerial imagery was collected over open water and there are minimal ground features available to "hide" the seamlines between image tiles, Photo Science used automatic seamlines.

The next aerial flight will be conducted at Year 3 to determine the effect of the management strategy (i.e., implementation of the PTZ) on the number and distribution of prop scars within the Snake Bight PTZ in comparison to Treatment Areas 1 and 2.

2.2. Digitization of Propeller Scars

2.2.1. Methodology

To estimate the quantity and distribution of prop scars within the three project areas, Photo Science staff biologists systematically examined the aerial photographs at an absolute resolution of 1:1,000 for the presence of linear features on the seagrass banks (i.e., potential prop scars). Using ESRI ArcMap software, each individual linear feature was digitized by tracing it as an individual line (Figure 7).

Figure 7. An illustration of the prop scar digitization process using images from Treatment Area 2. The potential prop scars visible in the top image have been mapped in red in the bottom image. Image scale is 1:1000.

2.2.2. Results

Using the method listed above, 6,040 potential prop scars were identified and mapped during the 2011 aerial image analysis and a GIS feature class was created depicting their respective locations (Figures 8 and 9). The summed length of all mapped prop scars was ~624 kilometers (km; Table 1). Using an average prop scar width of ~30 cm (Grablow 2008 and Sargent et al. 1995), this equates to a total of ~46 ac of prop scarring within all project areas. Individual prop scars ranged in length from ~2 meters (m) to ~4 km and the mean length was ~103 m (S. D. ± 179 m; Table 1). The Snake Bight PTZ had the highest number, length, and area of mapped prop scars (3,073 scars; ~347 km; ~26 ac) followed by Treatment Area 1 (1,629 scars; ~204 km; ~15 ac) and Treatment Area 2 (1,295 scars; ~64 km; ~5 ac). The number of mapped prop scars per acre was consistent across all areas with an average of 0.34 scars per acre.

The moats surrounding, and the internal creek within the easternmost island of the Buchanan Keys are regulated as “closed areas” by ENP (Figure 10). The prop scar data appears to indicate that several boats may have accessed the moats surrounding the Buchanan Keys, creating prop scars in the surrounding seagrass beds (Figure 10). This indicates that the regulations posted on the “closed area” signage may be misunderstood, not seen, or ignored by boaters. It is also possible that some of the prop scarring damage was created prior to signage installation in September 2009.

2.2.3. Discussion

The number, area, and distribution of potential prop scars digitized from the 2011 aerial imagery were compared to the 2004 and 2006 prop scar data collected by the NPS (NPS SFNRC 2008; Tables 1 and 2).

2.2.3.1. 2004/2011 Comparison

The 2004/2011 comparison was accomplished by performing a spatial join between the Snake Bight PTZ Monitoring Project areas and the 2004 prop scar data using ESRI ArcMap 9.3.1 (only those areas with data in both years were compared). In 2004, 1,717 line segments or prop scars were mapped within the three project areas compared to 6,040 prop scars in 2011 (Table 1). Using an average prop scar width of 30 cm and the length values of all mapped prop scars, the total area of prop scarring was calculated for the 2004 and 2011 datasets. The total acreage of prop scars reported in 2011 was more than 6 times the amount reported in 2004 (Table 1). In addition, the summed length of all prop scars and mean prop scar length were also much lower in 2004, ~1/6 of the total length of mapped prop scars and approximately half of the mean prop scar length calculated in 2011. These drastic differences between the 2004 and 2011 datasets are most likely attributed to differences in the resolution of the aerial imagery analyzed (i.e., 0.5-m resolution in 2004 and 0.3-m resolution in 2011). Similar differences were reported when comparing prop scar data between 2004 and 2006, whose aerial imagery resolution was 0.5 m and 0.3 m, respectively (NPS SFNRC 2008). The comparison performed between the 2004 and 2006 datasets suggested that the number of prop scars observed in the lower resolution imagery may have been underestimated by a factor of ~6.5 and the total length by a factor of ~11.5 (NPS SFNRC 2008).

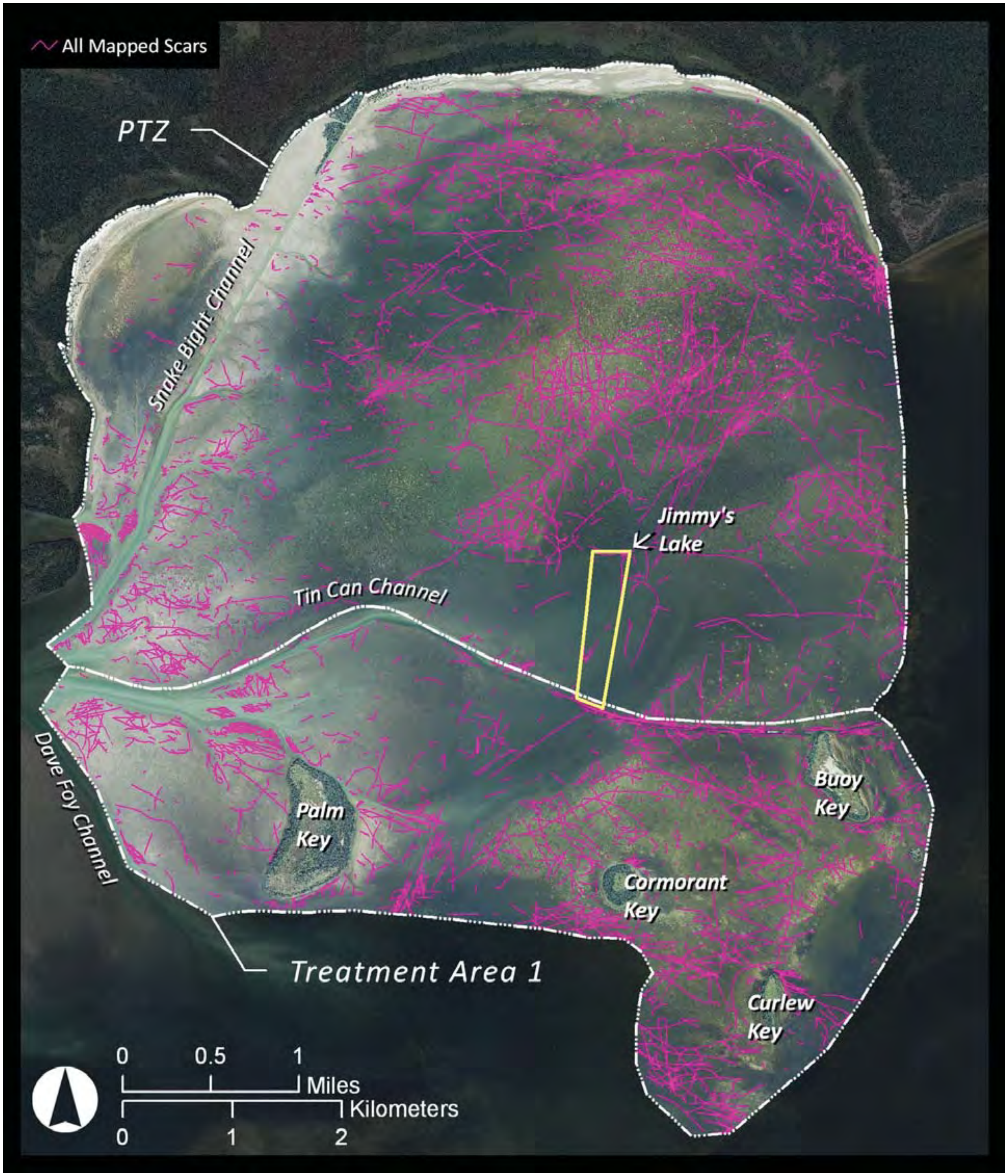

Figure 8. Location of all mapped prop scars identified in the Snake Bight PTZ and Treatment Area 1 during the 2011 aerial image analysis.

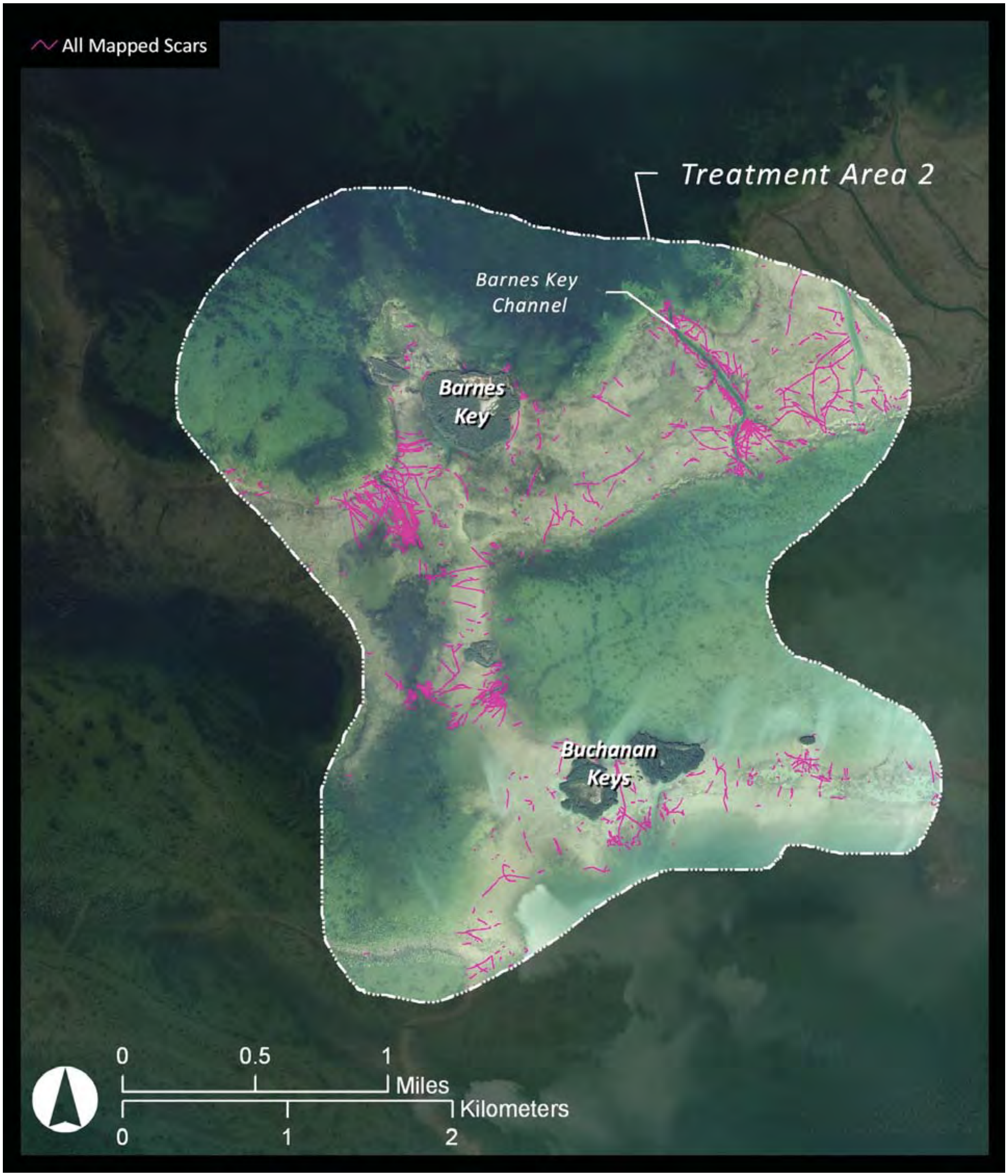

Figure 9. Location of all mapped prop scars identified in Treatment Area 2 during the 2011 aerial image analysis.

Table 1. Project area acreage and summary statistics of mapped potential prop scars within the Snake Bight PTZ, Treatment Area 1, and Treatment Area 2 in 2004 and 2011 aerial imagery. The 2004 dataset was provided by the NPS SFNRC.

Project Area	**Area (ac)**	**Total Number of Scars**		**Number of Scars Per Acre**		**Summed Length of All Scars (m)**		**Area of All Scars (ac)**		**Minimum Scar Length (m)**		**Maximum Scar Length (m)**		**Mean Scar Length (m)**	
		2004	**2011**	**2004**	**2011**	**2004**	**2011**	**2004**	**2011**	**2004**	**2011**	**2004**	**2011**	**2004**	**2011**
Snake Bight PTZ	9,400	206	3,073	0.02	0.33	12,390.82	347,302.58	0.92	25.75	9.54	2.25	485.77	3,654.88	60.15	113.02
Treatment Area 1	4,900	664	1,629	0.14	0.33	46,238.26	204,428.33	3.43	15.15	5.63	5.26	1,682.14	1,798.28	69.64	125.49
Treatment Area 2	3,700	835	1,295	0.23	0.35	40,487.75	64,207.92	3.00	4.76	4.99	3.41	364.38	700.41	48.49	49.58
Multiple Areas*	N/A	12	43	N/A	N/A	1,074.95	8,518.29	0.08	0.63	30.28	10.38	140.55	825.55	89.58	198.1
All Areas	**18,000**	**1,717**	**6,040**	**0.10**	**0.34**	**100,191.79**	**624,457.12**	**7.43**	**46.29**	**4.99**	**2.25**	**1,682.14**	**3,654.88**	**58.35**	**103.39**

*Mapped prop scars traversed multiple project areas, crossing over Tin Can Channel and entered both the Snake Bight PTZ and Treatment Area 1.

Figure 10. Locations of mapped prop scars in vicinity of "closed area" markers in the Buchanan Keys in Treatment Area 2.

Table 2. Summary statistics of mapped potential prop scars within a subset of the Snake Bight PTZ in 2006 and 2011 aerial imagery. The 2006 dataset was provided by the NPS.

Project Area	Area (ac)	Total Number of Scars		Number of Scars Per Acre		Summed Length of All Scars (m)		Area of All Scars (ac)		Minimum Scar Length (m)		Maximum Scar Length (m)		Mean Scar Length (m)	
		2006	2011	2006	2011	2006	2011	2006	2011	2006	2011	2006	2011	2006	2011
Snake Bight PTZ Subset	4,746	2,071	2,079	0.436	0.438	84,348.81	228,794.03	6.25	16.96	1.79	2.86	2,160.88	3,654.88	40.72	110.05

Some similarities were observed when comparing the distribution of prop scars between 2004 and 2011. In both years, concentrations of prop scars were observed in the area between Snake Bight and Tin Can Channels and along the unmarked channels northwest of Palm Key, southwest of Barnes Key, and along the east/west channel south of the mangrove island between Barnes and Buchanan Keys (Figures 11 and 12).

2.2.3.2. 2006/2011 Comparison

In addition to the 2004/2011 comparison, prop scar data were also compared between 2006 and 2011. In 2006, aerial imagery was collected within Garfield Bight as well as a subset of the Snake Bight PTZ area. To compare prop scars within the same area of the Snake Bight PTZ in both years, a convex hull was calculated around the 2006 prop scar data using ESRI ArcMap 9.3.1 (Figure 13). The convex hull encompassed ~4,746 ac of the Snake Bight PTZ (Figure 13). The number of prop scars per acre within this specified area was very similar between 2006 and 2011, 0.436 and 0.438 respectively (Table 2). However, the average prop scar length was much higher in 2011 compared to 2006. In 2011, the average prop scar length was ~110 m while in 2006 the average prop scar length was ~41 m. The longer prop scar lengths reported in 2011 resulted in a higher acreage of prop scarring, ~17 ac, compared to ~6 ac in 2006. Because the aerial imagery collected in 2006 and 2011 had the same ground pixel resolution (0.3-m resolution), changes observed between years are likely due to differences in analysis techniques (i.e., digitization of prop scars from aerial imagery) or changes in boating behavior over time.

Some similarities were observed when comparing the distribution of prop scars between 2006 and 2011, including the concentration of short prop scars at Porpoise Point (Figure 13). However, there was one noticeable difference. The clustering of prop scars observed north of Jimmy’s Lake in 2011 was absent in the 2006 images. This may indicate a change in boating behavior.

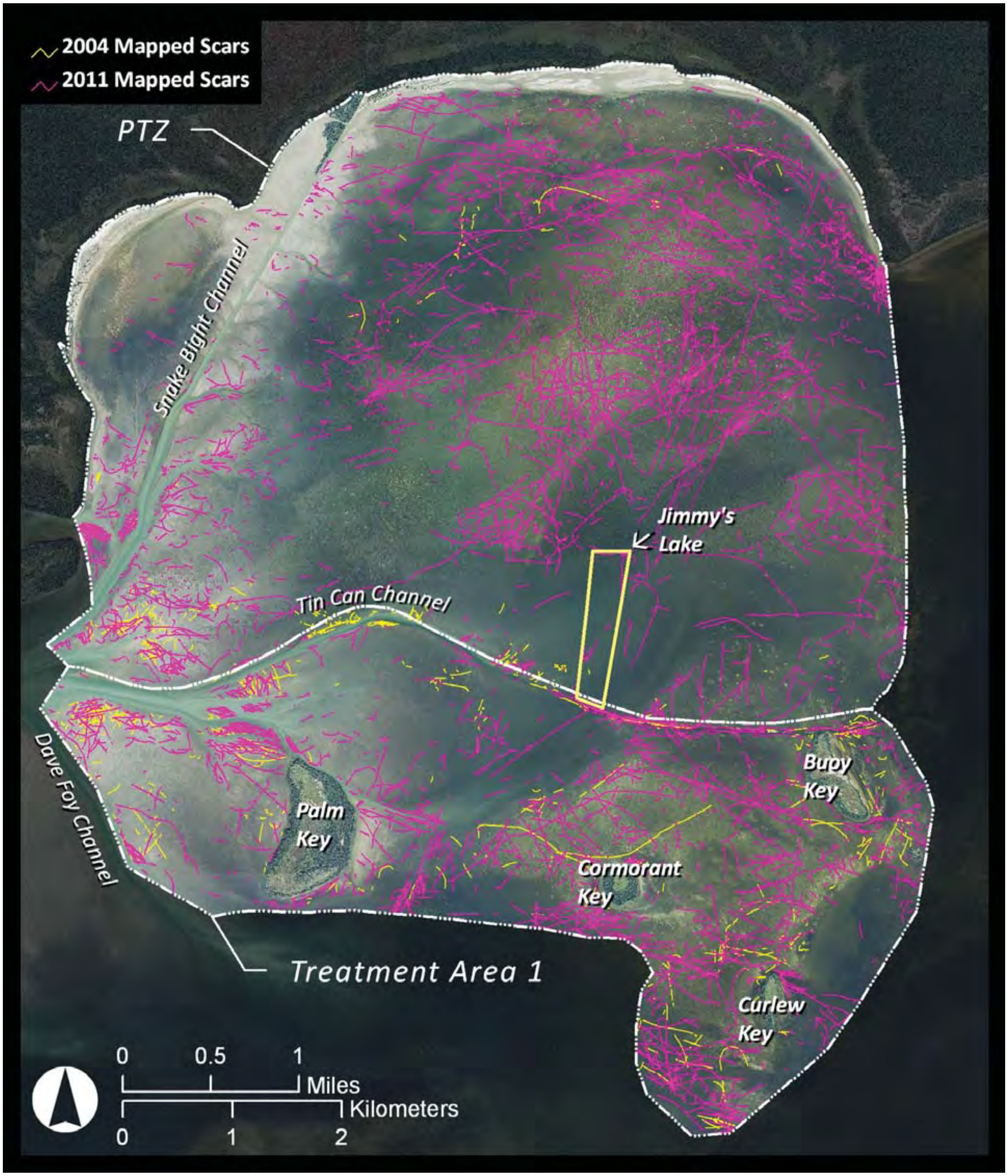

Figure 11. Location of mapped prop scars identified in the Snake Bight PTZ and Treatment Area 1 during the 2004 and 2011 aerial image analysis.

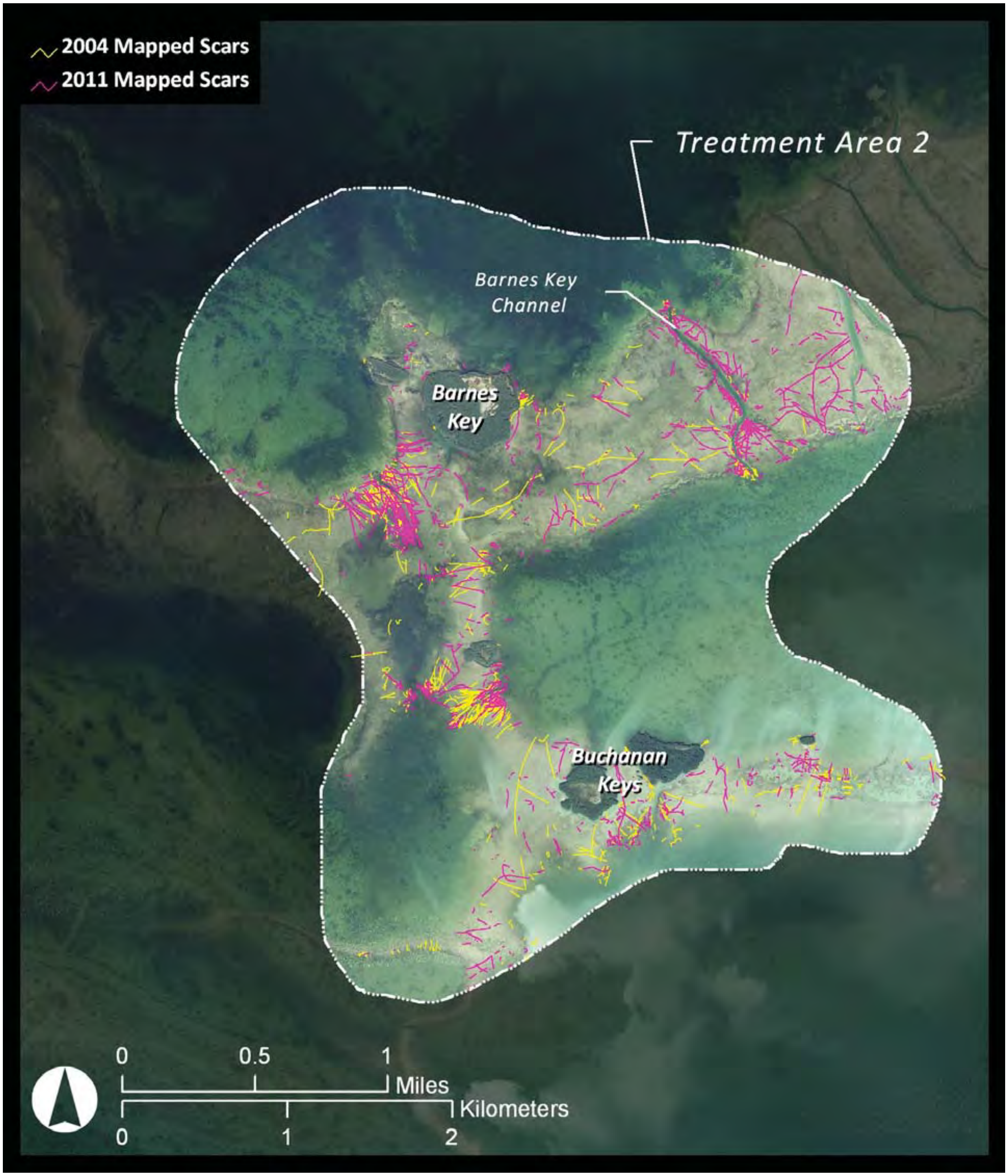

Figure 12. Location of mapped prop scars identified in Treatment Area 2 during the 2004 and 2011 aerial image analysis.

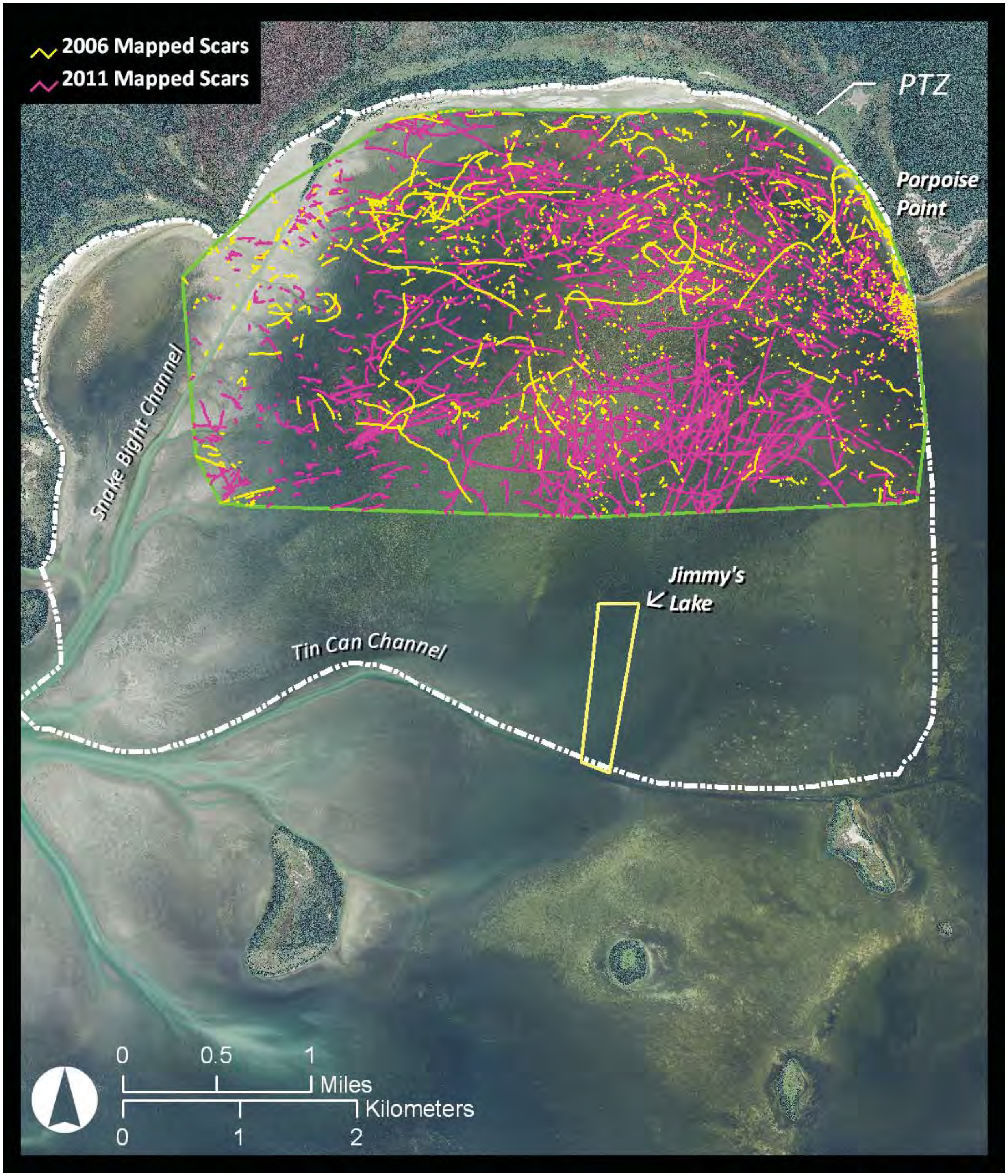

Figure 13. Location of mapped prop scars identified in a subset of Snake Bight PTZ during the 2006 and 2011 aerial image analysis. The boundaries of the convex hull calculated from the 2006 prop scar data are depicted in green.

3.0 Field Validation of Propeller Scars

3.1. Objectives

The overall objective of the field validation task was to validate or invalidate the greatest number of mapped potential prop scars within the project area. Due to the extremely large number of mapped prop scars, a sample number of scars were selected for field validation, with an effort made to distribute the samples evenly between all representative habitats within each of the three project areas.

Any attempt to characterize benthic components from high-resolution aerial imagery presents a suite of technical challenges, including changing optical properties of water with depth, variations in water constituents across the spatial extent of an image, and reflections caused by an imperfect water surface. In addition, methodological errors were confounded by lag time between the aerial flight and the field validation effort (time required to produce and analyze the aerials prior to fieldwork). The field validation effort commenced on March 29, 2011, which was 115 days post-flight. In the field, subsurface visibility was reduced in some areas, particularly in the vicinity of Snake Bight and Tin Can Channels. The turbid water quality inhibited the field of view, drastically reducing the ability to locate and categorize mapped prop scar features during the field validation effort. Despite these conditions, the field validation of the mapped prop scar locations was successfully accomplished using the results of the image analysis and guided by GIS/GPS technology (i.e. the use of a Trimble Geo-XT handheld DGPS unit, running ESRI ArcPad 7.0.1; hereafter referred to as “Trimble unit”).

3.2. Methodology

The 2011 aerial image analysis resulted in a large number of mapped potential prop scars (N=6,040). Based upon these numbers, field validation of all scars could not be carried out due to budgetary constraints. Thus, a sample of the total number of scars was selected for field validation. The sample consisted of 10% of the total number of mapped prop scars, which were randomly sampled using ESRI ArcGIS 9.3.1 software. This yielded a total of 604 field validation sampling sites (3 in multiple areas; 285 in Snake Bight PTZ; 174 in Treatment Area 1; 142 in Treatment Area 2). A statistical power analysis (α= 0.05, p=0.5, power = 0.9) was performed to determine whether the field validation visitation rate was sufficient to confirm the adequacy of using aerial photography to detect prop scars. Results indicated that a sample size of 200-300 sites would be needed to effectively test whether the probability of confirming a scar identified from aerial photography is better than 50%. Based on the results of the power analysis, the selected sample size of 604 was sufficient. Figures 14 and 15 depict all mapped prop scar locations, as well as the 10% sample sites selected for field validation.

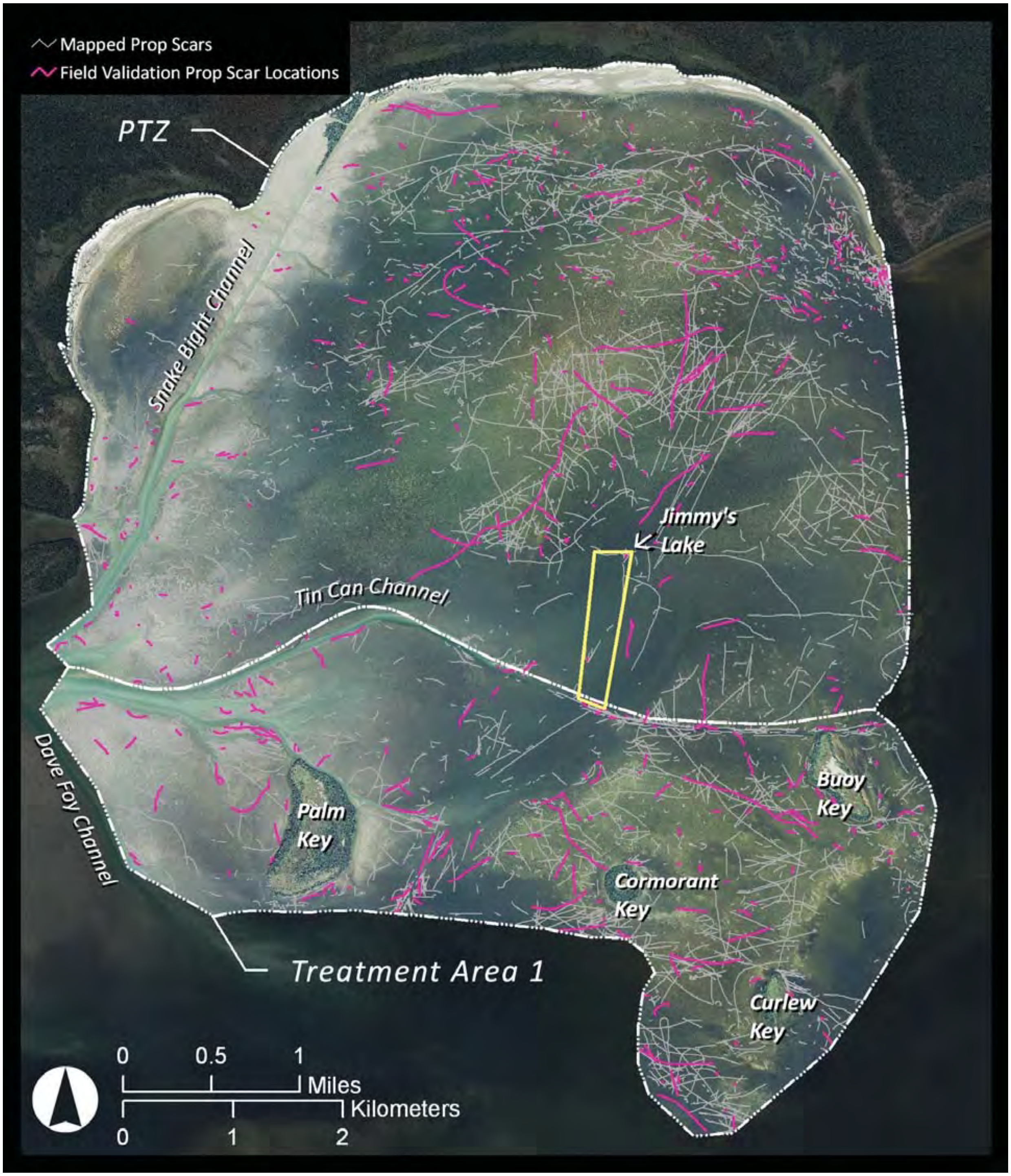

Figure 14. Locations of mapped prop scars identified within the Snake Bight PTZ and Treatment Area 1 during the 2011 aerial image analysis. Those locations depicted in pink represent the random sample of scars selected for field validation.

Figure 15. Location of mapped prop scars identified within Treatment Area 2 during the 2011 aerial image analysis. Those locations depicted in pink represent the random sample of scars selected for field validation.

The field validation effort was completed over the course of three weeks (Table 3). Using the Trimble unit, biologists with extensive seagrass experience navigated to the field validation sample sites using a 16-ft aluminum jon boat. The aluminum jon boat was outfitted with a 25 horsepower Yamaha engine, a bow-mounted 55-lb thrust Minn Kota trolling motor, and a 13-ft push pole. At each sample location, the presence or absence (based on visual analysis from the boat) of the mapped prop scar feature was recorded on the Trimble unit. Categorization of damage was provided for those sample sites that appeared to be a result of boat propeller scarring. A "low severity" class was assigned to those prop scars with little to no substrate exposure and a "high severity" class was assigned to prop scars with extensive substrate exposure.

Table 3. Number of sample sites visited each day during the field validation effort (March 29, 2011 to April 26, 2011).

	Project Areas				
Date	**Snake Bight PTZ**	**Treatment Area 1**	**Treatment Area 2**	**Multiple Areas**	**All Areas**
3/29/11	34	19	0	3	56
3/30/11	63	0	0	0	63
3/31/11	40	0	0	0	40
4/4/11 4/5/11	3	72	0	0	75
4/6/11	0	23	0	0	23
4/7/11	0	19	0	0	19
4/12/11	1	39	0	0	40
4/13/11	39	0	0	0	39
4/14/11	31	0	0	0	31
4/19/11	36	0	0	0	36
4/20/11	0	0	94	0	94
4/21/11	0	0	48	0	48
4/26/11	0	0	0	0	0
Total # Sample Sites Visited	**247**	**172**	**142**	**3**	**564**
Total # of Sample Sites Identified	**285**	**174**	**142**	**3**	**604**

3.3. Results and Discussion

As of April 26th, 2011, ~93% (564 of 604) of the field validation sample sites were visited (Table 3). Of the forty remaining sample sites, 38 were located within the PTZ and two were within Treatment Area 1 (Figure 16). The 38 PTZ sample sites were positioned along the northern boundary (northern wall) of the PTZ and within the center of the bight (Figure 16). An attempt was made to re-visit the 22 central locations on April 26th, 2011; however, the lack of water at high tide prevented access into the area. Similarly, the 16 sample sites along the eastern portion of the northern wall could not be accessed due to lack of water and a *Halodule* wrack line. Access to the two sample sites in Treatment Area 1 was restricted due to their isolated location and tidal restrictions (Figure 16). Additional attempts at accessing these forty sample sites were not made because doing so may have potentially caused additional damage to the benthic resource.

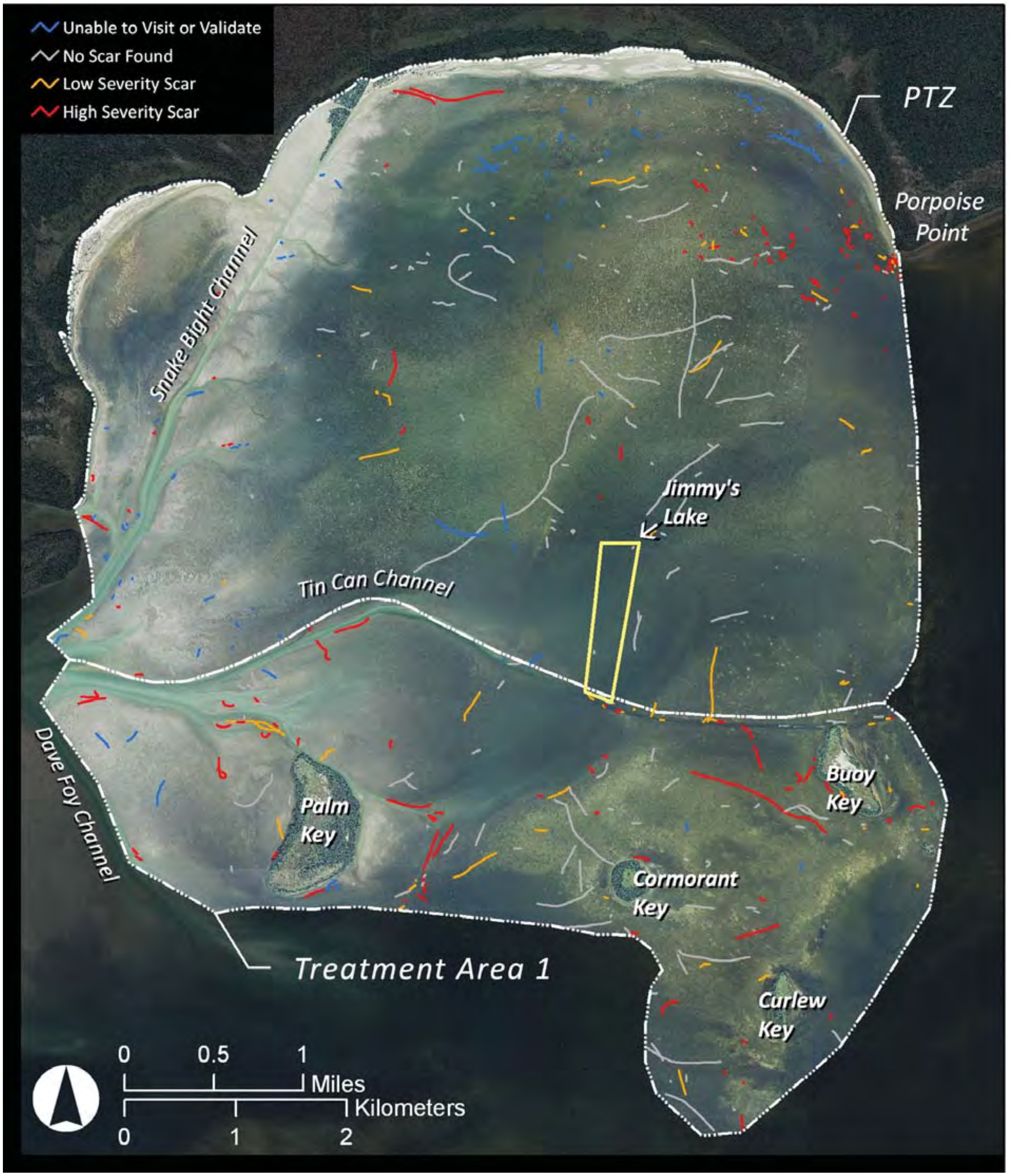

Figure 16. Locations of field validated prop scars (by severity) within the Snake Bight PTZ and Treatment Area 1. Also depicted are those sample sites that could not be visited or analyzed due to lack of water at high tide or turbidity, respectively.

Of the 564 sample sites visited during the field validation effort, 44 could not be validated due to turbid water conditions (Figures 16 and 17). A majority of these sites were located in the vicinity of Snake Bight and Tin Can Channels (Figure 16). Multiple attempts were made to visit some of these locations; however, water quality conditions did not improve to a point where validation was possible. For the purposes of time efficiency, and due to continued and persisting turbidity, the biologists noted the sites as turbid and proceeded to other sample sites.

Based upon the results of the field validation effort, the accuracy of remotely determined scar locations was ~60% (Table 4). Of the 520 field validation sample sites analyzed, 311 were verified prop scars (Table 4). Several factors may have contributed to the accuracy values of this project including:

1) The regrowth of seagrasses within "low severity" prop scars during the lag time between the photography and the field validation survey (approximately 115 days);

2) Visual observations from the boat may have been too narrow in scope to adequately locate minimal impacts in the field, thereby reducing "low severity" prop scar accuracy relative to what was visible in the aerial image;

3) The settlement of detrital material into prop scars, thus hiding them from view;

4) Tidal currents can interact with large seagrass canopy heights to produce seemingly linear features in undisturbed seagrass beds. Such hydrodynamically induced patterns may have been misinterpreted during analysis of the aerial images (PBSJ, an Atkins company 2011); and

5) Epiphytic loads and species composition of seagrass can create a mosaic of spectral differences that mimic prop scarring (PBSJ, an Atkins company 2011). Note that the contribution of this factor was minimal for this project and was only observed at fewer than five locations within the project area.

All of these factors likely contributed to the accuracy value for this project, particularly factor number two. Many of the prop scars identified from the aerial imagery consisted of varying degrees of severity. It is possible that the low severity portions of these prop scars were visited (which were not obvious in the field), rather than the sections with extensive substrate exposure (Figure 18).

Despite these factors, the field validation methodology produced a serviceably accurate assessment of damage type distribution and was largely successful in identifying the most severe damages (Figure 19). The presence of high severity prop scars was consistent across the three project areas, accounting for ~61% to ~68% of all verified prop scars (Table 4 and Figure 20). To compare the number of high and low severity prop scars between the three project areas, the data were normalized for each project area. This was accomplished by dividing the number of high and low severity prop scars observed in each project area by the total acreage of each area (Snake Bight PTZ: 9,400 ac; Treatment Area 1: 4,900 ac; Treatment Area 2: 3,700 ac). It should be noted that this analysis was conducted only on verified prop scars at field validation sampling sites. When normalizing for project area, Treatment Area 2 had the highest number of high severity scars (0.018 per acre), followed by Treatment Area 1 (0.013 per acre), and the Snake Bight PTZ (0.007 per acre; Figure 20).

Within the Snake Bight PTZ, a concentration of high severity prop scars was observed near Porpoise Point (Figure 16). While boating surveys were not performed as part of this project, the multitude of short, high severity prop scars observed in this area could potentially indicate areas where boats "pop up" onto plane from a resting or idle position.

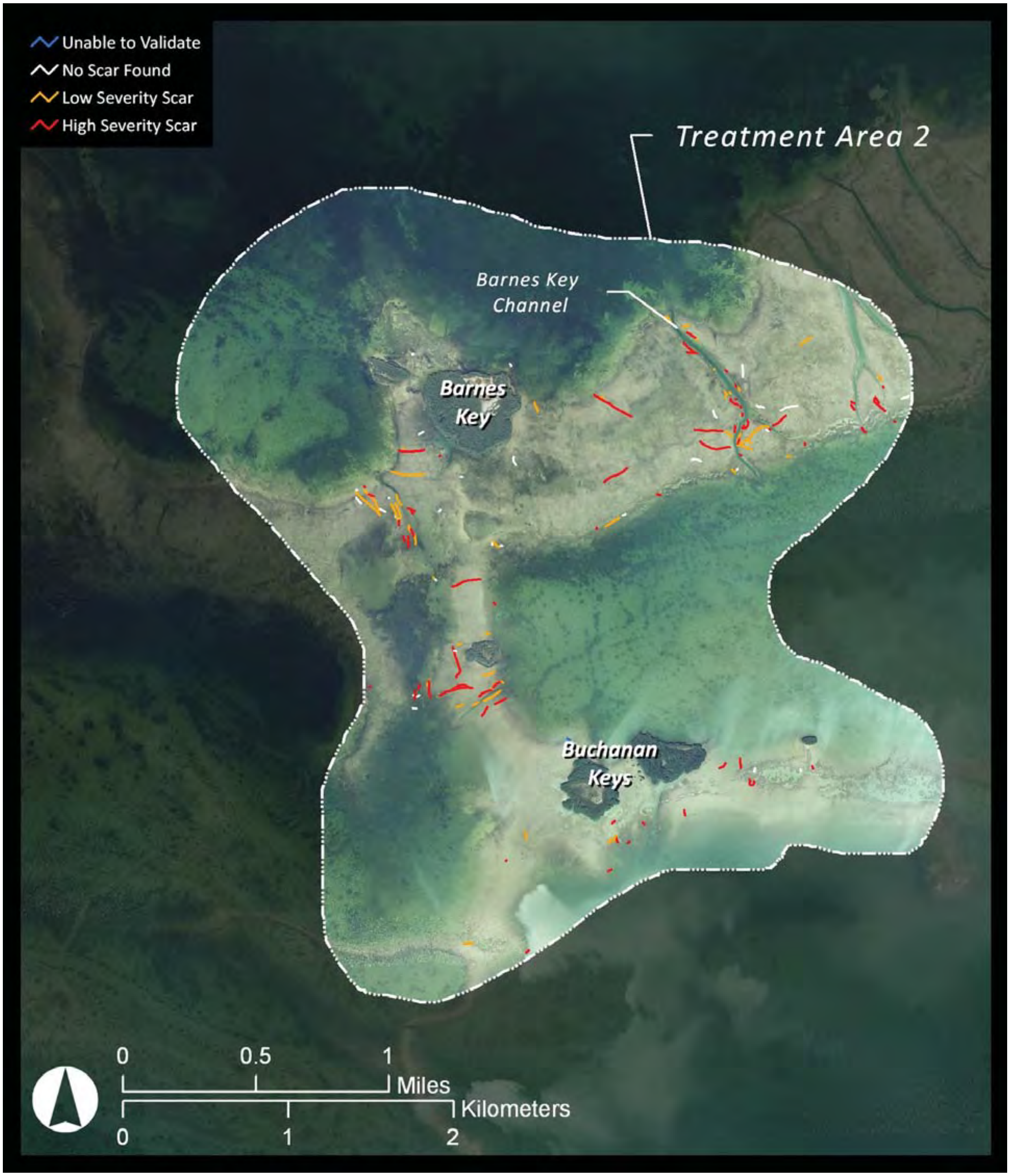

Figure 17. Locations of field validated prop scars (by severity) within Treatment Area 2. Also depicted is the single sample site that could not be analyzed due to turbidity.

Table 4. The number of sample sites analyzed and number of prop scars verified during the field validation effort within each project area. Accuracy and prop scar severity also reported.

Project Areas	Number of Sample Sites Analyzed	Number of Verified Prop Scars	Accuracy (%)	% of Low Severity Prop Scars	% of High Severity Prop Scars
Snake Bight PTZ	212	106	50	36	64
Treatment Area 1	165	94	57	32	68
Treatment Area 2	141	109	77	39	61
Multiple Areas*	2	2	100	100	0
All Areas	**520**	**311**	**60**	**36**	**64**

*Prop scars traversed multiple areas, crossing over Tin Can Channel and entered both the Snake Bight PTZ and Treatment Area 1.

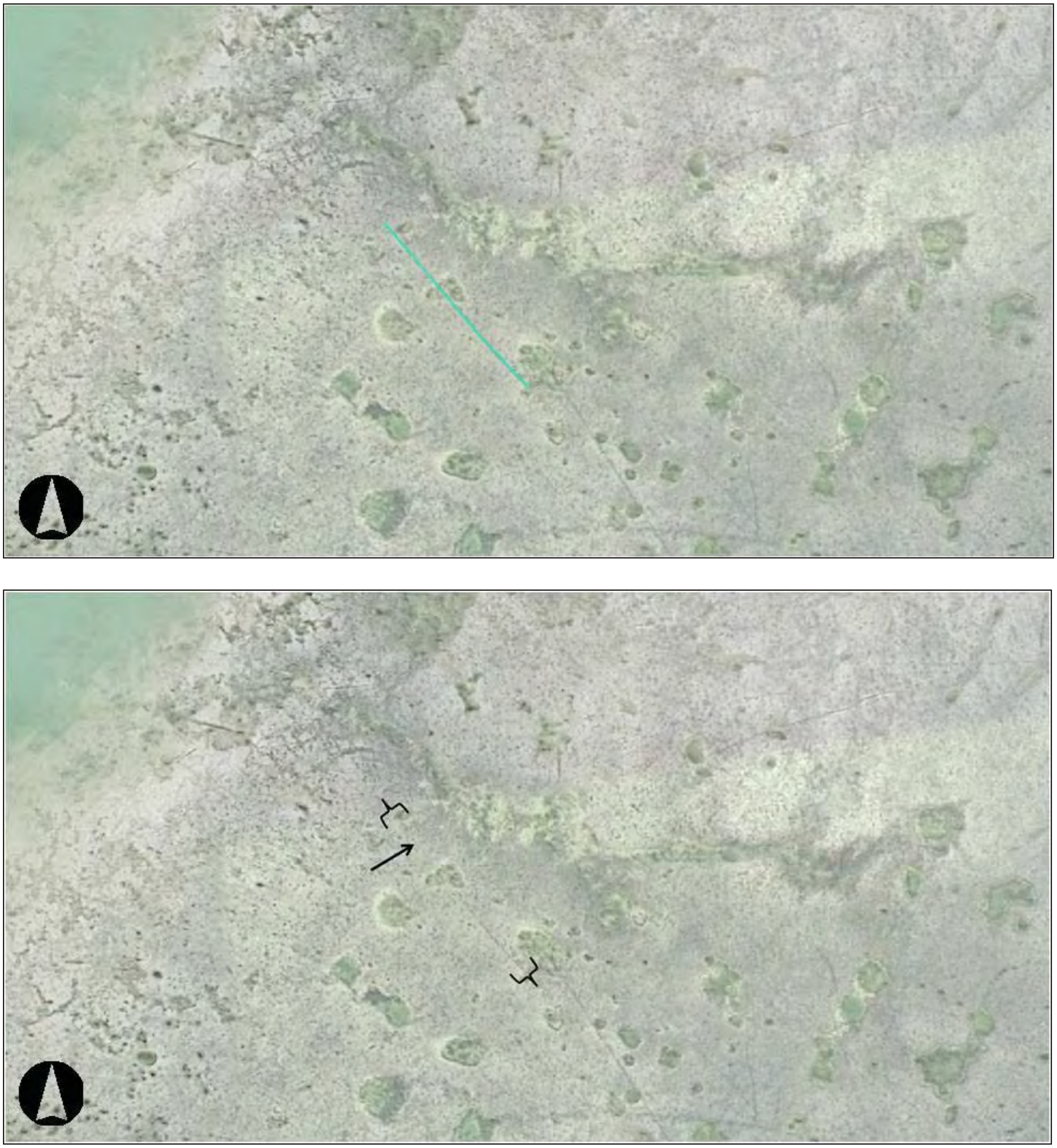

Figure 18. A prop scar in the Snake Bight PTZ visited during the field validation effort (scale 1:700). The top image shows the entire length of the scar. In the bottom image, note the varying degrees of severity while comparing the northwest end of this prop scar (arrow indicating low severity) to the southeast end (high severity). This prop scar was not located during the field validation effort, which may be a result of visiting the northwestern portion of the scar which exhibited a much lower severity than the southeast portion of the scar.

Figure 19. Prop scars in the Snake Bight PTZ that were visited during the field validation effort (scale 1:700). Arrows in the top image indicate the locations of the scars. In the bottom image, the green line indicates a prop scar classified as high severity and the orange lines indicate prop scars that were not identifiable during the field effort.

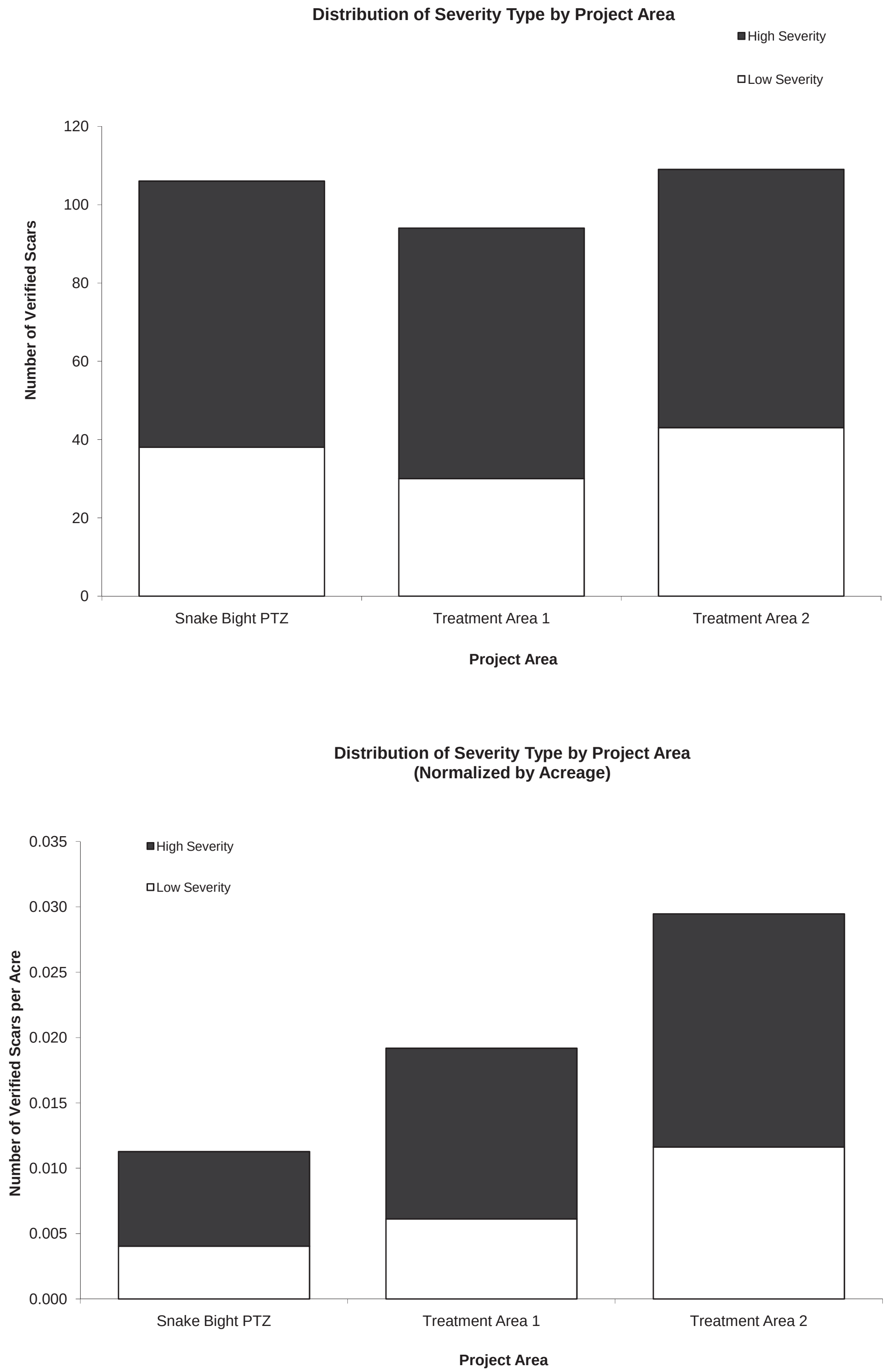

Figure 20. The distribution of prop scar severity type by project area (top) and normalized by acreage (bottom). The two verified prop scars observed within multiple areas were excluded from this analysis.

4.0 Spatial Statistical Analyses

In an effort to thoroughly describe the prop scar dynamics within the three project areas, geospatial tools and analysis techniques were utilized to spatially describe magnitude and clustering of prop scar incidence among the three project areas. The two spatial statistical analyses performed included prop scar density and the Getis-Ord Gi* spatial statistic. It is important to note that all digitized prop scar lines provided by Photo Science were used for these spatial statistical analyses.

The Getis-Ord Gi* spatial statistic compares each map feature to its neighboring features and computes a Z score indicating where features are highly clustered (ESRI Resource Center 2010). Z scores are measures of standard deviation and a Z score can indicate clustering of high or low values based on their deviation from the mean values. The actual score is computed by evaluating the local sum values of each feature and its neighboring features to the sum of all features. A high Z score indicates that the calculated local feature values are much different than the expected local sum values for that area and as such, must be more intensely clustered. Moreover, a smaller (more negative) Z score would indicate a stronger clustering of low values. For this investigation, we were only interested in highly clustered high values (hot spots). In addition to the Z score, probability statistics (p-values) for each feature were calculated to determine whether to accept or reject the null hypothesis. For the purposes of this analysis the null hypothesis is defined as:

H_0 = *The three project areas do not exhibit any significant patterns of prop scarring.*

4.1. Methodology

4.1.1. Propeller Scar Density

To visualize the highest incidence of prop scarring within all three project areas, prop scar density was calculated using the methodology described in Schaub et al. (2009). A layer of one-acre grid cells served as a sampling plot. The 2011 digitized prop scar lines were buffered by a distance of 15 cm, yielding a scar width of 30 cm (Grablow 2008 and Sargent et al. 1995). The scar line buffers and a 2010 seagrass map (Florida Fish and Wildlife Conservation Commission - Florida Wildlife and Research Institute 2010) were intersected with the one-acre grid cell sampling plots to provide areas of seagrass and scarred seagrass for each sampling plot. The percentage of scarred seagrass was calculated by dividing seagrass area by scar area for each sampling plot. The percentage of scarred seagrass for each sampling plot was then assigned one of the following scar density categories: >0-1%, 1-5%, or 5-10%.

4.1.2. Hot Spot Analysis

ESRI's ArcGIS 9.3.1 spatial statistics toolset and a combination of geoprocessing tools were used to distinguish areas of significant clustering of seagrass prop scars, if present. The initial step was to create a polygonal grid consisting of 1-ac^2 grid cells across all three project areas. This grid was used to aggregate and quantify the number of scars over a regular area. Once the grid was created, a spatial join was performed between the grid cells and the prop scar occurrences in order to count the number of scars in each grid cell. These grid cells became the analysis features. The scar count was used as the analysis field in the spatial statistic. In cases where the grid cells had a count = 0, those cells were clipped out prior to the analysis. The Getis-Ord Gi* spatial statistics tool in the Mapping Clusters toolset was utilized to quantify prop scar hot spots. The formula for this analysis is as follows:

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j} x_j - \bar{X} \sum_{j=1}^{n} w_{i,j}}{S \sqrt{\frac{\left[n \sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j} \right)^2 \right]}{n-1}}}$$

where x_j (count) is the attribute value for feature j (prop scarring), $w_{i,j}$ is the spatial weight between feature i and j, n is equal to the total number of features, and:

$$\bar{X} = \frac{\sum_{j=1}^{n} x_j}{n}$$

$$S = \sqrt{\frac{\sum_{j=1}^{n} x_j^2}{n} - \left(\bar{X}\right)^2}$$

Best practice recommendations guided the parameter inputs for this analysis. Since the source feature data were point based (aggregated to regular 1-ac^2 grids) the Conceptualization of Spatial Relationships parameter value used was *fixed distance band*. This particular method is best suited for point data when calculating Getis-Ord Gi* statistics and provides a superior model interaction among features in the calculation (ESRI Resource Center 2010). For this analysis run, the Euclidean Distance method was implemented.

4.2. Results and Discussion

The purpose of the prop scar density analysis was to quantify the amount of seagrass scarring within the three project areas. The hot spot analysis was performed to determine if prop scar patterns were random in nature or if the observed clustering of prop scars indicated a significant issue at specific locations within the project areas (Z Score > 2.58 standard deviations from the mean and $p<0.05$). Results of the hot spot and prop scar density analyses are depicted in Figures 21-24 and described in detail below. It is important to note that boating surveys were not performed as part of this project; however, a tentative evaluation and assessment of the distribution and density of prop scars observed is provided below.

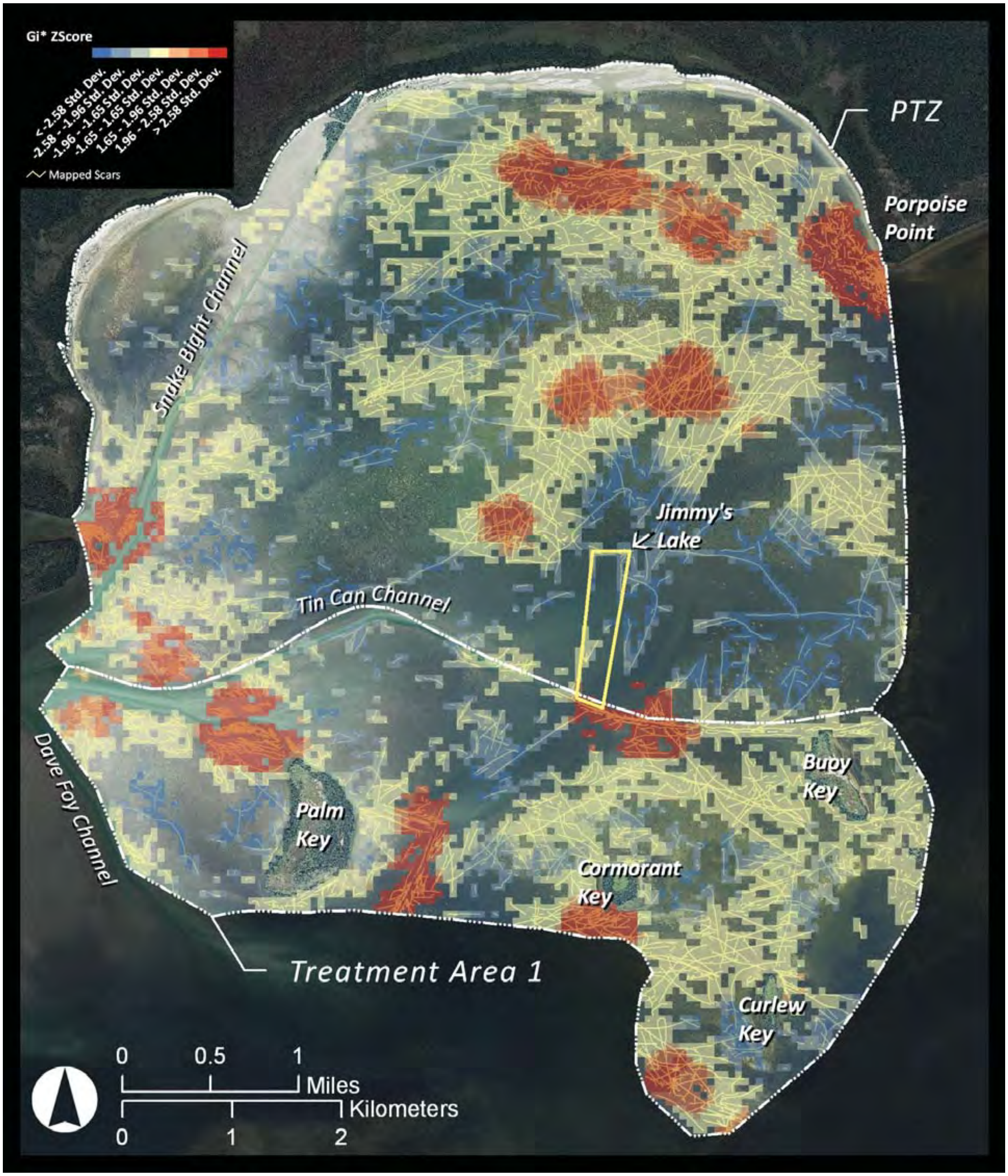

Figure 21. The map above depicts the Gi* Z Score for each one acre-grid cell in the Snake Bight PTZ and Treatment Area 1. The color of the grid cell indicates the relative intensity/strength of clustering (hot spots).

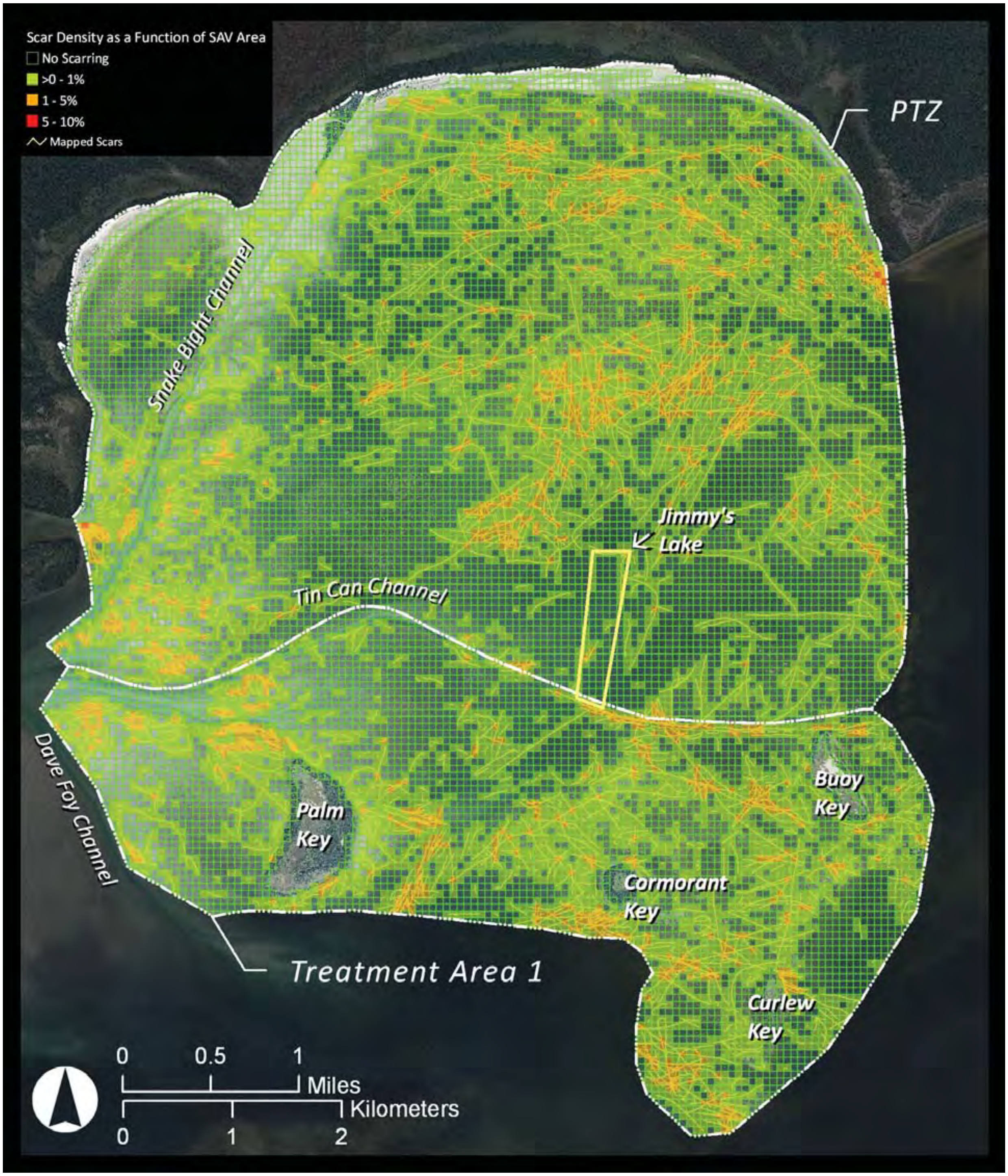

Figure 22. Prop scar density as a function of SAV area within the Snake Bight PTZ and Treatment Area 1.

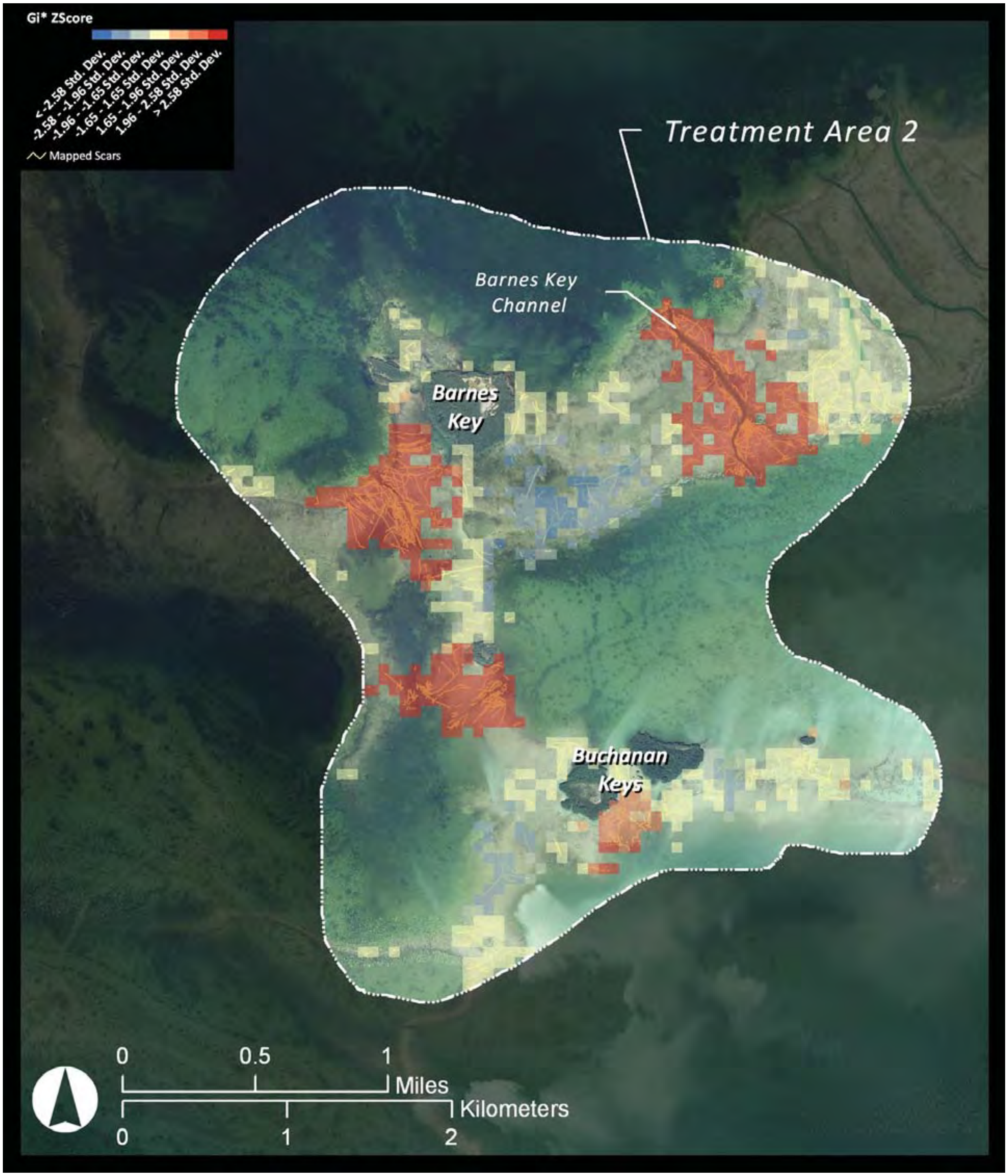

Figure 23. The map above depicts the Gi* Z Score for each one acre-grid cell in Treatment Area 2. The color of the grid cell indicates the relative intensity/strength of clustering (hot spots).

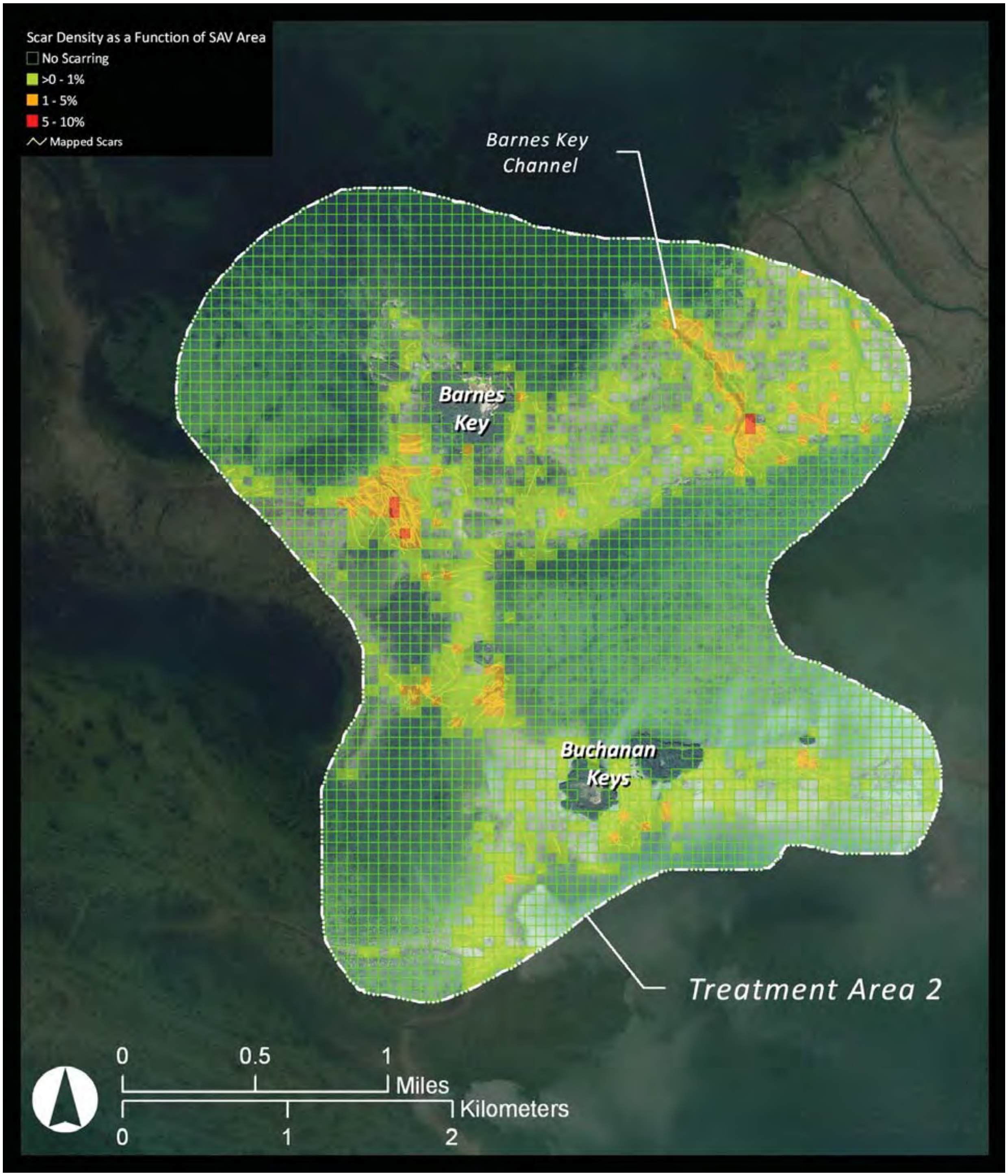

Figure 24. Prop scar density as a function of SAV area within Treatment Area 2.

4.2.1. Snake Bight PTZ

Significant clustering of prop scars or hot spots were found along the southern extent of Snake Bight Channel, within the area between Snake Bight and Tin Can Channels, along the northern and western boundaries of Jimmy's Lake, southwest/west of Porpoise Point, and throughout the northern region of Snake Bight (Figure 21). Within the 1-ac^2 grid cells in most of these areas, the percentage of scarred seagrass was less than 5% (Figure 22). However, in the area southwest of Porpoise Point, two of the 1-ac^2 grid cells had a higher percentage of scarred seagrass (i.e., 5-10%; Figure 22).

The prop scar densities and hot spots observed along the southern extent of Snake Bight Channel and within the area between Snake Bight and Tin Can Channels could potentially be a result of boats drifting out of the marked channel or creating short cuts around channels and over seagrass banks where there is insufficient water depth (Figures 21 and 22). Prop scarring can also be caused by a lack of understanding of the relationship between the draft of a boat and water depth (NPS SFNRC 2008). The prop scar densities and hot spots observed along the boundaries of Jimmy's Lake could potentially be a result of changes in water depth as boats exit Jimmy's Lake (relatively deeper) and enter the shallower seagrass flats, creating a prop scar through the seagrass bed. As previously mentioned, a higher prop scar density and hot spot was calculated for the area southwest/west of Porpoise Point. Aerial boat surveys within Florida Bay in 2006-2007 found flats boats in the area southwest/west of Porpoise Point in almost all surveys (Ault et al. 2008). The multitude of short, prop scars observed near Porpoise Point could potentially represent areas where boats "pop up" onto plane from a resting or idle position. It is also common practice for boats to enter Snake Bight from either Porpoise Point or Snake Bight Channel and travel east and west between these two locations. This behavior could potentially explain the east-west prop scar pattern across the northern region of the bight.

4.2.2. Treatment Area 1

Results of the prop scar density analysis revealed that all 1-ac^2 grid cells within Treatment Area1 had less than 5% seagrass scarring (Figure 22). Hot spots were observed throughout Treatment Area 1 in areas adjacent to unmarked channels and at the boundaries between deep water and seagrass banks (Figure 21). Prop scarring adjacent to unmarked channels could potentially be attributed to the lack of navigational markers, particularly along the network of channels located northwest of Palm Key and the north/south channel between the seagrass banks of Palm and Cormorant Keys. Previous boat surveys conducted between 2006 and 2007 showed high numbers of flats boats and small recreational boats within and adjacent to the unmarked channels northwest of Palm Key (Ault et al. 2008).

As previously mentioned, prop scars often result from a lack of understanding between the draft of a boat and water depth. Along the southern boundary of Treatment Area 1 (south of Cormorant Key and southwest of Curlew Key) and along the eastern portion of Tin Can Channel, there are many prop scars which could potentially be attributed to this factor (Figure 21). Boaters unfamiliar with shallow water boating may not recognize slight changes in water depth, thus creating a prop scar as the boat enters shallower water.

4.2.3. *Treatment Area 2*

Within Treatment Area 2, there are four significant concentrations (hot spots) of prop scars: two hot spots are associated with unmarked channels or passages (i.e., southwest of Barnes Key and the east/west channel south of the mangrove island between Barnes and Buchanan Keys), one with a marked channel (Barnes Key Channel located east of Barnes Key), and one south of the Buchanan Keys (Figure 23). Within the 1-ac^2 grid cells within these hot spots, ~1-10% of the seagrasses were scarred (Figure 24). Prop scarring along the channels could potentially be a result of poor signage, a lack of navigational markers, or the use of short cuts by boats across the seagrass banks as they navigate between basins or channels. Based upon our review, these factors were particularly evident along Barnes Key Channel. While traveling south, it is possible that boats miss the split at the southern end of the channel and enter the shallow seagrass flat ahead, resulting in prop scars (Figures 23 and 24). Prop scars were also oriented in an east/west direction just south of the split, suggesting that boats created short cuts across the seagrass flat to navigate between channels.

A hot spot was also observed south of the Buchanan Keys (Figure 23). A majority of the prop scars in this area were located adjacent to unmarked channels, across seagrass flats between unmarked channels, and at the boundary separating deeper water from shallow seagrass banks (Figure 23). Similar to the areas near Barnes Key, prop scars adjacent to and between unmarked channels may potentially be associated with the lack of navigational markers and the use of short cuts by boats. The significant clustering of prop scars at the boundary separating deeper water from shallow seagrass banks could potentially have resulted from a lack of understanding between the draft of a boat and water depth. All moats and internal creeks associated with the Buchanan Keys are regulated as ‘closed areas’ by ENP to offer additional protection to wildlife habitat. A few prop scars were observed along the seagrass banks adjacent to the moats surrounding Buchanan Keys (Figure 10), suggesting that boats may be accessing these prohibited areas. This indicates that the regulations posted on the “closed area” signage may be misunderstood, not seen, or ignored by boaters. It is also possible that some of the prop scarring damage was created prior to signage installation in September 2009.

5.0 *In Situ* Monitoring

5.1. Objective

For this study, *in situ* monitoring was conducted to track individual prop scars over time and qualitatively describe changes in prop scar geometry based on passive restoration (i.e., the natural recovery of prop scars over time).

5.2. Methodology

For the *in situ* monitoring effort, the following parameters were collected at a subset (27 locations) of the validated prop scar locations: length (m), scour depth (cm), severity (high vs. low), and surrounding seagrass species. Because prop scar length is a parameter of interest, the locations for *in situ* monitoring were limited to those prop scars with an appropriate scar length (i.e., ≤ 200 m). The length of 200 m was chosen because this was a reasonable distance to collect length measurements given the time allotted for this task. In addition, ~88% of the field validation sampling sites (i.e., 532 of 604) were less than or equal to 200 m. A best effort was made to ensure that the prop scars chosen for *in situ* monitoring represented a variety of habitat types (e.g., varied water depth, species composition, sediment type) and locations (e.g., differing proximities to navigation channels and landmasses) within each project area.

Estimates of prop scar length were collected by poling or trolling along the length of the prop scar at each *in situ* monitoring site, collecting location data throughout the length of the scar using the Trimble unit. Estimates of prop scar scour depth were measured at random locations along prop scars using a PVC pipe (marked in cm). Using the marked PVC, two water depth readings were collected at each *in situ* monitoring site. The first water depth reading was collected in the area directly adjacent to the prop scar and the second water depth reading was collected within the center (relative to the width) of the prop scar. The difference between the two water depth readings provided an estimate of prop scar scour depth (cm). Note that this method does not take into account the variable scour depths that may be present within a single scar. Prop scar severity was assigned to all field validated prop scars. A low severity class was assigned to those prop scars with little to no substrate exposure while a high severity class was assigned to prop scars with extensive substrate exposure.

5.3. Results and Discussion

A total of 27 sites were selected for *in situ* prop scar monitoring (Table 5; Figures 25 and 26). The overall mean length of all *in situ* monitoring scars was ~32 m, and the mean lengths ranged from ~31 m (Treatment Area 2, N=9) to ~35 m (Snake Bight PTZ, N=9; Table 5). The rate of seagrass recovery from prop scarring depends on a variety of factors, including sediment composition, water quality, current velocity, wave and wind energy, drift algae, scar depth, seagrass species, water depth, and latitude (Sargent et al. 1995). Several of these factors were measured at the *in situ* prop scar monitoring sites (Table 5). These data will be compared to data collected during the Year 3 monitoring event in order to qualitatively describe changes in prop scar geometry based on passive restoration.

Table 5. Prop scar length, scour depth, severity, and surrounding seagrass species observed at the *in situ* monitoring sites within each project area.

Project Area	ScarID	Scar Length (m)	Scar Scour Depth (cm)	Scar Severity	Surrounding Seagrass Species*
Snake Bight PTZ	PS3197	14	6	Low	*Hw*
	PS4540	18	12	High	*Hw* and *Tt*
	PS5482	38	5	High	*Hw*
	PS2354	70	12	Low	*Tt*
	PS2390	33	15	Low	*Tt* and *Hw*
	PS1781	10	5	High	*Tt* and *Hw*
	PS3328	51	6	High	*Tt* and *Hw*
	PS3976	31	11	High	*Tt* and *Hw*
	PS4864	46	7	High	*Tt* and *Hw*
Snake Bight PTZ Average		**35**	**9**		
Treatment Area1	PS1812	46	3	High	*Hw*
	PS2028	8	6	High	*Hw* and *Tt*
	PS2348	16	10	High	*Hw* and *Rm*
	PS3752	35	5	High	*Hw*
	PS5944	89	6	High	*Hw* and *Tt*
	PS1821	22	3	Low	*Hw* and *Tt*
	PS2957	12	7	High	*Tt*
	PS4616	29	10	High	*Tt*
	PS5761	30	5	High	*Tt*
Treatment Area 1 Average		**32**	**6**		
Treatment Area 2	PS0435	36	2	Low	*Tt*
	PS2089	13	6	Low	*Tt*
	PS0848	8	5	High	*Tt*
	PS1122	9	4	High	*Tt*
	PS1130	12	9	High	*Tt*
	PS1141	5	9	High	*Tt*
	PS1444	7	5	High	*Tt*
	PS1600	30	7	High	*Tt*
	PS2911	155	11	High	*Tt*
Treatment Area 2 Average		**31**	**6**		
All Areas Average		**32**	**7**		

* Observed seagrass species include Hw (*Halodule wrightii*), Tt (*Thalassia testudinum*), and Rm (*Ruppia maritima*).

Figure 25. Map of field validation prop scar locations, including those selected for *in situ* monitoring within the Snake Bight PTZ and Treatment Area 1.

Figure 26. Map of field validation prop scar locations, including those selected for *in situ* monitoring within Treatment Area 2.

Estimates of seagrass recovery from prop scarring range from as little as 0.9 years (Sargent et al. 1995) to 7.6 years (Andorfer and Dawes 2002). Some researchers have indicated that complete scar recovery may take as long as ten years, depending on the size of the denuded area (Lewis and Estevez 1988). Apical meristems (undifferentiated meristematic tissue found in the rhizomes of seagrass) control rhizome elongation, branching, and shoot production (Hall et al. 2006). When a boat propeller severs a seagrass rhizome, the portion of the seagrass plant lacking an apical meristem cannot grow until a new one is generated (Dawes et al. 1997). *Thalassia testudinum* forms new apical meristems slowly (over months or sometimes years) and its rhizomes branch only rarely (Tomlinson 1974). In contrast, *H. wrightii* can quickly produce new apical meristems (days or weeks) and its rhizomes branch frequently.

Prop scar recovery rates also depend upon scour depth and are much slower with increased depth of disturbance. Hammerstrom et al. (2007) evaluated the effect of scour depth on seagrass recovery in simulated prop scars and found that scour depths exceeding 10 cm had significant effects on the short-shoot counts of *Thalassia testudinum*. This may be partially explained by the morphological characteristics of *T. testudinum*. Approximately 80 to 90% of the dry weight of *T. testudinum* is belowground biomass (Van Tussenbroek 1998; Kaldy & Dunton 2000), and the belowground fraction may extend deeper than 1 m into the sediment (Marba et al. 1994). Shallow disturbances (≤10 cm) likely damage very little of the belowground biomass of *T. testudinum:* thus, shallow prop scars recover quickly due to regrowth of intact short shoots. With deeper disturbances, more of the belowground biomass is damaged and recovery is delayed (Hammerstrom et al. 2007). A majority of prop scar scour depths measured at *in situ* monitoring sites were ≤10 cm. The average scour depth was ~6 cm in Treatment Areas 1 and 2 and ~9 cm in the Snake Bight PTZ (Table 5). Scour depth measurements ≥10 cm were observed at only four sites in the Snake Bight PTZ and at one site within Treatment Area 2. Surrounding seagrass species at these five sites included *Thalassia testudinum* (observed at all sites) and *Halodule wrightii* (observed at three of the Snake Bight PTZ sites; Table 5 and Figure 27). The effects of both scour depth and seagrass species on prop scar recovery will be considered at all *in situ* monitoring sites over time.

Figure 27. Photograph of the two dominant seagrass species, *Thalassia testudinum* and *Halodule wrightii*, observed within the project areas. Photograph taken in the Snake Bight PTZ.

6.0 Management and Recommendations

The objective of the Snake Bight Pole and Troll Zone (PTZ) Monitoring Project is to quantify the amount of prop scarring within the Snake Bight PTZ and compare it to other areas in Florida Bay that do not have enforceable management (i.e., Treatment Area 1 and Treatment Area 2). Treatment Areas 1 and 2 have similar environmental and physical conditions as the Snake Bight PTZ, such as water depth and SAV coverage, but no management strategies designed to reduce prop scarring have been implemented within these areas. The prop scar data collected within the three project areas will be used to measure the success of the management strategy (i.e., implementation of the PTZ or prohibition of internal combustion motor use) within Snake Bight over time. Continued public education and law enforcement will be instrumental in the success and effectiveness of a PTZ within ENP. In addition, focused enforcement efforts in areas where prop scarring patterns indicate that boats frequently pop up onto plane may reduce the potential for additional prop scarring in those areas.

In addition to the implementation of the Snake Bight PTZ, other management strategies have been employed within the Florida Bay. The NPS has taken several steps to promote education regarding shallow water boating, the importance of seagrass habitat, and the rules and regulations of the PTZ. Previous education efforts include public outreach meetings, the release of educational videos and brochures regarding shallow water boating, and the installation of Snake Bight PTZ signage at the Flamingo Marina boat ramp (Figure 4). Additional preventative management options that have been considered include improved aids to navigation and area-specific access limits or closures. It is important to note that one of the “closed areas” within ENP (within the Buchanan Keys) did show signs of prop scarring, indicating that boaters may be accessing this prohibited area. The Snake Bight PTZ project and associated monitoring activities will inform future management decisions and strategies for ENP and will help with implementation of the GMP, once approved.

7.0 Literature Cited

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