**FINAL REPORT**
**FOR**
**The Pensacola and Perdido Bay Estuary Program**

**Prepared by**
**Dauphin Island Sea Lab**

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**Project Title:** Pensacola & Perdido Bays Estuary Program (PPBEP) Seagrass Mapping and Fish Trawling Survey Project.

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**Project Period of Performance:** March 29, 2022 - December 31, 2022

**Report Date:** March 31, 2023

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## Executive Summary

As part of the Pensacola & Perdido Bays Estuary Program (PPBEP) Seagrass Mapping and Fish Trawling Survey Project, the Dauphin Island Sea Lab (DISL) managed acquisition of aerial imagery in September 2022, collaborated and managed the development of the 2022 seagrass map, and conducted fish trawls between September – November 2022 in the Perdido and Pensacola Bays.

High resolution aerial imagery (30cm) was collected over the near-shore estuarine and marine aquatic ecosystems of Northwest Florida (Perdido Bay, Big Lagoon, Pensacola Bay, East Bay and Santa

Rosa Sound to Navarre) (see Appendix A for detailed report) and analyzed by Drs. Victoria Hill and Richard Zimmerman at Old Dominion University with a comparison to satellite-derived imagery obtained from PlanetScope (see Appendix B for detailed report). The Planet imagery captured >95% of seagrass that was identified in aerial imagery but was generally limited to resolving seagrass patches with a minimum size of 100 m^2 and meadows with a ground coverage of no less than 25%. Although there appear to be some losses based on prior reporting, this is due to the methodological change in how extent is determined. Overall, the SAV in the focus area remains stable with beds occurring in the same areas as in prior years. Future SAV mapping events should strongly consider using semi-automated classification creating GIS layers that account for actual SAV cover, especially in patchy areas where prior reported extents are likely an overestimate. Additionally, satellite-derived imagery should be used in addition to or instead of aerial imagery as not only does this imagery produce an accurate map of seagrass presence, but its daily repeat imaging of the globe enables investigation into seasonal and annual changes in seagrass presence and density, something not feasible with aerial imagery.

To assess the fish assemblage within this critical nursery habitat, trawl surveys were conducted in the seagrass beds within the estuarine areas of interest for the PPBEP (Lower Perdido Bay, Big Lagoon, and Santa Rosa Sound). Catch per unit effort (CPUE) and community assemblage were compared with historic data collected by Dr. Kenneth Heck from 2006-2021 to evaluate potential community shifts in the fish fauna of Pensacola and Perdido seagrass meadows.

During the 2022 survey, CPUE was highest in Perdido Bay (854 ± 525), closely followed by Santa Rosa Sound (408 ± 31.2), then Big Lagoon (243). When comparing by site, Rabbit Island and Range Point had the highest CPUEs, likely due to the extremely high abundance of pinfish. Sites in Big Lagoon and Santa Rosa Sound showed decreased CPUE over time while sites in Perdido Bay showed increased or similar CPUE values compared to their first years of trawling.

A total of 24 species was collected in 2022, with pinfish dominating the majority of sites in Perdido, Big Lagoon, and Santa Rosa sound. Three of the five most abundant taxa collected in each system included pinfish, mojarra and silver perch. Pinfish were also the most abundant species collected in trawls from 2006-2021, with very little difference in dominant species over time. Uniquely, 2022 was the first year that mosquito fish and spotted sea trout were among the most abundant taxa. Community assemblages compared using non-multidimensional scaling (NMDS) plots found high overlap between Santa Rosa Sound, Perdido Bay, and Big Lagoon. However, some sites were widely dispersed; for instance, Robinson Island was distinctly different from other locations, likely due to the presence of lane snapper and juvenile Sciaenids there.

Commercially important gray snapper, lane snapper, and spotted sea trout were measured for total length (mm), and CPUE (individuals/km) was compared across years and systems to document the use of seagrass as a nursery habitat for commercially important species. In 2022, all species had the highest CPUE in Perdido Bay. Interestingly, 2021 and 2022 are the first years that lane snapper was documented in Perdido Bay, indicating a potential westward shift of this species.

## Introduction (Project Purpose)

Submerged Aquatic Vegetation (SAV) is a foundational habitat which provides numerous ecosystem services including nutrient cycling (Short and Neckles 1999), carbon sequestration (Hillmann et al.,2020, Fourqurean et al. 2012), and sediment stabilization (Barbier et al. 2011). SAV beds are also well-established as an essential fish habitat, linking critical life stages and trophic interactions for organisms across numerous life stages by providing habitat for invertebrate prey, nursery for juvenile fishes, foraging grounds for predators, and more (Heck, Hays, Orth, 2003; Larkum et al 2006).

SAV includes both oligohaline and marine species (the latter are referred to as seagrasses) and have been used as an estuarine condition indicator, particularly at locations in and near open bay waters where it occurred historically but has declined in coverage or no longer exists. Pensacola and Perdido Bay SAV habitats are composed of primarily *Vallisneria americana* (wild celery or tape grass) in the oligohaline reaches of the Bays and Halodule *wrightii* (shoal grass), *Ruppia maritima* (widgeon grass), and *Thalassia testudinum* (turtle grass), with sparse patches of *Syringodium filiforme* (manatee grass) and *Halophila engelmannii* (star grass) in the estuarine and marine areas (Handley & Lockwood 2020).

Despite its provision of many valuable ecosystem services, seagrass is declining in the US and around the world (Waycott et al. 2009), with areal declines in states bordering the Gulf of Mexico ranging from 20-100% (Handley et al. 2007). Along the north central Gulf of Mexico historic records are sparse, but it is clear that tremendous losses have occurred, with more than 75% of the submerged vegetation lost from Perdido Bay since the 1940s and more than 90% from the Pensacola Bay system (Handley et al. 2007); however, in the recent past both systems have experienced slow and steady gains in SAV extent (Byron et al. 2018a, Byron et al. 2018b). Many factors, both natural and anthropogenic, contribute to seagrass decline, including tropical storms, abnormal rainfall patterns, the addition of wastewater and excess nutrients to coastal waters, dredging, coastal construction and direct damage caused by poor boating practices (Handley et al. 2007; Orth et al. 2006). Thus, due to their importance for a healthy nearshore ecosystem and their role as estuarine indicators, many coastal programs conduct mapping surveys of the SAV habitat on a regular basis.

The northern GoM has also experienced major shifts in seagrass associated fish species in the recent past, likely at least in part to climate change (Fodrie et al. 2010). A growing literature has documented the poleward shift of marine fishes in the world's oceans and hypothesized about the likely consequences of more range shifts as ocean temperatures continue to rise (Murawski, S.A., 1993; Perry et al, 2005; Fodrie et al. 2010). The effects of these shifts are exacerbated in the Gulf of Mexico (GOM), as native species are blocked by the North American landmass and cannot move north, resulting in the mixing of newly arriving tropical fishes with resident fishes and invertebrates (Fodrie and Heck, 2011; Gericke et al., 2014; Scheffel et al., 2017). For example, Fodrie et al (2010) documented dramatic community shifts in the composition of nGOM seagrass-associated fishes between the 1970's and 2000's, with increased snapper and parrotfish abundances of special interest. Specifically, they reported that *Lutjanus synagris* (lane snapper) were completely absent throughout the 1970s but were the $8^{th}$ most abundant seagrass-associated fish caught during the 2000s, with similar trends seen for *Lutjanus griseus* (gray snapper) and *Nicholsina usta* (emerald parrotfish) (Fodrie et al 2010). As these tropically-associated fishes successfully transition to nGOM seagrass habitats, novel predator prey interactions will likely change community dynamics and could have profound impacts on native species.

This project had two objectives. The first was to obtain digital benthic habitat data to document the extent of SAV using the same (e. g., aerial imagery) or updated methodology (e.g., satellite imagery) that will produce a result comparable or better than the results of prior SAV surveys conducted across the area. (SAV species composition data was collected separately by Dr. Kelly Darnell at University of Southern Mississippi using a modified tiered sampling approach program following Neckles et al. (2012)). The second was to document the fish community, including the economically valuable species, occurring in Pensacola and Perdido Bay seagrass habitats and compare it with data gathered during the past two decades. Specifically, the goals included:

- Document the extent of SAV using digital benthic habitat maps
- Document fish abundances (using catch per unit effort, CPUE) and species compositions at selected seagrass meadows in Perdido Bay, Big Lagoon, and Santa Rosa Sound
- Comment on the status of economically important and any newly identified tropically associated or non-native species collected, as well as the nursery function of seagrass meadows sampled.

The results and conclusions of this study will provide researchers and managers with a current assessment of the extent of SAV habitat across the area, an assessment of current methodologies used to create SAV habitat maps (aerial imagery vs satellite imagery), and an assessment of the composition of fish communities, with a comparison with previously collected fish assemblages in the Pensacola and Perdido Bays seagrass meadows. We anticipate that this information will be useful in the formulation and implementation of future ecosystem-based management measures. For simplicity, the remaining sections of the report describe only the basics of the seagrass mapping exercises, while detailed reports on both the aerial and satellite imagery acquisition methods and the those for the development of GIS polygons are found in Appendices A and B. In contrast, we focus in more detail on the trawling results and the analyses of these data in what follows.

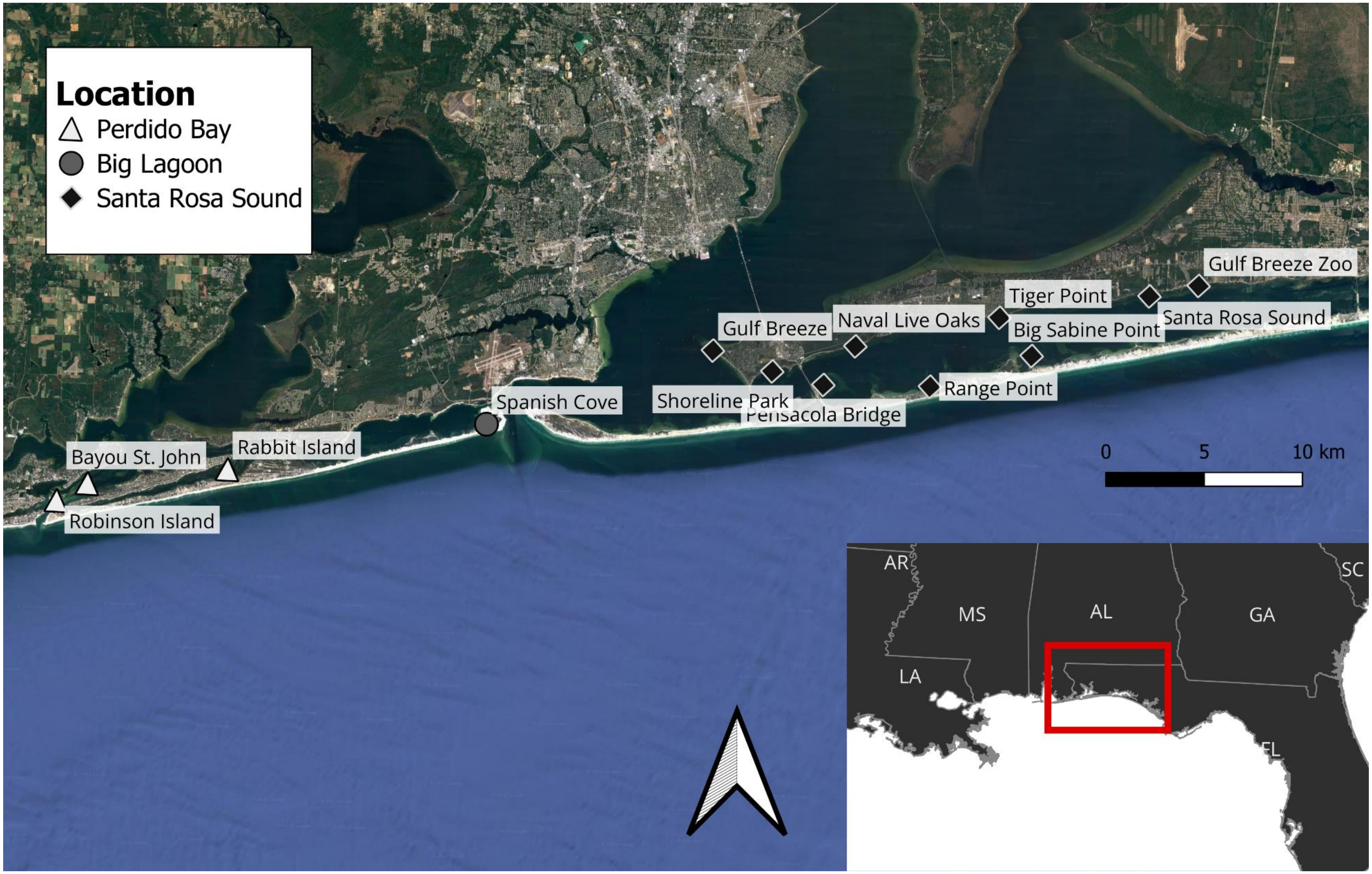



**Figure 1**. 2022 Fish trawl survey sites in Perdido and Pensacola Bays, Florida.

# Methodology

## Aerial and satellite imagery acquisition and processing

Leveraging existing funding from the RESTORE Act which was scheduled to map the SAV of Coastal Alabama in 2022, we were able to extend the mapping area to include the Florida portion of Perdido Bay and the Pensacola Bay system. In August of 2022, the Dauphin Island Sea Lab entered into a Professional Service Agreement with NV5 Geospatial to acquire aerial imagery of the Perdido and Pensacola Bay systems and Coastal Alabama. NV5 Geospatial was retained based on their prior acquisition of aerial imagery for both the 2015 and 2019 Coastal Alabama mapping efforts, their familiarity with the area, local weather, and the unique local environmental conditions (river flow, turbidity), their history of SAV mapping for other coastal programs and the Program Manager assistance on the NOAA Guidance for Benthic Habitat Mapping which is the standard guide for SAV mapping throughout the US. Aerial imagery acquisition occurred between September 15 -23, 2022 and details regarding the methods and output can be found in Appendix A.

To create the GIS of the SAV extent (i.e., SAV polygon development), the Dauphin Island Sea Lab collaborated with Dr. Richard Zimmerman and Dr. Victoria Hill at Old Dominion University to use a semi-automated classification workflow to identify SAV areas from the satellite-derived imagery from PlanetScope taken during the same approximate time as the aerial imagery was collected. Briefly, an aquatic vegetation raster was created to identify areas with >80% presence of SAV, and was converted into a polygon layer in ArcGIS Pro. The ArcGIS Pro aggregate polygon tool was applied with an aggregation distance of 20 m and a minimum hole size of 10 $m^2$. All polygons less than 100 $m^2$ in area were then deleted from the layer. Further details regarding the methods and output can be found in Appendix B.

The satellite imagery derived SAV polygon layer was then compared to the SAV areas observed in the aerial imagery provided by NV5 Geospatial. Unfortunately, due to striping and significant tile to tile variability in the aerial imagery it was not possible to run the semi-automated/supervised classification to create a SAV polygon layer from this imagery, Manual delineation of small patches, a time-intensive process, is still ongoing, and will provide a more accurate comparison between the two imagery types.

## Fish Surveys

The 2022 fish trawl surveys were conducted at 13 locations spanning the lower Perdido and Pensacola Bay coastlines in September-October 2022. Sampling locations included Lower Perdido Bay (specifically Bayou St John, Rabbit Island, and Robinson Island), Big Lagoon, and Santa Rosa Sound (Figure 1). These sites were chosen based on their historically high seagrass coverage and overlap with long-term fish trawling survey locations (Fodrie et al. 2010; Fodrie and Heck 2011; Heck et al, unpublished).

Basic water quality data, trawling details, fish abundances and species compositions were recorded at each of the 13 locations in the Pensacola and Perdido Bays. Data collected included:

- Water quality data:
    - Salinity (ppt)
    - Water depth (m)
- Trawl details:
    - Speed (km/hr)
    - Duration (min)

- Distance (m)
- Engine RPM

- Fish biological data:
    - Identification of specimens to the lowest practical taxonomic level (usually species)
    - Total and species-specific abundances
    - Total length and number of individuals of commercially important species

Water quality data were collected at each site before the first trawl was conducted. Trawls consisted of 3 – 4-minute tows using a 5-m otter trawl (2.0-cm body mesh; 0.6-cm bag mesh) behind a small (~7 m) research vessel traveling at approximately 3.5 – 5.5 knots targeting depths from 0.5 -2.0m, in accordance with the methods used by Fodrie et al (2010; Fodrie and Heck 2011. Two to four replicate trawls were conducted at each site depending on the availability of continuous seagrass coverage. Species were identified using the "Second Edition: Fishes of the Gulf of Mexico" guide (Hoese and Moore 1998) and enumerated in the field unless species-level identifications could not easily be made, in which case 1 specimen of each unidentified taxon was put on ice and brought back to the lab for identification. Commercially important species, such as gray and lane snappers (*Lutjanus griseus and Lutjanus synagris)*, spotted sea trout (*Cynoscion nebulosus*), and flounder (*Paralichthys* spp*)*, were measured for total length (mm) (Figure 3). All trawl samples were supervised by IACUC certified DISL personnel and safety procedures were adhered to in accordance with IACUC Protocol #1914481-1. Species were released to the surrounding water immediately after identification, enumeration, and measurement.

Fish abundance data was converted to catch-per-unit effort (CPUE), a common metric used to assess fish abundance, based on the linear distance each trawl covered (no. of fish per km towed). CPUE and fish community assemblages were compared across sites, systems, and years when applicable.

**Figure 2.** DISL and PPBEP team sorting, enumerating, and measuring a trawl catch from the 2022 fish trawl survey. Photo credit: PPBEP


**Figure 3.** Juvenile gray snapper (*Lutjanus griseus)* collected in the 2022 fish trawl surveys. Photo credit: PPBEP

# Results

## Aerial and Satellite estimates of submerged aquatic vegetation extent

SAV in the focus area remained stable with beds occurring in the same areas as in prior years. Acreage in the Pensacola Bay system appears to have some losses in the estuarine and marine areas of Big Lagoon, Santa Rosa Sound and Southern Pensacola Bay, gains in the upper reaches of Pensacola Bay (Escambia Bay and Blackwater Bay), and gains in the Perdido Bay system (Table 1).

SAV polygons that were generated from the satellite-derived imagery showed good fidelity with the SAV areas seen in the aerial imagery. Visual inspection of the satellite imagery from PlanetScope captured roughly 95% of seagrass that was identified in aerial imagery but was generally limited to resolving seagrass patches with a minimum size of 100 m^2 and meadows with a ground coverage (i.e. visual percent cover) of more than 25%.

Manual highlighting of those small patches seen in the aerial imagery but not in the satellite imagery, an ongoing exercise, will provide a more accurate comparison between the two imagery types and determine how much area is not included in the calculated extent from the satellite imagery.

**Table 1.** SAV acreage in Perdido and Pensacola Bays. Acreages listed from 1987-2015 as reported in the *FMRI Seagrass Integrated Mapping and Monitoring Program Mapping and Monitoring Report No. 3 (Byron et al. 2018a, b), † Seagrass Status and Trends Update for the Northern Gulf of Mexico: 2002-2017 (Handley and Lockwood, 2020), and this study (2022).

| | 1987 | 1992 | 2002 – 2003 | 2010 | 2015 | 2022 |
|---|---|---|---|---|---|---|
| Perdido Bay* | 575 | 256 | 122 | 338 | 430 | 536 |
| Pensacola Bay* | – | 3418 | 3808 | 3697 | 4197 | 3575 |
| Big Lagoon* | – | 489 | 508 | 511 | 571 | 402 |
| Santa Rosa Sound* | – | 2674 | 2963 | 2844 | 3080 | 2230 |
| Southern Pensacola Bay* | – | 254 | 337 | 342 | 544 | 336 |
| Northern Pensacola Bay (Escambia Bay and East Bay/Backwater Bay)† | – | 849 | – | 474 | – | 607 |

## Fish Abundance & CPUE

In total, 41 trawls that spanned a total linear distance of ~7.7 km were conducted. Trawls covered mosaics of seagrass meadows that included *Thalassia testudinum* (turtlegrass), *Halodule wrightii* (shoal grass), *Ruppia maritima* (widgeon grass), and *Syringodium filiforme* (manatee grass), along with scattered unvegetated patches. Salinity during the trawling activities ranged from 20.3 – 27.6, depth ranged from 0.83 m – 2 m, and temperature ranged between 29.6 – 29.9C.

Because the number of trawls at each site varied from 2 to 4, depending on the availability and area of seagrass beds, each trawl catch was converted into catch per unit effort (CPUE), based on the linear distance trawled and expressed as the number of fish collected per km towed.

In the 2022 survey, CPUE ranged from 250 to 3,235 in Perdido Bay, 74.1 to 1,684 in Santa Rosa Sound and 55.1 to 609 in Big Lagoon. Rabbit Island had the highest CPUE (1,901.2 ± 595.25) followed by Range Point (1,095.7 ± 296.15) with all other sites having substantially lower CPUE (Table 2; Figure 4). By system, Perdido Bay had the highest mean CPUE (854 ± 525), closely followed by Santa Rosa Sound (408 ± 31.2), and then Big Lagoon (243). A non-parametric Kruskal-Wallis test was conducted to examine the effects of System on CPUE and found that Perdido Bay had a significantly higher CPUE than Santa Rosa Sound ($p = 0.04$).

**Figure 4**. Average CPUE (individuals/km) ± 1 S.E. by site in 2022. Sites are listed from west to east.

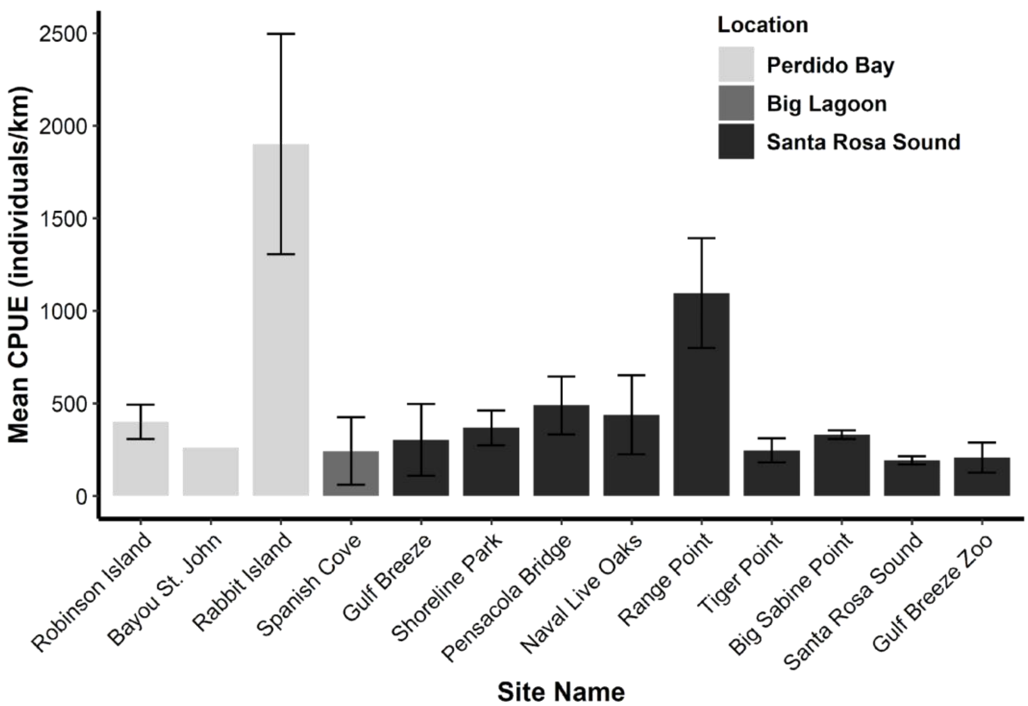



**Table 2.** CPUE (individuals/km) ± 1 S.E. by system in 2022.

| System | Number of sites | Mean CPUE (individuals/km) | S.E. CPUE |
|---|---|---|---|
| **Big Lagoon** | 1 | 242.99 | - |
| **Perdido Bay** | 3 | 854.46 | 525 |
| **Santa Rosa Sound** | 9 | 407.76 | 92.2 |

Historical CPUE (individuals/km towed) data from 2006 – 2021 were compared to present day values to evaluate potential community shifts in the fish fauna of Pensacola and Perdido seagrass meadows. Historical data used in the analysis were collected by personnel in the Heck lab at DISL during the months of August-October from 2006 – 2021 and are shown here only for sites sampled in the 2022 survey (cf. Fodrie et al 2010; Fodrie and Heck 2011). Sites were only considered if 3 or more trawls were collected each year. In total, 296 trawls from 8 sites were used in the historical analysis (Table 3).

Trawl data from 2006-2010 used 2 estimates to calculate CPUE: (1) speed (km/hr) and duration (min) and (2) odometer (m) provided by the handheld Garmin GPS system. Data from 2010-2021 calculated CPUE exclusively with the odometer (m) provided by the Garmin GPS.

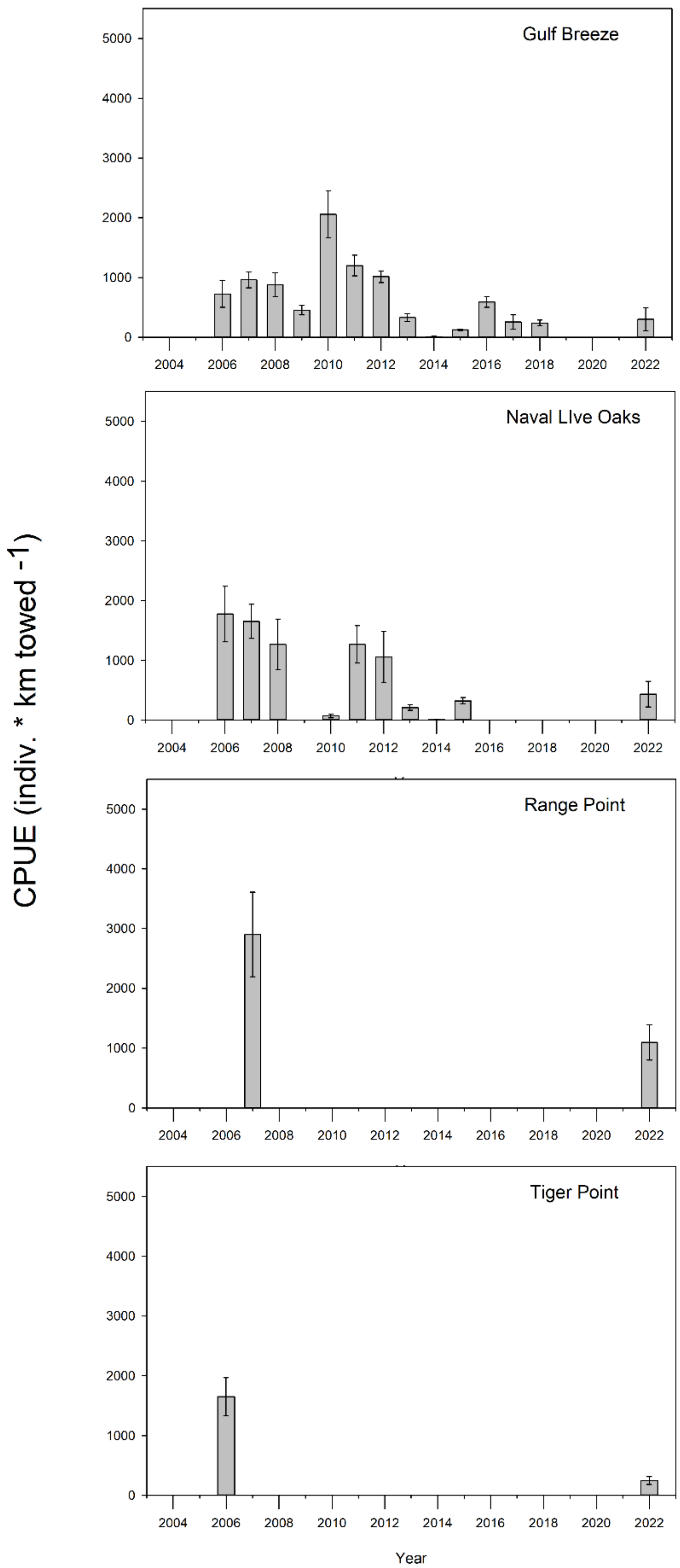
All sites in Big Lagoon (Spanish Cove) and Santa Rosa Sound (Gulf Breeze, Naval Live Oaks, Range Point, Tiger Point, and Big Sabine Point) showed decreased CPUE values in 2022 compared to their first year of trawling in 2006 (Figure 5). In contrast, all sites in Perdido Bay (Rabbit Island and Robinson Island) showed increased or similar CPUE values compared to their first year of trawling (Figure 5). Spanish Cove and Gulf Breeze had noticeably higher CPUEs in 2010, which may be attributed to the indirect effect of large-scale fisheries closures in the northern GoM in response to the Deepwater Horizon Oil Spill (Fodrie 2011). Additionally, CPUE was noticeably lower in 2014 across all sites for reasons that are unclear. Overall, as is common in many fish stocks, variability in annual abundance was quite large, and in some cases approached an order of magnitude.

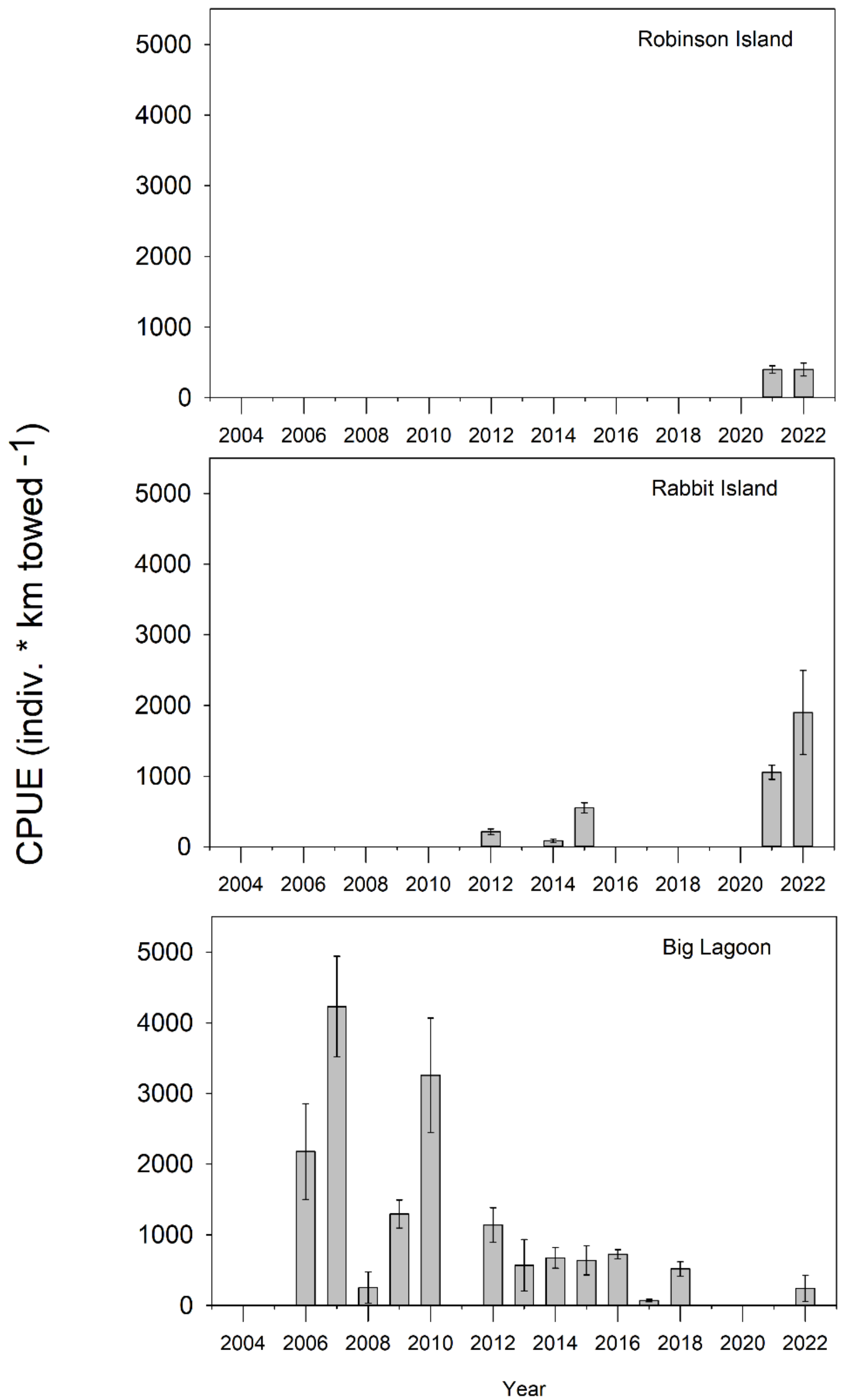
**Table 3.** Mean CPUE (individuals/km towed) ± 1 S.E. of sites from 2006-2022.

| Location | Site | Year | Number of trawls | Mean CPUE (indv./km) | SE CPUE |
|---|---|---|---|---|---|
| Perdido Bay | Rabbit Island | 2012 | 5 | 213.5 | 39.2 |
| | | 2014 | 5 | 84.5 | 24.0 |
| | | 2015 | 4 | 551.7 | 72.2 |
| | | 2021 | 3 | 1054.6 | 99.8 |
| | | 2022 | 4 | 1901.2 | 595.2 |
| | Robinson Island | 2021 | 3 | 398.9 | 53.8 |
| | | 2022 | 3 | 401.3 | 92.5 |
| Big Lagoon | Spanish Cove | 2006 | 4 | 2177.2 | 678.2 |
| | | 2007 | 8 | 4228.7 | 714.2 |
| | | 2008 | 8 | 253.2 | 220.5 |
| | | 2009 | 9 | 1294.9 | 198.9 |
| | | 2010 | 5 | 3255.6 | 811.1 |
| | | 2012 | 7 | 1138.1 | 245.8 |
| | | 2013 | 3 | 569.1 | 362.3 |
| | | 2014 | 7 | 672.9 | 145.5 |
| | | 2015 | 9 | 639.7 | 208.3 |
| | | 2016 | 6 | 725.3 | 66.1 |
| | | 2017 | 6 | 68.8 | 17.8 |
| | | 2018 | 7 | 517.5 | 99.8 |
| | | 2022 | 3 | 243.0 | 183.2 |
| Santa Rosa Sound | Big Sabine Point | 2006 | 5 | 2151.6 | 512.2 |
| | | 2012 | 4 | 972.0 | 296.6 |

| | | | | | |
|---|---|---|---|---|---|
| | | 2013 | 4 | 236.0 | 47.9 |
| | | 2022 | 3 | 330.8 | 23.1 |
| | Gulf Breeze | 2006 | 8 | 725.4 | 224.6 |
| | | 2007 | 10 | 962.2 | 131.7 |
| | | 2008 | 11 | 882.8 | 198.6 |
| | | 2009 | 10 | 456.1 | 79.8 |
| | | 2010 | 8 | 2058.5 | 391.9 |
| | | 2011 | 18 | 1200.6 | 173.5 |
| | | 2012 | 5 | 1014.0 | 97.7 |
| | | 2013 | 3 | 330.0 | 65.9 |
| | | 2014 | 6 | 12.3 | 6.7 |
| | | 2015 | 5 | 127.4 | 12.3 |
| | | 2016 | 10 | 591.4 | 90.7 |
| | | 2017 | 7 | 256.7 | 120.4 |
| | | 2018 | 8 | 241.5 | 47.5 |
| | | 2022 | 3 | 302.4 | 193.4 |
| | Naval Live Oaks | 2006 | 5 | 1778.0 | 462.7 |
| | | 2007 | 5 | 1655.7 | 284.3 |
| | | 2008 | 4 | 1267.4 | 426.0 |
| | | 2010 | 3 | 71.7 | 30.8 |
| | | 2011 | 5 | 1269.0 | 312.4 |
| | | 2012 | 3 | 1057.4 | 429.8 |
| | | 2013 | 4 | 213.2 | 44.7 |
| | | 2014 | 5 | 12.8 | 6.7 |
| | | 2015 | 6 | 326.0 | 53.2 |
| | | 2022 | 4 | 438.1 | 213.6 |
| | Range Point | 2007 | 4 | 2902.1 | 707.8 |
| | | 2022 | 3 | 1095.7 | 296.2 |
| | Tiger Point | 2006 | 5 | 1653.0 | 319.6 |
| | | 2022 | 3 | 246.4 | 65.0 |

**Figure 5**. Historical trawl data for each site.




Robinson Island
Rabbit Island
Big Lagoon
5000
4000
3000
2000
1000
0
2004
2006
2008
2010
2012
2014
2016
2018
2020
2022
CPUE (indiv. * km towed -1)
Year

## Community assemblage

A total of 24 species was collected during the 2022 survey (Table 4), with pinfish (*Lagodon rhomboides)* dominating the majority of sites in Perdido Bay (72.47%), Big Lagoon (81.69%) and Santa Rosa Sound (64.61%). Within each system, 3 of the 5 most abundant taxa (pinfish, silver perch (*Bairdiella chrysoura*), and mojarras (*Gerreidae)*) were shared. Additionally, in Perdido Bay, mosquito fish (*Gambusia*) and spotted sea trout (*Cynoscion nebulosus*) were among the top 5 most abundant species. In Santa Rosa Sound, pigfish (*Orthopristis chrysoptera*) and pipefish (*Syngnathidae*) were the next most abundant species. In Big Lagoon, pigfish and spotted sea trout were among the top 5 most abundant species (Table 4; Table 5). Historical trawls from 2006 – 2021 were also primarily dominated by pinfish and silver perch (Table 5). This is the first year that mosquito fish and spotted sea trout were among the most abundant taxa collected in the trawls.

Community assemblages from the 2022 sampling were compared using the Bray Curtis dissimilarity index and non-metric multidimensional scaling (NMDS)(Figure 6). The NMDS plot ($R^2$ fit = 0.985, stress = 0.12) showed high overlap between Santa Rosa Sound, Perdido Bay, and Big Lagoon sites despite some samples within sites being widely dispersed. The unique assemblage seen at Robinson Island was likely driven by lane snapper (*Lutjanus synagris*) and juvenile Sciaenids which were only collected at Robinson Island.

**Table 4.** Total and relative abundance of species collected in trawls at each system in the 2022 fish trawl survey. The 5 most abundant species in each system are bolded.

| | **Perdido Bay** | | **Big Lagoon** | | **Santa Rosa Sound** | |
|---|---|---|---|---|---|---|
| **Species** | **Total Count** | **Relative Abundance (%)** | **Total Count** | **Relative Abundance (%)** | **Total Count** | **Relative Abundance (%)** |
| Brown Shrimp [*Farfantepenaeus aztecus*] | 0 | 0 | 0 | 0 | 2 | 0.08316 |
| Croaker/Atlantic [*Micropogonias undulatus*] | 1 | 0.13 | 0 | 0 | 0 | 0 |
| Flounder spp [FM: *Paralichthyidae*] | 0 | 0 | 0 | 0 | 3 | 0.12474 |
| Goby [FM: *Gobiidae*] | 2 | 0.27 | 0 | 0 | 0 | 0 |
| Gray Snapper [*Lutjanus griseus*] | 9 | 1.20 | 0 | 0 | 25 | 1.039501 |
| Gulf Toadfish [*Opsanus beta*] | 0 | 0 | 0 | 0 | 1 | 0.04158 |
| Inshore Lizardfish [*Synodus foetens*] | 0 | 0 | 0 | 0 | 3 | 0.12474 |
| Lane Snapper [*Lutjanus synagris*] | 1 | 0.13 | 0 | 0 | 0 | 0 |
| Minnow [FM: *Cyprinidae*] | 0 | 0 | 0 | 0 | 4 | 0.16632 |
| Mojarra [FM: *Gerreidae*] | 87 | **11.56915** | 6 | **4.225352** | 140 | **5.821206** |
| Mosquito Fish [*Gambusia affinis*] | 16 | **2.12766** | 0 | 0 | 0 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Juvenile sciaenid | 1 | 0.132979 | 0 | 0 | 0 | 0 |
| Pigfish<br>[*Orthopritis chrysoptera*] | 11 | 1.462766 | 7 | **4.929577** | 89 | **3.700624** |
| Pinfish<br>[Lagodon rhomboides] | 545 | **72.4734** | 116 | **81.69014** | 1554 | **64.61538** |
| Pipefish<br>[*Syngnathus sp.]* | 4 | 0.531915 | 0 | 0 | 60 | **2.494802** |
| Planehead Filefish<br>[*Stephanolepis hispidus*] | 0 | 0 | 0 | 0 | 1 | 0.04158 |
| Puffer<br>[*Sphoeroides spp*] | 0 | 0 | 0 | 0 | 1 | 0.04158 |
| Scaled Sardine<br>[*Harengula jaguana*] | 0 | 0 | 0 | 0 | 38 | 1.580042 |
| Silver Perch<br>[*Bairdiella chrysoura*] | 60 | **7.978723** | 12 | **8.450704** | 468 | **19.45946** |
| Spadefish<br>[*Chaetodipterus faber*] | 0 | 0 | 0 | 0 | 1 | 0.04158 |
| Spot<br>[*Leiostomus xanthurus*] | 2 | 0.265957 | 0 | 0 | 0 | 0 |
| Spotted Scorpionfish<br>[*Scorpaena plumieri*] | 0 | 0 | 0 | 0 | 1 | 0.04158 |
| Spotted Sea Trout<br>[*Cynoscion nebulosus*] | 13 | **1.728723** | 1 | **0.704225** | 9 | 0.37422 |
| Striped Burrfish<br>[*Chilomycterus schoepfi*] | 0 | 0 | 0 | 0 | 5 | 0.2079 |

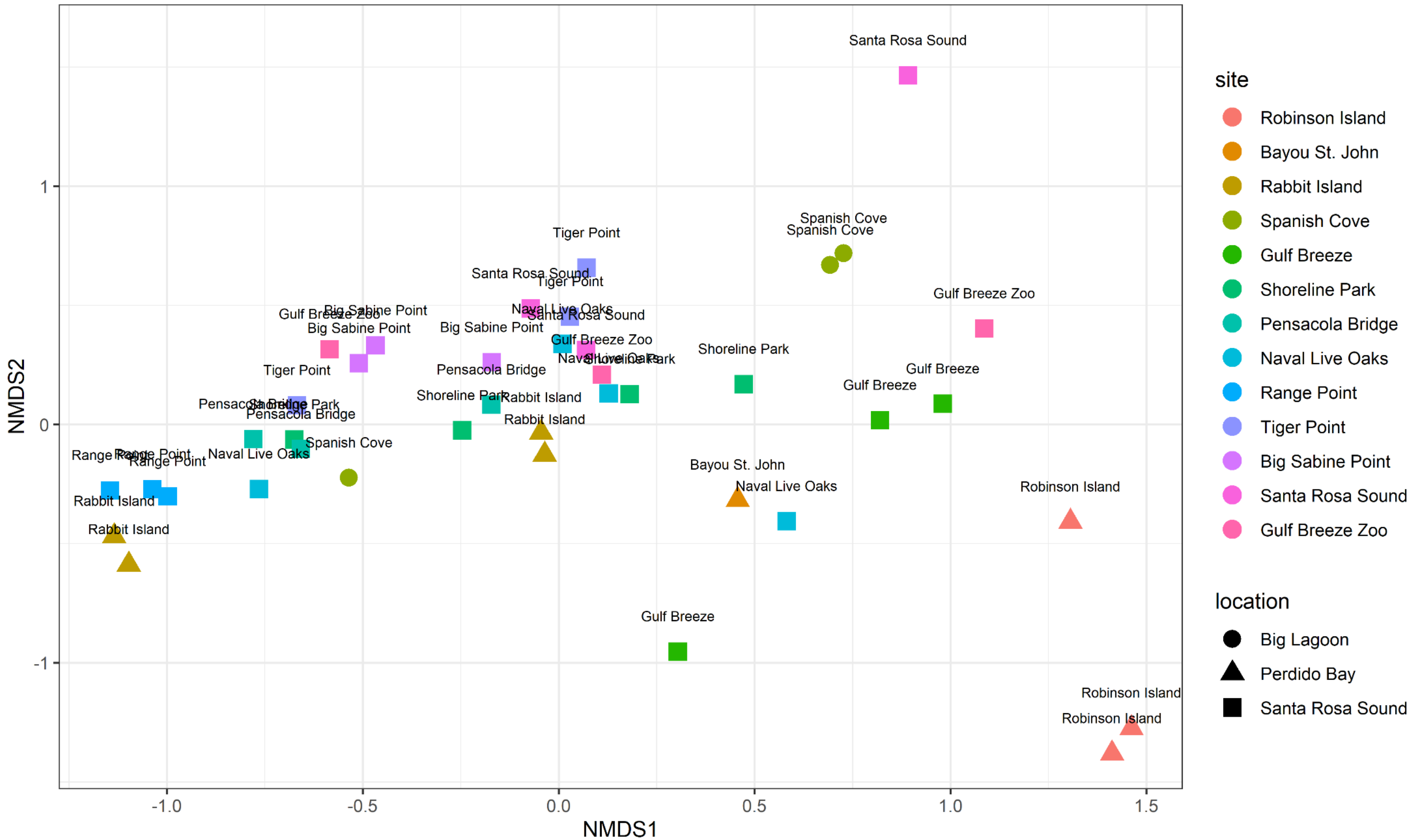



**Figure 6**. Non-metric multi-dimensional scaling of community assemblage by Site (color) and Location (shape). Each datum represents a single trawl sample.

**Table 5.** The 5 most abundant taxa in order by year and system. A (-) indicates that no trawls were collected in that system for that year.

| Year | Perdido Bay | Big Lagoon | Santa Rosa Sound |
|---|---|---|---|
| 2006 | Pinfish | Pinfish | Pinfish |
| | Silver Perch | Pigfish | Anchovy |
| | Pigfish | Mojarra | Silver Perch |
| | Spotted Sea Trout | Gray Snapper | Pigfish |
| | Spot | Silver Perch | Grey Snapper |
| 2007 | - | Pinfish | Pinfish |
| | - | Pigfish | Pigfish |
| | - | Silver Perch | Mojarra |
| | - | Gray Snapper | Silver Perch |
| | - | Mojarra | Blenny |
| 2008 | - | Pinfish | Pinfish |
| | - | Mojarra | Silver Perch |
| | - | Pigfish | Pigfish |
| | - | Lane Snapper | Mojarra |
| | - | Silverside | Scaled Sardine |
| 2009 | Pinfish | Pinfish | Pinfish |
| | Mojarra | Silver Perch | Mojarra |
| | Silver Perch | Scaled Sardine | Pigfish |
| | Anchovy | Mojarra | Gray Snapper |
| | Spot | Pigfish | Silver Perch |
| 2010 | - | Pinfish | Pinfish |
| | - | Silver Perch | Planehead Filefish |
| | - | Pigfish | Gray Snapper |
| | - | Planehead Filefish | Pigfish |
| | - | Gray Snapper | Silver Perch |
| 2011 | - | Pinfish | Pinfish |
| | - | Silver Perch | Pigfish |
| | - | Pigfish | Silver Perch |
| | - | Mojarra | Planehead Filefish |
| | - | Scaled Sardine | Pipefish |
| 2012 | Pinfish | Pinfish | Pinfish |
| | Silver Perch | Silver Perch | Silver Perch |
| | Mojarra | Pigfish | Mojarra |
| | Pipefish | Pipefish | Pigfish |
| | Gray Snapper | Planehead Filefish | Pipefish |
| 2013 | - | Pinfish | Silver Perch |
| | - | Silver Perch | Pinfish |

| | | | |
|---|---|---|---|
| | - | Pigfish | Mojarra |
| | - | Mojarra | Scaled Sardine |
| | - | Planehead Filefish | Pigfish |
| **2014** | Pinfish | Pinfish | Pinfish |
| | Silver Perch | Silver Perch | Silver Perch |
| | Mojarra | Mojarra | Mojarra |
| | Speckled Sea Trout | Gray Snapper | Speckled Sea Trout |
| | Anchovy | Pigfish | Anchovy |
| **2015** | Silver Perch | Pinfish | Pinfish |
| | Pinfish | Silver Perch | Scaled Sardine |
| | Speckled Sea Trout | Pigfish | Silver Perch |
| | Anchovy | Mojarra | Pigfish |
| | Spot | Pipefish | Mojarra |
| **2016** | - | Pinfish | Pinfish |
| | - | Pigfish | Pigfish |
| | - | Silver Perch | Planehead Filefish |
| | - | Puffer | Puffer |
| | - | Gray Snapper | Striped Burrfish |
| **2017** | - | Pinfish | Mojarra |
| | - | Silver Perch | Pinfish |
| | - | Gray Snapper | Gray Snapper |
| | - | Scaled Sardine | Silver Perch |
| | - | Lane Snapper | Lane Snapper |
| **2018** | - | Pinfish | Silver Perch |
| | - | Silver Perch | Pinfish |
| | - | Scaled Sardine | Scaled Sardine |
| | - | Pigfish | Mojarra |
| | - | Mojarra | Gray Snapper |
| **2021** | Pinfish | - | - |
| | Mojarra | - | - |
| | Silver Perch | - | - |
| | Pipefish | - | - |
| | Gray Snapper | - | - |
| **2022** | Pinfish | Pinfish | Pinfish |
| | Mojarra | Silver Perch | Silver Perch |
| | Silver Perch | Pigfish | Mojarra |
| | Mosquito Fish | Mojarra | Pigfish |
| | Spotted Sea Trout | Spotted Sea Trout | Pipefish |

## Commercial species distributions

In the northern GoM, Red snapper (*Lutjanus campechanus)* are a highly valuable and ecologically important species with an extremely regulated fishery due to historic overharvesting and stock depletions. Recent range shifts, likely due to climate change, have resulted in dramatic increases of other snapper species in the northern GoM, including gray snapper (*Lutjanus griseus)* and lane snapper (*Lutjanus synagris)*. Prior to 1979 (Livingston, 1985), lane snapper was not commonly documented in nGoM seagrass meadows; however by 2007 they were one of the most abundantly trawled species (Fodrie et al 2010). Currently, lane and gray snapper are commercially and recreationally fished in the GoM with an annual catch limit of ~1 million lbs and ~2.2 million lbs, respectively, in 2023 (Gulf of Mexico Fishery Management Council). They compose a major portion of both the sport and recreation catches in Florida and other tropical areas in the western Atlantic and could supplement overharvested fisheries like the red snapper in the future.

Spotted sea trout is another commercially important fishery that has increased 2-fold since the 1980s and was one of the most abundant taxa collected in Perdido Bay and Big Lagoon in the 2022 survey.

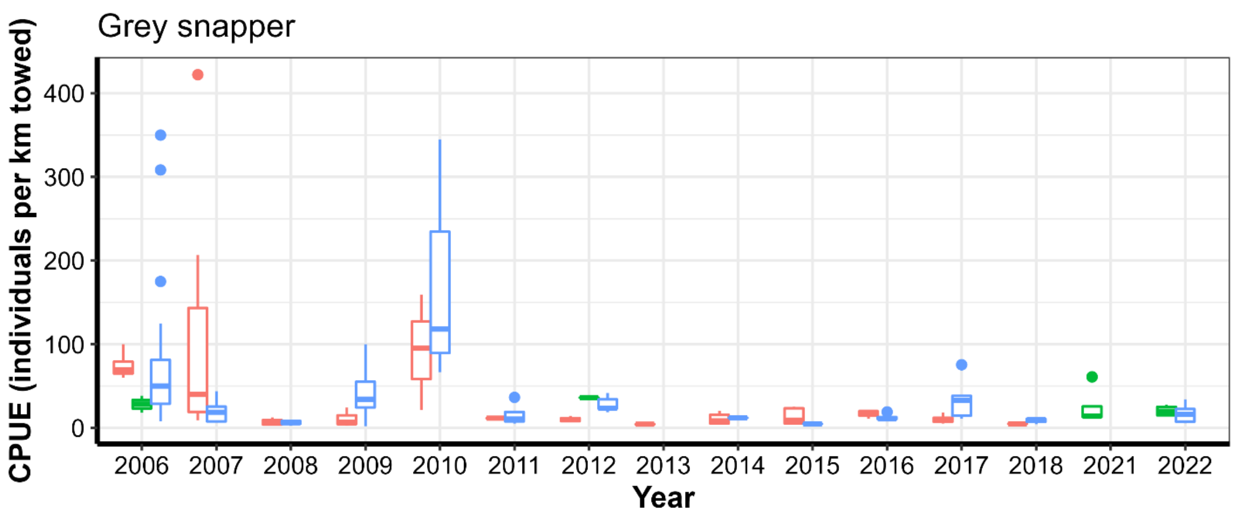
Juvenile gray snapper, lane snapper and spotted sea trout collected in 2022 were measured for total length (mm) and CPUE (individuals/km) and were compared across years to document the continued use of seagrass beds as a nursery habitat by juveniles. Gray snapper are considered juvenile under 18-33 cm, lane snapper under 10-23 cm, and spotted sea trout under 20-24 cm (Florida Museum of Natural History). All commercially valuable species in this study were within these juvenile size classes (Table 6).

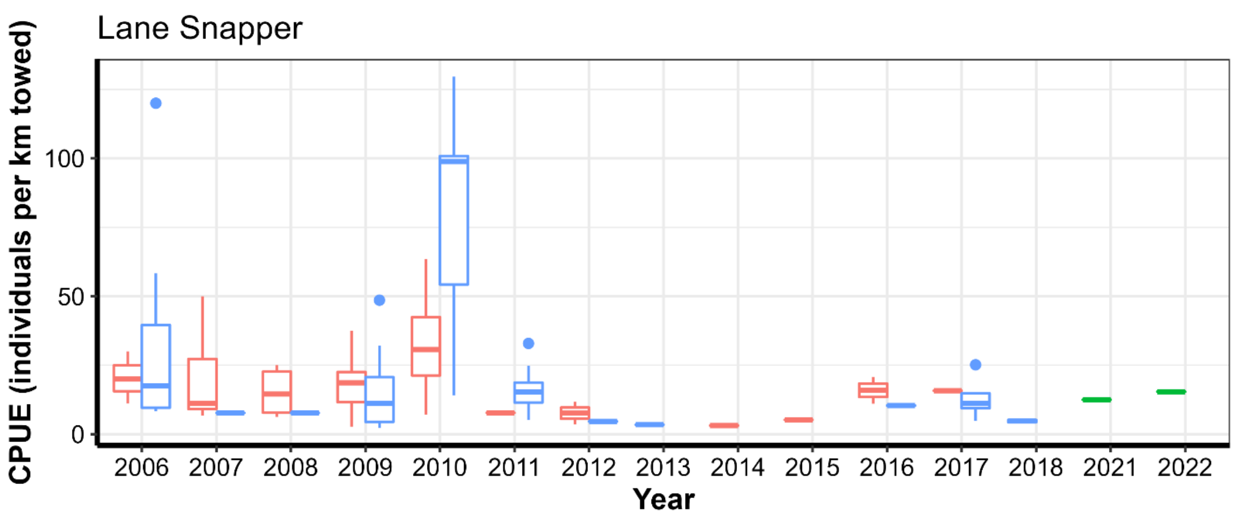
Gray and lane snapper showed a slight decrease in CPUE over the years, with a notable increase in 2010 and decrease from 2013-2015 (Figure 7). In 2022, CPUE (individuals/km) was the highest for all species (gray snapper = 20.3 ± 3.37; lane snapper = 15.4; and spotted sea trout = 25.1 ± 5) in Perdido Bay. Interestingly, 2021 and 2022 were the first years that lane snappers were documented in Perdido Bay.

**Table 6.** Total length (mm) of spotted sea trout, gray snapper, and lane snapper from the 2017-2022 surveys.

| Year | Location | Species | CPUE ± S.E. | Min. length (mm) | Max length (mm) | Mean length (mm) | S.E. |
|---|---|---|---|---|---|---|---|
| 2017 | Big Lagoon | Gray Snapper | 10.35 ± 2.85 | 41 | 77 | 58.3 | 4.9 |
| | | Lane Snapper | 15.75 | 52 | 61 | 56.5 | 4.5 |
| | Santa Rosa Sound | Gray Snapper | 34.49 ± 11.48 | 44 | 71 | 52.7 | 1.4 |
| | | Lane Snapper | 13.05 ± 4.30 | 60 | 80 | 72.33 | 1.9 |
| | | Spotted Sea Trout | 5.55 ± 0.74 | 98 | 105 | 101.5 | 3.5 |
| 2018 | Big Lagoon | Gray Snapper | 4.81 | - | - | 75 | - |
| | Pensacola Bay | Gray Snapper | 8.69 ± 2.20 | 54 | 91 | 66.2 | 5.4 |
| | | Lane Snapper | 4.74 ± 0.85 | 82 | 84 | 83 | 1 |
| | | Spotted Sea Trout | 5.59 | - | - | 149 | - |
| 2021 | Perdido Bay | Gray Snapper | 26.46 ± 6.76 | 38 | 79 | 48.5 | 2.7 |
| | | Lane Snapper | 12.50 | 60 | 60 | 60 | 0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Spotted Sea Trout | 30.56 ± 11.48 | 30 | 87 | 47.6 | 5.2 |
| **2022** | Big Lagoon | Spotted Sea Trout | 5.21 | - | - | 35 | - |
| | Perdido Bay | Gray Snapper | 20.30 ± 3.37 | 40 | 270 | 76.4 | 24.4 |
| | | Lane Snapper | 15.38 | - | - | 55 | - |
| | | Spotted Sea Trout | 25.13 ± 5.01 | 30 | 230 | 71.2 | 16.1 |
| | Santa Rosa Sound | Gray Snapper | 16.86 ± 4.56 | 47 | 114 | 63.8 | 2.9 |
| | | Spotted Sea Trout | 10.03 ± 1.75 | 34 | 195 | 77.1 | 17 |



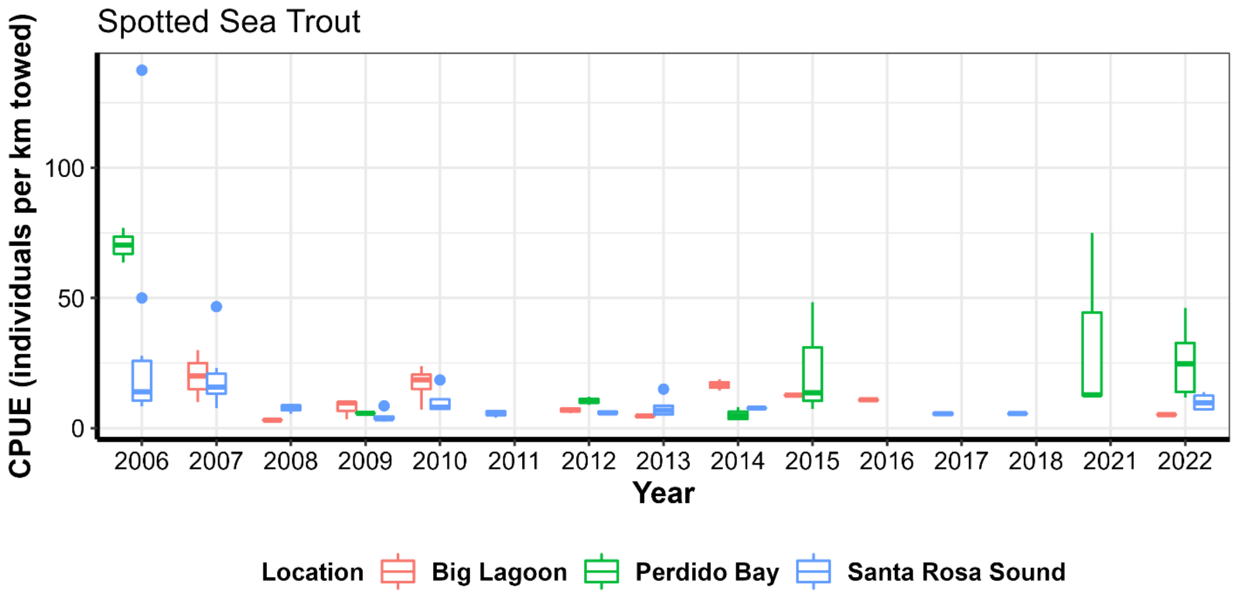



**Figure 7**. CPUE of (A) gray snapper, (B) lane snapper, and (C) spotted sea trout from 2006-2022 in Big Lagoon (pink), Perdido Bay (green), and Santa Rosa Sound (blue). The horizontal line represents the median, the upper and lower hinges correspond to the first and third quartiles (25th and 75th percentiles), the upper and lower whiskers represent the largest and smallest value no further than 1.5*IQR (inter-quartile range), and dots represent outliers.

## Conclusions and Recommendations

The extent of submerged aquatic vegetation across the entire study area remains relatively stable with beds occurring in the same areas as in prior years. While there appears to be some losses in the Pensacola Bay region since the last mapping effort in 2015, this change is more likely to be an artifact of the method used to classify SAV areas than an actual change in extent. Semi-automated/supervised classification are a more reproducible method for estimation of seagrass coverage because it removes individual cartographer biases (i.e., human bias) and provide a more accurate and consistent measure of extent over time. Traditional methods of manually drawing polygons around SAV areas usually overestimate the acreage of patchy SAV areas because the individual patch size versus sand coverage is unknown, and total area estimates are calculated for the entire polygon that includes both SAV and sand. Future SAV mapping events should strongly consider using semi-automated classification creating GIS layers that account for actual SAV cover, especially in patchy areas where prior reported extents are likely an overestimate.

The seagrass meadows of the Perdido and Pensacola Bays, and the Santa Rosa Sound, support an abundance of commercially and recreationally important species; however, the composition of this assemblage could shift as temperatures continue to rise and northward range shifts of native species are blocked by the North American landmass. While some noteworthy shifts have occurred in the nGoM, namely the recently increasing abundance of lane and gray snapper, similarity in dominant species has remained steady from 2006-2022. Specifically, pinfish and silver perch have remained in the top 5 most abundant species in Perdido Bay, Big Lagoon, and Santa Rosa Sound since 2006. Uniquely, 2022 was the first year that mosquito fish and spotted sea trout were among the most abundant taxa. Additionally, 2021 and 2022 are the first years in which lane snapper was documented in Perdido Bay.

Catch per unit effort varied across sites and systems, with Perdido Bay having the highest CPUE, likely driven by the extremely high abundance of pinfish. Over time, sites in Big Lagoon and Santa Rosa Sound showed decreased CPUE while sites in Perdido Bay showed increased or similar CPUE values compared to their first years of trawling.

Overall, variability in annual abundance was quite large across both systems; however, annual monitoring of the juvenile fish community can provide data to inform hypotheses regarding the source of this variability and serve to inform coastal managers of large changes that may impact fish stocks. As climate change threatens to impact the timing of spawning and allow for range shifts of tropically-associated species, these data will provide a benchmark for coastal managers to use in formulating policies to protect our vital coastal resources.

Finally, regarding monitoring of the critical SAV habitat that serves as a nursery for numerous finfish and shellfish, future SAV mapping events should strongly consider using satellite-derived imagery, such as those available from PlantScope. Not only does the satellite-derived imagery produce an accurate map of seagrass presence, but its daily imaging of the globe will enable investigation into seasonal and annual changes in seagrass presence and density, which is not feasible with aerial imagery over a large spatial extent.

## Project Highlights/Work Accomplished

- Professional Service Agreement for Aerial Imagery Acquisition established on August 5, 2022
- Acquisition of Aerial Imagery occurred between September 15 -23, 2022
- Fish Trawl surveys conducted on September 26 and October 11, 2022
- Ground truthing of Upper Perdido Bay following the same Tier II methodology used by Dr. Kelly Darnell conducted on October 13, 2022
- Collaboration with Drs. Victoria Hill and Richard Zimmerman initiated November 21, 2022.
- Semi-automated classification of satellite imagery and aerial imagery occurred between January 1 and February 28, 2023.

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# Appendix A: NV5 Geospatial Mobile Bay Report

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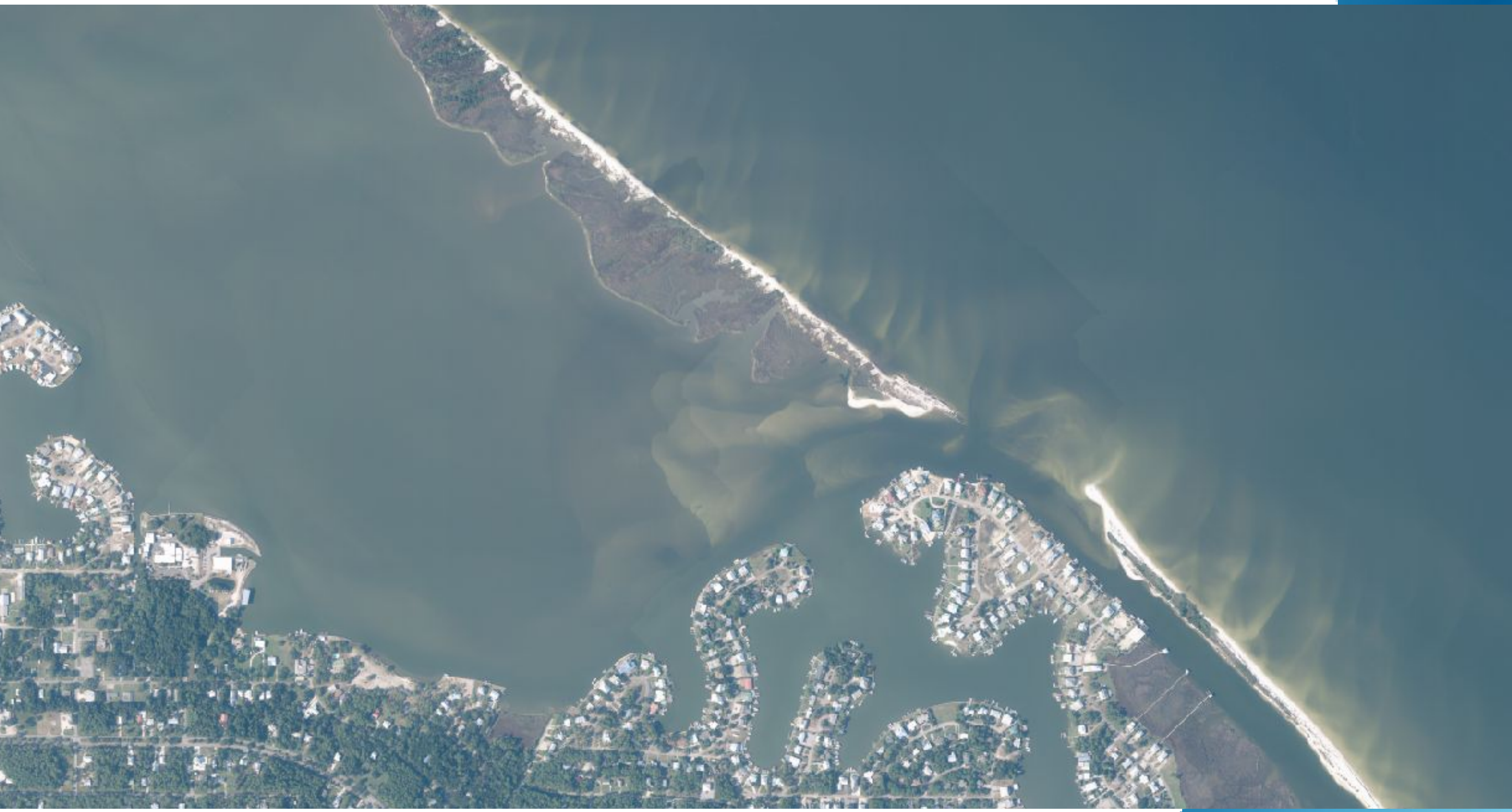
NV5 GEOSPATIAL



Submitted: December 21, 2022

# 41260_Mobile_Bay ORTHOIMAGERY PROJECT REPORT

# 2022

Prepared for:

Dauphin Island Sea Lab
Alabama Center for Marine Education and Research

Prepared by:

NV5 GEOSPATIAL

# Contents

# List of Figures



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# List of Appendices

# 1. Summary / Scope

## 1.1. Summary

This report contains a summary of the 41260_Mobile_Bay orthoimagery project, issued by Dauphin Island Sea Lab. The task order yielded a project area covering 1,243 square miles over Alabama and Florida. The intent of this document is only to provide specific validation information for the data acquisition/collection, processing, and production of deliverables completed as specified in the task order.

## 1.2. Scope

High resolution 1 meter, 8-bit, 4Band digital imagery was acquired and used for digital orthophoto production. Imagery collection was planned using the specifications listed below in Table 1.

**Table 1. Originally Planned Imagery Specifications**

| GSD | Flight Altitude (AGL) | Min. Sun Angle | Side Overlap | Front Overlap |
|---|---|---|---|---|
| 1 meter | 3800 m | 29° | 30% | 60% |

## 1.3. Coverage

The project boundary totals 1,243 square miles and includes Alabama and Florida. Project extents can be seen in Figure 1.

## 1.4. Duration

Imagery was acquired in 4 lifts from September 15, 2022 through September 23, 2022. See "Section: 2.4. Time Period" for more details.

## 1.5. Issues

There were no issues to report.

| 41260_Mobile_Bay Deliverables<br>Projected Coordinate System: NAD_1983_2011_UTM_Zone_16N<br>Horizontal Datum: NAD83 (2011)<br>Units: Meters | |
|---|---|
| Orthorectified Imagery<br>Compressed Imagery | • 1-foot 8-bit, 4-band images in GeoTIFF format |
| Shapefiles, Text Files, ASCII Files | (*.shp)<br>• Tile Index |
| Reports | Reports in PDF format<br>• Project Report<br>• Flight Logs (appended)<br>• Base Stations (appended) |
| Metadata | XML Files (*.xml)<br>• Tile level<br>• Project level |

# 41260_Mobile_Bay
# Project Boundary

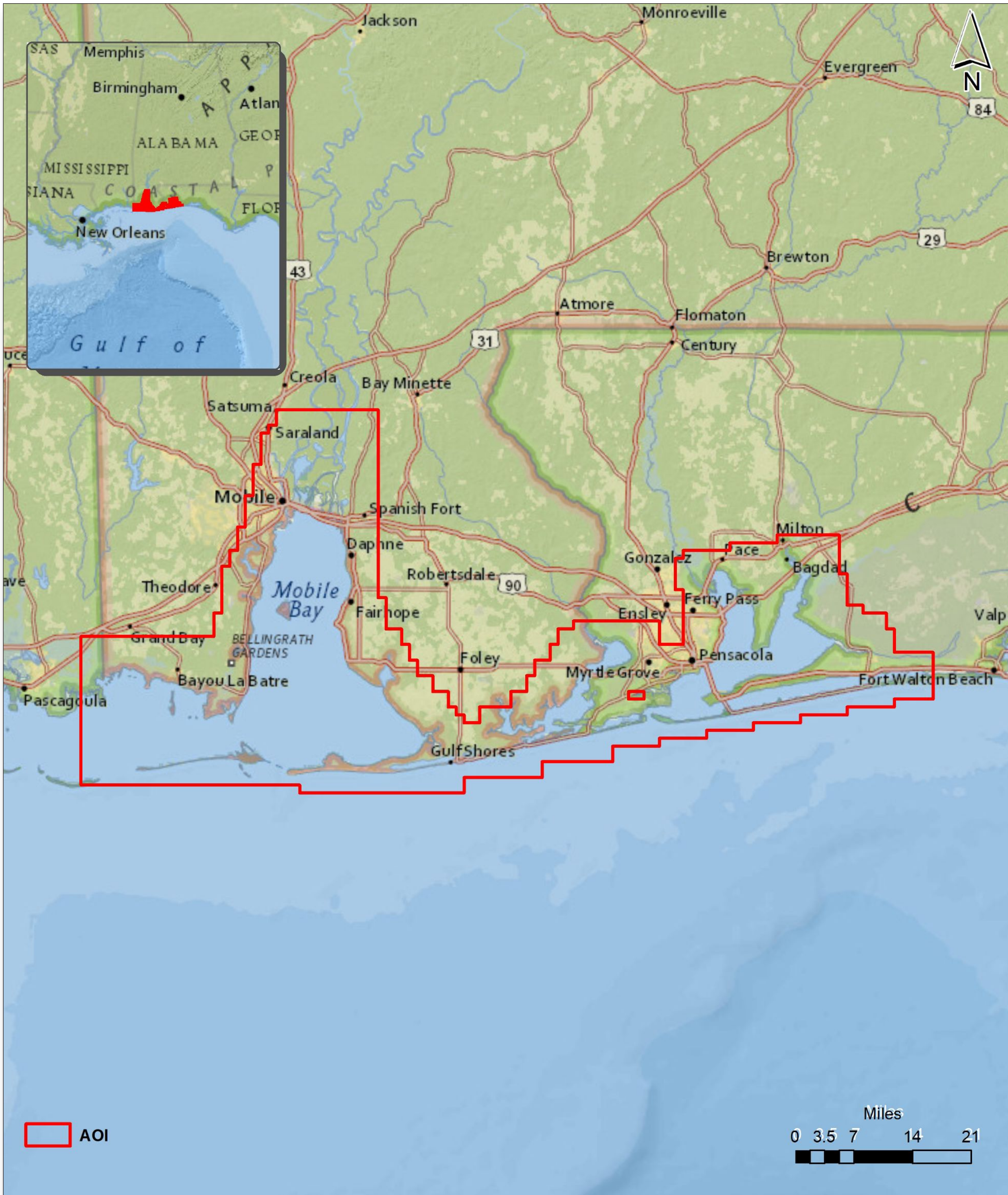


**Figure 1. Project Boundary**

# 2. Planning / Equipment

## 2.1. Flight Planning

Flight planning was based on the unique project requirements and characteristics of the project site. The basis of planning included: required accuracies, type of development, amount / type of vegetation within project area, required data posting, and potential altitude restrictions for flights in project vicinity.

Detailed project flight planning calculations were performed for the project using Leica MissionPro planning software.

## 2.2. Imagery Camera

NV5 Geospatial also utilized a Microsoft UltraCam Eagle M3(Figure 3), serial number(s) 2114.

This system has 4 channel (RGB & NIR) multi-spectral capability. The combination of the camera's Forward Motion Compensation, along with the gyro stabilized mount, ensures the best possible image collection. A single full resolution image is 26,460 by 17,004 pixels in size and utilizes a 100mm lens focal distance.

A brief summary of the aerial acquisition parameters for the project are shown in the Camera System Specifications in Table 2.

**Table 2. System Specifications**

| | | UltraCAM Eagle |
|---|---|---|
| **Terrain and Aircraft** | Flying Height AGL | 12,500 ft |
| **Overlap** | Forward Overlap | 60% |
| | Side Overlap | 30% |
| **Coverage** | Strip Width | 2,800 m |
| **Resolution** | Ground Sample Distance | 15 cm |

**Figure 2. Microsoft UltraCam Eagle Camera**

## 2.3. Aircraft

All flights for the project were accomplished through the use of customized planes. Plane type and tail numbers are listed below.

- Piper Navajo (twin-piston), Tail Number(s): N26GP

These aircraft provided an ideal, stable aerial base for imagery acquisition. These aerial platforms have relatively fast cruise speeds which are beneficial for project mobilization / demobilization while maintaining relatively slow stall speeds which proved ideal for collection of high-density, consistent data posting using a state-of-the-art UltraCam imagery system. Some of NV5 Geospatial's operating aircraft can be seen in Figure 4 below.

**Figure 3. NV5 Geospatial Planes**

## 2.4. Time Period

Project specific flights were conducted over one month. Four lifts were completed. Accomplished aircraft lifts are listed below.

- 9/15/2022, N26GP
- 9/16/2022, N26GP
- 9/22/2022, N26GP
- 9/23/2022, N26GP

# 3. Processing Summary

## 3.1. Flight Logs

Flight logs were completed by sensor technicians for each mission during acquisition. These logs depict a variety of information, including:

- Job / Project #
- System
- Flight Date / Lift Number
- Flight Line Number
- Flight Line Start Time
- Flight Line Stop Time
- Image Range
- F-Stop Setting
- Shutter Setting

Notes: (Visibility, winds, ride, weather, temperature, dew point, pressure, etc). Project specific flight logs for each sortie are available in Appendix A.

## 3.2. Imagery Processing Summary

Within the UltraMap software suite, raw acquired images are radiometrically and geometrically corrected using the camera's calibration files and output as Level 2 images. The resulting radiometry is then manually edited to ensure each image has the appropriate tone, no pixels are clipped, and to blend each image with its neighbors. Once radiometry has been edited, separate RGBI and Panchromatic images are blended together to form single level 4 band TIFF images. This data set was produced to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014)  for a 1.2 (m) RMSEx/RMSEy Hoirzontal Accuracy Class A

Image radiometric values were calibrated to specific gain and exposure settings associated with each capture using Microsoft's UltraMap software suite. The calibrated images were saved in TIFF format for input to subsequent processes. Photo position and orientation were calculated by linking the time of image capture, the corresponding aircraft position and attitude, and the smoothed best estimate of trajectory (SBET) data in POSPAC. Aerotriangulation was then performed using ImageStation AT (ISAT). Adjusted images were then draped upon a ground model and orthorectified. Individual orthorectified tiffs were blended together to remove seams and corrected for any remaining radiometric differences between images using Inpho's OrthoVista.

## 3.3. Airborne GPS and IMU Post Processing

During the sensor trajectory processing (combining GPS & IMU datasets) certain statistical graphs and tables are generated within the Applanix POSPac processing environment which are commonly used as indicators of processing stability and accuracy. This data for analysis include: Max horizontal / vertical GPS variance, separation plot, altitude plot, PDOP plot, base station baseline length, processing mode, number of satellite vehicles, and mission trajectory.

## 3.4. Aerotriangulation

Using RAW images, Airborne ABGPS/IMU external orientation parameters and ground control data, the imagery control solution was further extended and densified using analytical aerotriangulation adjustment techniques. This adjustment of the measurements was performed using a robust aerotriangulation software package, Image Station Aero Triangulation (ISAT) software, on softcopy photogrammetric workstations.

## 3.5. Orthophotography Creation

Digital orthophoto frames are created by using existing public domain elevation data sets, which were in turn combined with Level 3 processed imagery, aerotriangulation data, as well as government supplied airborne topographic LiDAR bare earth data sets of various vintages. This orthorectification process is done in Hexagon Geomedia on the three data sources (processed imagery, aerotriangulation data and surface data).

Manual Seamlines were drawn in ArcMap on every frame. Then, using the grid created with in-house software a set of "base" mosaicked tiles were created in ImageStation OrthoPro using a bilinear interpolation method on the three data sources (rectified imagery, aerotriangulation data and surface data). At this stage a final color balancing is also done to ensure a superior balance across the entire dataset. Color balancing for the level 3 imagery was balanced to enhance the water.

The first step to the quality control process is to draw circles on areas of concern. Reviewers look for mismatches at seamlines, smears caused by elevation discrepancies (building lean, bridge warping) and radiometric distortions. Then, a different technician corrects the edit calls. There are a total of 2,394 tiles in GeoTIFF format.

Tile layout is shown in Figure 5 on the following page.

# 41260_Mobile_Bay
# Tile Layout

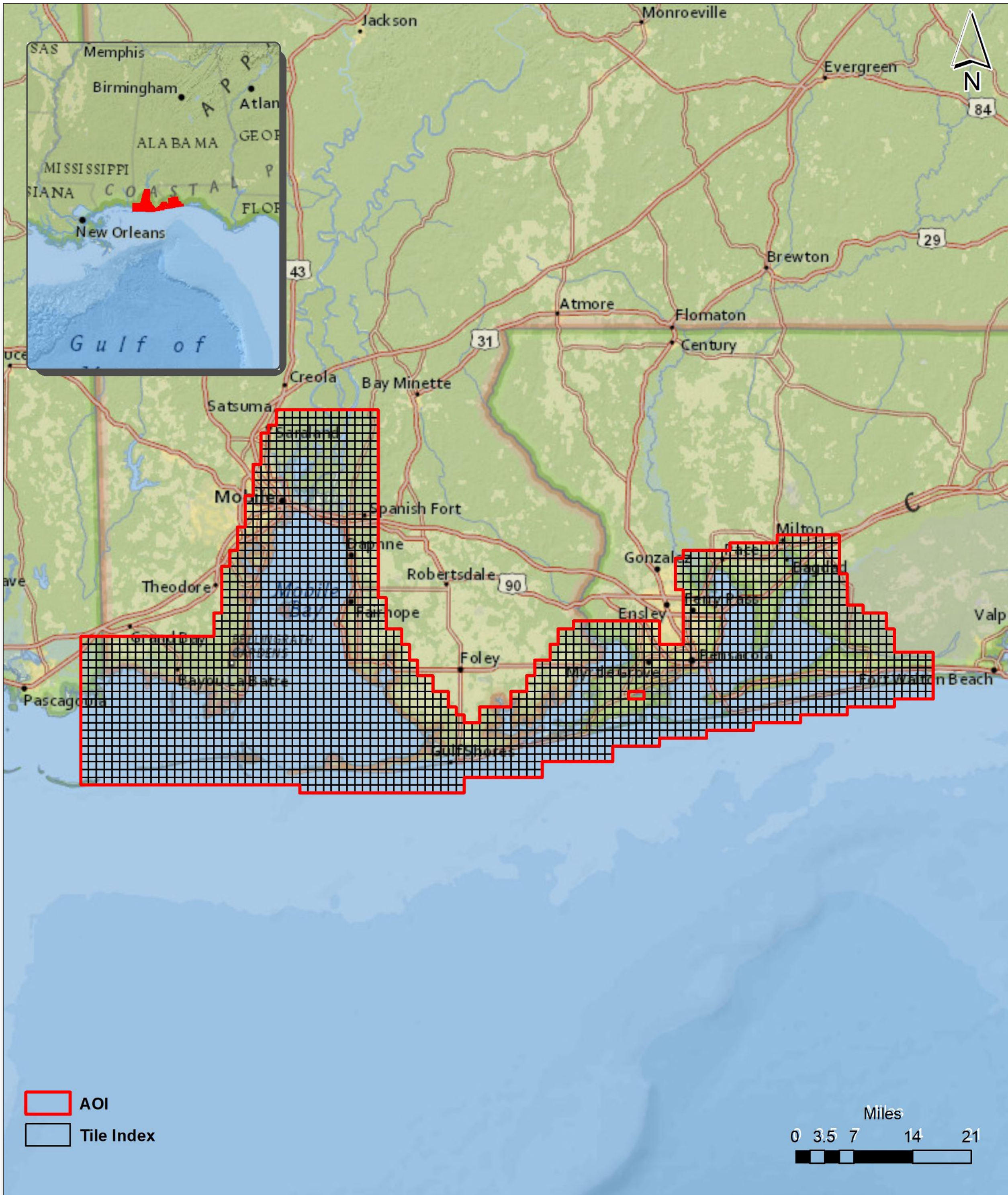


Figure 4. Tile Layout

# 4. Project Coverage Verification

Imagery coverage (see Figure 6) and content verification was performed and validated by visual review. This action was performed in the field by flight crew during the acquisition phase as well as by imagery QA technicians at our processing center. The ABGPS/IMU and base station data was uploaded to the company FTP site after each flight for the INS processing team in Lexington, Kentucky to verify accuracy of data collected.

# 41260_Mobile_Bay
# Imagery Coverage

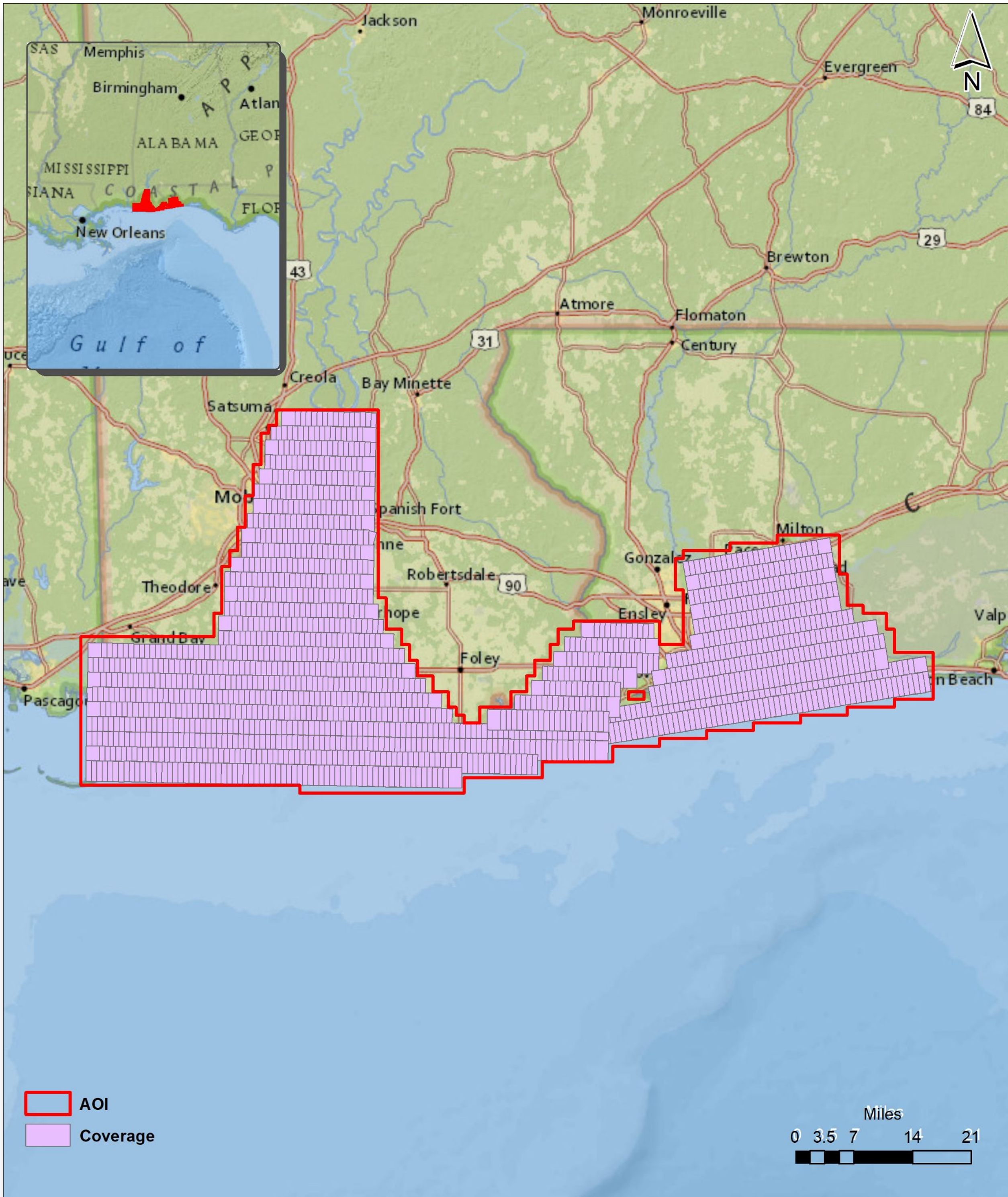


Figure 5. Imagery Flight Line Coverage

# Project Report Appendices

The following section contains the appendices as listed in the 41260_Mobile_Bay Orthoimagery Project Report.

# Appendix A

## Flight Logs

GPI

## FLIGHT ACQUISITION FORM

| Job # | Job Name | Date | Sensor | Lift | Aircraft | Pilot | Operator |
|---|---|---|---|---|---|---|---|
| 2200721 | Mobile Bay | 9/15/2022 | S2 - UCE Mk3 | 2 | N26GP - PA31 | K. Norup | R. McIntyre |

| Line # | Record | Images | Direction | Sun Angle | Start UTC | Stop UTC | Settings | Comments and Conditions |
|---|---|---|---|---|---|---|---|---|
| | | | | | 19:29 | 19:34 | 5.6 1/500 DU2 3547 | Static at KDTS |
| 32 | | 368 - 423 | W | 45.3 | 20:12 | 20:23 | | |
| 33 | | 424 - 482 | E | 43.5 | 20:24 | 20:36 | | Clouds |
| 34 | | 483 - 543 | W | 40.1 | 20:38 | 20:50 | | Clouds |
| 36 | | 544 - 607 | E | 38.1 | 20:51 | 21:04 | | Clouds |
| 38 | | 608 - 673 | W | 34.6 | 21:06 | 21:19 | | Clouds |
| 40 | | 674 - 768 | E | 32.2 | 21:20 | 21:40 | | Clouds |
| | | | | | | | | Shut down in flight 21:52 |
| | | | | | | | | |
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T = Turbulence, OVC = overcast clouds, BKN = broken clouds, SCT = scattered clouds, XWND = high cross wind

ver 2.1

GPI

## FLIGHT ACQUISITION FORM

| Job # | Job Name | Date | Sensor | Lift | Aircraft | Pilot | Operator |
|---|---|---|---|---|---|---|---|
| 2200721 | Mobile Bay | 9/15/2022 | S2 - UCE Mk3 | 1 | N26GP - PA31 | K. Norup | R. McIntyre |

| Line # | Record | Images | Direction | Sun Angle | Start UTC | Stop UTC | Settings | Comments and Conditions |
|---|---|---|---|---|---|---|---|---|
| | | | | | 13:05 | 13:10 | F5.6 1/500 DU2 3913 | Static @ KDTS |
| 16 | | 1 - 16 | W | 28.9 | 13:48 | 13:51 | | |
| 17 | | 17 - 34 | E | 29.7 | 13:53 | 13:56 | | |
| 18 | | 35 - 53 | W | 30.5 | 13:58 | 14:01 | | |
| 19 | | 54 - 72 | E | 31.7 | 14:03 | 14:07 | | |
| 20 | | 73 - 92 | W | 32.9 | 14:08 | 14:12 | | |
| 21 | | 93 - 113 | E | 33,8 | 14:14 | 14:18 | | |
| 22 | | 114 - 134 | W | 35.1 | 14:19 | 14:23 | | |
| 23 | | 135 - 156 | E | 35.9 | 14:24 | 14:29 | | |
| 24 | | 157 - 179 | W | 37.4 | 14:31 | 14:34 | | |
| 25 | | 180 - 202 | E | 38.5 | 14:36 | 14:41 | | |
| 26 | | 203 - 227 | W | 39.3 | 14:43 | 14:47 | | |
| 27 | | 228 - 253 | E | 40.9 | 14:49 | 14:45 | | |
| 28 | | 254 - 279 | W | 42.2 | 14:56 | 15:00 | | |
| 29 | | 280 - 306 | E | 43.3 | 15:02 | 15:07 | | |
| 30 | | 307- 335 | W | 44.8 | 15:09 | 15:14 | | |
| 31 | | 336 - 366 | E | 45.6 | 15:16 | 15:22 | | Shut down in flight 15:32 |
| | | | | | | | | |

T = Turbulence, OVC = overcast clouds, BKN = broken clouds, SCT = scattered clouds, XWND = high cross wind

GPI

## FLIGHT ACQUISITION FORM

| Job # | Job Name | Date | Sensor | Lift | Aircraft | Pilot | Operator |
|---|---|---|---|---|---|---|---|
| 2200721 | Mobile Bay | 9/16/2022 | S2 - UCE Mk3 | 1 | N26GP - PA31 | K. Norup | R. McIntyre |

| Line # | Record | Images | Direction | Sun Angle | Start UTC | Stop UTC | Settings | Comments and Conditions |
|---|---|---|---|---|---|---|---|---|
| | | | | | 13:32 | 13:37 | F5.6 1/500 DU2 3145 | Static @ KDTS |
| 12 | | 770 - 780 | E | 33.8 | 14:12 | 14:15 | | Collected at 10500. ATC would not authorize 12500. |
| 13 | | 781 - 796 | W | 34.9 | 14:16 | 14:20 | | Collected at 10500. ATC would not authorize 12500. |
| 14 | | 797 - 814 | E | 35.7 | 14:22 | 14:25 | | Collected at 10500. ATC would not authorize 12500. |
| 15 | | 815 - 831 | W | 37.1 | 14:27 | 14:31 | | Collected at 10500. ATC would not authorize 12500. |
| 35 | | 832 - 847 | E | 38.3 | 14:33 | 14:36 | | Collected at 10500. ATC would not authorize 12500. Clouds |
| | | | | | | | | Shut down in flight 14:50 |
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T = Turbulence, OVC = overcast clouds, BKN = broken clouds, SCT = scattered clouds, XWND = high cross wind

ver 2.1

# Appendix B

## Acquisition Parameters

# PROPOSAL

## For Professional Services

Mobile Bay Imagery
Resourcing

NV5 Geospatial
Sheboygan Falls, WI


Submitted by:
GPI Geospatial, Inc., Inc. (GPI)
Richard R. Wohler
rwohler@gpinet.com


8/23/2022


2124 Kohler Memorial Drive
Suite 305
Sheboygan, WI 53081
920.449.5298
www.gpinet.com/geospatial


GPI

Geomatics | LiDAR | Photogrammetry

August 23, 2022

Ryan Boll
Flight Operations Manager
**NV5 Geospatial, Inc.**
N6216 Resource Dr.
Sheboygan Falls, WI 53085
(920)418-3813
Ryan.Boll@nv5.com

**Subject**: Mobile Bay Imagery Resourcing-Sept 2022
**GPI Geospatial, Inc. Proposal No**. 2200721.00

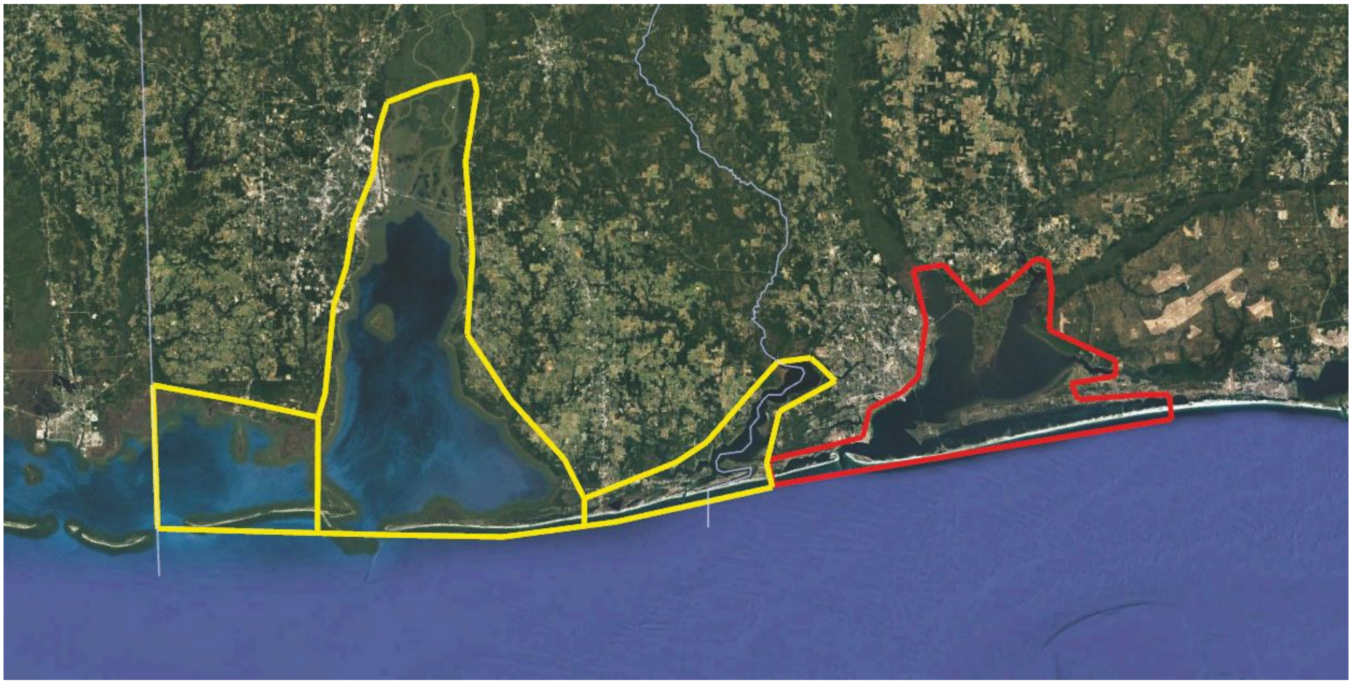
GPI Geospatial, Inc., (GPI) greatly appreciates this opportunity to provide NV5 Geospatial, Inc., hereafter referred to as the Client, with our proposal to perform professional geospatial services as requested. The following proposal is based on our understanding of the scope of work.

## Project Description

The acquisition AOI is located at the egress of the Charleston Harbor on specific shoreline sandbars and islands in the Harbor. GPI will acquire aerial Lidar and Imagery for three AOIs.

All geospatial tasks will be performed in accordance with the current Standards of Practice for Surveying and Mapping in the State of Alabama where the project is located.

## Project Limits



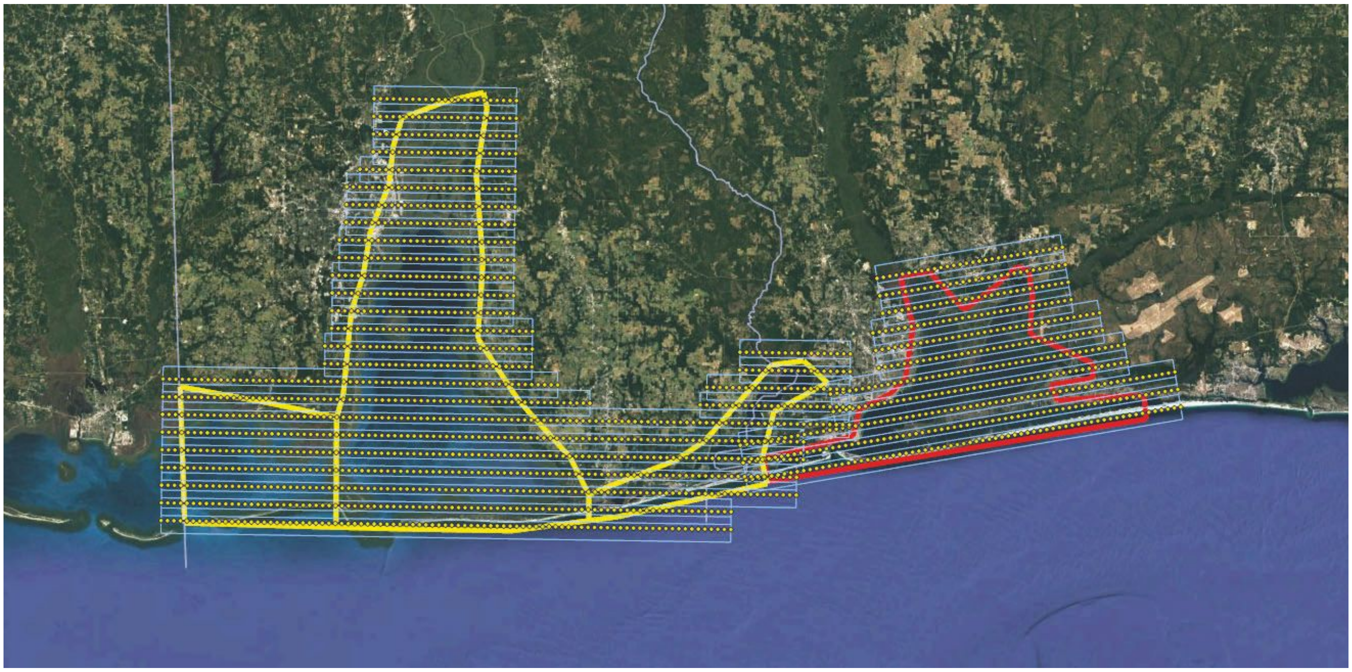
## Aerial Data Acquisition

| | |
|---|---|
| Simultaneous Acquisition | N |

| Imagery Acquisition | |
|---|---|
| **Sensor** | UltraCAM Eagle |
| **Flight Altitude** | 12500’ AGL |
| **Sidelap** | 30% |
| **Forward Lap** | 60% |
| **Ground Sample Distance (GSD)** | 15 cm |
| **Number of Flight Lines** | 40 |
| **Flight Time** | 17.7 hr. |
| **Number of Exposures** | 1829 |
| **Number of Targets** | N/A |
| **Project Area** | 1243.56 Sq. Miles |

- The imagery shall be free of haze, snow, clouds and smoke.
- The photography shall not contain any excessive tip, tilt, or crab.
- All flight plans shall be designed by a Certified Photogrammetrist and approved prior to acquisition.
- Weather conditions and access to airspace can affect acquisition schedules.
- Certain restricted airspace may require the presence of an appropriate law enforcement official.

The proposed flight plan(s) are attached.



## Deliverables

### Acquisition:

- Raw Imagery - RGB, 4 band, IR(Level 0)
- Format - TIFF
- Flight Plans
- Flight Report

## Exclusions

- Tree surveys (size, type, etc.)
- Obscured area survey
- Drainage surveys (pipe size, material, invert, etc.)
- Subsurface utilities
- Feature labeling (point or line features)
- Symbol rotation
- File or data merging
- No boundary, property or right-of-Way determination
- Field reviews
- Sign identification
- Paint lines
- Parking Stripes

## Schedule

### Imagery / LiDAR

Imagery and LiDAR Acquisition: 2-3 weeks from NTP (weather permitting).
Final Delivery: 2 weeks from completion of remote sensing data acquisition.

## Fees

Based upon the above services and the following Terms and Conditions, our fee for these Services shall be as follows:

| Location – Mobile Bay | |
|---|---|
| Aerial Imagery/Lidar Acquisition (Total Fee) | $49,640.00 |

This proposal can be individually modified to meet your requirements, upon request.

# Contract Terms and Conditions

### Time for Acceptance
This agreement is void if not signed and returned to GPI Geospatial, Inc. within 90 days of the date of the agreement.

### Time for Rendering Services
GPI Geospatial, Inc. will perform the services described in these documents (“the Services”) following a mutually agreeable schedule consistent with usual and customary practices. GPI Geospatial, Inc. agrees to use reasonable efforts to commence the Services on the date specific in the Agreement or contained in the agreed upon schedule, and shall proceed with reasonable diligence to complete the Services. Should GPI be delayed in the completion of the Services due to causes beyond GPI Geospatial, Inc.’s control or other excused delays, then GPI Geospatial, Inc. shall be awarded additional time to perform such Services and the price stated in the Agreement shall be equitably adjusted for any additional costs incurred by GPI Geospatial, Inc. due to such delay.

### Information Provided
Before GPI Geospatial, Inc. commences the Services, the Client shall provide GPI Geospatial, Inc., in writing all necessary information to permit its proper performance of the Services. GPI Geospatial, Inc. shall be under no duty or obligation to verify the completeness or accuracy of the information provided by the Client and shall be entitled to fully rely thereon. GPI Geospatial, Inc. shall have no obligation to perform any Services until all necessary information has been provided in writing by the Client. GPI Geospatial, Inc. shall not be responsible for any locations, dimensions, depths, elevations, or a similar metric which are provided by the Client in error.

### Additional Services
Services not expressly included in these documents are defined as additional services, and will not be performed until approved and authorized in writing by the Client. If the fee set forth in the proposal is for a Lump Sum, then Additional Services shall be provided on an hourly basis, invoiced at GPI Geospatial, Inc.’s prevailing hourly rates, which are set forth in Exhibit B to the Proposal, “GPI Geospatial, Inc. Prevailing Hourly Rates” which is incorporated here and will be invoiced separately.

### Change Orders
If Client wishes to change the scope of performance of the Services, Client must submit written details of the requested change to GPI Geospatial, Inc. GPI Geospatial, Inc. shall, within a reasonable amount of time after such request, provide a written estimate to Client of (a) the likely time required to implement the change; (b) any necessary variations to the fees and other charges for the Services arising from the change; and (c) any other impact the change might have on the Agreement. Promptly after receipt of the written estimate, the parties shall negotiate and agree in writing on the terms of such change (a “Change Order”). Neither party shall be bound by any Change Order unless mutually agreed upon in writing.

### Hourly Rate Schedule (Not applicable to Lump Sum Fees)
Services provided on an hourly basis will be invoiced at GPI Geospatial, Inc.’s prevailing hourly rates. Prevailing hourly rate changes occurring during the contract period will be applicable as of the effective date of rate change. Hourly rates are subject to change the first of January and July.

### Payment for Services
Services will be invoiced monthly based on work accomplished. Payment for Services rendered is due upon receipt of GPI Geospatial, Inc.’s invoice. Invoice payments not received within 30 days from the date of the invoice are past due and subject to a service charge equal to 1.5% per month (18% per annum). If payment is not received within 60 days of invoice, GPI Geospatial, Inc. has the unilateral right to discontinue work on the project and terminate this Agreement with no legal recourse by the Client. The Client will be liable for all costs of collection, including, but not limited to, court costs, filing fees, service fees, reasonable attorneys’ fees, and staff time at our prevailing hourly rates should a default in payment occur.

### Reimbursable Expenses
Reimbursable expenses will be billed to the Client, in addition to the fee, at the rate of 1.1 times actual expenditures. Reimbursable expenses include the cost of travel, reproductions, deliveries, postage, photographs, and handling of drawings, specifications, reports, or other project related material.

### Permits and Licenses
Client shall timely, so as to not delay the Services, secure and pay for all easements, permits and licenses required by law, and shall give all notices required thereunder.

### Standard of Practice and Care
Services performed by GPI Geospatial, Inc. will be consistent with the level of care and skill ordinarily exercised by members of this profession currently practicing in the same locality and under similar conditions. No other representation, expressed or implied, and no warranty or guarantee is included or intended in this Agreement or any report, opinion, document or otherwise.

### Site Access
Client will provide the necessary access and right of entry for GPI Geospatial, Inc. to enter and inspect all locations of the Project Site and to all offsite locations as necessary in order to allow GPI Geospatial, Inc. to perform its Services. GPI Geospatial, Inc. is not obligated to provide scaffolding or personnel hoists in order to perform the Services.

### Limitation of Liability
NEITHER PARTY WILL BE LIABLE TO EACH OTHER FOR ANY SPECIAL, INDIRECT, PUNITIVE, INCIDENTAL, LIQUIDATED, OR CONSEQUENTIAL DAMAGES ARISING OUT OF THIS AGREEMENT OR THE SERVICES PERFORMED HEREUNDER. IN NO EVENT SHALL GPI GEOSPATIAL, INC.'S AGGREGATE LIABILITY TO CLIENT EXCEED THE AMOUNT OF AVAILABLE INSURANCE OR GPI GEOSPATIAL, INC.'S FEES TO THE SERVICES PERFORMED HEREUNDER, WHICHEVER IS LESS.

### Field Observation Services
Field observation services performed by GPI Geospatial, Inc. pursuant to this contract, whether performed prior to, during, or after completion of construction, are performed solely for the purpose of determining general conformity of work with the contract plans and specifications. Nothing contained herein shall create or be deemed to create any duty or authority upon GPI Geospatial, Inc. or its employees to direct, supervise, or control the work (including safety procedures), of other contractors, subcontractors, consultants or their respective employees or by any other person at the project site (collectively "Client's Contractors"). The Services do not include any form of guarantee or insurance with respect to the performance of Client's Contractors. GPI Geospatial, Inc. does not assume responsibility for the means, methods, sequences, and techniques employed by the Client's Contractors in their work. GPI Geospatial, Inc. is only responsible for the health and safety of its own employees.

### Ownership of Documents
All documents created, prepared, or furnished by GPI Geospatial, Inc. pursuant to the Agreement, including plans, drawings, specifications, construction documents, displays, graphic art, photographs, and other images and devices of any medium, including electronic data (including but not limited to LiDAR) or files (collectively "Design Materials"), are instruments of GPI Geospatial, Inc., and GPI Geospatial, Inc. shall retain an ownership and property interest therein, including copyrights. Upon payment in accordance with the Agreement, GPI Geospatial, Inc. grants Client a perpetual, non-exclusive, royalty-free license to use the Design Materials for the sole purpose of use at the Project. Reuse or modification of any such documents by Owner, without GPI Geospatial, Inc.'s express written consent, shall be at Client's own risk, and Client agrees to defend, indemnify and hold GPI Geospatial, Inc. harmless from all claims, damages and expenses, including attorneys' fees, arising out of such reuse or modification by Client or by others acting through Client. Client agrees that it shall not use the Design Materials or the name of GPI Geospatial, Inc. or its insignia or seal in any manner without GPI Geospatial, Inc.'s express written consent.

### Project Suspension or Termination
If the project is suspended for more than 90 days, abandoned in part or terminated, the Client will pay GPI Geospatial, Inc. for services performed and reimbursable expenses incurred up to and including the effective date of such suspension, abandonment or termination, and all termination expenses. The contract fee will require renegotiations should the project be restarted.

### Severability
If any of the provisions herein shall be invalid or unenforceable under applicable law, such invalidity or unenforceability shall not invalidate or render these Terms and Conditions unenforceable, which shall be construed as if not containing the particular invalid or unenforceable provision, provided that the intent of the parties can be achieved in all material respects.

### Governing Law
This Agreement shall be construed and governed in accordance with the laws in the state in which the Project is located.

### Merger and Counterparts
This Agreement may be executed in counterparts and exchanged by facsimile, email or pdf, each of which shall be deemed an original and all of which, when taken together, constitute one and the same documents. This Agreement contains the complete, full and exclusive understanding of the parties and shall supersede any prior agreement between the parties.

### Claims and Disputes
Owner and Consultant shall endeavor to resolve claims, disputes and other matters in question between them in good faith and an efficient business-like manner. The Consultant shall continue providing Services during such time as the dispute exists, provided that Owner continues to pay all amounts that are not in dispute and such dispute does not continue in excess of ninety (90) consecutive days.

If the parties do not resolve a dispute through good faith negotiations, the Parties shall first endeavor to resolve the dispute by mediation, which shall be administered by the American Arbitration Association in accordance with its Construction Industry Mediation Procedures in effect on the date of this Agreement. The Parties shall share the mediator's fee and any filing fees equally. The mediation shall be held in the place where the Project is located. Agreements reached in mediation shall be enforceable as settlement agreements in any court having jurisdiction.

If the Parties are unable to resolve the matter following mediation, then the method of binding dispute resolution shall be as follows: (Check the appropriate box.)

[ X ] **Arbitration** – Either Party may submit any unresolved claim or dispute to binding arbitration in accordance with the Construction Industry Arbitration Rules of AAA, and shall be conducted by a single Arbitrator mutually acceptable to both Parties. If the Parties cannot agree on the arbitrator, then the arbitrator shall be selected by the President of the American Arbitration Association. Arbitration shall be held and conducted in the state where the project is located, unless the Parties agree otherwise. The filing fee and arbitrator's fees shall be shared equally by the Parties.

[ « » ] **Litigation** – Any claim or dispute arising hereunder shall be commenced in a court of competent jurisdiction located in state where the project is located. This Agreement shall be interpreted in accordance with the laws of the state where the project is located.

[ « » ] Other: *(Specify)*

### Insurance
GPI Geospatial, Inc. will maintain the following insurance for the duration of the project:

22.1 Commercial General Liability – Bodily Injury/Property Damage - $2,000,000 each occurrence and $4,000,000 in the aggregate.
22.2 Worker's Compensation – as per Statute. Premiums for additional insurance coverage required for work on or over the water will be charged to the project and are subject to reimbursement.
22.3 Automobile Liability – in the amount of $1,000,000 each accident covering owned, non-owned, and hired vehicles.
22.4 Excess/Umbrella – in the amount of $5,000,000.
22.5 Professional Liability – in the amount of $1,000,000 each claim/ $2,000,000 in the aggregate.
22.6 GPI Geospatial, Inc. will furnish to Client Certificates of Insurance upon request naming Client as an additional insured on the General Liability policy.
22.7 Aircraft Liability – in the amount of $10,000,000.

If Client requires limits greater than provided herein above, such additional limits may be offered, if commercially available, at Client's sole cost and expense.

### Contractor's Responsibilities
GPI Geospatial, Inc. has no control over, charge of, or responsibility for construction. Client shall retain a qualified contractor, licensed in the jurisdiction of the project ("Contractor"), to implement the construction of the project ("Work"). The Contractor shall coordinate, supervise and direct all aspects of the Work and shall be solely responsible for, and have control over, construction means, methods, techniques, sequences and procedures, safety, and security. To the fullest extent permitted by

law, the Contractor shall defend, indemnify and hold harmless Client, GPI Geospatial, Inc., GPI Geospatial, Inc.'s subconsultants, and their respective directors, officers, employees and agents or any of them from and against all claims, damages, losses and expenses, including attorney's fees, arising out of or in connection with the Contractor's Work. Contractor shall provide insurance and shall name Client, GPI Geospatial, Inc. and GPI Geospatial, Inc.'s subconsultants as additional insured on Contractor's Commercial General Liability Insurance policies.

### Indemnification

24.1 GPI Geospatial, Inc., subject to the limitation in Section 12 herein, agrees to hold the Client harmless from and against all claims arising out of the negligent professional acts, errors, and omissions of GPI Geospatial, Inc. in connection with the performance of the Services described in this Agreement.

24.2 GPI Geospatial, Inc. shall not be responsible for the acts or omissions of the Client, Contractor or any third parties in connection with or arising out of the project. Client hereby holds harmless and indemnifies GPI Geospatial, Inc. against all claims, damages, costs, suits, expenses, and attorney's fees which may be incurred by GPI Geospatial, Inc. which arise out of the foregoing. Expenses shall include, but not be limited to time charges by GPI Geospatial, Inc.'s employees at GPI Geospatial, Inc.'s then standard hourly fees.

24.3 Client shall make no claim for professional negligent acts, errors, omissions and/or alleged breach of contract either directly or in a third party claim, against GPI Geospatial, Inc. unless the Client has first provided GPI Geospatial, Inc. with a written certification executed by an independent design professional practicing in the same discipline as GPI Geospatial, Inc. and licensed in the state in which the project for which GPI Geospatial, Inc.'s services were rendered is located. This certification shall: a) identify the name and license of the certifier; b) specify each and every act or omission that the certifier contends is a violation of the standard of care expected of a design professional performing professional services under similar circumstances; and c) state in complete detail the basis for certifier's opinion that each such act or omission constitutes a violation. This certificate shall be provided to GPI Geospatial, Inc. not less than thirty (30) calendar days prior to the presentation of any claim or the institution of any legal proceeding.

### Force Majeure

If the performance of Services by Consultant is affected by causes beyond its reasonable control, force majeure shall result. Force Majeure includes acts of God, acts of a legislative, administrative, or judicial entity, governmental order, war, fires, floods, labor disputes, pandemic, COVID-19 and unusually severe or unanticipated weather which prevent Consultant from performing the Services hereunder (**"Force Majeure"**). Should a Force Majeure event occur, Consultant shall receive day-for-day Schedule relief based on the number of days the Force Majeure prevents Consultant from performing the Services. Consultant shall not be liable for failure to comply with any Force Majeure event.

# Appendix B: ODU Florida SAV Report

**Experimental Evaluation of the Utility of Dove/PlanetScope Imagery for Mapping SAV Distributions on the Florida Gulf Coast**

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Richard C. Zimmerman rzimmerm@odu,.edu
Phone: 757-683-5991
Department of Ocean & Earth Sciences
Old Dominion University
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Norfolk VA 23529

## 1. Objectives

To compare the extent and distribution of SAV derived from machine learning analysis of high resolution satellite imagery to those derived from digital aerial photography across coastal Florida from the Alabama State Line eastward to the Navarre Beach Causeway (Fig.1). The landward boundary of the study area Perdido Bay and all of Pensacola Bay, Escambia Bay & East Bay south of U.S. Hwy 90. The area was bounded on the south by northern coast of the barrier islands as no SAV have been reported on the open coast south of the barrier islands.

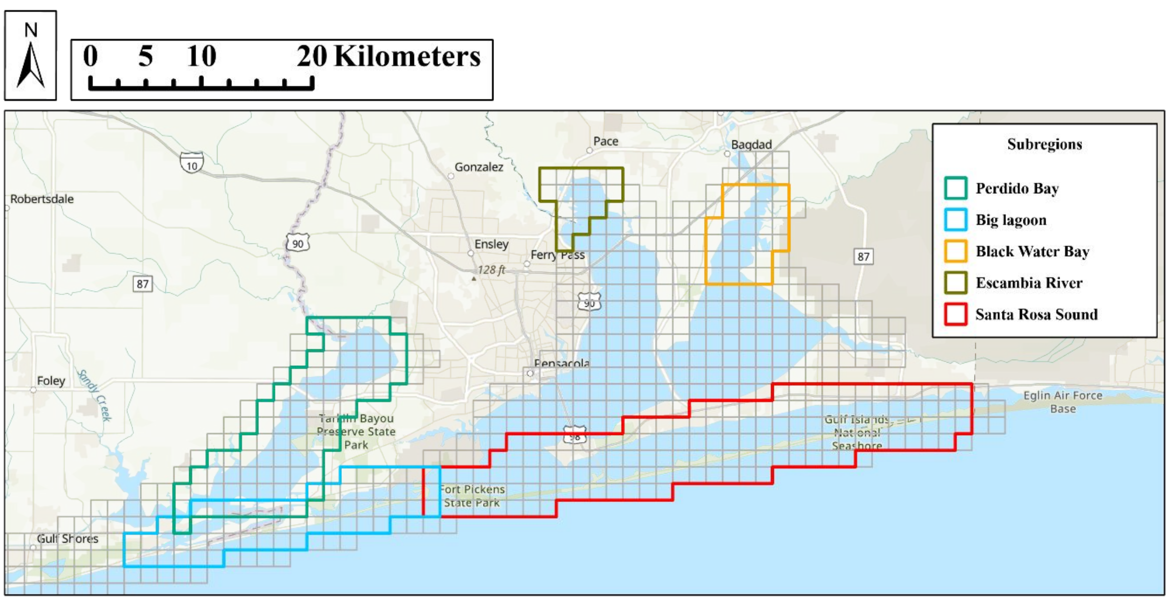


*Figure 1. Map of the study area, grey tiles are the aerial coverage. Colored polygons represent subregions used for image processing*

## 2. Methods:

### *2.1.Study Area*

The study area was split into several subregions for image processing and classification (Fig. 1). Subregions were designated Santa Rosa Sound, Black Water Bay, Escambia Bay, Big Lagoon and Perdido Bay.

### *2.2 Planet satellite imagery*

The Planet archive was searched for cloud free, low turbidity images of regions highlighted in Figure 1 from September 13th through 30th 2022, to coincide with the aerial photography collection. The 8 band, harmonized to Sentienl-2 surface reflectance product was downloaded.

### *2.3.1 Planet processing*

Downloaded tiles collected from satellite overpass on same day and same sensor were mosaiced using the ArcGIS Pro mosaic to new raster tool using the blend method for overlapping pixels.

ArcGIS Pro tool composite bands was used to add bathymetry to the 8 band data generating a new 9 band raster. This was done to improve classification results. Bathymetry was generated from NOAA's Continuously Updated Digital Elevation Model (Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado, 2014) and was reprojected and resampled to the spatial resolution of the Planet satellite imagery in ArcGIS Pro.

### *2.3.2. Classification*

Supervised classification of each individual image was undertaken using support vector machine (SVM) classification model in ArcGIS Pro. First an overall classification schema for the study region was developed including the following targets, submerged aquatic vegetation (SAV), emergent aquatic vegetation (EAV), submerged sand, optically deep water, beach sand, marsh, terrestrial vegetation, and urban landcover. Representative patches of each class referred to as regions of interest (ROI, rectangular polygons) were identified in each subregion through a combination of local knowledge and visual confirmation. Not all schema targets were present in each subregion. Emergent aquatic vegetation occurred in the Mobile and Escambia River regions and has a strong reflectance in the NIR allowing it to be separated from submerged aquatic vegetation.

After classification, the digital elevation model was used to remove all pixels that were above 0 m, and that were deeper than 2 m. This removed misclassifications that occurred on land in ponds and in deeper water.

### *2.3.3. Final aquatic vegetation (AV) presence*

From each original raster an aquatic vegetation (SAV + EAV) presence/absence product was produced. All presence/absence raster's for each region were then used to produce a percent frequency presence (***Figure 2b***, number of times AV was identified as a function of number of times a pixel was imaged). Percent frequency presence threshold of 80% was used as a cutoff to identify the presence of AV (***Figure 2c***). The >80% presence raster was then converted into polygon layer using the ArcGIS Pro raster to polygon tool with simplify polygons turned off. The ArcGIS Pro aggregate polygon tool was applied with aggregation distance of 20 m and a minimum hole size of 10 $m^2$. All polygons less than 100 $m^2$ in area were then deleted from the layer (***Figure 2d***).

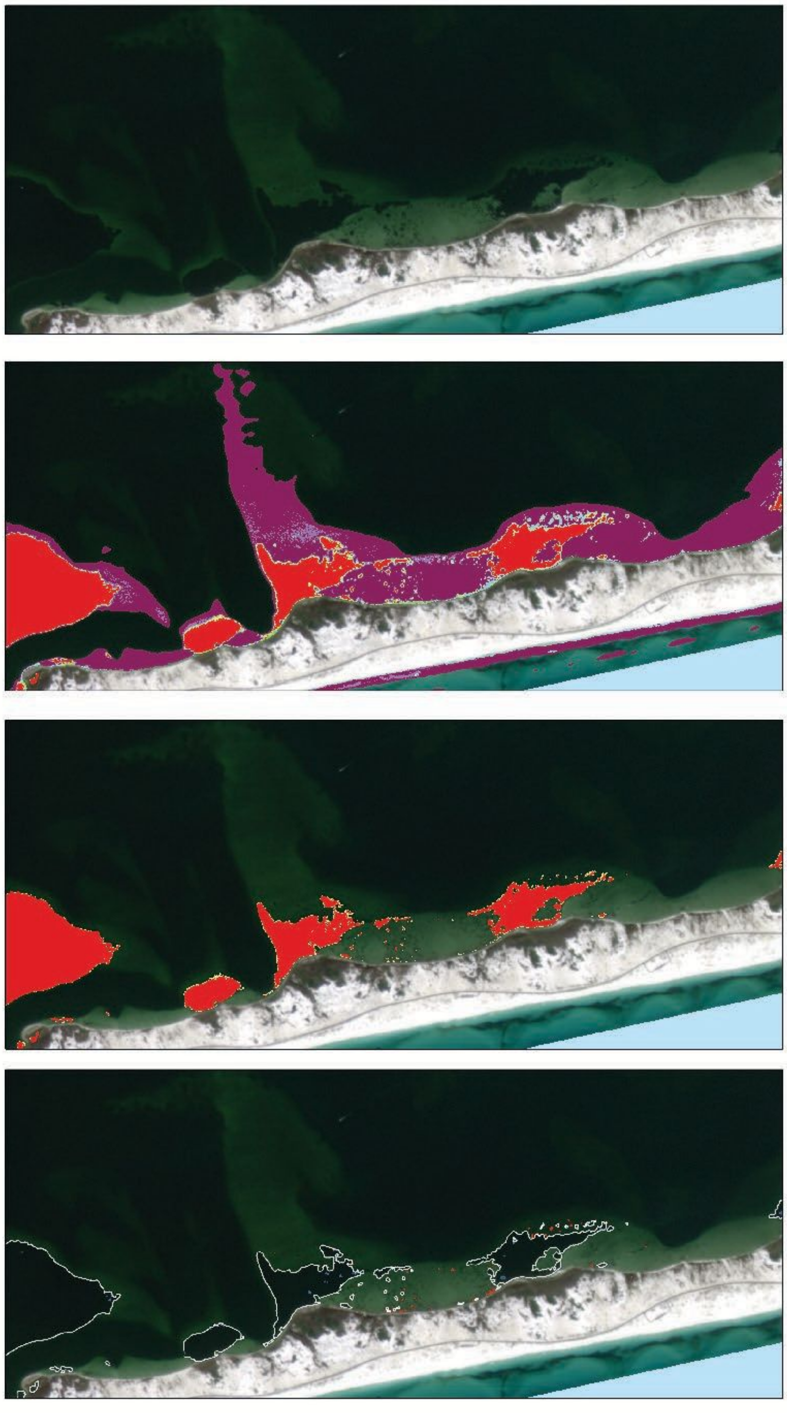

*Figure 2. a. RGB Planet image of Santa Rosa Sound, b. frequency presence layer, c. Frequency over 80%, d. Raster to Polygon example*

## 3. Results

Table 1. Planet based aquatic vegetation coverage

| Florida subregion | Total area (km^2) |
|---|---|
| Santa Rosa Sound | 10.45 |
| Escambia Bay | 0.82 |
| Blackwater Bay | 1.64 |
| Big Lagoon | 3.84 |
| Perdido Bay | 0 |
| **Total** | **16.74** |

Please note the value listed for Perdido Bay is not correct. This value should be 2.17 km^2, with the majority of the coverage occurring in what is technically Alabama State waters.
DBD- 03/20/2023

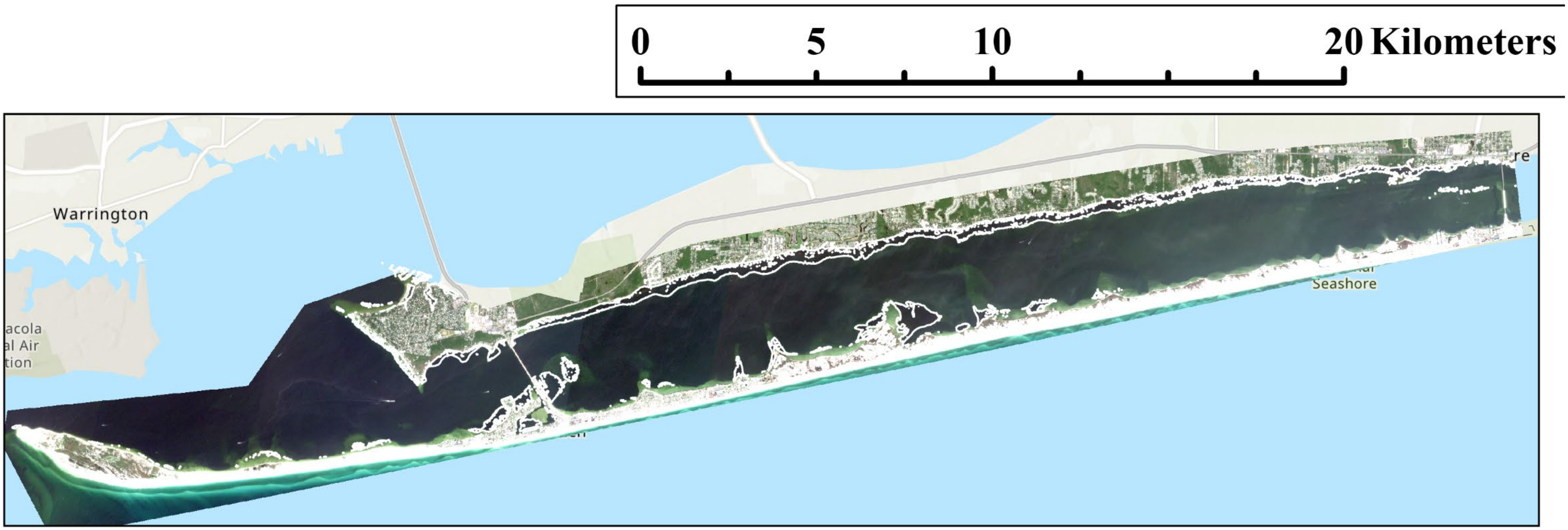


*Figure 3 Santa Rosa Sound*

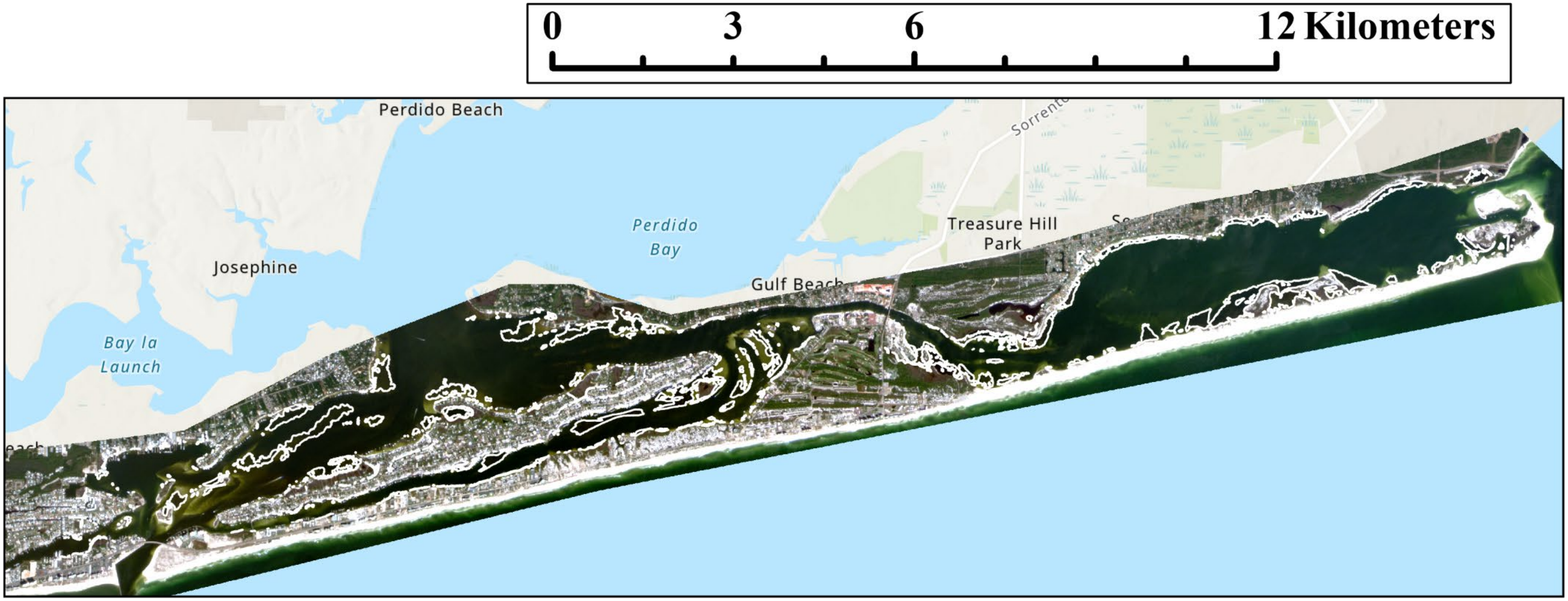


*Figure 4. Big Lagoon*


*Figure 5. Escambia Bay*


*Figure 6. Blackwater Bay*