SUBMERGED AQUATIC VEGETATION MAPPING IN MOBILE BAY AND ADJACENT WATERS OF COASTAL ALABAMA IN 2015

Prepared for

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EXECUTIVE SUMMARY

This document is the technical report for 2015 mapping of submerged aquatic vegetation (SAV) in coastal Alabama, for the Mobile Bay National Estuary Program and Alabama Department of Conservation and Natural Resources State Lands Division, Coastal Section. A remote sensing approach was used to provide detailed information on the distribution of SAV species, based on aerial imagery obtained during summer (July and August) and fall (October) 2015.

Ortho imagery was created from true color aerial photography acquired with a digital mapping camera. The orthorectification process relied on the aerial imagery, camera calibration data, aerotriangulation data, and a digital elevation model. The procedure was performed in a fully digital workflow environment, using measurements obtained from airborne global positioning system and an inertial measurement unit to provide accurate exterior orientation of the imagery.

Outlines of SAV signatures in the ortho imagery were digitized in a GIS environment, using the seasonal mosaics as base maps. Digitized areas were field-verified to document habitat characteristics at the surface level. Field data were collected at 1,437 locations. Separate independent sets of field points were used to test the spatial and thematic accuracies of the GIS database. The average spatial error of polygon boundaries, compared with field-measured locations, was 3.17 meters (10.4 feet). Thematic accuracy was determined to be 87%.

The Bridgehead quad contained 65% (5,905.0 ac) of the total 9,124.3 acres mapped, while the Mobile quad added another 1,021 acres. Overall, there were 3,875 more acres mapped in 2015 compared to 2009, due mostly to a 2,455 increase in the Bridgehead quad area and a 511 acre increase in the Mobile quad (Table ES-1). Compared to 2002, the 2015 survey had 2,535 more acres mapped in the Bridgehead quad. Acreages in the Mobile quad were similar in 2015 and 2002.

In addition to the lower Mobile-Tensaw Delta, other locations had greater SAV acreage in 2015 compared to both 2009 and 2002, including in the Chickasaw and Daphne Quadrangles. In the Theodore and Hollingers Island quads, which include areas of the Dog River watershed and adjacent Mobile Bay, there was substantial acreage (117 ac) in 2015 but no mapped SAV in 2009. There was no mapped SAV in the Theodore quad in 2002, either, though in the Hollingers Island quad area there was significant SAV present (126.7 ac) that year in Mobile Bay. This western shore area of the Bay did not have SAV in 2015.

Small beds of patchy SAV along the north side of western Dauphin Island have progressively expanded to the east and west in recent years. Since 2002 the extent of the SAV patches in this area has increased by 340%, from 59.6 acres in 2002 to 203.8 acres in 2015.

EXECUTIVE SUMMARY (continued)

Table ES-1. Total SAV acreage (continuous + patchy) by U.S.G.S. 7.5-Minute Quadrangle[1] for the summer 2015, 2009, and 2002 surveys.

USGS QUADRANGLE	2015 ACREAGE	2009 ACREAGE	2002 ACREAGE
Bellefontaine	1.7	0.0	0.0
Bridgehead	5,905.3	3,450.3	3,641.0
Chickasaw	107.9	21.2	26.9
Coden	5.1	0.0	0.0
Daphne	209.3	35.1	9.5
Fort Morgan	1.7	0.0	0.0
Fort Morgan NW	28.6	25.2	0.0
Grand Bay	414.6	364.2	296.4
Grand Bay SW	93.6	61.8	79.9
Gulf Shores	164.6	1.5	1.2
Heron Bay	10.2	0.0	0.0
Hollinger's Island	61.3	0.0	126.7
Hurricane	125.7	1.9	517.3
Isle aux Herbes	163.7	129.2	87.6
Kreole	162.1	218.8	295.9
Little Dauphin Island	0.4	0.0	0.0
Magnolia Springs	2.3	0.0	0.0
Mobile	1,021.3	509.8	1,007.0
Orange Beach	179.7	150.8	60.0
Perdido Bay	164.2	135.4	114.6
Petit Bois Pass	203.8	142.3	59.6
Pine Beach	3.8	1.2	0.1
Spring Hill	37.4	0.0	0.0
Theodore	55.7	0.0	0.0
The Basin	0.0	0.0	265.2
TOTAL	9,123.5	5,248.7	6,588.9

[1]Quadrangles without mapped SAV are not listed.

The Orange Beach and Perdido Bay quads had more SAV compared to 2009 and 2002, due in part to more extensive SAV in Soldier's Creek and Palmetto Creek. In the Gulf Shores quad, Shelby Lake had 163.1 acres of patchy SAV mapped in 2015, whereas the lake did not have SAV during the prior surveys.

EXECUTIVE SUMMARY (continued)

For the 2015 seasonal comparison, there were 1,201 fewer acres mapped in the fall survey compared to summer (Table ES-2). The decline was mostly due to a 920-ac decrease (15.6%) in the Bridgehead Quadrangle, and 203-ac (97%) in the Daphne Quadrangle.

Table ES-2. SAV acreage by U.S.G.S. 7.5-Minute Quadrangle[1] for the 2015 summer and fall surveys.

USGS QUADRANGLE	SUMMER 2015			FALL 2015		
	Total	Continuous	Patchy	Total	Continuous	Patchy
Bellefontaine	1.8	0.3	1.5	1.7	0.3	1.4
Bridgehead	5,905.0	5,331.8	573.4	4,984.8	3,439.8	1,545.0
Chickasaw	107.9	80.5	27.4	150.6	112.4	38.3
Coden	5.1	0.1	5.0	5.1	0.1	5.0
Daphne	209.3	42.3	167.1	6.2	0.0	6.2
Fort Morgan	1.7	1.7	0.0	1.7	1.7	0.0
Fort Morgan NW	28.6	0.0	28.6	28.6	0.0	28.5
Grand Bay	414.6	169.3	245.3	413.5	168.8	244.7
Grand Bay SW	93.6	64.0	29.6	93.7	64.2	29.5
Gulf Shores	164.6	0.8	163.8	164.6	0.8	163.8
Heron Bay	10.2	8.8	1.5	9.9	5.2	4.7
Hollingers Island	61.3	44.4	16.9	52.2	36.4	15.8
Hurricane	125.7	87.7	38.0	120.4	88.7	31.7
Isle Aux Herbes	163.7	18.2	145.6	163.8	18.3	145.5
Kreole	162.1	2.4	159.7	162.1	2.4	159.7
Little Dauphin Island	0.4	0.4	0.0	0.4	0.4	0.0
Magnolia Springs	2.3	0.0	2.3	2.3	0.0	2.3
Mobile	1,021.2	891.5	129.7	929.2	495.1	434.1
Orange Beach	179.7	157.2	22.5	179.7	157.3	22.5
Perdido Bay	164.2	152.5	11.7	164.2	152.5	11.8
Petit Bois Pass	203.8	0.1	203.7	203.8	0.1	203.7
Pine Beach	3.7	3.6	0.2	3.7	3.6	0.1
Spring Hill	37.4	13.4	24.0	37.4	13.4	24.0
Theodore	55.7	46.6	9.1	42.8	30.0	12.8
TOTAL	9,123.5	7,117.3	2,006.2	7,922.3	4,791.4	3,130.9

[1]Quadrangles without mapped SAV are not listed.

EXECUTIVE SUMMARY (continued)

In addition to a seasonal decline in areal extent, there were changes in the proportion of patchy SAV in fall (40%) compared to the summer (22%), particularly in upper Mobile Bay and the lower Delta. Other areas with less SAV in the fall included Hollingers Island (-9 ac) and Theodore (-13 ac). Most of the study area had comparable acreages across the summer and fall surveys, including in Mississippi Sound and lower Perdido Bay. The only area to show a seasonal increase in extent was the Chickasaw quad.

Twenty-six vascular plant species representing 14 taxonomic families were recorded during the field surveys. Most of the species encountered were minor components of SAV assemblages, generally restricted to a few, discrete locations in the low salinity zones of the study area. The most frequently encountered species were wild celery (*Vallisneria neotropicalis*) (555 field locations), Eurasian watermilfoil (*Myriophyllum spicatum*) (544), southern naiad (*Najas guadelupensis*) (251), widgeon grass (*Ruppia maritima*) (249), water stargrass (*Heteranthera dubia*) (229), shoal grass (*Halodule wrightii*) (167), and coon's tail (*Ceratophyllum demersum*) (96).

Habitat (species) categories were developed based on the most prevalent species observed at field survey locations. Most categories contained mixtures of species typically found in the northern portion of Mobile Bay and the lower Delta. The most extensive categories in terms of mapped acreage included monotypic beds of Eurasian watermilfoil, an invasive exotic SAV, and numerous mixed assemblage categories that included this species. Many of these habitats declined in areal extent by the time of the fall survey.

Wild celery also occurred in monotypic beds and in several mixed species categories. The monotypic category of wild celery increased by 844 ac (189%) from summer to fall, not because of an increase in its extent, but because other species disappeared from summer mixed assemblage beds that included wild celery, particularly in upper Mobile Bay. Species such southern naiad, water stargrass, and sago pondweed, common during the summer survey, were rare or absent at fall survey locations in the upper Bay. The disappearance of SAV in the upper Bay during the fall survey might have been a response to higher salinity, which rapidly increased between mid-September and early October.

The loss of SAV extent documented in the lower Mobile-Tensaw Delta between 2002 and 2009 had largely recovered by 2015, an exception being the northernmost portion of the study area in the Hurricane and The Basin quads. In addition to increased SAV extent in the Delta compared to 2009, substantial SAV was present in 2015 at several locations that did not support it in 2002 or 2009. The Dog River watershed in particular contained large areas of SAV, with pondweed associations in Halls Mill Creek, Rattlesnake Bayou, and Rabbit Creek grading into wild celery, Eurasian watermilfoil, and widgeon grass in Dog River proper. Other areas in Mobile County with mapped SAV in 2015 but not in the 2009 or 2002 surveys included Duck

Lake, Heron Bayou, Threemile Creek, and East Fowl River. In Baldwin County, SAV was mapped in Nolte Creek (Magnolia River), Shelby Lake, and Bon Secour Bay. These areas did not contain mapped SAV in 2009 or 2002.

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1.0 INTRODUCTION

The Mobile Bay National Estuary Program (MBNEP) and Alabama Department of Conservation and Natural Resources State Lands Division (SLD) funded the study entitled "Mapping of Submerged Aquatic Vegetation in Mobile Bay and Adjacent Waters of Coastal Alabama in 2015", administered through a Dauphin Island Sea Lab contract (P.O. 37670). This report summarizes the results of 2015 submerged aquatic vegetation (SAV) mapping in the MBNEP study area and analyzes changes since the previous MBNEP/SLD surveys in 2002 and 2008-2009 (Barry A. Vittor & Associates, Inc., 2004, 2010). The study area comprises the estuarine and marine systems of coastal Alabama (Figure 1).

This study contributes to the fulfillment of the MBNEP 2013-2018 Comprehensive Conservation Management Program goal to improve understanding of how the estuarine ecosystem responds to anthropogenic stressors through recurrent monitoring of habitats, including SAV. Submerged plants provide habitat for invertebrates and fishes, which are consumed by other fish and wildlife species, and are an important component of the diet of waterfowl, turtles, and other wildlife, including manatees. The extent of SAV in coastal Alabama has declined from historic levels, and habitat loss is a high priority area of concern for the MBNEP.

2.0 PROJECT APPROACH

Remote sensing methods were used for the 2002 and 2008-2009 SAV mapping projects, following the approach outlined in the NOAA Coastal Services Center Guidance for Benthic Habitat Mapping (Finkbeiner et al., 2001). Color aerial photography was acquired during optimal environmental windows, and geo-referenced for use as a base map in a geographic information system (GIS) environment to outline the location and extent of SAV. Complementary field surveys collected data on species occurrence, bed patchiness, depth, and other habitat characteristics. This same approach was used for the 2015 mapping.

Prior to 2002, Stout and Lelong (1981) and Stout et al. (1982) were the most comprehensive SAV mapping efforts in coastal Alabama. Those investigations utilized intensive ground surveys complemented by assessment of black and white aerial photography to map SAV, which was documented in several study area locations that had no mapped SAV in the 2002 or 2009 MBNEP/SLD studies. All of these efforts found that most SAV in coastal Alabama occurs in upper Mobile Bay and the Mobile-Tensaw Delta, northern and southern Mississippi Sound, and in southern Perdido Bay. In the previous MBNEP/SLD surveys, upper Mobile Bay and the Delta had more extensive SAV in 2002 compared to 2009, whereas Mississippi Sound and Perdido Bay had increased 2009 coverage compared to 2002. For the 2015 investigation, summer and fall surveys were performed to assess potential seasonal changes in SAV distribution.

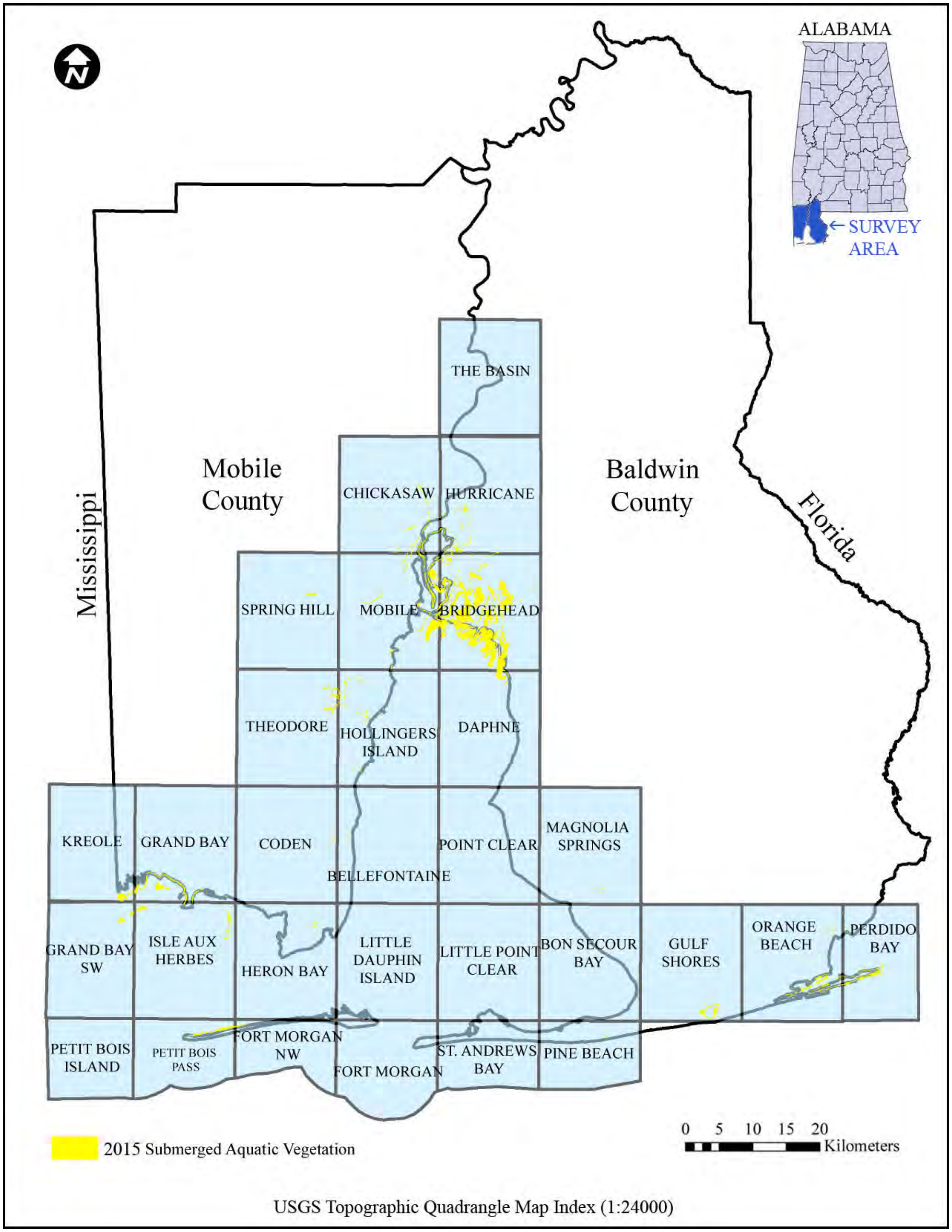

Figure 1. Study area for the 2015 SAV survey.

3.0 METHODS

3.1 Aerial Imagery Acquisition

Quatum Spatial, Inc. (QSI) of St Petersburg, FL acquired the aerial photography and produced the geo-referenced ortho imagery. The summer imagery was acquired July 17-19 (Mobile Bay, Mobile-Tensaw Delta, Dauphin Island, Ft Morgan, and Perdido Key) and August 23, 25 and 26 (northern Mississippi Sound, Weeks Bay, Wolf Bay, and upper Perdido Bay). The fall imagery was acquired October 10 through 15. Environmental conditions during the project flights had minimal wind (<10 mph) and mostly cloudless conditions. All flights were conducted during hours with sun angles ranging between 35 and 45°.

For the summer flight QSI utilized an Aero Commander 500 aircraft. A Cessna 206 was used for the fall flight. Both seasonal flights were flown at of 15,000 feet during imagery acquisition. The aerial imagery was acquired using a Z/I Imaging digital mapping camera (DMC). The DMC was equipped with eight (8) cameras heads, four (4) for panchromatic and one (1) each for red, blue, green and near-infrared. Imagery was acquired to render a native pixel resolution of 1 meter for the study area. Imagery frames were formatted for 60% endlap and 30% sidelap.

To accurately position each aerial photo center (principal point), the aerial mapping technology used an airborne global positioning system (ABGPS) and inertial measurement unit (IMU). The computerized flight-management system used ABGPS supported aircraft navigation, interfaced with flight control software. Flight line start and stop points were processed by the onboard navigation system.

During flight missions the ABGPS/IMU recorded the position and orientation of the camera platform. An Applanix IMU system ensured that tip, tilt, and swing of the camera was less than 3 degrees for each frame. Resolution loss due to blurring was avoided by a forward image motion compensation system. Image motion did not exceed 0.005 cm. The IMU system measured the position of the camera perspective center and orientation angles of each photograph at the midpoint of exposure, to an accuracy of 5-10 cm and 20-30 arc seconds, respectively.

ABGPS coordinates were automatically collected in-flight for the principal point for each photographic frame. Dual-frequency GPS observation data were collected at a one second epoch. Additionally, inertial data were collected at a rate of 0.005 seconds. The ABGPS and inertial data were post-processed using Applanix MMS version 5.2 software, to provide accurate positional (x, y, and z) and rotation (omega, phi, and kappa) data of the camera. The three dimensional position of each exposure was determined from the ABGPS data, while the three-dimensional rotation of each exposure was determined from the inertial data.

3.2 Ortho Imagery Production

Intergraph's ISAT systems for softcopy aerotriangulation were used for photogrammetric production of the ortho imagery. The orthorectification process relied on the aerial imagery, camera calibration data, aerotriangulation data, and a digital elevation model (DEM). The procedure was performed in a fully digital workflow environment, using measurements obtained from the ABGPS and IMU to provide accurate exterior orientation of the imagery. The process included use of the location and coordinate positions of the ABGPS and GPS photo control points as well as a precise camera calibration for the DMC used to capture the images.

The aerotriangulation process extended horizontal control from relatively few ground survey control points to additional supplemental control points (*i.e.*, pass points). Common pass points and tie points among overlapping image frames were collected. Any large residuals were double checked and corrected, or replaced if necessary. Bundle adjustments were run with ground control and ABGPS separately, and then combined using different weighting units. Final adjustments assured that all measurements were in balance with each other and properly represented actual conditions. The final solution was produced using a rigorous simultaneous least squares adjustment on the ABGPS and IMU data, to adjust and verify the positional tolerances of individual images. The root mean square errors of the ABGPS were X=0.078 m, Y=0.068 m, and Z=0.081 m. The output for the orientation angles (a measurement of the orientation of one image to another) was X=0.004 m, Y=0.003 m, and Z=0.006 m.

Digital orthophoto frames were created using National Elevation Dataset (NED) Digital Elevation Models (DEM), which were combined with the processed raw imagery and aerotriangulation data. Intergraph's OrthoPro software was used to produce the orthophotos. A final color balancing was performed across the entire dataset. For each seasonal survey, 1,068 individual ortho frames were produced, and a mosaic was created in MrSID (.sid) format. These products are projected to North American Datum of 1983, Universal Transverse Mercator (UTM) Zone Number 16 North.

3.3 SAV Data Development

Field Surveys

The results of the 2002 and 2008-09 SAV mapping were reviewed as part of field survey planning. Recent imagery datasets such as 2015 USDA National Agriculture Imagery Program (NAIP) imagery were also inspected to identify locations of interest and aid in the resolution of SAV signatures. Locations with potential SAV were preplotted in GIS to assist in field navigation and inspection.

Field surveys documented SAV presence or absence, species present, bed patchiness, water depth, and other habitat characteristics. Field location points were logged using a Trimble Pro XR differential GPS unit, following common GPS practices. At each field location with SAV the immediate area was visually assessed as continuous (>50%) or patchy (<50%). Species identifications were made through *in-situ* observations or hand collected and identified in the field. In some cases specimens were placed in Ziploc bags and subsequently identified in the laboratory. Depth (m) was measured with a graded sounding pole.

Field surveys began in June 2015 and continued to mid-November. The raw imagery for the summer survey was available for inspection and review in mid-September, by which time around 60% of the 2015 field data had been collected. The fall imagery was available for review in late October 2015. The remaining 2015 field surveys focused on areas of obvious change, which were most evident in the upper Bay and lower Delta. A total of 1,243 field points were assessed in 2015. A few locations were visited in the late spring and early summer of 2016 to survey sites that were not inspected during 2015. These included areas in East Fowl River, West Fowl River, Halls Mill Creek, Rabbit Creek, Fish River, Magnolia River, Bon Secour River, and lower Perdido Bay. In total, field data were collected at 1,437 locations.

Creation of Polygonal Data and the GIS Database

ESRI polygon coverage of SAV was created in ArcGIS 10.3. Polygon boundaries were digitally drawn to outline the spatial extent of SAV, using the summer and fall imagery mosaics as base maps. Figure 2 shows sample images from the summer and fall base maps. Initial estimations of SAV location and extent were performed at an approximate scale of 1:6000 (1" = 500'). Subsequent refinement was focused on bed boundaries. Polygons were visually assessed for vegetation density on-screen and categorized as continuous (>50%) or patchy (<50%) coverage. After completion of the preliminary vector data, the line work was edited and labeled using the field data. Each documented species was assigned a unique two-letter code based on the initials of its genus and specific epithet. Habitat categories were developed based on observation of the most prevalent species at field survey locations.

QA/QC

The raw digital imagery was inspected prior to orthorectification to ensure a condition suitable for SAV mapping. For ortho imagery production, extensive quality assurance (QA) / quality control (QC) was performed to validate production accuracy, completeness, and visual quality throughout the workflow process. The tonal quality of the data was tweaked specifically for benthic applications. At least three individuals reviewed the imagery for mismatches at seamlines and smears caused by elevation discrepancies and radiometric distortions.

Two mapping analysts visually reviewed the SAV polygons superimposed on the digital imagery to check completeness and edges, and consulted regarding questionable areas. The analysts reviewed the attribute classification for each delineated area and made determinations of accuracy of the habitat categories based on the species and bed density data. The entire data set was reviewed after completion.

Figure 2. Aerial imagery showing SAV in Rattlesnake Bayou (Dog River watershed) in July (top) and Duck Lake (Chickasaw Creek watershed) in October (bottom).

Data Validation

A quality control assessment was performed to test the spatial and thematic accuracy of the completed GIS data set. The spatial test was performed to assess the horizontal spatial error of SAV polygon boundaries, based on comparison with actual SAV boundaries in the field. The thematic test was performed to assess the correctness of habitat attributes, such as SAV presence and habitat type. Independent data sets of field points were used to test the spatial and thematic accuracies. The accuracy test points were removed from the overall 2015 data set and were not used in producing the SAV polygons or their attributes.

After completion of the polygonal database, 48 locations logged with GPS as field edge points were imported into ArcGIS and compared with the locations of their corresponding polygons. Edge points collected prior to September 15 were used for testing summer polygons, whereas edge points collected after September 15 were used to test fall polygons. All polygons were spatially buffered 5 m inside and 5 m outside the estimated bed edge to produce a 10-m-wide zone along the delineated boundaries. If a test point fell within the 10-m buffer it was considered to meet spatial accuracy requirements. Of the 48 test points, six fell outside the buffer (12.5%). The average spatial error of all 48 spatial test points was 3.17 meters (10.4 feet).

To test thematic accuracy, an error matrix was created using 225 field points selected from the master field point list using a random number generator. The error matrix compared the field data with the predicted polygon classes. All oligohaline (low-salinity) categories were designated as “Freshwater Mix”. Other classes were Shoalgrass, Shoalgrass-Widgeon grass, and No SAV. The overall accuracy was computed as the total number of correct class predictions divided by the total number of cells in the matrix. Thematic accuracy was determined to be 87%. Thematic errors included bare locations (No SAV) within patchy SAV polygons, or patchy or sparse SAV that was not delineated because of poorly defined or non-existent aerial imagery signatures.

Metadata

Separate metadata files for summer polygon, fall polygons, and field points were created using ArcGIS 10.3. The metadata was generated according to guidelines in the Federal Geographic Data Committee's (FGDC) *Content Standard for Digital Spatial Metadata*, in HTML and Word formats.

4.0 RESULTS

Table 4-1 presents the total SAV acreage by USGS Quadrangle area (Figure 1) for the summer 2015, 2009, and 2002 surveys. All three surveys found that the major concentration of SAV occurs in upper Mobile Bay and the lower Mobile-Tensaw Delta. The Bridgehead quad contained 65% (5,905.0 ac) of the total 9,124.3 acres mapped in 2015, while the Mobile quad added another 1,021 acres of coverage. In addition, Mississippi Sound and lower Perdido Bay supported extensive SAV during all three surveys. Appendix A presents maps showing the 2015 SAV distribution in the three main areas of occurrence.

Overall, there were 3,875 more acres mapped in 2015 compared to 2009, due mostly to 2,455 more acres in the Bridgehead quad area and 511 ac in the Mobile quad. Figure 4-1 shows a comparison of SAV extent in 2015 and 2009 in a portion of the upper Bay. Compared to 2002, the 2015 survey had 2,535 more acres mapped in the Bridgehead quad. Acreages in the Mobile quad were similar in 2015 and 2002 (Table 4-1).

Table 4-1. Total SAV acreage (continuous + patchy) by U.S.G.S. 7.5-Minute Quadrangle[1] for the summer 2015, 2009, and 2002 surveys.

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Grand Bay	414.6	364.2	296.4
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TOTAL	9,123.5	5,248.7	6,588.9

[1]Quadrangles without mapped SAV are not listed.

Despite some recovery since 2009 in the Hurricane Quad, this area had significantly more SAV in 2002 compared to 2015, particularly in and around Chuckfee Bay and Gravine Island. Similarly, The Basin quad had a large area of SAV in 2002 that disappeared prior to 2009, but as of 2015 had not returned.

In addition to most of the lower Delta, other locations had greater SAV acreage in 2015 compared to both 2009 and 2002, including the Chickasaw and Daphne Quadrangles. In the Chickasaw quad, the area known as Duck Lake (see Figure 2) and parts of lower Chickasaw Creek accounted for much of the 2015 change compared to the 2009 and 2002 surveys, when there was no mapped SAV in these areas. The Daphne quad had a substantially greater extent of SAV in 2015 than the prior surveys, though in much of the newly delineated areas the grass was patchy or sparse.

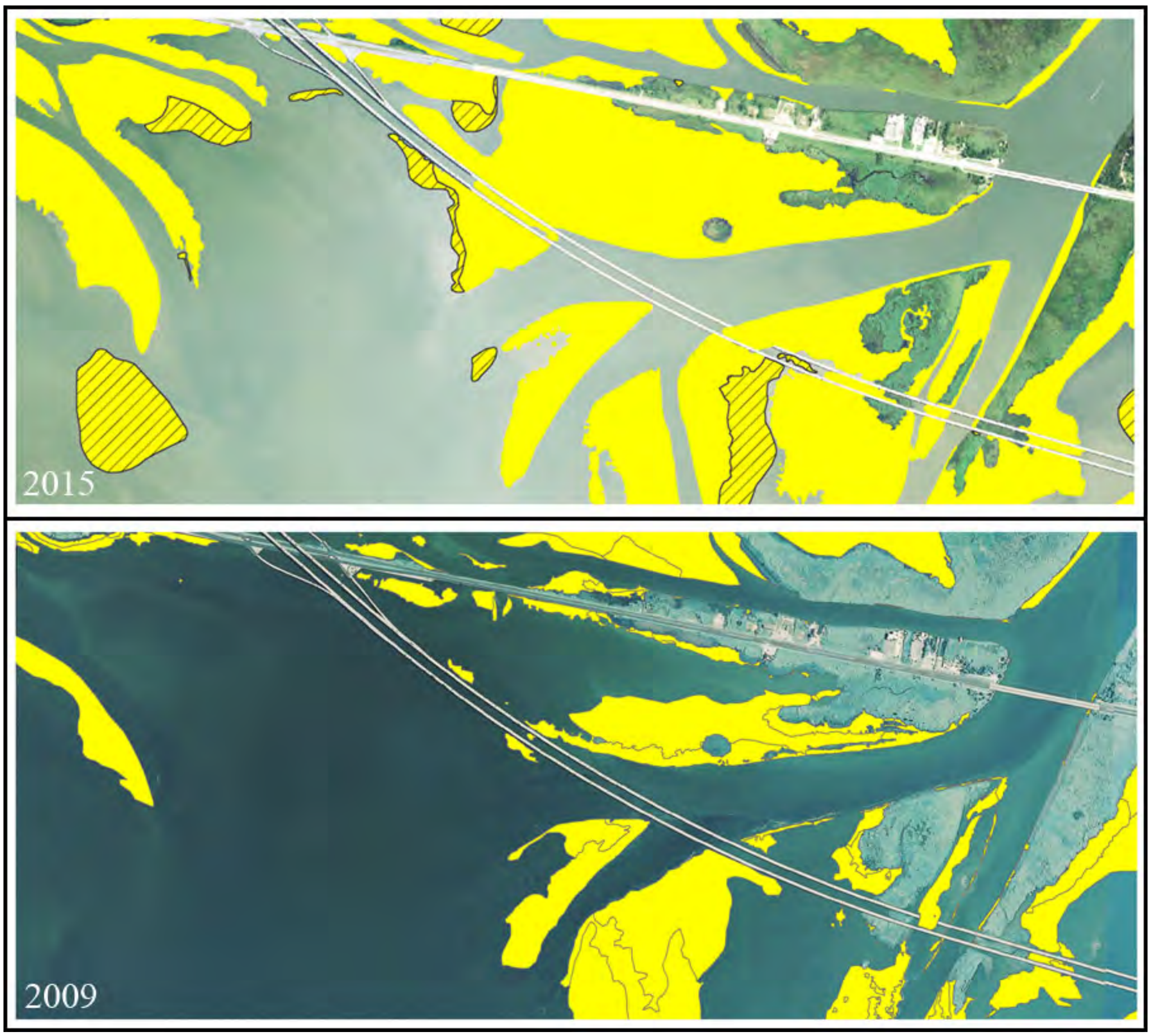

Figure 4-1. SAV coverage (shaded yellow) in a portion of the Bridgehead Quadrangle, comparing the 2015 and 2009 surveys.

In the Theodore and Hollingers Island quads, which include areas of the Dog River watershed and adjacent Mobile Bay, there was substantial acreage (117 ac) in 2015 but no mapped SAV in 2009. This area comprises Dog River and its tributaries, including Halls Mill Creek, Rabbit Creek, and Rattlesnake Bayou (see Figure 2). There was no mapped SAV in the Theodore quad in 2002, either, though in the Hollingers Island quad area there was significant SAV present (126.7 ac) that year in Mobile Bay. This western shore area of the Bay did not have SAV in 2015. In southern Mobile County, the Heron Bay quad had mapped SAV in 2015 but none in the 2009 or 2002 surveys.

In Mississippi Sound, the Grand Bay, Grand Bay SW, and Isle aux Herbes quads all had a greater extent of SAV in 2015 compared to the prior surveys, though in much of these areas the grass was patchy to sparse. The 2015 Kreole quad had less extensive, patchy SAV compared to 2009 and 2002. Small beds of patchy SAV along the north side of western Dauphin Island, in the Petit Bois Pass quad area, have progressively expanded to the east and west in recent years. Since 2002 the extent of the SAV patches in this area has increased by 340%, from 59.6 acres in 2002 to 203.8 acres in 2015.

The Orange Beach and Perdido Bay quads had more SAV compared to 2009 and 2002, due in part to more extensive SAV in Soldier's Creek and Palmetto Creek. Some beds around Ono Island have also expanded since 2009. In the Gulf Shores quad, Shelby Lake had 163.1 acres of patchy SAV mapped in 2015, whereas the lake did not have SAV during the prior surveys. Patches of SAV were documented on the south side of eastern Little Lagoon in 2015. This area did not have SAV in the prior surveys. Quadrangles that did not have SAV during any of the three surveys included Bon Secour Bay, Little Point Clear, Petit Bois Island, Point Clear, and St. Andrews Bay.

Several ponds in the study area had SAV in 2015, including on Dauphin Island, Little Dauphin Island, the University of South Alabama campus, and Langan Park in Mobile County. In Baldwin County, SAV was mapped in ponds adjacent to the south side of Little Lagoon and Shelby Lake. None of these areas had mapped SAV in the prior surveys.

For the 2015 seasonal comparison, there were 1,201 fewer acres mapped in the fall survey compared to summer. The decline was mostly due to a 920-ac decrease (15.6%) in SAV extent in the Bridgehead Quadrangle, and a 203-ac decline (97%) in the Daphne Quadrangle (Table 4-2). In addition to the decline in the extent of SAV, there were changes in the overall proportion of patchy SAV in fall (40%) compared to the summer (22%), particularly in upper Mobile Bay and the lower Delta. The Bridgehead quad had a 90/10 continuous to patchy ratio in the summer, narrowing to a 70/30 ratio in the fall. Figure 4-2 shows the seasonal change in an area of the Bridgehead quad, near the mouth of the Apalachee River.

Table 4-2. SAV acreage by U.S.G.S. 7.5-Minute Quadrangle[1] for the 2015 summer and fall surveys.

USGS QUADRANGLE	SUMMER 2015			FALL 2015		
	Total	Continuous	Patchy	Total	Continuous	Patchy
Bellefontaine	1.8	0.3	1.5	1.7	0.3	1.4
Bridgehead	5,905.0	5,331.8	573.4	4,984.8	3,439.8	1,545.0
Chickasaw	107.9	80.5	27.4	150.6	112.4	38.3
Coden	5.1	0.1	5.0	5.1	0.1	5.0
Daphne	209.3	42.3	167.1	6.2	0.0	6.2
Fort Morgan	1.7	1.7	0.0	1.7	1.7	0.0
Fort Morgan NW	28.6	0.0	28.6	28.6	0.0	28.5
Grand Bay	414.6	169.3	245.3	413.5	168.8	244.7
Grand Bay SW	93.6	64.0	29.6	93.7	64.2	29.5
Gulf Shores	164.6	0.8	163.8	164.6	0.8	163.8
Heron Bay	10.2	8.8	1.5	9.9	5.2	4.7
Hollingers Island	61.3	44.4	16.9	52.2	36.4	15.8
Hurricane	125.7	87.7	38.0	120.4	88.7	31.7
Isle Aux Herbes	163.7	18.2	145.6	163.8	18.3	145.5
Kreole	162.1	2.4	159.7	162.1	2.4	159.7
Little Dauphin Island	0.4	0.4	0.0	0.4	0.4	0.0
Magnolia Springs	2.3	0.0	2.3	2.3	0.0	2.3
Mobile	1,021.2	891.5	129.7	929.2	495.1	434.1
Orange Beach	179.7	157.2	22.5	179.7	157.3	22.5
Perdido Bay	164.2	152.5	11.7	164.2	152.5	11.8
Petit Bois Pass	203.8	0.1	203.7	203.8	0.1	203.7
Pine Beach	3.7	3.6	0.2	3.7	3.6	0.1
Spring Hill	37.4	13.4	24.0	37.4	13.4	24.0
Theodore	55.7	46.6	9.1	42.8	30.0	12.8
TOTAL	9,123.5	7,117.3	2,006.2	7,922.3	4,791.4	3,130.9

[1]Quadrangles without mapped SAV are not listed.

Other areas with less SAV in the fall than in summer were Hollingers Island (-9 ac) and Theodore (-13 ac). Most of the other areas maintained SAV extent in the fall, including areas of Mississippi Sound and lower Perdido Bay. There was an increase in SAV from summer to fall in the Chickasaw quad area.

Figure 4-2. Summer (top) and fall (bottom) SAV extent near the mouth of the Apalachee River, in upper Mobile Bay.

Twenty-six vascular plant species representing 14 taxonomic families were recorded during 2015 field surveys (Table 4-3).

Table 4-3. SAV species documented in the 2015 field surveys († denotes non-native, invasive taxa).

FAMILY	SPECIES	COMMON NAME
Apiaceae	*Lilaeopsis chinensis* (Linnaeus) Kuntze	eastern grasswort
Cabombaceae	*Cabomba caroliniana* A. Gray	Carolina fanwort
Ceratophyllaceae	*Ceratophyllum demersum* Linnaeus	coon's tail
Cymodoceaceae	*Halodule wrightii* Ascherson	shoal grass
Cyperaceae	*Eleocharis baldwinii* (Torrey) Chapman	Baldwin's spikerush
Haloragaceae	*Myriophyllum aquaticum* (Vellozo) Verdcourt	parrot's feather †
	Myriophyllum heterophyllum Michaux	southern watermilfoil
	Myriophyllum spicatum Linnaeus	Eurasian watermilfoil †
Hydrocharitaceae	*Egeria densa* Planchon	Brazilian waterweed †
	Hydrilla verticillata (Linnaeus.f.) Royle	hydrilla †
	Najas guadelupensis (Sprengel) Magnus	southern naiad
	Thalassia testudinum Banks & Sol. ex J. König	turtle grass
	Vallisneria neotropicalis Marie-Victorin.	wild celery
Lentibulariaceae	*Utricularia foliosa* Linnaeus	leafy bladderwort
	Utricularia inflata Walter	floating bladderwort
	Utricularia sp. (cf. *biflora*/*gibba*)	bladderwort species
Nymphaeaceae	*Nuphar ulvacea* (G.S. Miller & Standley) Standley	sea lettuce pondlily
Poaceae	*Luziola fluitans* (Michaux) Terrell & H. Rob	southern watergrass
Pontederiaceae	*Heteranthera dubia* (Jacq.) MacMill.	water stargrass
Potamogetonaceae	*Potamogeton crispus* Linnaeus	curly pondweed †
	Potamogeton diversifolius Rafinesque	water thread pondweed
	Potamogeton nodosus Poiret	longleaf pondweed
	Potamogeton pusillus Linnaeus	small pondweed
	Stuckenia pectinata (Linnaeus) Böerner	sago pondweed
	Zannichellia palustris Linnaeus	horned pondweed
Ruppiaceae	*Ruppia maritima* Linnaeus	widgeon grass
Typhaceae	*Sparganium americanum* Nuttall	American bur reed

Most of the documented species were minor components of SAV assemblages, generally restricted to a few, discrete locations in the low salinity zones of the study area. The most frequently encountered species were wild celery (*Vallisneria neotropicalis*) (555 field locations), Eurasian watermilfoil (*Myriophyllum spicatum*) (544), southern naiad (*Najas guadelupensis*) (251), widgeon grass (*Ruppia maritima*) (249), water stargrass (*Heteranthera dubia*) (229), shoal grass (*Halodule wrightii*) (167), and coon's tail (*Ceratophyllum demersum*) (96).

Table 4-4 lists the summer and fall acreage for each habitat category in the 2015 GIS database. The categories were developed based on the most prevalent species observed at field survey locations. Most categories contained mixtures of species typically found in the northern portion of Mobile Bay and the lower Delta, and some riverine areas of the sub-watersheds surrounding the Bay. The most extensive categories in terms of mapped acreage included monotypic beds of Eurasian watermilfoil, an invasive exotic SAV that was also included in numerous mixed assemblage categories. Many of these habitats declined in areal extent by the time of the fall survey (Table 4-4).

Wild celery also occurred as monotypic beds and in several mixed species categories. The monotypic category of wild celery increased by 844 ac (189%) from summer to fall, not because of an increase in its areal extent, but because other species disappeared from mixed assemblage beds that included wild celery prior to the fall survey, particularly in upper Mobile Bay. Species such southern naiad, water stargrass, and sago pondweed, common during the summer survey, were rare at fall survey locations in the upper Bay. Beds of wild celery were predominantly patchy in the fall, with just 12% of the category acreage comprised of continuous SAV.

Extensive beds of small pondweed (*Potamogeton pusillus*) and southern naiad (*Najas guadelupensis*), mapped in Rattlesnake Bayou during the summer survey, mostly disappeared by the fall. Beds of southern watermilfoil (*Myriophyllum heterophyllum*) increased in extent from summer to fall in the Duck Lake area of Chickasaw Creek. Areas with widgeon grass, shoal grass, and mixtures of the two species, which occur in the southern portion of the study area, were stable across seasons.

Table 4-4. Total 2015 acreage by species (habitat) category. Multiple species indicates co-dominance.

Species Category	Acreage	
	Summer	Fall
Eurasian water milfoil	1,915.9	1,297.9
Eurasian water milfoil, southern naiad, water stargrass, wild celery	1,864.6	1,419.1
Coon’s tail, Eurasian water milfoil, southern naiad, water stargrass, wild celery	1,473.8	716.2
Eurasian water milfoil, southern naiad, widgeon grass, wild celery	735.6	314.4
Shoal grass, widgeon grass	708.6	707.4
Shoal grass	593.1	593.2
Eurasian water milfoil, sago pondweed, southern naiad, widgeon grass, wild celery	454.6	0.0
Wild celery	445.3	1,289.1
Eurasian water milfoil, southern naiad, water stargrass	418.8	278.1
Eurasian water milfoil, widgeon grass, wild celery	338.3	159.2
Eurasian water milfoil, water stargrass	270.2	109.9
Eurasian water milfoil, southern naiad	179.7	172.8
Eurasian water milfoil, wild celery	177.0	762.1
Widgeon grass	129.1	125.8
Carolina fanwort, southern water milfoil	66.4	66.4
Eurasian water milfoil, small pondweed, southern naiad, wild celery	24.5	24.3
Carolina fanwort, coon’s tail, Eurasian water milfoil	22.1	15.1
Widgeon grass, wild celery	17.6	17.4
Small pondweed, southern naiad, bladderwort sp.	14.4	14.9
Coon’s tail, widgeon grass	13.6	14.4
Small pondweed, southern naiad	10.9	0.7
Southern water milfoil	10.7	36.5
Small pondweed, southern naiad, widgeon grass, wild celery	5.3	2.4
Water stargrass	4.9	2.8
Baldwin’s spikerush. southern water grass, southern water milfoil, sea lettuce pond lily	2.9	2.8
Coon’s tail, Eurasian water milfoil, southern naiad	2.3	11.4
Carolina fanwort, southern naiad	0.4	0.4
Turtle grass	0.05	0.05

5.0 DISCUSSION

The loss of SAV in the lower Mobile-Tensaw Delta and upper Mobile Bay between 2002 and 2009 had largely recovered by 2015, an exception being the northernmost portion of the study area in the Hurricane and Basin quads. In addition to an increased SAV extent in the upper Bay and Delta in 2015, substantial SAV was present at several study area locations where it did not occur in 2002 or 2009.

The Dog River watershed in particular contained large areas of SAV in 2015, with pondweed associations in Halls Mill Creek, Rattlesnake Bayou, and Rabbit Creek grading into wild celery, Eurasian watermilfoil, and widgeon grass in Dog River proper. Other areas in Mobile County with mapped SAV in 2015 but not in the 2009 or 2002 surveys included Duck Lake, Heron Bayou, Threemile Creek, and East Fowl River. In Baldwin County, SAV was mapped in Nolte Creek (Magnolia River), Shelby Lake, and Bon Secour Bay. These areas did not contain mapped SAV in 2009 or 2002.

The 2009 and 2002 aerial imagery sets were re-inspected as part of this investigation, and do not appear to have SAV in most of these areas. The 2009 imagery does show apparent SAV signatures in at least one of the Little Lagoon ponds, which was not included in the 2009 map.

Small patches of SAV were documented in several riverine areas of the coastal subwatersheds in 2015, including in Fish River, Magnolia River, Dog River, and East Fowl River, but were mostly not mappable due to a lack of corresponding imagery signatures. These locations are noted in the field point database.

The decrease in SAV extent in upper Mobile Bay between mid-September and early October 2015 might have been a response to salinity stress. Salinity measurements taken on the south side of the Highway 90 Causeway, at the Meaher Park environmental monitoring station, showed a daily average of 2.8 PSU on September 15th, and steadily increased to 8.8 PSU by October 1st. By the first week of October, much of the SAV in areas across the northern bay, such as in D'Olive Bay, had already disappeared. North of the Highway 90 Causeway, particularly off of the main rivers, SAV assemblages remained more consistent between summer and fall. Species such as southern naiad, water stargrass, coon's tail, and Carolina fanwort, which have relatively low salinity tolerances, persisted in these areas into November.

In addition to the usefulness of a second survey for documenting seasonal variation, potentially aiding in the identification of biotic or abiotic factors affecting SAV species occurrence, the fall imagery set was valuable for assessing areas that in the summer imagery had turbid conditions, in particular Mississippi Sound. The Sound tends to have a dynamic sea state during summer months, and SAV typically occurs there as patchy or sparse beds that present delineation difficulties even during optimal conditions. Additionally, narrow SAV bands along creeks and rivers that aren't visible during summer, due to water clarity issues or tree shadows, in some cases show up in fall imagery because of more oblique sun angles compared to summer. While peak summer biomass is the most important time of year for long-term SAV monitoring and assessment, periodic seasonal surveys can provide supplemental data to more fully analyze these resources.

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APPENDIX A

SAV Maps for the Mobile-Tensaw Delta and upper Mobile Bay, Mississippi Sound, and Perdido Bay.

2015 Submerged Aquatic Vegetation

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2015 Submerged Aquatic Vegetation
Mobile Bay National Estuary Program and
Alabama Department of Conservation and Natural Resources, State Lands Division

Area shown corresponds to The Mobile-Tensaw Delta, AL
Source: Barry A. Vittor & Associates, Inc., 2016

0 1.5 3 4.5 6 Kilometers

2015 Submerged Aquatic Vegetation

0 1.5 3 4.5 6 Kilometers

2015 Submerged Aquatic Vegetation
Mobile Bay National Estuary Program and
Alabama Department of Conservation and Natural Resources, State Lands Division

Area shown corresponds to Mississippi Sound, AL
Source: Barry A. Vittor & Associates, Inc., 2016

2015 Submerged Aquatic Vegetation

0 1 2 3 4 Kilometers

2015 Submerged Aquatic Vegetation
Mobile Bay National Estuary Program and
Alabama Department of Conservation and Natural Resources, State Lands Division

Area shown corresponds to Perdido Bay, AL
Source: Barry A. Vittor & Associates, Inc., 2016