Sebastian Inlet Seagrass Monitoring Program

2022 Annual Seagrass Monitoring Report

Sebastian Inlet District

30 January 2023

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Document history

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Client signoff

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1. Introduction

In August 2007 the Sebastian Inlet District (SID) completed the construction of a navigation channel connecting Sebastian Inlet from Channel Markers No.18 and 19 westward to the Intracoastal Waterway (ICW). The purpose of this 3,120-ft long, 10.7-acre (5:1 side slope; -9 ft NGVD) channel extension was to provide the growing maritime community with a safe, clearly designated passage to/from the Atlantic Ocean as a matter of public safety and for the future protection of associated aquatic resources. To offset impacts to 3.08 acres of seagrass habitat and 7.62 acres of non-vegetated soft bottom, and pursuant with the U.S. Army Corps of Engineers (USACE) and the Florida Department of Environmental Protection (FDEP) permits SAJ-2002-7868 (IP-TSD) and 05-264486-001, issued March of 2007, the permittee, the SID, provided the following over the course of a five-year (2008-2012) seagrass mitigation and monitoring program (PBS&J 2011, Atkins 2012, Atkins 2013):

1) The recovery of 459 seagrass planting units (179 *Halodule wrightii*; 279 *Syringodium filiforme*; 1 *Halophila johnsonii*) from the proposed channel alignment and subsequent planting of 41 propeller scars (hereafter, "prop scars"), filling an estimated 366.95 m of linear damage.
2) The balance of financial support needed to install the Indian River County Main Relief Canal Pollution Control Structure, estimated at $750,000.00. The structure came online in July 2008.
3) The establishment and/or monitoring of the St. Johns River Water Management District (SJRWMD) fixed seagrass transect No. 51, plus 9 additional transects in the vicinity of the Main Relief Canal Outfall (Vero Beach, Florida). The monitoring protocol and periodicity followed those previously established and utilized by the SJRWMD. Three baseline monitoring events and eight post-activation monitoring events occurred from May 2007- August 2012.
4) The placement of "*Caution, Shallow Water, Seagrass Area*" signs clearly delineating 145 acres of the flood tidal shoal as seagrass habitat, protecting an initially estimated 110.26 acres (2007) of mixed meadow seagrasses. Current (2022) estimates place this area of live seagrass habitat at 117 acres.
5) The quantification of seagrass coverage within the six designated protected areas ("A" thru "F") using low-level, high resolution, digital orthophotography.
6) A complete inventory and tracking of annual changes to anthropogenic damage within the protected areas.
7) The successful deployment of 2,031 Sediment Tubes® into 32 previously identified propeller-related scars, including 22 significant "blow-out" features. Work was conducted in partnership with Seagrass Recovery, Inc.

The five-year monitoring program associated with the Sebastian Inlet navigation channel was completed in 2012 (Atkins 2013). However, the SID completed the Sebastian Inlet channel realignment project (FDEP Permit No. 05-264486-005-EM) from May 2012 to July 2012, which corrected the severe angle of the channel west of the shoal by widening the turn. The widening resulted in additional seagrass impacts which were included in the available mitigation from the original channel construction project. The widening project resulted in the continuation of an abbreviated version of the seagrass monitoring program (Atkins 2014). As part of this abbreviated monitoring program, the SID continued to quantify seagrass coverage (#5 above) and inventory and tracked anthropogenic damage (#6 above) within the protected areas on the flood tidal shoal over a period of three years (terminating in 2015) (Atkins 2014, 2015, 2016). The SID contracted Atkins to continue the abbreviated seagrass monitoring program in 2016, 2017, 2018, 2019, 2020, and 2021 with a focus on the quantification of seagrass coverage within the protected areas of the flood tidal shoal (Atkins 2017, Atkins 2018, Atkins 2019a, Atkins 2019b, Atkins 2021, Atkins 2022).

During the lead-up to the 2022 seagrass monitoring event, Atkins and SID discussed improvements to the monitoring plan. Shortly before the 2012 realignment, the Indian River Lagoon (IRL) experienced a severe harmful algal bloom and subsequent seagrass die-off which drastically reduced coverage within the monitored protected areas. While the abbreviated monitoring plan has tracked the quantitative area of seagrass regrowth and provided some qualitative data on species composition, little data has been collected on seagrass density. This has become an acute issue since 2021, when the Florida Fish and Wildlife Conservation Commission (FFWCC) declared a statewide Unusual Mortality Event (UME) for the Florida manatee (*Trichechus manatus latirostris*), which has been most severe in the IRL (FFWCC 2022). As such, it was agreed that the 2022 seagrass monitoring event would focus more effort on obtaining species composition and density data across the six protected shoals, as well as discussing options for retaining sand in observed areas of erosion. Conversely, changes were made to the collection of data on anthropogenic damage within the protected areas, i.e., since 2012, field verification of scars has been limited due to the changes in seagrass density and composition.

2. Aerial Image Analysis

2.1. Objectives

To assess changes in the submerged aquatic resources within the protected areas or mitigation zone, a Geographic Information System (GIS)-based approach using low-level, digital aerial photography was implemented in June 2007 and has continued annually thereafter. The 2022 aerial image analysis had four primary objectives:

1) To quantify the aerial extent of existing seagrasses within the mitigation zone (*see Section 2.3.1*),
2) To assess changes to the spatial distribution and aerial extent of seagrass (*see Section 2.3.2*),
3) To identify visible anthropogenic impacts (i.e., prop scarring) within the mitigation zone (*see Section 2.3.3*), and
4) To field verify (hereafter referred to as "groundtruthing") the validity of observations made remotely (i.e., by analyzing the aerials) (*see Section 3.2*).

2.2. Methods

GPI Geospatial, Inc. (previously Aerial Cartographics of America, Inc.) was selected to supply low-altitude, high-resolution, color imagery for the 500-acre region of the shoal. Aerial imagery was captured on May 25, 2022 during an incoming tide. The resultant digital imagery was georectified and had an effective ground pixel resolution of 0.25 feet (Figure 2-1).

To estimate seagrass coverage within the mitigation zone, the 2022 aerial photographs were assessed for the presence or absence of perceived seagrasses (i.e., features that appeared to be seagrasses) using the Environmental Systems Research Institute (ESRI) ArcGIS Pro 2.9 software and recorded manually as a polygonal feature class. All GIS analyses were conducted using source data projected in the State Plane system for East Florida:

Projected Coordinate System: NAD_1983_HARN_StatePlane_Florida_East_FIPS_0901_Feet
Projection: Transverse_Mercator
False_Easting: 656166.66666667
False_Northing: 0.00000000
Central_Meridian: -81.00000000
Scale_Factor: 0.99994118
Latitude_Of_Origin: 24.33333333
Linear Unit: Foot_US

Geographic Coordinate System: GCS_North_American_1983_HARN
Datum: D_North_American_1983_HARN
Prime Meridian: Greenwich
Angular Unit: Degree

Generally, the distinction between seagrass and the surrounding habitat was made while viewing the photography at an absolute resolution of 1:400 to 1:500. In most cases, water depth and clarity provided a seemingly clear view of the benthos (bottom flora), with little ambiguity regarding bed boundaries.

However, during systematic sweeps of the image, several locations were unidentifiable or visually skewed by wave activity, turbidity, color, density (salinity) discontinuity layers, and/or artifacts of image manipulation made during production. These locations, and all positions of uncertainty, were recorded on a separate point feature class (N=8) or polyline feature class (N=16) and visited during the field verification or “groundtruthing” exercise (*see Section 3 Groundtruthing below*).

For the 2022 monitoring event, an additional level of detail was used while delineating the GIS polygons; based on the shading level of the aerial photographs the seagrass polygons were separated into Dense, Medium, and Faint classifications. Dense polygons were used to delineate areas of dark shading where some sort of continuous bottom cover was clearly obscuring the substrate, Medium was for lighter signatures which still stood out against the substrate, and Faint was for light signatures or areas where a contrast with the substrate could not be detected but seagrass presence was deemed likely based on recent monitoring events. This was done for two reasons. First, as the aerials would not be available to the field team during the groundtruthing event, it provided more detailed information; a faint patch that previously would have been indicated by an uncertainty point was now available as a polygon that could be verified in the field. Second, as the data collection in 2022 was intended to provide more information on seagrass density, this allowed species and density data collected at sampling points to be extrapolated to areas of similar visual signature.

In order to provide species and coverage data, a total of 126 sampling points were placed within seagrass polygons delineated from the aerials in GIS; these were given a roughly even distribution with adjustment to capture examples of distinct visual signatures in the polygons. This was done to eliminate a potential issue with using the uncertainty point and polyline features to record species presence as in previous monitoring events; typically, seagrass density was not recorded at these locations and their primary function (resolution of indistinct aerial signatures) skewed the distribution towards sparser areas within the shoals.

As with previous years, suspected propeller scars observed in the aerial images were delineated; however, the focus was shifted from field verification of individual scars to identifying areas of frequent scarring. Efforts to delineate scars in recent years have been hampered by the typically sparse seagrass density; additionally, the dominant species present (*Halodule wrightii* and *Halophila johnsonii*) regrow relatively rapidly after a disturbance. Coupled with the more pressing need to collect shoal-wide data, evaluation of propeller scars and other damage was limited to desktop identification of repeatedly scarred areas.

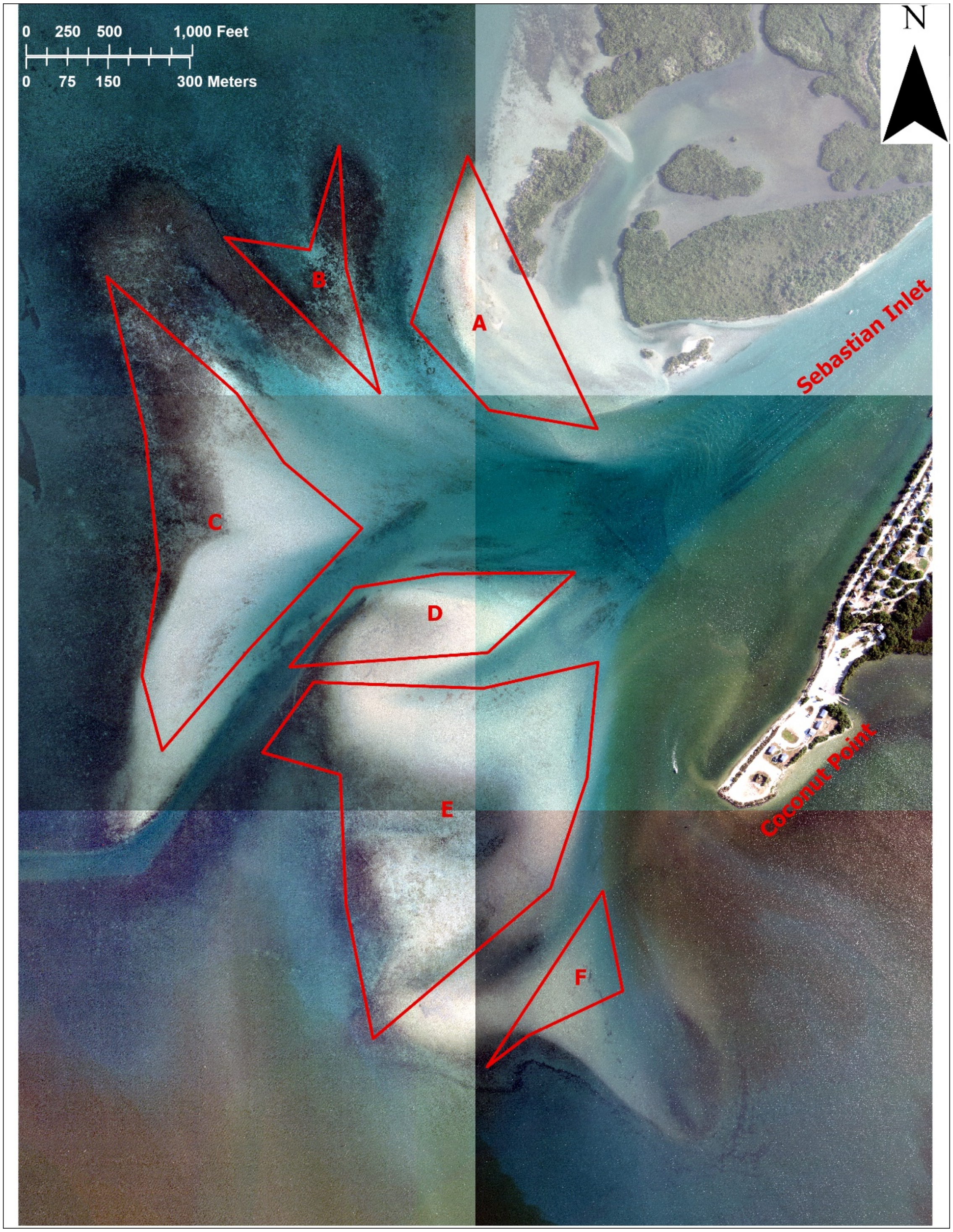


Figure 2-1. Aerial imagery of Sebastian Inlet flood tidal shoal (Florida). The image was taken on May 25, 2022 by GPI Geospatial, Inc. for the Sebastian Inlet District.

2.3. Results

2.3.1. 2022 Seagrass Coverage

The finalized seagrass coverage feature class (post-groundtruthing) yielded ~117.01 acres of seagrass in 2022, equivalent to 81% of the mitigation zone (Figure 2-2). Zone-specific seagrass acreage estimates ranged from 4.93 acres (Zone F) to 52.22 acres (Zone E) with percent cover values (i.e., the percentage of the zone area covered by seagrass) from 45.78% (Zone A) to 99.26% (Zone B). A complete listing of 2022 zone values can be found in the inset table of Figure 2-2.

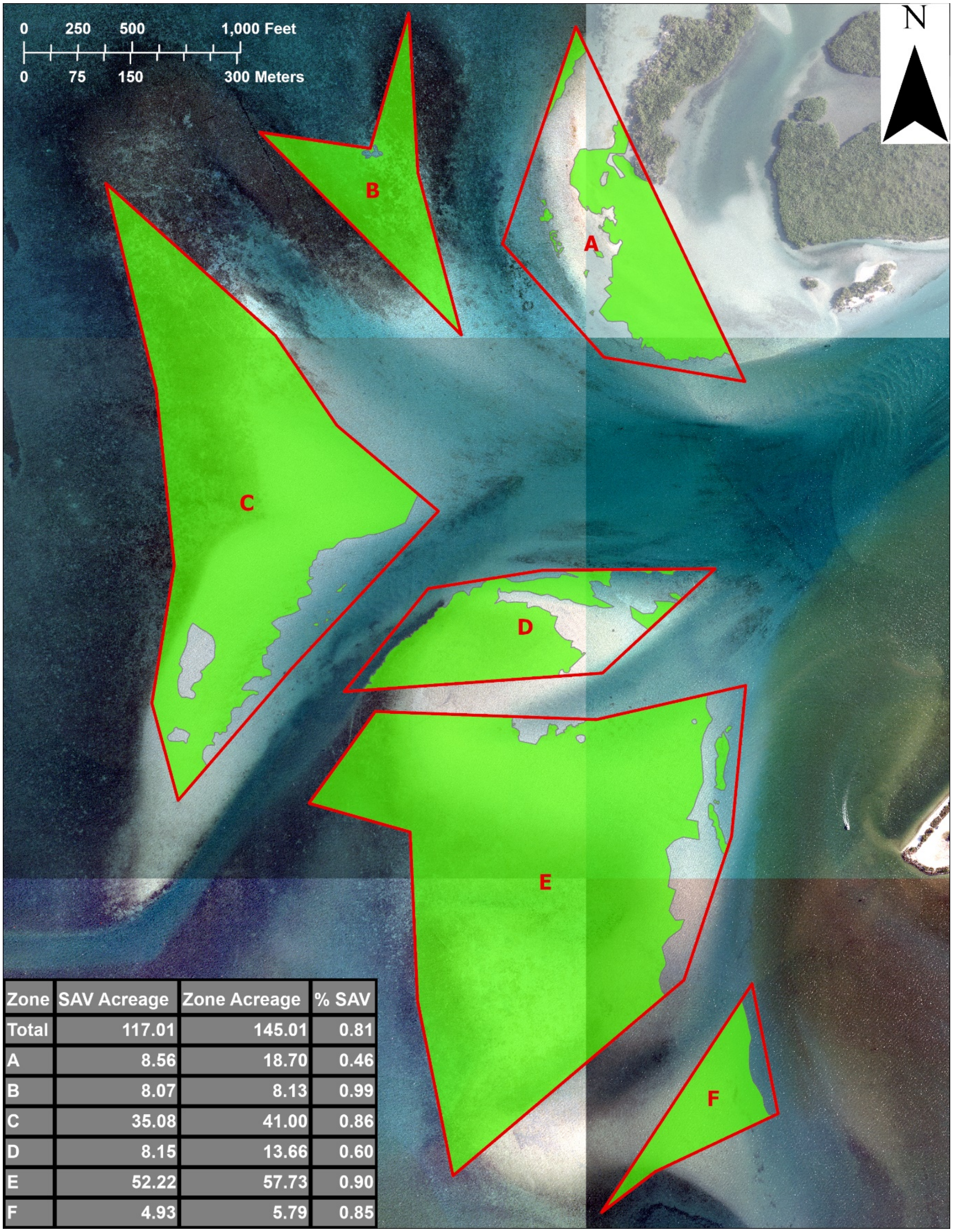
2.3.2. Change Analysis

To estimate changes in the distribution of seagrass within the flood tidal shoal, finalized seagrass coverage feature classes were compared between 2021 and 2022 for regions of “Gain” and “Loss.” ESRI ArcGIS Pro was used to cut the areas of non-overlap from alternating comparisons of the two datasets, leaving a remaining portion as a static region of “No Change.” A visual depiction of these changes can be seen in Figures 2-4 and 2-5.

From 2021 to 2022, there was a decrease in seagrass shoal-wide of 6.03 acres. All zones except Zone A (net increase of 0.91 acres) exhibited net decreases in seagrass coverage ranging from 0.06 acres (Zone B) to 2.88 acres (Zone D) (Figure 2-4). Zones E and F respectively had the highest and lowest total acreage of seagrass in both 2021 and 2022; however, this is unsurprising as these are respectively the largest and smallest shoals. In terms of percent coverage of the zone occupied by seagrass, Zone B had the highest coverage in both 2021 and 2022 (equalled by Zone F in 2021), while Zone A had the lowest coverage in both years.

2.3.3. Propeller Scarring Concentrations

A total of 16 potential propeller scars were identified from aerials, with one in Zone B, five in Zone C, four in Zone D, and six in Zone E (Figure 2-3). No scars were observed in Zones A or F. Of the 16 delineated propeller scars, all but three were concentrated in two distinct areas – the northeast side of Zone C (of which four of the five potential scars share a similar general south-southeast vector) and the westernmost portions of Zones D and E adjoining the channel. As these features were not field-verified, they were not definitively classified as propeller scars; however, the majority are correlated with likely vessel traffic routes.



Zone	SAV Acreage	Zone Acreage	% SAV
Total	117.01	145.01	0.81
A	8.56	18.70	0.46
B	8.07	8.13	0.99
C	35.08	41.00	0.86
D	8.15	13.66	0.60
E	52.22	57.73	0.90
F	4.93	5.79	0.85

Figure 2-2. **ESRI feature class depicting the estimated extent of seagrass within the mitigation zone in 2022. The associated table summarizes area and percent coverage of seagrass by zone. Aerial image taken May 25, 2022.**

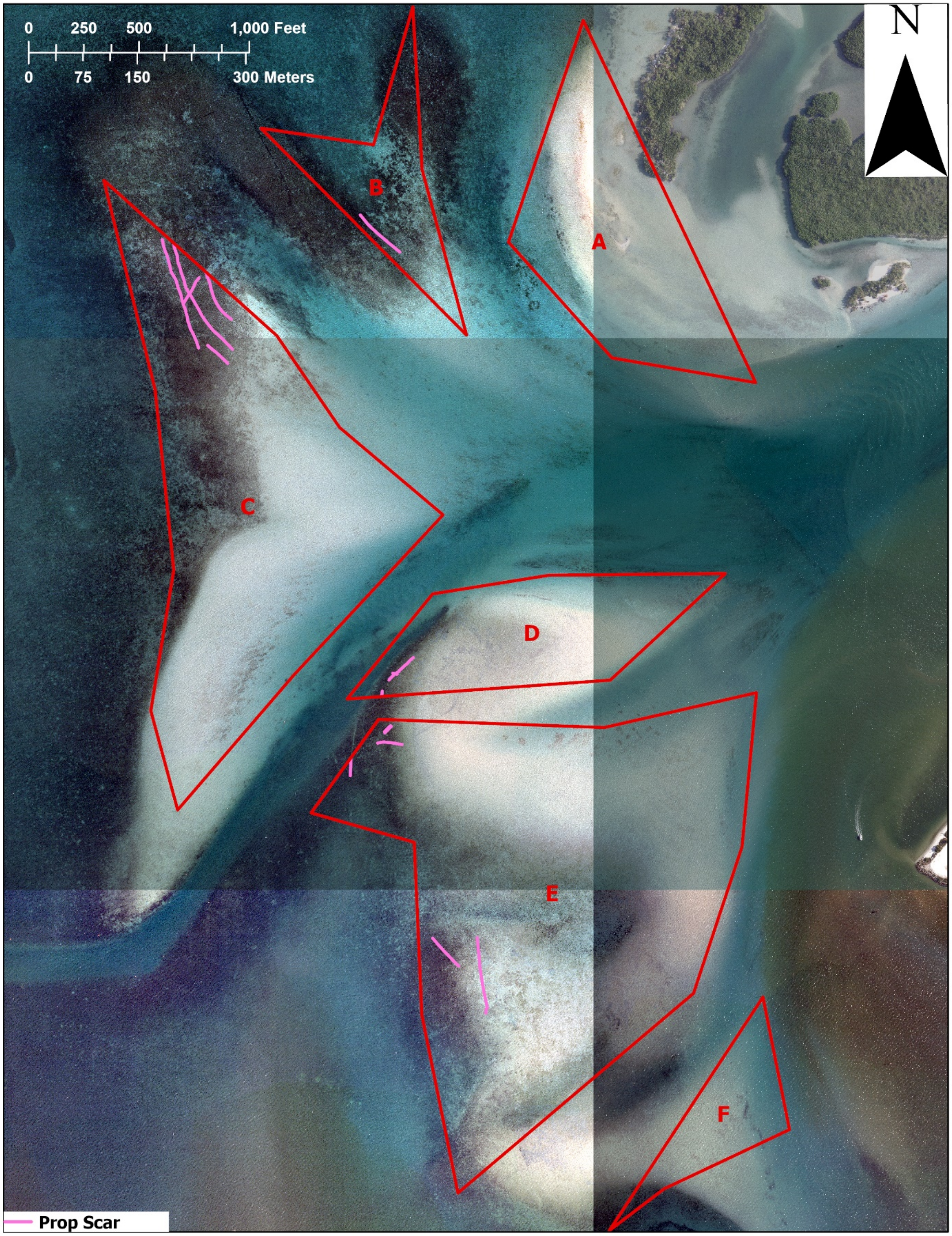


Figure 2-3. Potential propeller scar concentrations mapped from aerials.

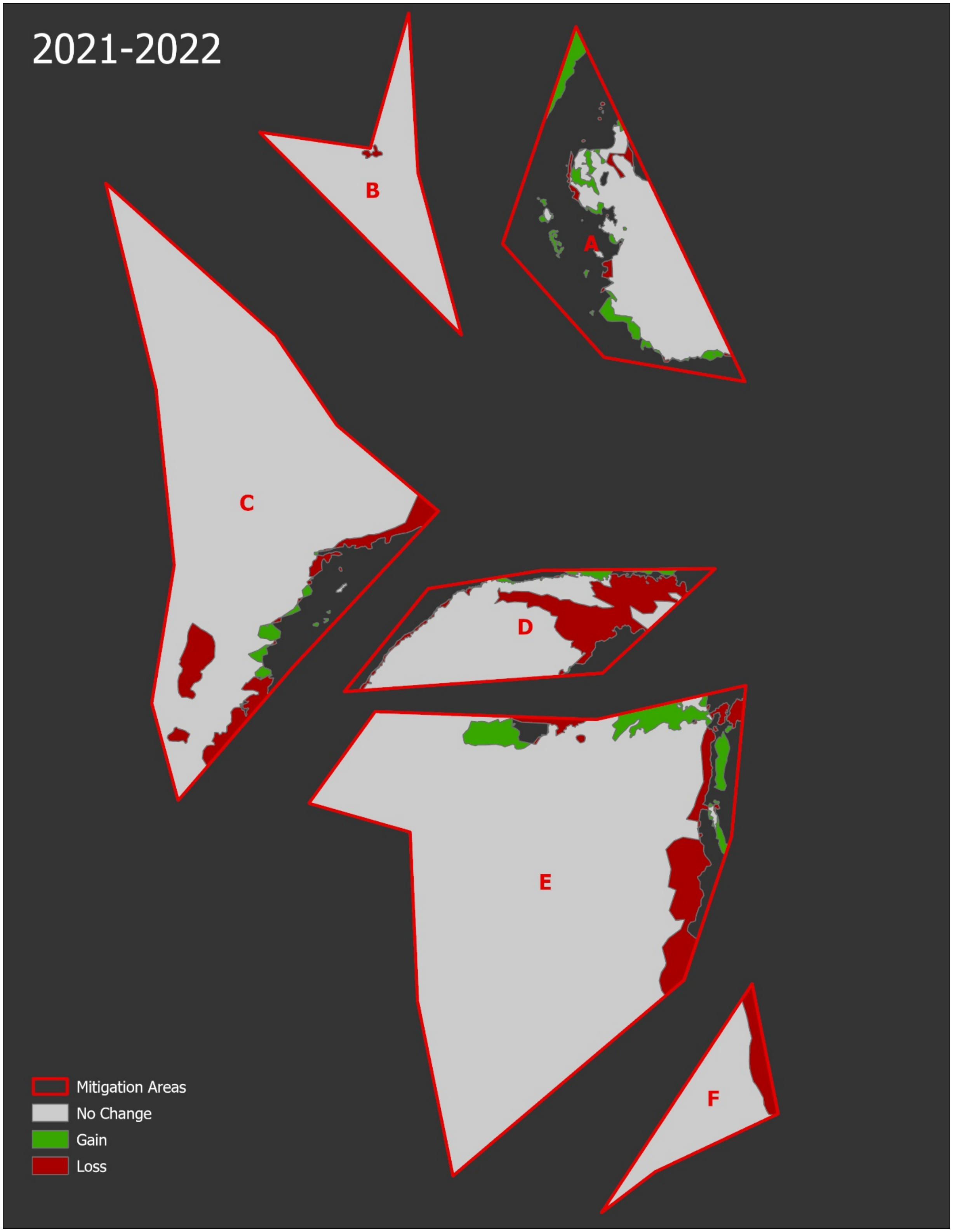


Figure 2-4. Spatial distribution of inter-year change in seagrass coverage within the mitigation boundaries. Gains are depicted as - green, losses - red, and areas consistent between years - gray. Analysis includes 2021 and 2022 data.

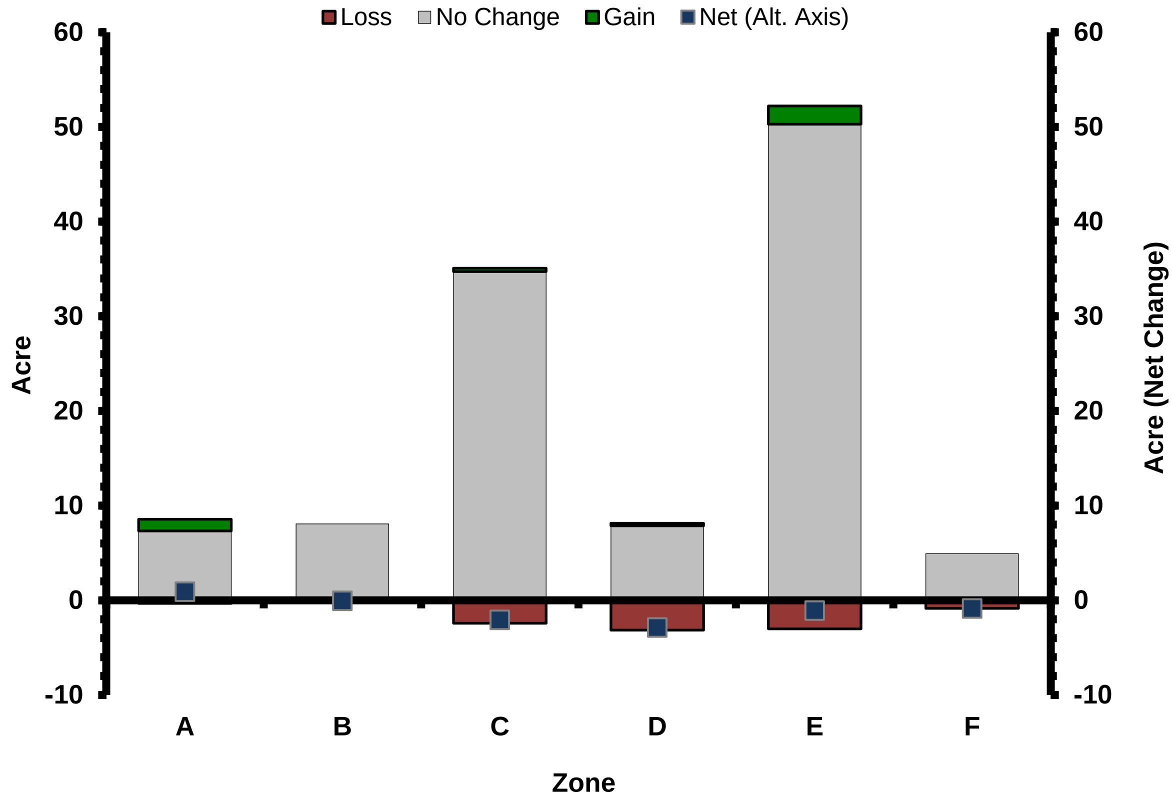


Figure 2-5. Zone-specific changes in seagrass cover (acres) between 2021 and 2022. Net change in total acreage depicted on alternate axis.

3. Groundtruthing/Field Verification

3.1. Objectives

Any attempt to characterize benthic composition from high-resolution aerial imagery presents a suite of technical challenges, including changing optical properties of water with depth and water density, variations in water constituents across the spatial extent of an image (e.g., tannins), reflections caused by an imperfect water surface, and shadows from taller features. These issues are exacerbated at the Inlet by the confluence of two distinctly different water bodies (i.e., sometimes lower salinity, tannin-rich lagoon water and more saline, comparatively clearer, but at times sand/silt containing, nearshore Atlantic Ocean water), creating a heterogeneous mixture of optical properties over a range of depths. Since 2012, aerial interpretation has also been complicated by the large-scale changes in seagrass composition and density on the shoals; sparse distributions of smaller seagrasses such as *Halodule wrightii* and *Halophila johnsonii* are extremely difficult to distinguish from bare sand and the visual signature of these areas may be from other associated material (e.g., drift algae, cyanobacteria, snail eggs) caught in the blades.

Uncertainties with aerial imagery signatures may be compounded by lag time between the aerial flight and actual physical groundtruthing (time needed to produce and review the aerials before fieldwork can be performed). During the 2022 monitoring event, official groundtruthing efforts commenced July 25, 2022, which was 60 days post-flight (aerial imagery collected May 25, 2022). The sampling of the shoal was successfully accomplished using the results of the aerial image analyses and guided by a Trimble R1 handheld DGPS unit, interfacing with a Samsung Galaxy S3 handheld tablet running ESRI Field Maps.

The objectives of the 2022 groundtruthing event were to:

1) Field-verify points or lines (i.e., groundtruthing points or transects) of uncertainty encountered during the aerial image analyses,
2) Collect species and overall percent cover data at designated sampling points,
3) Refine the original seagrass coverage GIS dataset using *in situ* mapping and field annotation.
4) Obtain adjacent seagrass species data for each position visited,
5) Identify areas undergoing erosion and practicable means of retaining sediment, and
6) Delineate the inshore edge of seagrass along the southeast shoreline of Coconut Point.

3.2. Methods

Question points (N=8) were also identified during the 2022 aerial image analysis and generally consisted of areas where seagrass was observed in 2021, yet no visual signature was present in 2022 aerials (Figure 3-1). These question points were uploaded to ESRI Field Maps, which was used for data collection and navigation purposes. Physical confirmation of seagrass presence or absence at each of these sites consisted of a haphazard swim, resulting in a broad assessment of bottom type, as well as seagrass species identification (where applicable). The point feature class was then appended on site and used for later refinement of the bed boundaries within the seagrass coverage GIS dataset.

A total of 16 groundtruthing transects were also identified during the aerial image analysis (Figure 3-1), typically to either confirm the edge of a seagrass bed or to evaluate a larger area of uncertainty. These groundtruthing transects were uploaded to ESRI Field Maps. Biologists performed a broad assessment of the bottom type along these transects including seagrass species identification (where applicable). The polyline feature class was then appended on site. In certain instances, point data were also collected along the transects to signal a change in benthic composition (e.g., seagrass presence/absence or seagrass species observed).

Seagrass percent cover data (both overall and by species) was collected at all 126 sampling points on the shoals, with a roughly even spatial distribution within the originally delineated seagrass polygons, adjusted to capture a range of visual signatures from the aerial images. Within the sampling points, seagrass coverage would be quantified as a whole and by species within a 1 meter by 1 meter area using Braun-Blanquet scoring (Table 3-1). This allowed for a rapid assessment of total seagrass coverage and species-specific coverage at each point.

Using ESRI Field Maps, biologists were able to confirm in real-time the accuracy of the seagrass coverage data and/or collect new seagrass data that were not observed during the aerial image analysis. In these instances, using ESRI Field Maps, biologists collected data around the boundaries of seagrass patches. Point, line, and polygon data were used for refinement of the seagrass bed boundaries within the seagrass coverage GIS dataset. The finalized 2022 seagrass GIS dataset can be seen in Figure 2-2 and was used in all acreage calculations reported within this document.

Braun-Blanquet Score	Percent Cover Range (per m^2)
0	No seagrass present
0.1	Single shoot
0.5	Few (2-5) shoots, < 5% cover
1	Multiple (> 5) shoots, < 5% cover
2	5% - 25% cover
3	25% - 50% cover
4	50% - 75% cover
5	75% - 100% cover

Table 3-1. Braun-Blanquet scoring system.

3.3. Results

3.3.1. Shoal Monitoring

All positions identified during the image analysis and verified in the field to contain seagrass (111 sampling points, 3 question points, and 7 transects), as well as additional seagrass data collected during the groundtruthing event (227 points), were sampled for benthic composition. While in previous years seagrass species composition would be analyzed using the total number of visited features, this approach can skew the dataset. Groundtruthing question points (including points collected as part of the field mapping effort) and transects are more likely to be placed in areas where seagrass cover is sparse and/or dominated by diminutive species, causing disproportionate oversampling of these areas. For consistency with previous reports, Figure 3-2 presents the total seagrass acreage and species composition across all of these features (n=348). Overall, 70.98% of the total sites containing seagrass were monospecific patches, including *Halodule wrightii* (52.59%), *Halophila johnsonii* (14.08%), *Syringodium filiforme* (4.02%), and *Halophila decipiens* (0.29%). The remaining 29.02% consisted of species combinations, including *Halodule wrightii*/*Halophila johnsonii* (the predominant species combination at 21.55%), *Syringodium filiforme*/*Halodule wrightii* (2.59%), *Syringodium filiforme*/*Halodule wrightii*/*Halophila johnsonii* (3.45%), and several other minor (single example) combinations (one of which, the groundtruthing transect along the eastern edge of Zone F, included *Halophila engelmanii*). See Figure 3-3 for reference photos.

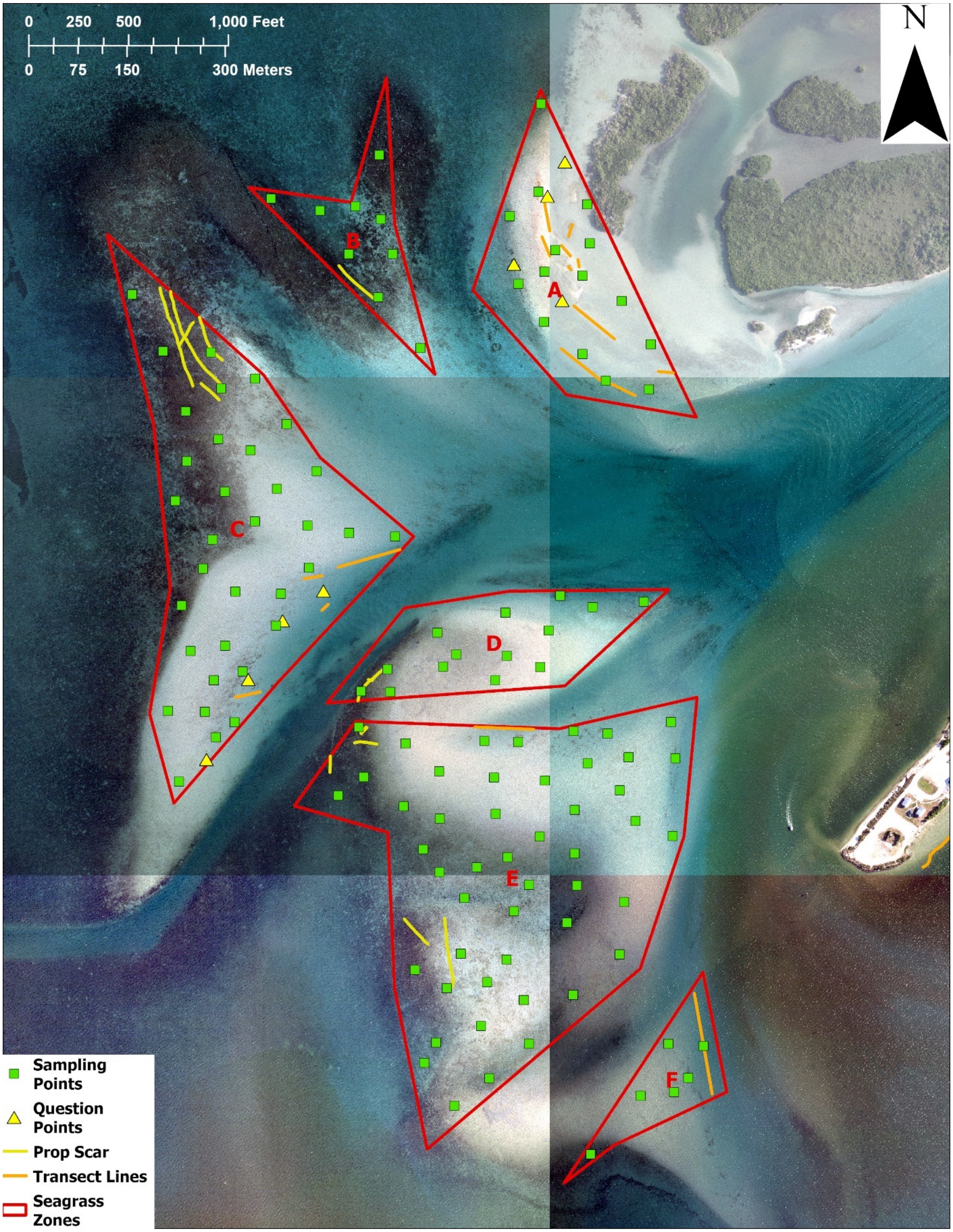


Figure 3-1. Location of potential prop scars, points of uncertainty, and groundtruthing transects established for the 2022 groundtruthing event. Aerial image taken May 25, 2022.

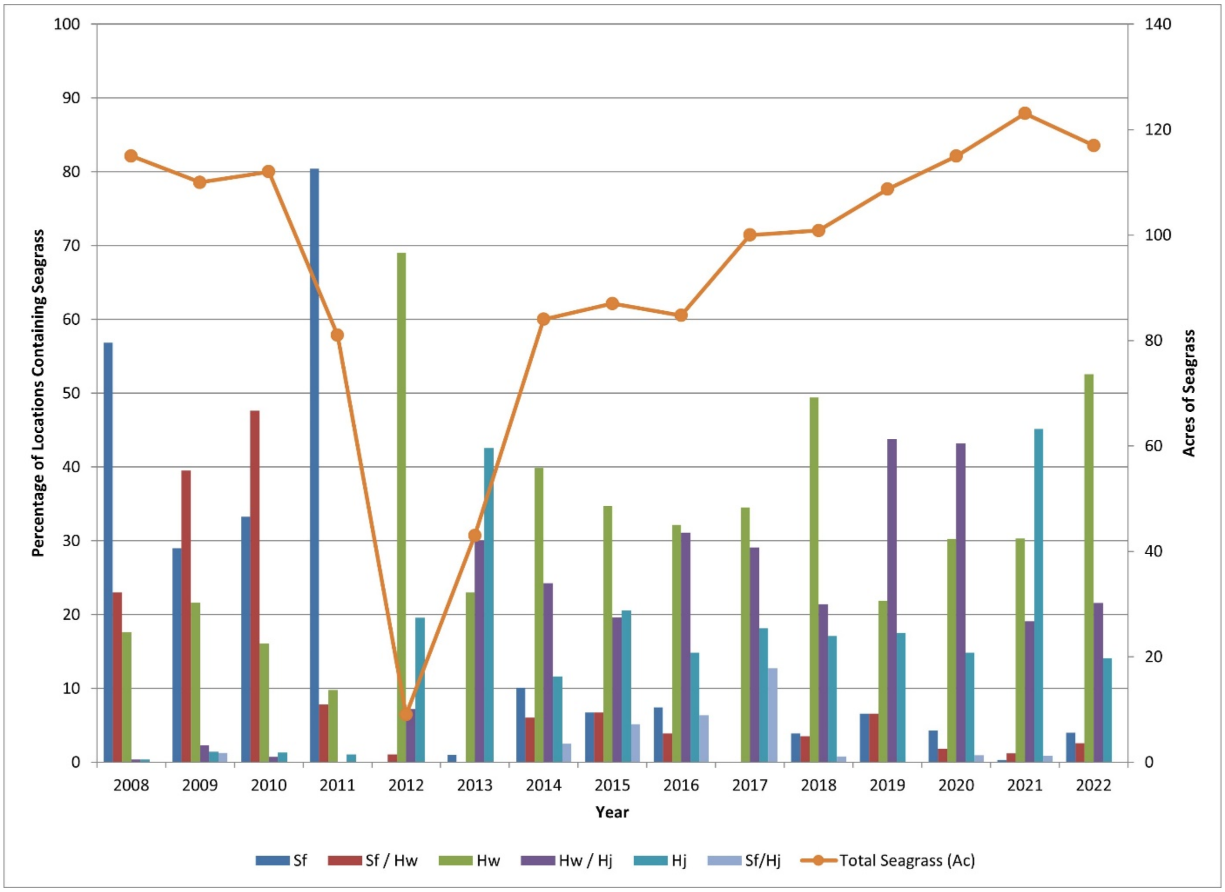


Figure 3-2. **Predominant seagrass species/species combinations observed from 2008 to 2022 (all groundtruth points/transects/propeller scars) showing the effects of and recovery after the region-wide seagrass loss. Abbreviations: Sf = *Syringodium filiforme*, Sf/Hw = *Syringodium filiforme/Halodule wrightii*, Hw = *Halodule wrightii*, Hw/Hj = *Halodule wrightii/Halophila johnsonii,* Hj = *Halophila johnsonii,* and Sf/Hj = *Syringodium filiforme/Halophila johnsonii*. Total seagrass acreage within the mitigation zone displayed on the secondary y-axis.**

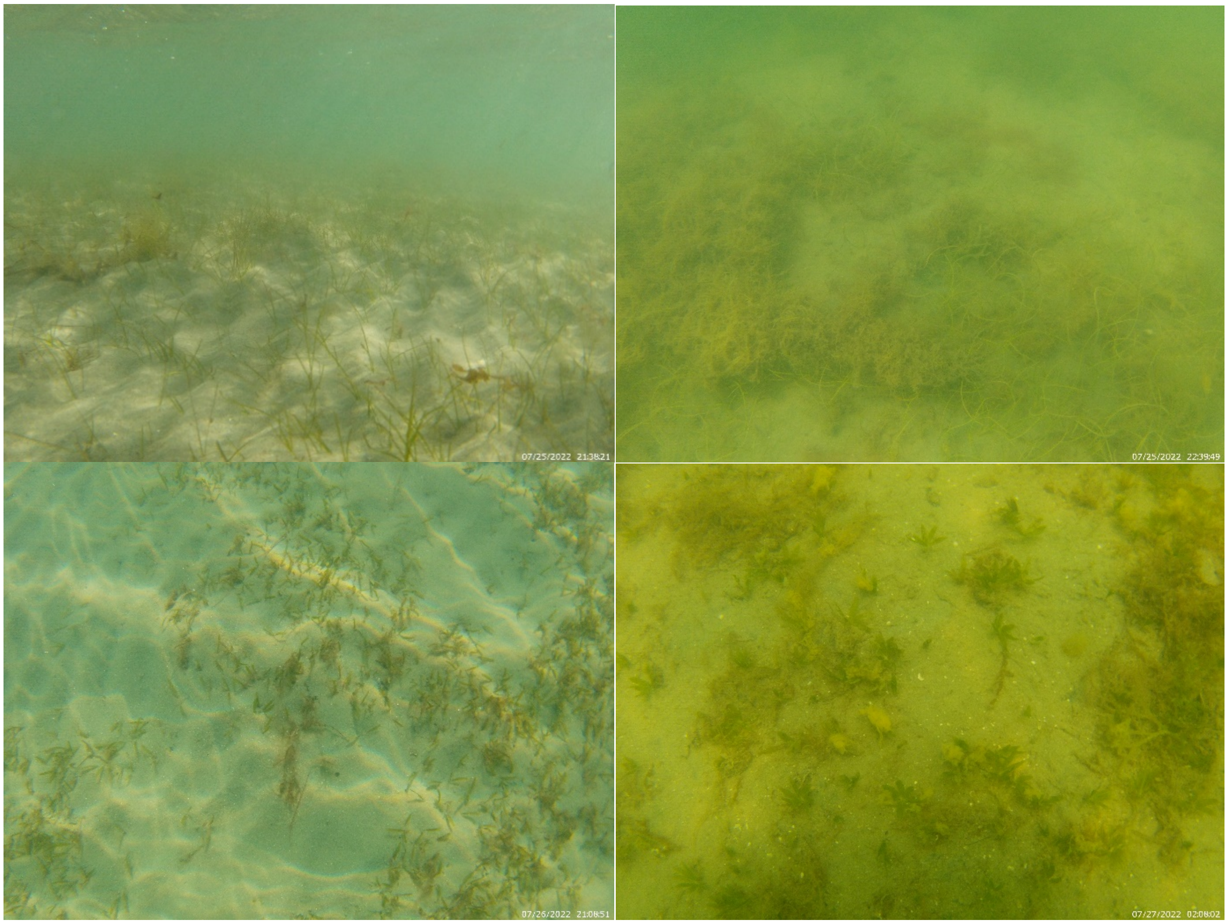


Figure 3-3. Seagrass species found on the shoal in 2022 – *Halodule wrightii* (upper left, Zone E); *Syringodium filiforme* (with attached drift algae; upper right, Zone E), *Halophila johnsonii* (lower left, Zone A); and *Halophila engelmanii* (lower right, Zone F) (not pictured – *Halophila decipiens*).

Analysis of just the quadrat sampling points is less heavily weighted towards monospecific seagrass in general and *Halodule wrightii* and *Halophila johnsonii* in particular, although these two species are still clearly dominant. Of the 126 sampling points, 111 (88.1%) contained seagrass (Figure 3-4). Species-specific data revealed that ~50.5% of the sites that contained seagrass were monospecific patches of seagrass, including *Halodule wrightii* (36%), *Halophila johnsonii* (12.6%), *Syringodium filiforme* (0.9%), and *Halophila decipiens* (0.9%). The remaining ~49.5% consisted of species combinations, including *Halodule wrightii/Halophila johnsonii* (the predominant species combination at 30.6%), *Syringodium filiforme/Halodule wrightii* (6.3%), *Syringodium filiforme/Halodule wrightii/Halophila johnsonii* (10.8%), *Syringodium filiforme/Halodule wrightii/Halophila decipiens/Halophila johnsonii* (0.9%), and *Halophila johnsonii/Halophila decipiens* (0.9%).

Figure 3-4 depicts the total Braun-Blanquet scores and distributions for all seagrass species across the shoals. Figures 3-5, 3-6, and 3-7 depict the Braun-Blanquet scores and distributions for *S. filiforme*, *H. wrightii*, and *H. johnsonii* respectively. The total average Braun-Blanquet score for all seagrass species across all quadrats was approximately 3, or a 25-50% coverage range; scores in Zones B and E averaged between 3 and 4, scores in Zones C, D, and F averaged between 2 and 3, and scores in Zone A averaged slightly below 2 (5 to 25%).

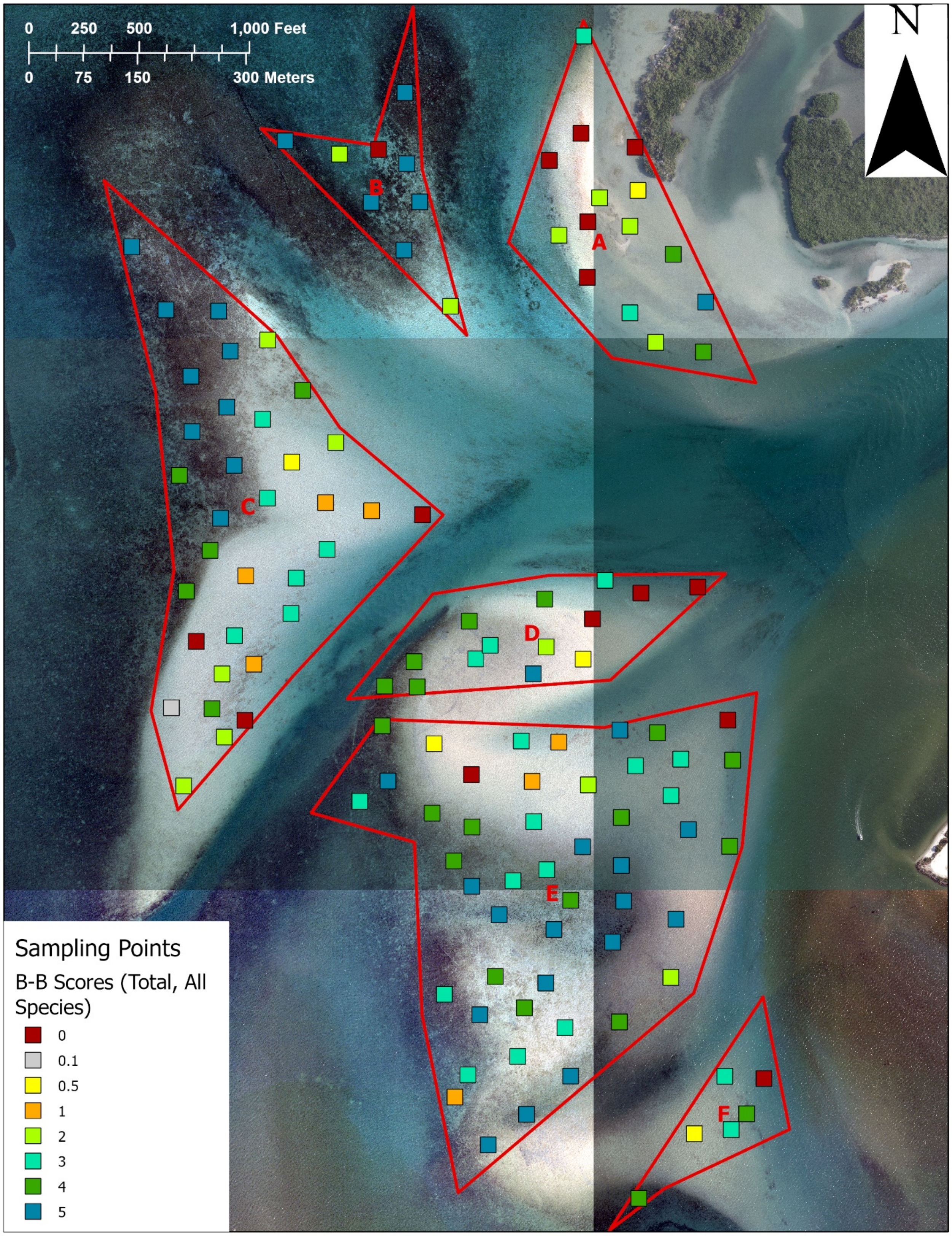


Figure 3-4. Total (all species) Braun-Blanquet (B-B) score results for predetermined seagrass sampling points.

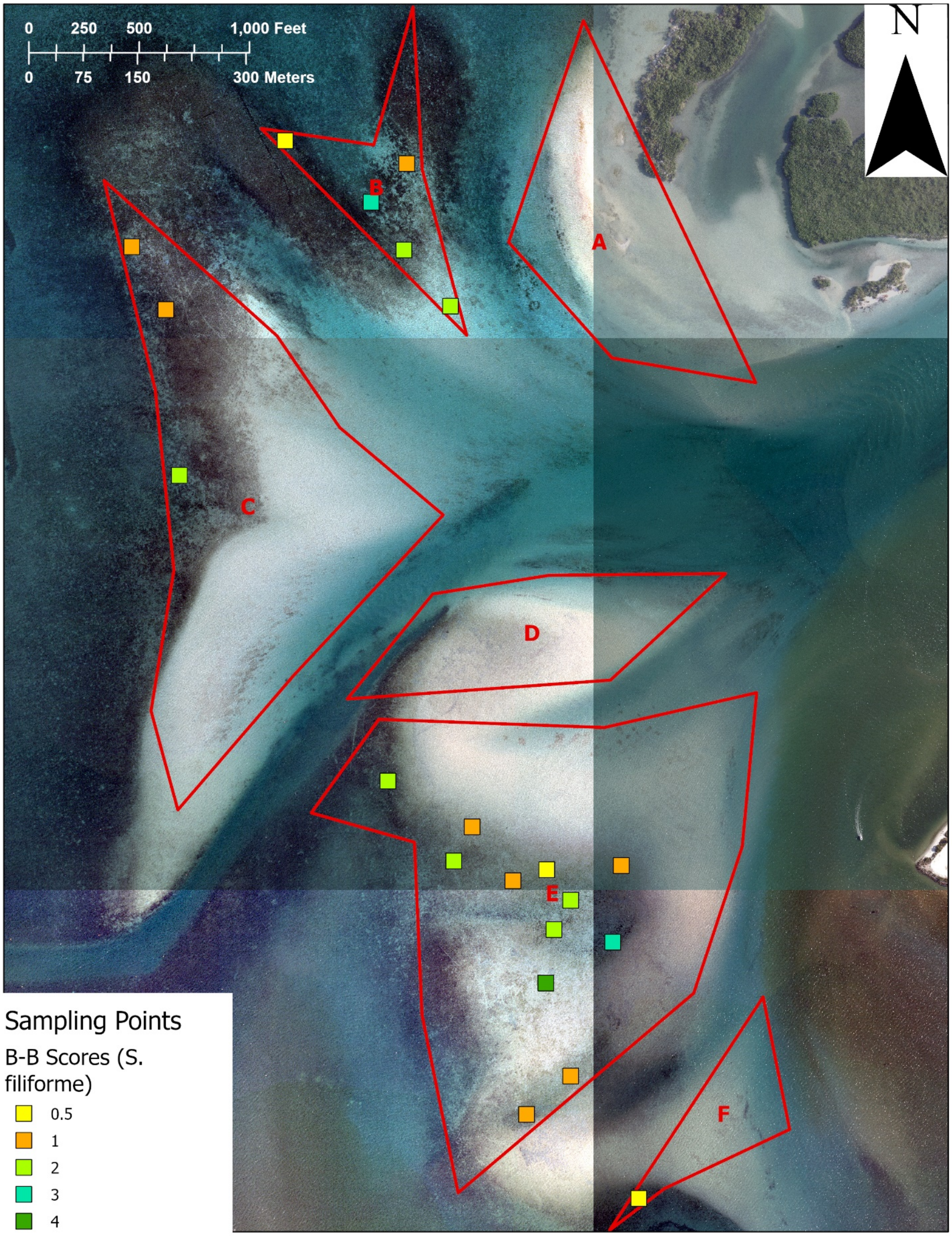


Figure 3-5. Sampling point locations and Braun-Blanquet (B-B) score results for points containing *Syringodium filiforme*.

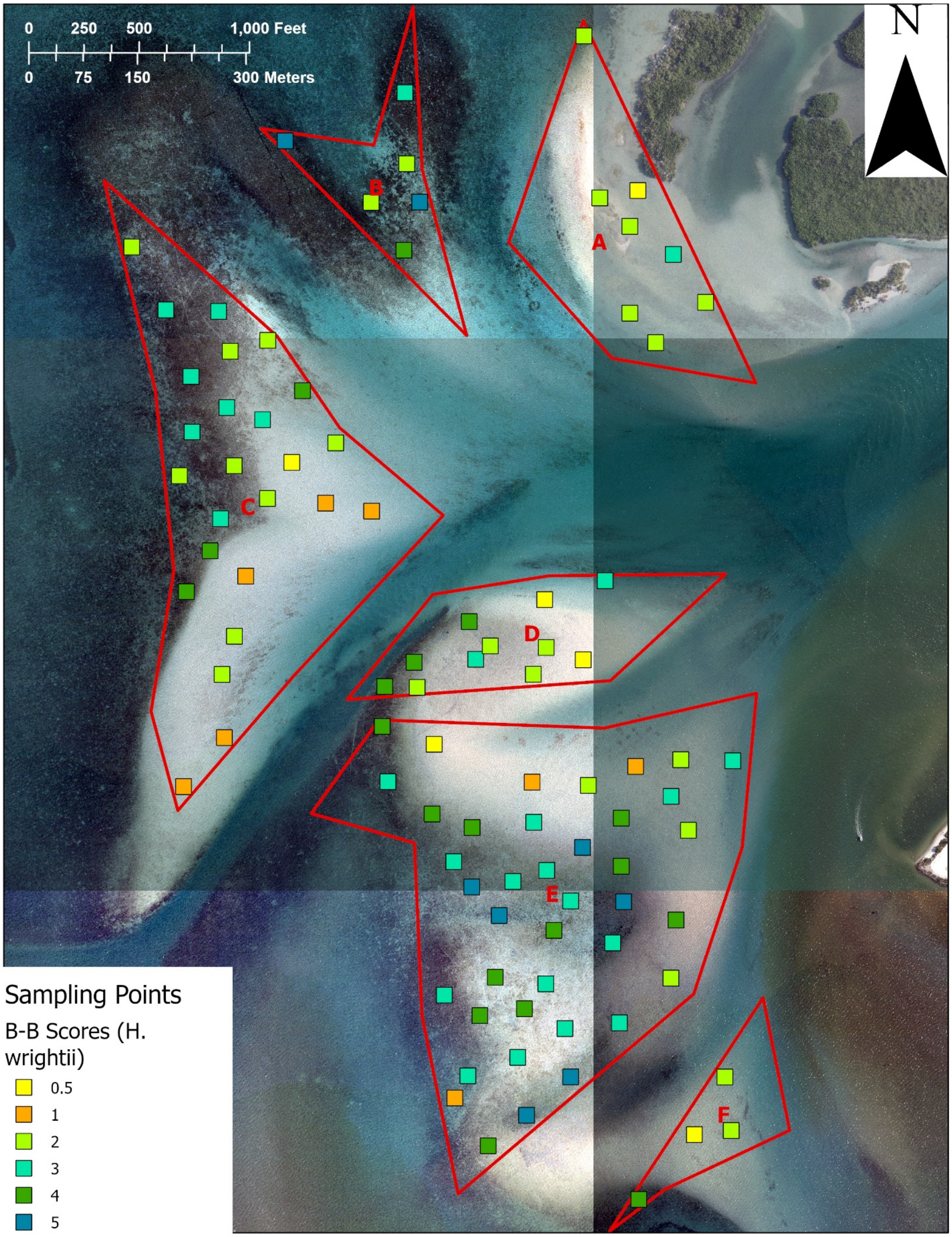


Figure 3-6. Sampling point locations and Braun-Blanquet (B-B) score results for locations containing *Halodule wrightii*.

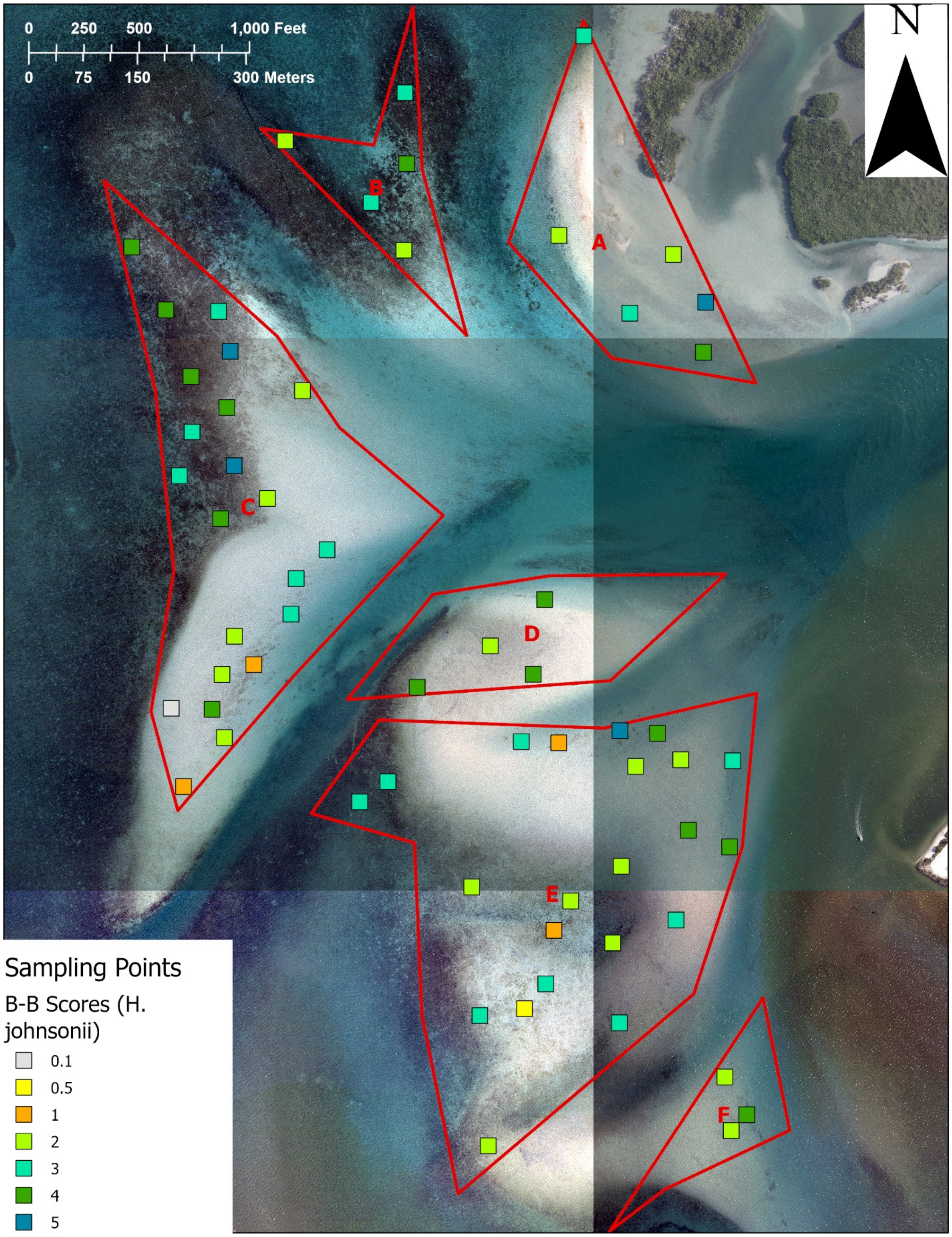


Figure 3-7. Sampling point locations and Braun-Blanquet (B-B) score results for locations containing *Halophila johnsonii*.

3.3.2. Coconut Point Shoreline Seagrass Edge

As an additional scope item for the 2022 monitoring event, SID requested the Atkins delineate the nearshore seagrass edge along the southeast side of Coconut Point (for a straight-line distance of approximately 600 linear feet), south of the Sebastian Inlet State Park boat ramp. The seagrass line was collected in the field using the R1 and ESRI Field Maps to collect a polyline feature tracing the inshore edge (Figure 3-8). The northern portion of this seagrass edge (approximately 380 linear feet) conformed to the shoreline, with the southern edge being 25-65 ft offshore. The shoreline edge along the southern part of this line is severely eroded, with rubble strewn between the current shoreline and the nearshore seagrass edge. Most likely, the offset is due to erosion of the shoreline, rather than recession of the seagrass edge. Species composition was sparse (~30% coverage) *Halodule wrightii*; clumps of cyanobacteria were observed attached to the grass blades, indicating some level of stress on the grass.

Figure 3-8. Coconut Point shoreline viewed from the south end of the assessment area, looking northeast along the shoreline. Erosion at south end of the shoreline and cyanobacteria growing on seagrass and rubble visible.

Figure 3-9. Nearshore seagrass edge mapped along southeast shoreline of Coconut Point on July 28, 2022.

4. Discussion

4.1. 2022 Seagrass Coverage Data

From 2021 to 2022, Atkins documented a net decrease in seagrass coverage of 6.03 acres across the six marked flood tide shoals (Zones A-F). Almost half of this (2.88 acres) was from Zone D, with another 2.06 acres lost from Zone C, 1.09 acres from Zone E, and 0.86 acres from Zone F. Zone B had a minor net loss of 0.06 acres from 2021; however, it should be noted this zone was at 100% coverage in 2021. Zone A had a net gain of 0.91 acres from 2021; however, this zone still had the lowest proportional coverage at 46%. It should be noted that of the 117.01 acres of seagrass mapped, 113.21 acres was retained from the 2021 seagrass area (approximately 80% of 2021's 123.04 acres). Seagrass losses in Zones E and F were largely on the eastern edges of the shoals, although in Zone E this was somewhat offset by new seagrass patches appearing or expanding east of the previous 2021 limits. This pattern was also observed along the south (channel-facing) side of Zone C, although bare patches opened up within the southwestern interior portion of the shoal. In Zone D, a large swath along the east-central portion of the shoal was unvegetated.

It is possible these are short-term losses. Of the two seagrass species that dominate the shoals, *Halophila johnsonii* can be ephemeral in nature; it was subject to a June 1 – September 30 survey window when it was listed as a Threatened species under the Endangered Species Act (ESA). While the field groundtruth survey was done in late July 2022, which should have been the height of the growing season, it is possible these areas were temporarily barren and could rapidly revegetate. Except for the southeastern corner of Zone E, the observed losses were in areas that during the post-2012 recovery period have been among the slowest and most tenuous to regain seagrass coverage. In particular, a large portion of the lost Zone D acreage (the swath almost cutting the main seagrass bed in half from southeast to northwest) was in an area that had been a narrowing sandy area across the shoal from 2012 until 2021 (see Figures 4-3 to 4-7), and even in 2021 the seagrass coverage in this area was noted to be extremely sparse with isolated shoots of *Halodule wrightii* and/or *Halophila johnsonii*.

Other potential causes for the observed seagrass losses are sand movement and/or vessel utilization. Prior to 2011, the eastern portion of Zone D was known to experience sand shoaling that displaced or buried seagrass (evident in 2007-2010 aerial imagery and gain-loss analyses; see Figures 4-1 and 4-2). Previously, this was attributed to overflow from the inlet sand trap just to the northeast of Zone D. During the 2022 groundtruthing field effort, portions of this area were only covered by about 6 inches of water near a slight (0.3 ft peak) high tide. During the groundtruth survey, this area was also frequented by recreational boaters; on the first morning of the groundtruth survey at least seven outboard craft (as documented by photos) were anchored around this portion of the shoal. While there was no obvious sign of vessel-related disturbance in this area (i.e., sand disturbance or excavation), it's possible that high anchoring and wading traffic could degrade seagrass coverage.

4.2. Long-Term (2010-2022) Changes

The Sebastian Inlet flood tide shoals have undergone a drastic change in seagrass cover over the past decade. Prior to 2011, the dominant seagrass species on the shoals were *Syringodium filiforme* (present in approximately 67% of locations visited in 2010) and *Halodule wrightii* (present in approximately 53% of locations visited in 2010). *Halophila johnsonii* was only present in 2% of the seagrass locations sampled in 2010 (PBS&J 2011). Seagrass coverage was estimated at nearly 112 acres; seagrass density was not recorded at the time but both aerial and in situ field photographs show dense, thick grass beds (Figures 4-1 and 4-2). The following year coverage dropped to approximately 81 acres, with seagrass losses most evident on the west side of Zone C – the area farthest from the channel and likely least exposed to tidal flushing, as can typically be observed by the presence of tannic water in the aerials (Atkins 2012). *Syringodium filiforme* continued to be the dominant species, being identified in 89% of locations visited, while *Halodule wrightii* was only present in approximately 18% of locations visited (Figure 4-2). In 2012 seagrass coverage fell to approximately nine acres, with Zones B and F essentially defoliated, Zones C and D reduced to small patches, and continuous grass pockets in the shallows of Zone A and the northeast tip of Zone E (Figure 4-3) (Atkins 2013). This widespread loss of seagrass is believed to have been the result of a large-scale phytoplankton bloom lasting from early spring to late fall 2011; while the Sebastian Inlet area was less affected than other parts of the IRL, cyanobacteria rafts were observed throughout the shoals during the 2011 field event (Atkins 2012). Notably, in 2012 *Syringodium filiforme* was found in only about 1% of seagrass locations visited; the majority of locations were either monospecific patches of *Halodule wrightii* (the dominant species) or *Halophila johnsonii*.

Despite the widespread loss of seagrass acreage in 2011-2012, in 2013 and 2014 a rapid recovery of seagrass acreage on the shoals occurred, plateauing in 2014-2016 and then continuing a general upward trend from 2016 onwards (Figures 4-3 to 4-7). The 2021 aerial delineation and groundtruthing survey results indicated that total seagrass coverage across Zones A-F had exceeded the acreage present in 2010 prior to the die-off, with 123 acres of seagrass mapped (Atkins 2022). While the 2022 results saw a net decline of approximately six acres from 2021, the mapped extent of grass is still above what was present prior to the 2011 algal bloom. However, a focus on acreage totals does not provide a complete picture, and the changes to the Sebastian Inlet shoals over the past decade have presented new challenges for gathering data.

A particular challenge during the post-bloom recovery has been gathering qualitative and quantitative data on seagrass composition on the shoals. In previous years, seagrass species composition (but not density) has been recorded at all GPS point, line, and polygon features collected in the field. The problem is that as part of the groundtruthing process, these locations tend to be concentrated in areas where the visual signature of seagrass is not evident or unclear in aerial images, creating an uneven sampling distribution. Even the addition of random sampling points across the shoals, which was used in the 2020 and 2021 monitoring events, tended to be "washed out" by the number of points recorded when verifying uncertain visual signatures or delineating seagrass beds in the field. As a result, while the previous dataset does provide some useful qualitative data on seagrass species distribution across the shoals, there is little to no quantitative data on seagrass density and the quantitative species abundance data in some years is skewed. In particular, Zone A is usually difficult to delineate from aerial images and large numbers of groundtruth points tend to be clustered on this shoal.

Since 2012, *Syringodium filiforme* has typically featured in an extremely small percentage of seagrass locations sampled (23% or less, with some years as low as 1-5%). In 2022, when analyzing the total dataset (all quadrat sampling points, groundtruth points, and groundtruth transects), a total of 38 locations (approximately 10.92% out of 348) contained *Syringodium filiforme*. When analyzing just the more evenly distributed quadrat sampling points, that proportion rises to 18.92% (present in 21 locations out of 111). As the proportions of locations containing *Halodule wrightii* and *Halophila johnsonii* are also higher when considering only the quadrat sampling locations, this appears to be due to the nearly even split between multi-species and single-species sampling locations, versus the > 70% proportion of monospecific sampling locations for the entre groundtruth dataset. It should be noted that in both the total (n=348) and sampling quadrat-only (n=126) datasets, *Syringodium filiforme* was most often found associated with *Halodule wrightii* and *Halophila decipiens* and was seldom found in monospecific patches.

The changes to seagrass density and species composition since 2011-2012 have likely affected the overall seagrass biomass available on the shoals. *Syringodium filiforme* has cylindrical blades which can grow to approximately 18 inches in length; *Halodule wrightii* and *Halophila johnsonii* both have flat blades that are significantly shorter. As such, while the overall seagrass acreage may have returned to or exceeded pre-2011 totals, the average density (25-50% per the 2022 quadrat sampling data) and reduced coverage of *Syringodium filiforme* likely represents an exponential reduction in seagrass biomass from prior to 2011. This is of particular note since the 2021 declaration of an Unusual Mortality Event (UME) for the Florida manatee population, with 637 manatee deaths recorded statewide in 2020, 1,101 in 2021, and 800 in 2022 (FFWCC 2022). Of these, the largest shares for each year (173 in 2020, 358 in 2021, and 346 in 2022) were recorded in Brevard County waters. While the Florida Fish and Wildlife Conservation Commission and U.S. Fish and Wildlife Service are still investigating the UME, starvation is currently believed to be the key driver of this mortality event. During the aerial interpretation phase of the 2022 monitoring event, at least five manatees were identified grazing within Zones D and E in the May 25 aerial images (Figure 4-8). Notably, these were seen in more densely vegetated areas.

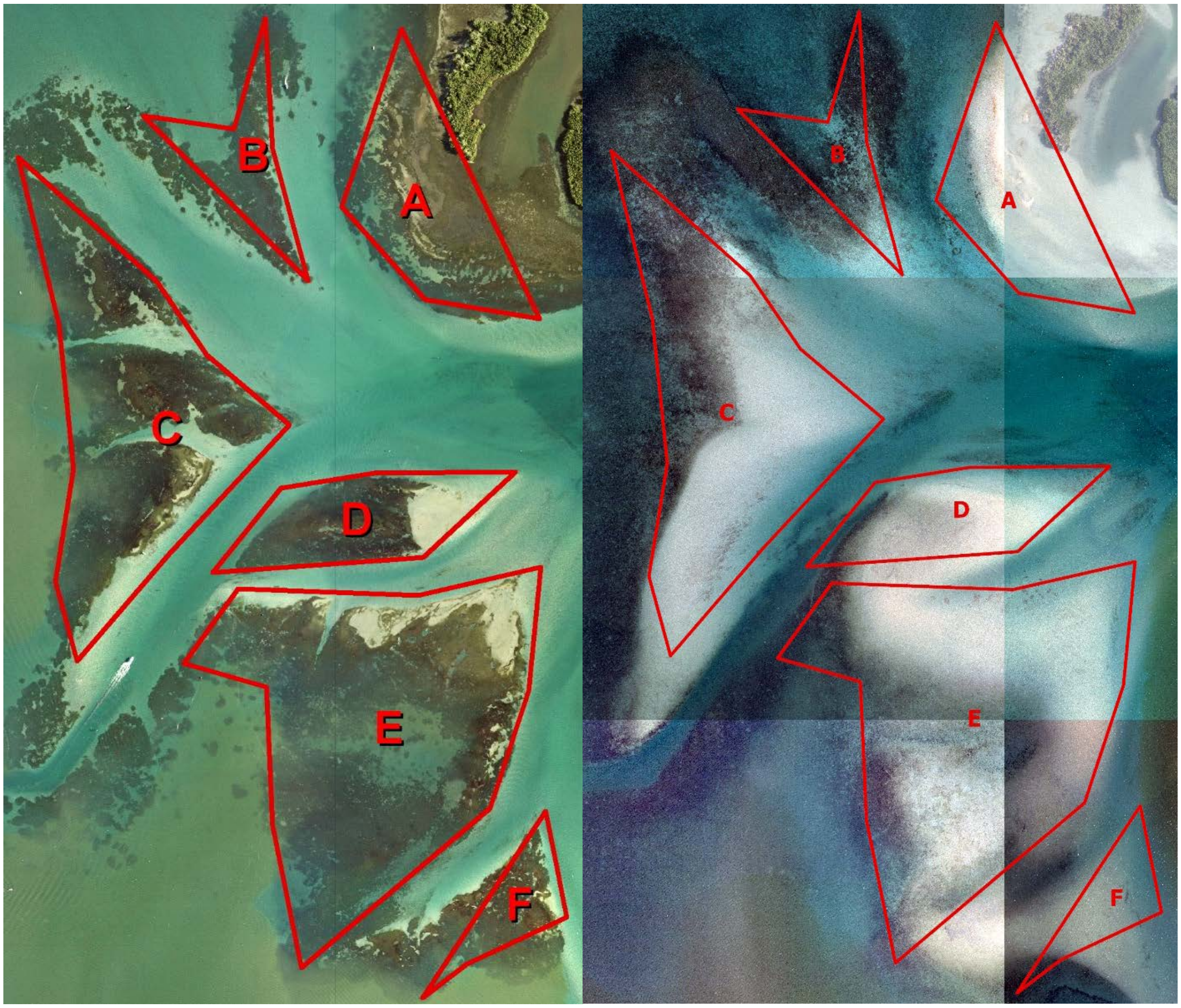


Figure 4-1. **Aerial images from 2010 (left, Atkins 2011) and 2022 (right), showing the change in visual signatures since the 2011-2012 seagrass die-off.**

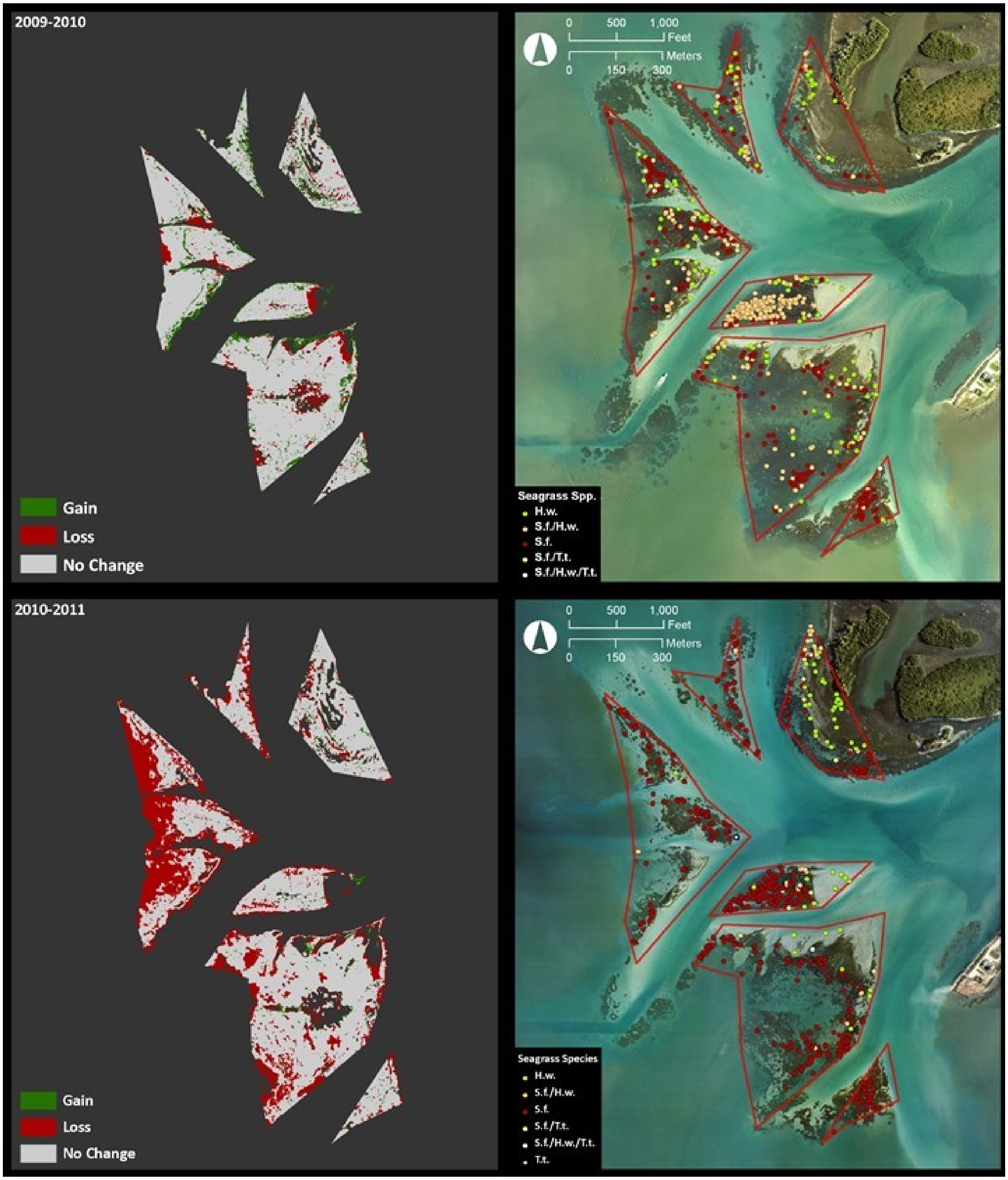


Figure 4-2. Year-to-year seagrass gain/loss changes and species distributions from 2009 to 2010 (top, PBS&J 2011) and 2010-2011 (bottom, Atkins 2012).

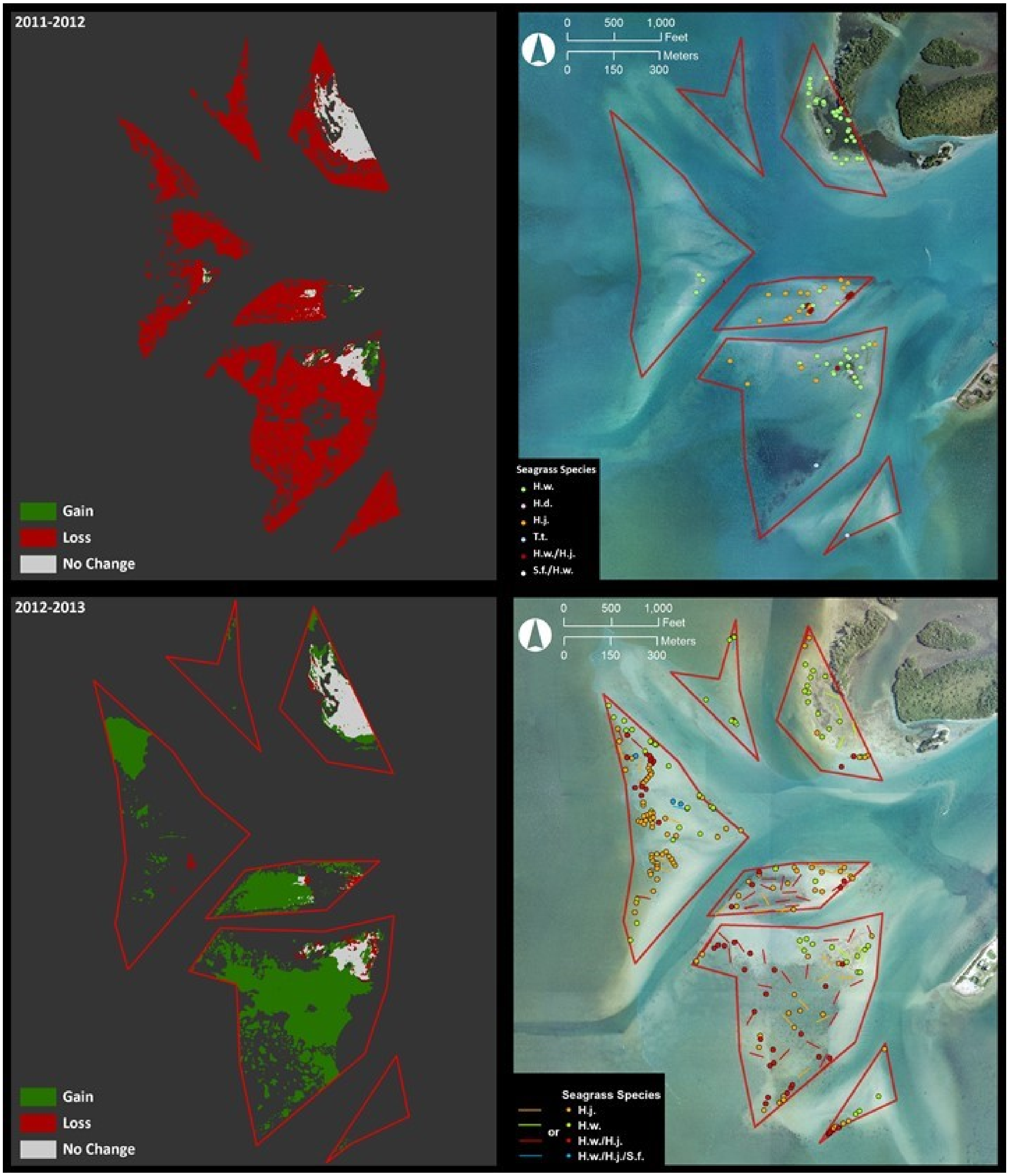


Figure 4-3. Year-to-year seagrass gain/loss changes and species distributions from 2011 to 2012 (top, Atkins 2013) and 2012-2013 (bottom, Atkins 2014).

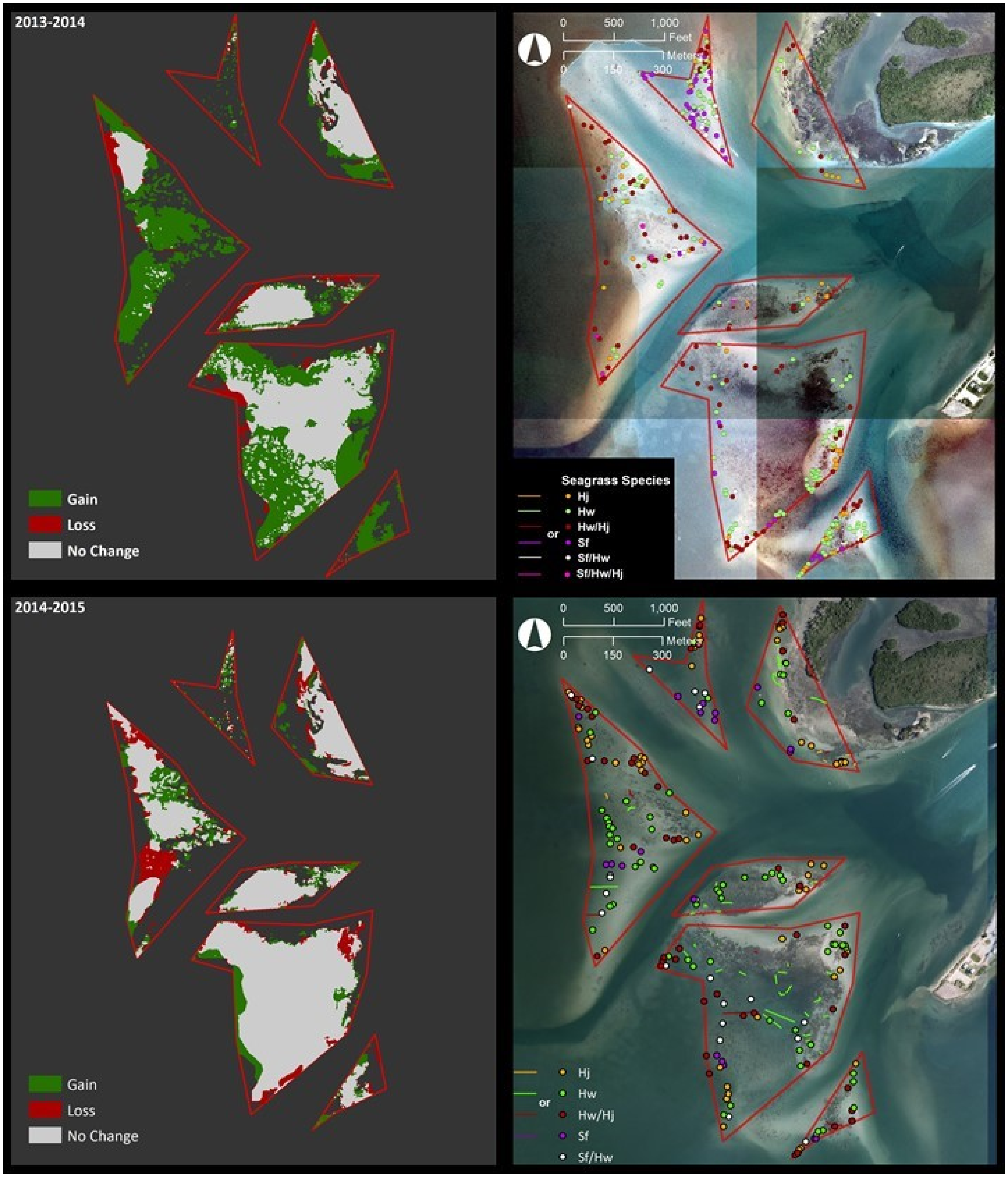


Figure 4-4. Year-to-year seagrass gain/loss changes and species distributions from 2013 to 2014 (top, Atkins 2015) and 2014-2015 (bottom, Atkins 2016).

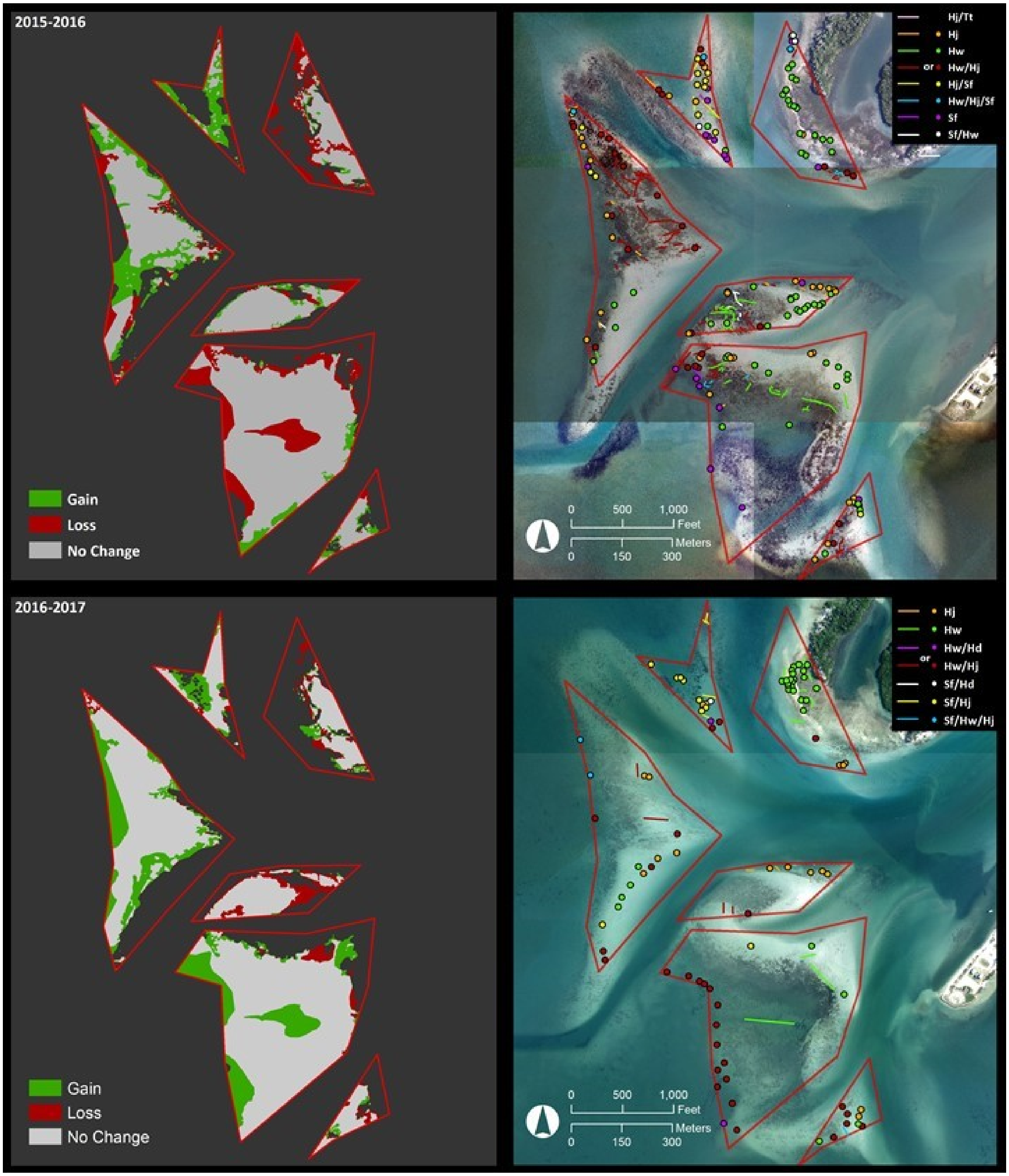


Figure 4-5. Year-to-year seagrass gain/loss changes and species distributions from 2015 to 2016 (top, Atkins 2017) and 2016-2017 (bottom, Atkins 2018).

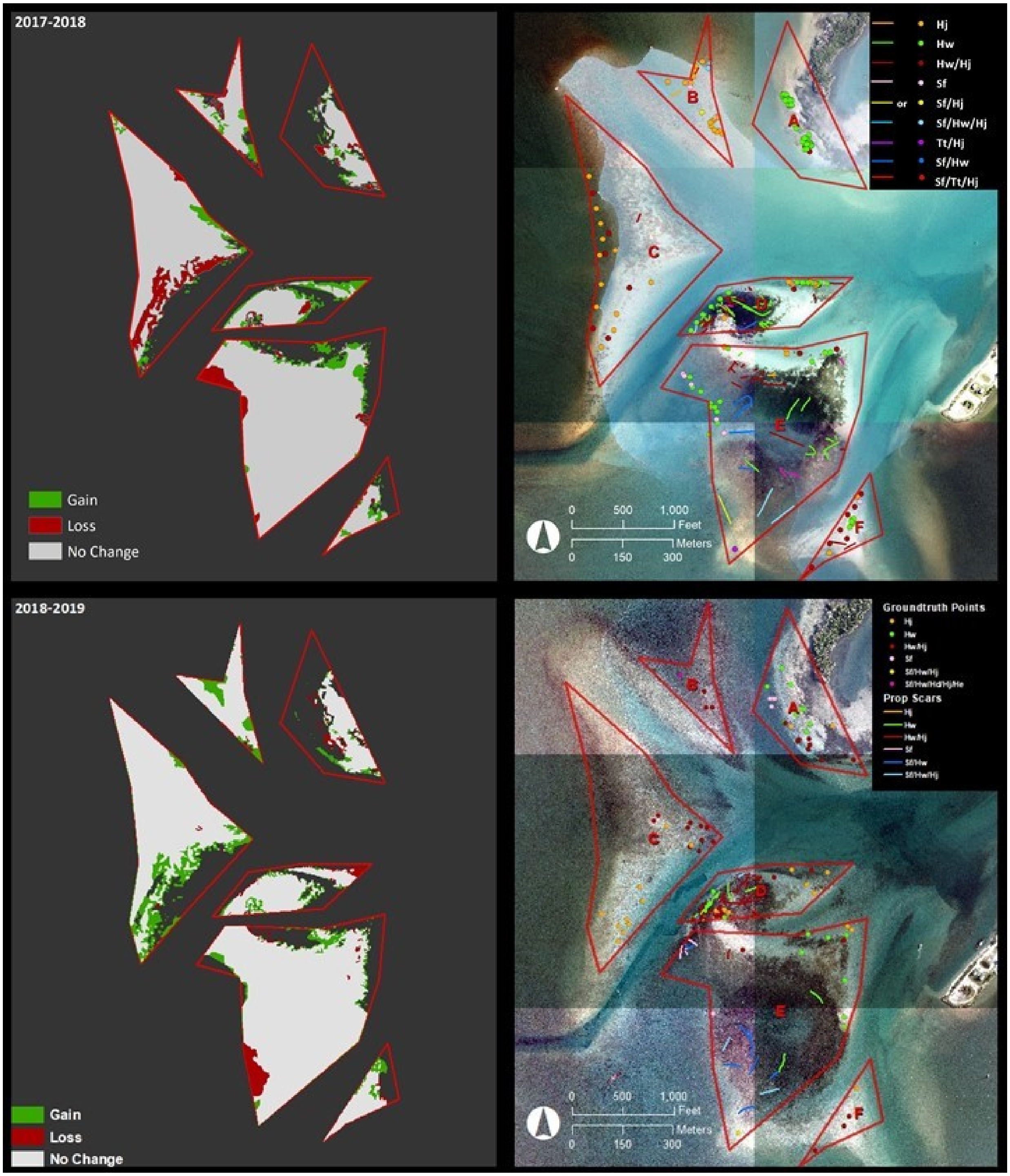


Figure 4-6. **Year-to-year seagrass gain/loss changes and species distributions from 2017 to 2018 (top, Atkins 2019a) and 2018-2019 (bottom, Atkins 2019b).**

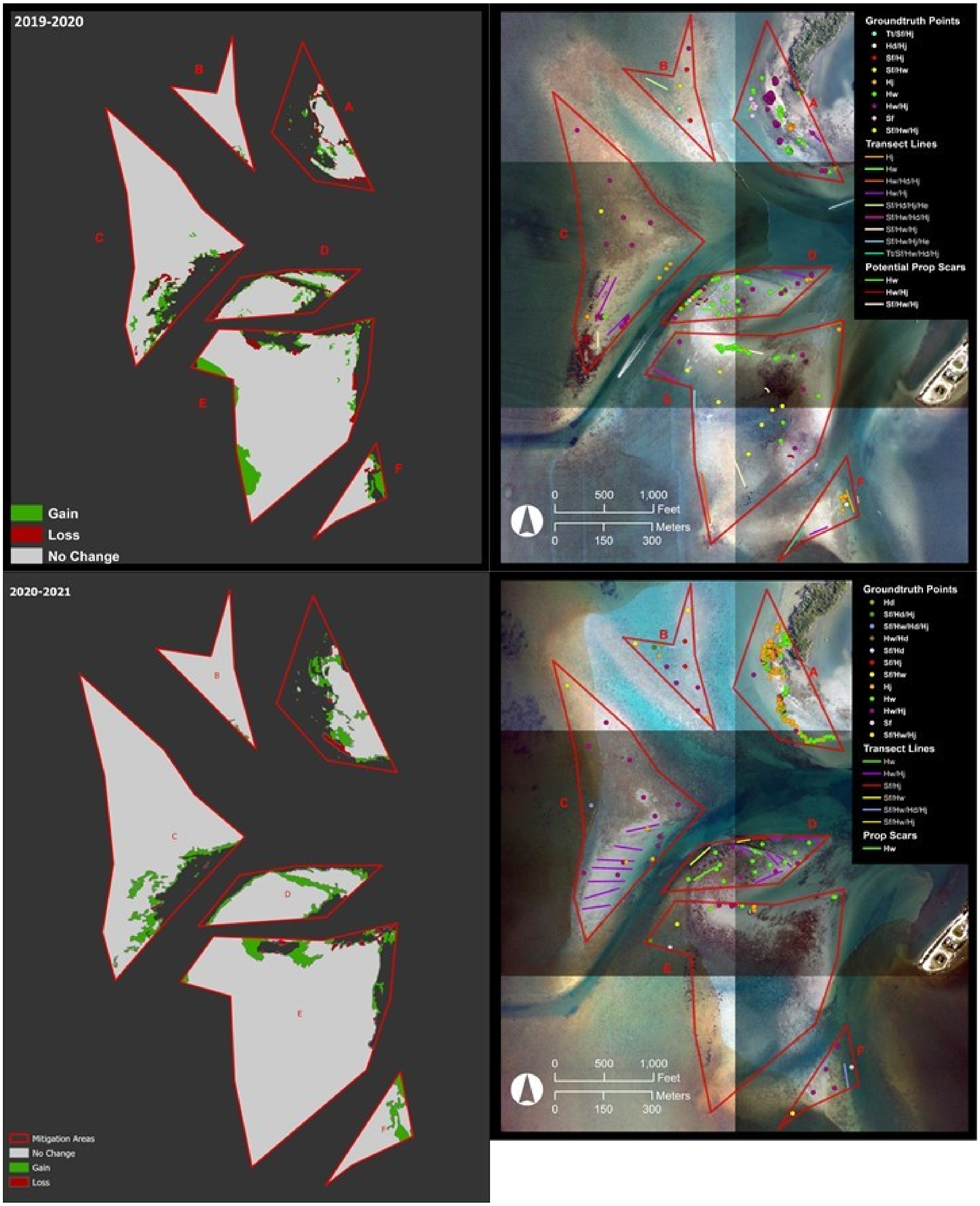


Figure 4-7. Year-to-year seagrass gain/loss changes and species distributions from 2019 to 2020 (top, Atkins 2020) and 2020-2021 (bottom, Atkins 2022).

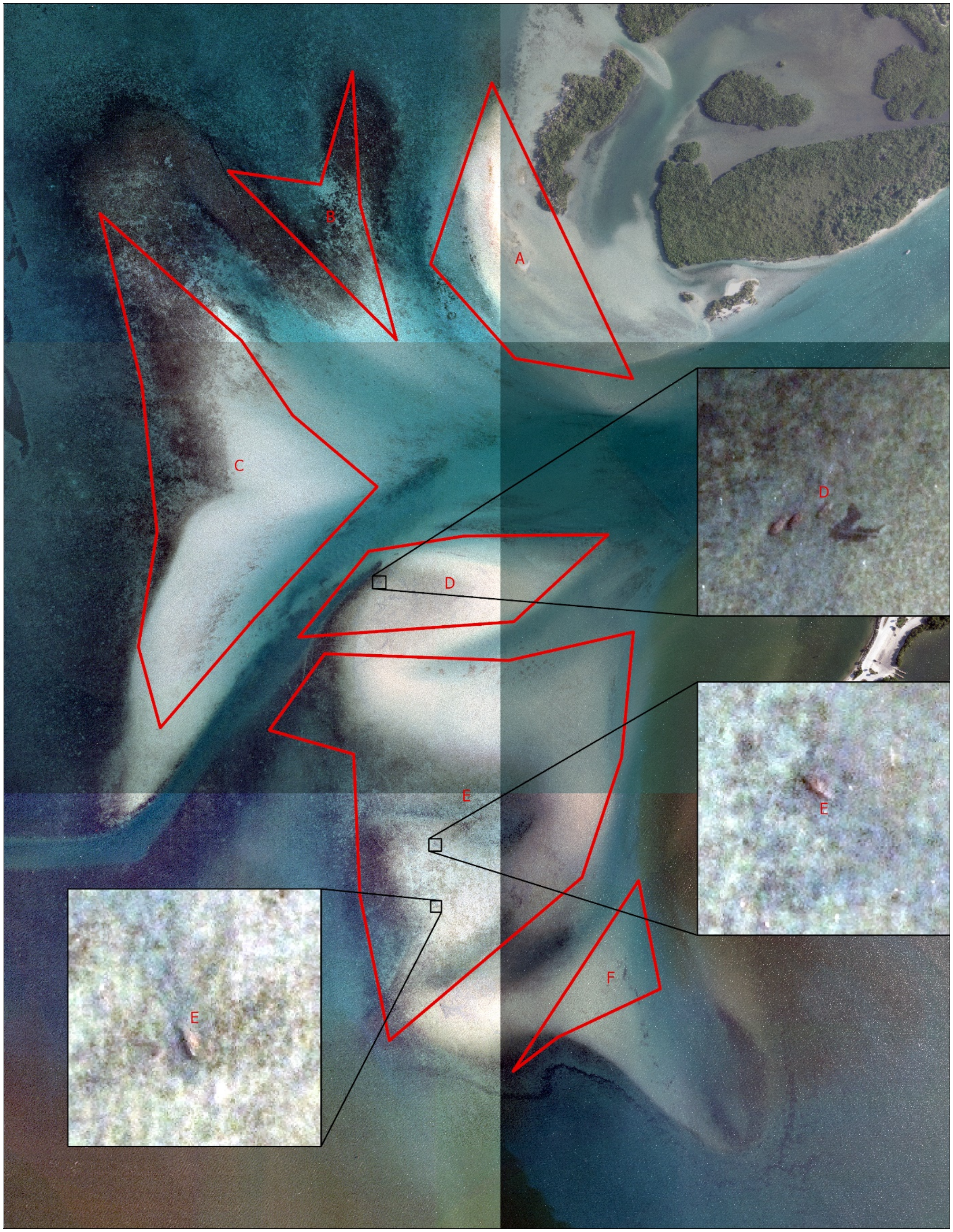


Figure 4-8. May 25, 2022 aerial image with enlarged insets showing manatees feeding in Zones D and E.

5. Future Recommendations

2022 marked 10 years since the initial extension of the monitoring plan and the 2012 seagrass die-off event, during which the Sebastian Inlet flood tidal shoals have experienced drastic changes in seagrass area, density, and species composition. For the 2022 monitoring event, changes were made to the focus and data collection methods; listed here are items to continue, refine, change, or add to the 2023 monitoring event.

5.1. Seagrass Species Composition

As stated in the discussion, previous monitoring events have obtained little to no quantitative data on seagrass density and the quantitative species abundance data in some years is skewed towards the fringes of seagrass beds or indistinct and likely sparse areas. Additionally, in 2022 *Halophila johnsonii* was removed from its Threatened listing under the Endangered Species Act; in previous monitoring events the distribution of this species was singled out for specific attention. With the current understanding that *Halophila johnsonii* is in fact a non-reproductive clone of an invasive Indo-Pacific seagrass species (*Halophila ovalis*) (Waycott et al. 2021), its increased presence on the Sebastian Inlet shoals since 2012 may be viewed as a fast-growing species taking advantage of vacant substrate following the removal of a slower-growing species (*Syringodium filiforme*) that would otherwise overshadow and crowd out smaller competitors.

While the widespread growth of *Halophila johnsonii* has facilitated a rapid recovery of seagrass acreage and has likely helped to hold sediment in place on the shoals, the vegetative biomass of even dense *Halophila johnsonii* growth is orders of magnitude below that of a similar area of *Syringodium filiforme* and does not provide the same sediment retention benefits as the denser and more robust rhizome network of *Syringodium filiforme*. As such, in future monitoring events emphasis should be placed on documenting changes in the spatial distribution and density of *Syringodium filiforme* on the shoals.

5.2. Seagrass Density and Distribution

For the 2022 monitoring event, 126 quadrat sampling locations were placed within the aerially delineated seagrass boundaries. Quadrats were distributed so that within each zone there was approximately one quadrat per acre of aerially delineated seagrass, with some adjustment of placement to capture different visual signatures within the shoal. This approach appears to have been broadly successful in capturing a more representative assessment of seagrass density and species distribution; however, it is acknowledged that at approximately one quadrat per acre this is a quite granular picture. Future monitoring efforts should increase the number of sampled quadrat points (suggest a minimum of 250-300).

5.3. Coconut Point Seagrass

SID has expressed interest in a more detailed assessment of the seagrass bed along the southeast side of Coconut Point. Specifically, the 2023 monitoring event should incorporate similar techniques to assess seagrass density and species composition as the overall shoal monitoring, as well as collecting the offshore edge of the seagrass bed. This will assist SID in future planning for dredging and/or shoreline stabilization in this area.

5.4. Shoal Alterations

In addition to the changes in seagrass coverage, the physical features of the shoals themselves have been altered over time. While the main channel between Zones C, D, and E is maintained by regular dredging events, the remainder of the flood tidal shoals have been subject to natural accumulation and erosion. The period after the 2011/2012 seagrass die-off likely diminished the integrity of the shoals by removing rhizomes from the sediment. While some of these changes may have resulted in no net loss of seagrass habitat (e.g., the effective merger of Zones D and E via partial filling of the gap between them, Zone F losing material at the northeast end but spreading out to the southeast and west), Zone A appears to have experienced a large net loss of material on its western side since 2011. Based on discussions with SID and review of aerial images over the past decade, the general direction of sediment transport seems to be south-southeast towards the inlet sand trap. This likely contributes to Zone A still showing a net loss of seagrass coverage from prior to 2012, as well as an increase in sand transport into the inlet sediment trap southeast of Zone A.

In future phases of the project, the potential use of living shorelines for shoal stabilization along the southern and western edge of Zone A in Sebastian Inlet could be further investigated. Living shorelines are commonly built using natural or recycled materials, such as plants, sand, stone, or other oyster products. Living shorelines are used to reduce wave energy, increase shoreline resiliency, and in some cases create or restore marine habitat. Living shorelines are commonly built using natural or recycled materials, such as plants, sand, stone, or other oyster products. There are a variety of living shoreline solutions which can range from soft techniques that use only natural components (such as vegetative plantings) or hybrid structures that use a combination of hard structures (stone/oyster breakwaters, stone sills, other oyster products) with vegetative plantings. Living shoreline alternatives that are more nature-based are better suited for low energy environments, while hybrid solutions could potentially be used for areas with moderate to high wave energy, such as those experienced at Sebastian Inlet.

Some hybrid living shorelines incorporate oyster products, which primarily consist of free-standing modular concrete cast units that can be submerged or placed in the intertidal zone. The oyster products can be placed individually or used to create breakwaters by aligning the modular units into segmented structures located parallel to the shoreline. Prior to implementing oyster products, it is important to understand if the area has historically had oysters, and if the salinity and other conditions are appropriate for oyster success.

Figure 5-1. Example of concrete cast oyster products – Reef Innovations Reef Balls (left); Reef Maker Wave Attenuator (right).

At the conceptual level, stabilizing material could be placed along the southern and western sides of Zone A (see Figure 5-2), with the recommended placement location, extents, dimensions, gap spacing, etc. to be determined based on future engineering design and analysis. Regulatory authorization requires openings measuring at least five feet in width every 75 linear feet to allow passage for water and wildlife; the observed prevalence of cyanobacteria east of the oyster bars at the center of Zone A demonstrates the potential pitfalls of too much flow restriction. Given the proximity of seagrass habitat and distance from the approximate mean high water line, coordination with regulatory agencies would be anticipated for any proposed stabilization project. Overall, further investigation on sediment transport, proper structure placement (water depth, structure alignment, structure crest elevation, etc.), and verification of no impacts to navigation would be needed to better understand the potential applicability of living shorelines to this area.

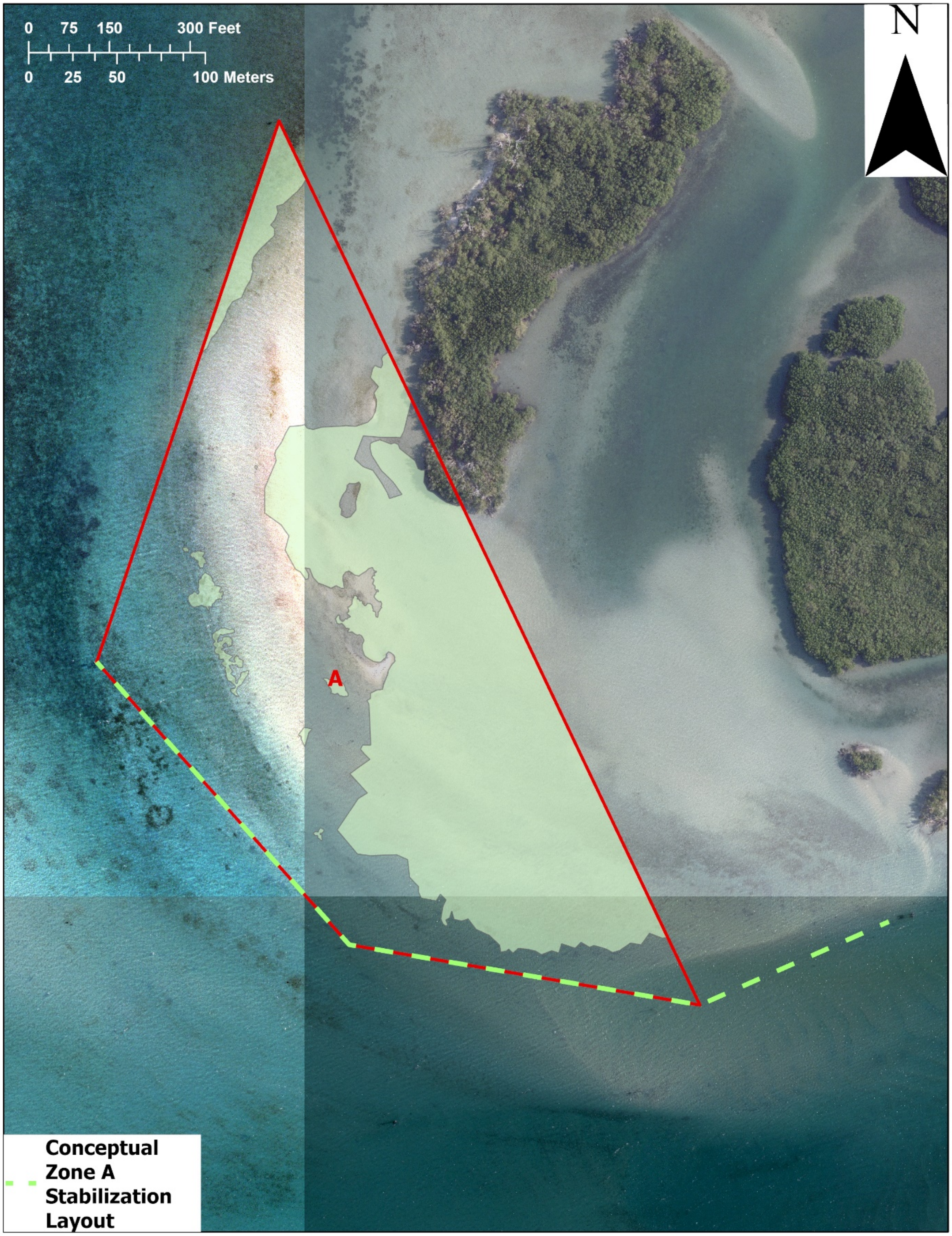


Figure 5-2. Conceptual depiction of stabilizing material along Zone A (placement not to scale). Configuration will require further study; objective is to stabilize south side of shoal and encourage sediment accumulation along west side.

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