COASTAL RECREATIONAL FISHING LICENSE
FINAL REPORT*

Grant Number: 2015-H-048

Grant Title: Submerged Aquatic Vegetation SONAR Mapping Surveys in low-salinity habitats: Pamlico River

Grant Award Period: 07/01/2015 – 12/31/2016

Final Project Summary:

We surveyed the submerged aquatic vegetation (SAV) resources in the Pamlico River estuary and its tributaries during 2015 and 2016 using the protocols established by a previous CRFL-funded project by Kenworthy et al. (2012). The protocols use single-beam Lowrance/ciBiobase and BioSonics DTX SONAR surveys taken from a small boat with underwater video images as a verification of SAV presence or absence. Rapid Assessment SONAR transects (53 transects each 10 km or a total of 327 miles in length) were done along the entire shoreline of the Pamlico River and its tributaries in 1-m water depth and video verification points were obtained at 330-m intervals. Most SAV was discovered in the low-salinity regions near Whichard's Beach and in the tributaries Durham Creek, Bath Creek, South Creek, North Creek, and St. Clair Creek. In addition, six sentinel sites (1000 m x 500 m) were established in areas that had historical SAV cover, SAV cover during our surveys. Accuracy estimates comparing Lowrance/ciBiobase and Biosonics DTX SONAR and underwater video at 100 randomly selected video comparison points in the sentinel sites were 87-94% in agreement. Percentage area covered by SAV in the sentinel sites ranged from 2.4 % to 44%, averaging 16 %; this amounts to 7 ha per 50-ha sentinel site or a total of 35 ha at all six sites. These sentinel sites are scheduled to be monitored annually in the future and were first monitored as reported here during the spring and summer of 2016. Loss of SAV was observed in Blount's Bay, which had previously been observed to have SAV in 2010 (Kenworthy, et al. 2012). The area of the SAV in the sentinel sites was 35 ha (86.5 acres).

Introduction

Need for SAV Monitoring

Coastal recreational fishing depends on good quality habitat in the juvenile stages to support populations of adult fishes. In general, seagrasses and submerged aquatic vegetation (SAV) provides complex habitat in which juvenile fishes and invertebrates can take shelter when threatened by a predator (Rozas and Odum 1988; Ferrell and Bell 1991; Boström and Mattila 1999; Jackson et al. 2001; Horinouchi 2007); in addition, SAV provides a food resource (Rozas and Odum 1988; Luczkovich and Stellwag 1993; Deehr et al. 2014). However, there has been a worldwide decline in seagrass and SAV distribution and abundance (Orth et al. 2006; Waycott et al. 2009) and there is a concern that a decline has been occurring in North Carolina's SAV resources. The North Carolina Coastal Habitat Protection Plan (Deaton et al. 2005) requires an SAV monitoring plan for SAV habitat so that trends in SAV habitat can be documented. Previously, CRFL has funded a SAV monitoring protocol using small boats moving along transects and revisiting sentinel sites, with SONAR surveys and underwater video verification (W. J. Kenworthy et al. 2012). We first used this monitoring protocol to survey SAV in Albemarle Sound 2014-2016 with funding provided by APNEP (Luczkovich and Zenil, unpublished). The Pamlico River Estuary was selected by the APNEP SAV monitoring partners for another low-salinity region to be surveyed using the same protocols. CRFL approved the use of this protocol for this project.

Objectives of this study

Submerged Aquatic Vegetation (SAV) was monitored to complete the tasks that were proposed in the NC Coastal Recreational Fishing License (CRFL) Program Grant that was awarded to East Carolina University. Between August 2015 and November 2016, we utilized single-beam SONAR methods, underwater video, and quadrat sampling in the Pamlico River and at some of its tributaries to identify areas with SAV along the shore at 1-m depth isobath. In addition, we established and monitored six sentinel sites for one season. The work was done to address the following objectives:

1) to survey SAV using the Rapid Assessment Protocol described in Kenworthy et al. (2012), surveying along the 1-m depth isobath along the entire shoreline of the Pamlico River Estuary and some of its major tributaries.
2) to survey the SAV using the Sentinel Site Protocol with shore-normal transects at 6 sentinel sites at selected locations to be revised in a 5-year rotation.

These objectives are related to the following CRFL strategic plan objectives:
Strategy H.2.1 Map coastal fisheries habitat such as submerged aquatic vegetation, shell bottom, and other bottom types.
Strategy H.2.3 Conduct research and monitoring to determine status of and trends in the six basic fish habitats (submerged aquatic vegetation, shell bottom, wetlands, water column, hard bottom, soft bottom).

Methods

Rapid Assessment of SAV in Alongshore Survey

Approximately 550 kilometers of shoreline were sampled between the fall of 2015 and the spring and summer of 2016. A total of 53 10-km (329 miles) transects were sampled (Figure 1). In the original proposal, we were only going to sample 31 10-km transects in the fall of 2015. However, during the survey we sampled the first 31 transects, and we found very little SAV. Therefore, we decided (after consulting with Dean Carpenter of APNEP, Anne Deaton of NCDMF, and Jud Kenworthy, retired employee of NOAA, parties involved in the original protocol development (W. J. Kenworthy et al. 2012) to include 22 additional 10-km transects that included some of the Pamlico River tributaries. The NCDMF staff and the historical SAV data layer suggested that SAV beds were common in the Pamlico River tributaries. We sampled the tributaries between the spring and summer of 2016. Past reports (W. Kenworthy et al. 2012),

had indicated that the fall could be the best time for sampling SAV in this area because temperatures begin to rise in the months of April and May through October.

Environmental data

Salinity, temperature, and secchi (proxy for transparency) were measured at each of the sentinel sites the days that we sampled with video and SONAR. The salinity and temperature were collected *in situ* using the YSI-Cast Away system. In addition, the Lowrance system constantly measures temperature. We used the ciBiobase average temperature to populate Table 2 because the Lowrance system sampled constantly as we were taking SONAR samples. Salinity, temperature and Secchi depth measurements were taken at the beginning of each Rapid Assessment transect and once at each sentinel site. These water quality point samples were associated with the transect data collected on SAV in the SONAR and underwater video that followed. Maps were plotted on salinity and Secchi depth points samples, with the median salinity (the average of Salinity minimum and Salinity Maximum) from the data recorded historically for the Pamlico River estuary in the Salwise data base (Lindquist and Fegley 2015)

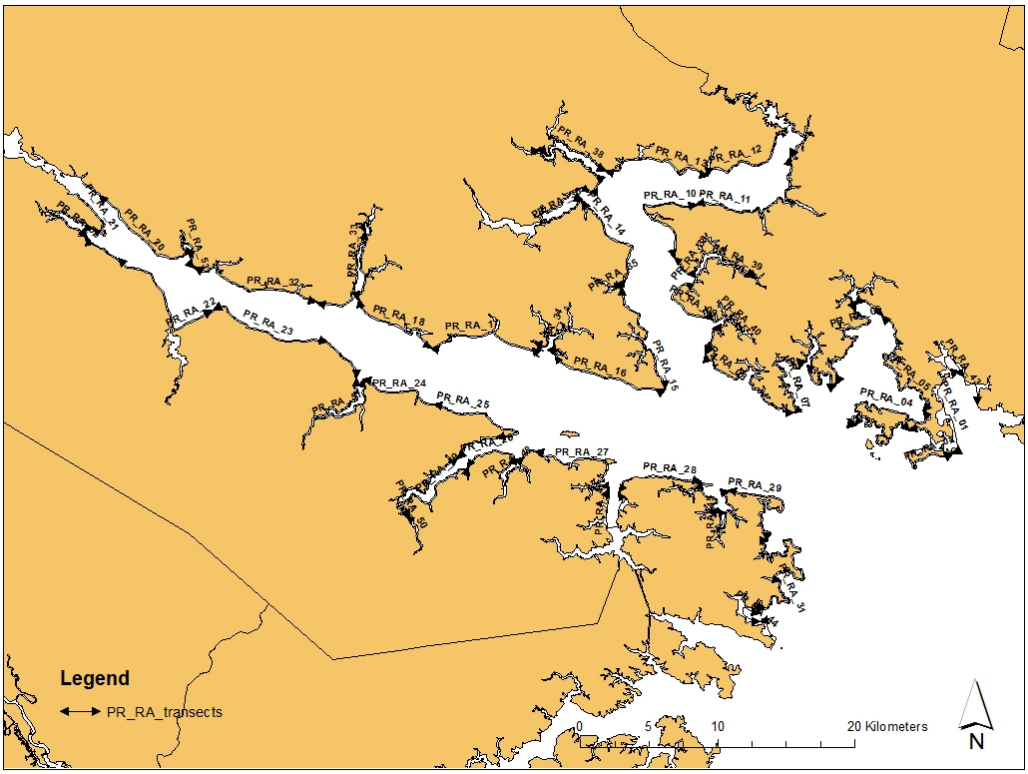


Figure 1 Pamlico River and tributaries rapid assessment ~10-km transects in the 2015 fall and spring/summer 2016.

SONAR data collection

The SONAR data was utilizing two different SONAR systems: Biosonics DTX (hereafter called the Biosonics system) and ciBiobase Lowrance system (hereafter called the Biobase system). The two system were utilized simultaneously for comparison. The 53 10-km Rapid Assessment (RA) transects were delineated utilizing the ArcGIS shoreline map (DENR coastal layer) for the state of North Carolina. The original RA transects were created at 500 m from the shore; however, the actual SONAR and video sampling took place along the 1-m depth isobath as determined in the field using the SONAR system. The shoreline was subdivided in ArcGIS using the "split" tool to create 10-km sections along the shore. Note that some of the transects for the tributaries could not be precisely divided in 10-km, but we tried to split them at 10-km whenever possible. The transects were assigned a transect ID from 1 to 53 (Figure 1). Upon arrival at the starting waypoint for each transect, we located the 1-m depth isobath by heading from the nominal transect 500 m off shore towards the shore, stopping and then turning parallel to the shore when we located the first 1-m depth reading on the Lowrance echosounder. The SONAR data was collected at an

average speed of 8 km hr^{-1} (4.3 knots). We collected approximately 30 files per 10-km transect because we stopped the SONAR file every 330 m to take video samples.

Biosonics SONAR system

The Biosonics system was comprised of the BioSonics DT-X echosounder with a 420-kHz single-beam transducer. The SONAR echosounder was mounted on an aluminum mount fixed at the gunwale of the East Carolina University's R/V Pinfish, a 19' Jones Brothers skiff with 90 HP motor. The transducer was mounted 28 cm below the water surface. SONAR signals were received and recorded to a Panasonic Toughbook laptop computer model CF-31 using BioSonics Visual Acquisition software. The BioSonics DTX SONAR data was later imported to Visual Habitat (Biosonics 2015) to classify percent cover of SAV. Visual Habitat software was used to classify SAV in the acquired SONAR data, and this is the successor software to ECOSAV2, which was used in the original protocol development (W. J. Kenworthy et al. 2012).

Biobase SONAR system

The Biobase system was comprised of the Lowrance HDS-7 combination GPS chart plotter and echo-sounder display, and a 200-kHz single-beam down-scan transducer. The transducer was installed on an aluminum mount fixed at the gunwale of the East Carolina University's R/V Pinfish, a 19' Jones Brothers skiff with 90 HP motor. The transducer was mounted 28 cm below the water surface. SONAR log files, GPS coordinates, and depth were stored in the Lowrance system. These data can be interpreted as aquatic plant biovolume. In addition, these SONAR log files provide temperature data and geographical coordinates for the SONAR sampling. All the data was saved to a SD card in the Lowrance HD-7. The data was later uploaded to a cloud base system for SAV presence/absence analysis.

The data was analyzed utilizing Biobase's algorithm to determine SAV presence, and they have a kriging software for plotting the data on a map. According to Navico (2014a), the map is generated by predicting SAV presence based on the geostatistical relationship between the input points. The kriging algorithm is an interpolation of the points that were sampled which were in proximity and did not vary widely.

The Biobase signal-processing algorithm estimates plant height as the difference between the bottom depth and the top of the plant signal. The GPS position is recorded approximately every second and the bottom feature from pings that elapse between different GPS positional reports are averaged for each coordinate or data point. I will use a sampling rate of 15 pings per seconds. The attribute value comprises a summary of approximately 15 pings. Each of the pings goes through a quality test to determine if a feature (i.e. bottom type) can be extracted from the ping. If a feature can be extracted from the pings; it is sent to the feature algorithm detection. Note that the distance covered by each set of 15 pings varies with the speed of the boat, but the average boat speed will be 9 km/h).

The acoustic signal from the 200-kHz transducer travels through SAV on the way to the bottom. The bottom usually returns a sharper signal (because it is harder) than that of the SAV canopy. Therefore, the plant height can be estimated for each ping by subtracting the bottom from the top of the canopy. Plant heights are averaged across all pings within a GPS coordinate point. To avoid false positives, plant heights from pings within a coordinate point that together average less than 5% of depth are not considered as vegetation. In addition, to avoid false vegetation detections at depths well beyond the deepest rooting depth of vegetation, Biobase discards 2% of the deepest coordinate points registering vegetation. The minimum depth for vegetation detection is 0.5 m. Biobase generates kriging maps based on the processed data. It predicts the vegetation values for areas that were not sampled based on the geostatistical relationship of the input points (Navico 2014b). The Biosonics DTX SONAR system was utilized alongside the Lowrance system for comparison.

Underwater video data collection

The video data was collected utilizing an underwater camera (Sartek, model #SDC-MSS). The camera was mounted on a pole approximately 13 cm (the Sartek camera's focal length) from the end of the

pole to ensure lens was pointing down, and the substrate was in focus once it was deployed. The camera was lowered every 330 meters from the previous point along each 10-km transect; this was called an underwater video verification point. The latitude and longitude where the camera was dropped was recorded in the GPS unit integrated with the Lowrance HDS-7. It was not possible to continuously record the SONAR data while recording underwater video because the video sampling was interfering with the Biobase SONAR data. When the camera was dropped bubbles would be produced, and the ciBiobase algorithm later used to analyze the SONAR data confused the bubbles with SAV. To avoid such false positive points in our data, the SONAR sampling was stopped each time before taking video data. We tried to deploy the video camera as close as possible to the nearest SONAR sample, so video and SONAR point would be as close as possible. Nonetheless, positioning error with GPS coordinates (± 3 m), winds and tides caused the boat to drift preventing the video and SONAR points being in the same location.

Sonar data analysis – Biosonics

All the data collected at the sites was then important into Visual Habitat (Biosonics 2015). Visual Habitat works very similarly to EcoSAV2 which was described on a previous CRFL report (W. Kenworthy et al. 2012). The specific setting used to analyze data in Visual Habitat are described in the Appendix.

SONAR data analysis - Lowrance

All the SONAR data collected with the Lowrance system was uploaded to ciBiobase SAV mapping data analysis and long-term storage website (www.cibiobase.com). The bathymetry and vegetation biovolume were imported from the ciBiobase account to ArcGIS as .csv files. As each of the transects had approximately 10 files, these files were merged by transect utilizing the "Merge trips" function in the ciBiobase interface. Once the files were merged, they were reprocessed by the ciBiobase' algorithm analysis. The ciBiobase generated "vegetation" data that was exported. The data was exported as "point data" into a .csv file. The exported file included an individual record id number, latitude and longitude, depth to plant, plant height, Biovolume, and the date file was created. The .cvs files were imported to ArcGIS, where the data was projected on a map utilizing the "add XY data" tool. The coordinate system for the map and the data was set to be in the NAD 1983 State Plane North Carolina FIPS 3200 Feet projected coordinate system. Biovolume and SAV presence and absence maps were generated utilizing ArcGIS.

Underwater video data analysis

The underwater water video was analyzed to determine the presence/absence of SAV in the recordings. The presence/absence results along with their respective latitude and longitude were store in an excel spreadsheet. The data was then imported into ArcGIS and projected in a similar manner as the SONAR data.

Video verification points

At the along-shore transects, we verified the performance of the SONAR compared to the video. As mentioned previously, the video points could not be taken at the exact same location as the SONAR due to bubble interference when we deployed the camera. We had to stop the SONAR before we deployed the underwater camera and due to wind and tides the boat drifted; therefore, the video point are approximately 3 meters from its respective SONAR points depending on wind conditions and currents. The "Spatial Join" tool was utilized to join the attributes from the video data to the SONAR data on a spatial relationship of 10 m. The video was set as the "Target Feature" and the SONAR data the "Join feature." The tables were joined "one to one". After joining the data from the video and the SONAR by their spatial relation, it was possible to calculate accuracy based on the following formula:

$$Accuracy\ \% = \frac{True\ Positive\ Points + True\ Negative\ Points}{Video\ Points} \times 100$$

Where:

True Positive Points are those in agreement that SAV is present on both SONAR and video at a given point. True Negative Points are those in agreement that SAV is absent on both SONAR and video at a given point.

Sentinel Sites

Sentinel Site Selection

In order to address objective 2, we utilized the alongshore data collected in the 2015 fall and the 2016 spring and summer to establish sentinel sites. For a site to become a sentinel site it had to meet these specific criteria:

1) SAV had been present in the past (prior to 2015)
2) SAV was present per underwater video sampling in 2015 or 2016 sampling
3) SAV was present per SONAR sampling in 2015 or 2016 sampling

Originally, we wanted to use the same methodology that we used for the Albemarle Sound to select sentinel sites. In the Albemarle Sound, we randomly selected 10 sites that met these criteria; however, very few areas met the criteria in the Pamlico, so we had a limited number of areas where we could establish sentinel sites. Therefore, we decide to manually select the sentinel sites. We were concerned that if we randomly selected these sites, sampling would be cluster only in certain areas. We selected 6 sentinel sites that were spread out throughout the Pamlico River, and its tributaries. The original proposal suggested to sample 20 sentinel, but after the semi-annual report, it was decided that it was better to sample the tributaries and reduce the number of sentinel sites because we found so little SAV in the fall of 2015. In addition, we had agreed to sample sentinel sites in the spring and fall; however, the tributaries sample was a huge undertaking that took much longer to sample than previously expected. We selected a total of 6 sentinel sites (

Figure 2 Sentinel sites (upper left: PR SS Whichard's Beach, PR SS Riverside; upper right: PR SS Bath Creek; lower left: PR SS Blount's Bay) elected in the 2016 summer. A total of 6 sentinel sites were selected in the Pamlico River and some of its tributaries.

and Figure 3). Only 5 of them met the criteria previously discussed, but we decided to include a site that did not show SAV in the 2015 or 2016 SONAR and video sampling because the ECU team had sampled this site (i.e. Blount's Bay) in 2010, 2011, and 2013. We thought it would be important to continue sampling a site we had sampled for a few years now, as accurate historical SAV distribution data is limited. In addition to SONAR and underwater video sampling like it was stated in the proposal, we sampled the shore at each sentinel site utilizing 1x 1 m quadrats with 10x10-cm grid and sampled visually (snorkeling) for SAV presences with the 100-cells of each quadrat.

Sentinel Site Transect Delineation

Each of these sentinel sites were defined by an area of 1000 m X 500 m (500 km^2). The sentinel sites were monitored for SAV utilizing similar SONAR and underwater video as explained in the alongshore section. Each of these sentinel sites were monitored with 40 transect lines. The lines were selected a priori using Digital Shoreline System (DSAS), which is a free ArcGIS tool commonly used to generate transect lines (Thieler et al. 2003). The transect lines were 25 meters apart. In addition, 100 random video verification points were generated in ArcGIS to compare the SONAR accuracy to the video data. Figure 4 shows the sentinel sites that were monitored, and Figure 4 shows the sight near Washington, NC.

Pamlico River Sentinel Site Survey video and SONAR sampling

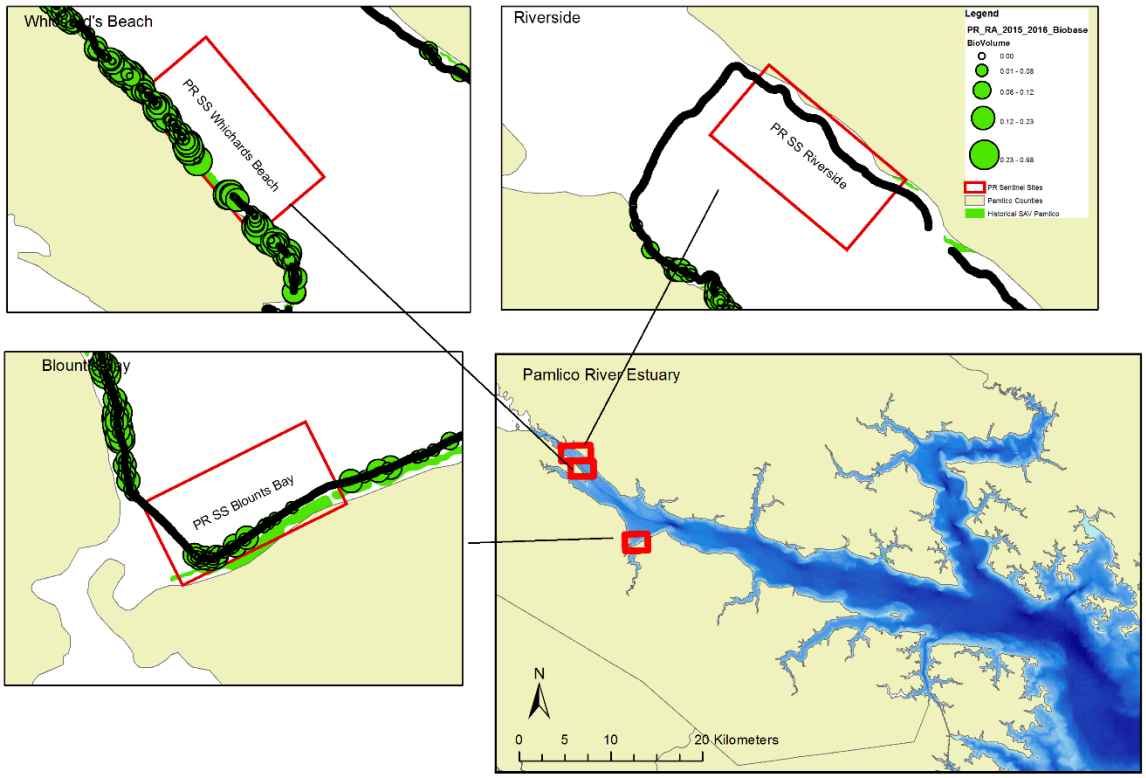


Figure 2 Sentinel sites (upper left: PR SS Whichard's Beach, PR SS Riverside; upper right: PR SS Bath Creek; lower left: PR SS Blount's Bay) elected in the 2016 summer. A total of 6 sentinel sites were selected in the Pamlico River and some of its tributaries.

Pamlico River Sentinel Site Survey video and SONAR sampling

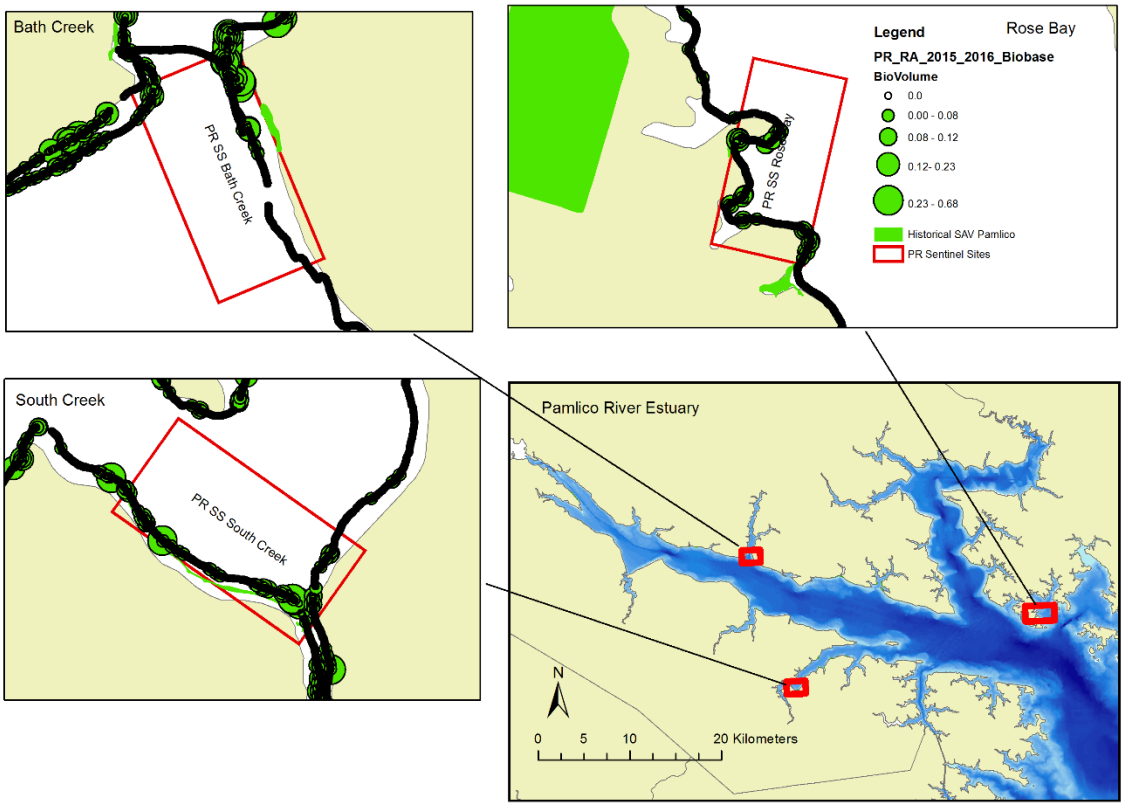


Figure 3 South Creek and Rose Bay (PR SS South Creek and PR SS Rose Bay) sentinel sites selected in the 2016 summer. A total of 6 sentinel sites were selected in the Pamlico River and some of its tributaries.

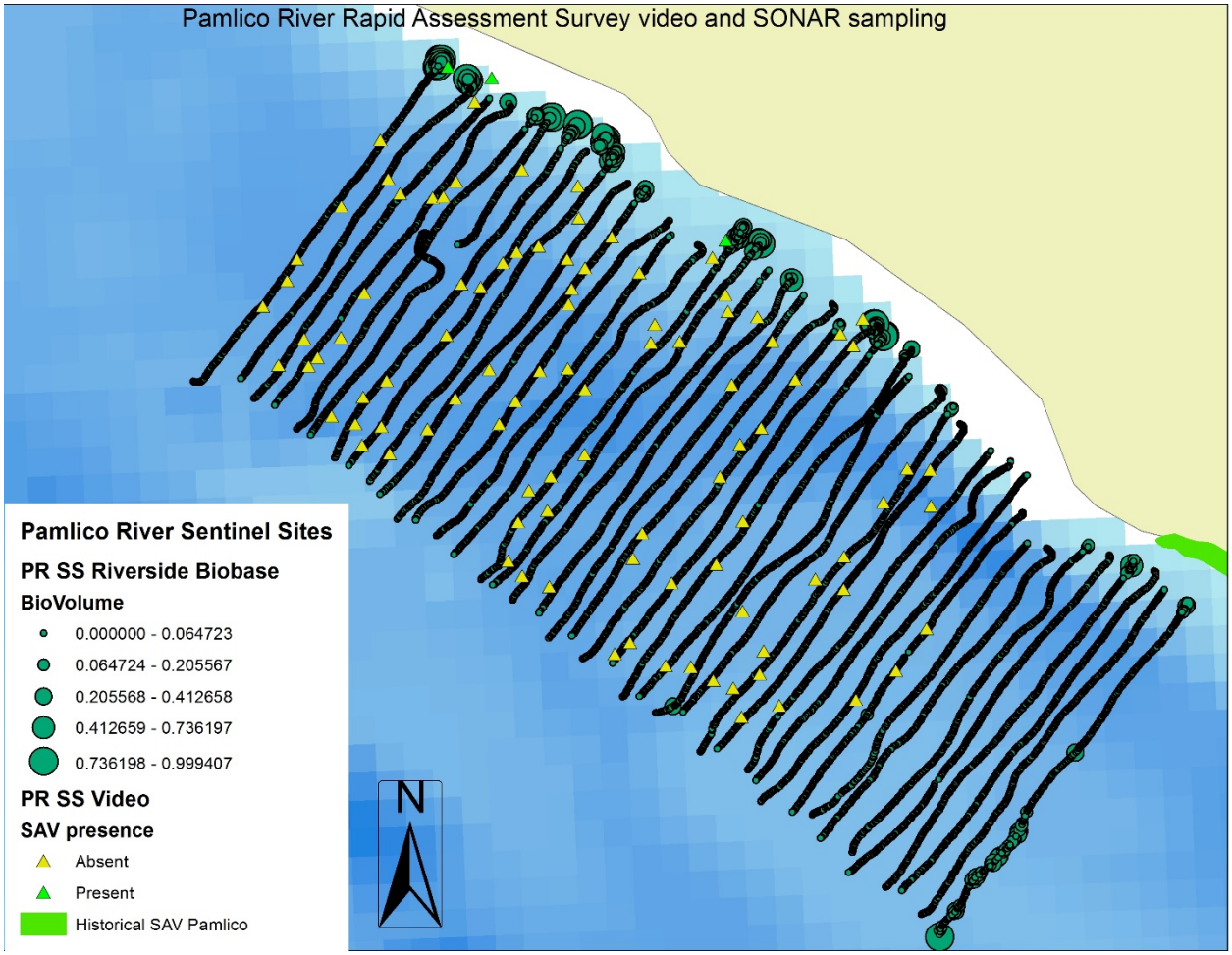


Figure 4 Riverside Sentinel Site in the Pamlico River, NC. Transects, video, and historical SAV are shown.

SONAR data collection

SONAR data was collected using the same Lowrance and Biosonics transducers and equipment described in the Rapid Assessment alongshore study. The sentinel sites were sampled once in the late summer/fall in 2016.

Underwater video collection

Underwater video was collected with same equipment as described in the Rapid Assessment alongshore study. 100 random video points were taken within each sentinel site. The random points were determined *a priori* utilizing the Random Point tool in ArcGIS (Figure 4).

SONAR and video data analysis

The analysis for both SONAR and video followed the same protocol discussed in the Rapid Assessment alongshore section. The verification points were compared in a similar fashion.

Video-verification points

The video-verification points were taken the same day after collecting the SONAR transects data. The video points and SONAR points could not be taken at the same location because the ciBiobase algorithm was confusing the camera's bubbles with SAV. Due to wind and tides the boat drifted, so the video point was approximately 3 meters from pre-determined SONAR transect routes. Proximity analysis in ArcGIS was utilized to compare each video point and SONAR point(s). The "Spatial Join" tool was utilized to join the attributes from the video data to the SONAR data on a spatial relationship of 10 m. After joining the data

from the video and the SONAR by their spatial relation, it was possible to calculate accuracy based on the formula given above.

Quadrat sampling

We used quadrat methodology to estimate abundance of SAV in shallow areas where the boat cannot access (<0.5-m). Quadrat sampling at the sentinel sites followed similar methodology as described in Duarte and Kirman (1989). We selected 10 random transects from the 40 transects monitored with SONAR and video at each sentinel site. We sampled using a 1x1-m quadrat with a 100 cell grid. Snorkelers counted number of cells with SAV present. At each randomly selected transect, we sampled at four different depths (0.25, 0.5, 0.75, and 1 m) with three replicate samples per depth. The three replicate quadrats at each of the depths were arranged along a perpendicular line. At positions determined by randomly selecting 3 distances between 0 and 25 m (the distance of the perpendicular line at each random transect). In total we had 120 quadrants per sentinel site (10 transects x 4 depths x 3 replicate quadrats at each depth; unless transect lines were in deeper areas or could not be sampled due to rocks, stumps, etc.).

Surface interpolation analysis

We utilize simple cokriging to interpolate the presence of SAV at sentinel sites were SAV was detected. The cokriging used in this report is similar to that what was described in a previous CRFL report (W. Kenworthy et al. 2012). The SAV kriging models shown in this report were generated in ArcGIS using the ordinary kriging in the Geostatistical Wizard of ArcGIS 10.4.1. The two variables used to generate SAV kriging surface were SAV percent cover and depth (obtained from Visual Habitat, Biosonics (2002). When running the Geostatistical Wizard, maximum percent cover and minimum depth were used when two or more points exist in the same location.

Results

Rapid Assessment Transects

Environmental data

Salinity, temperature, and secchi (proxy for transparency) were measured at each of the sentinel sites the days that we sampled with video and SONAR. The salinity and temperature were collected *in situ* using the YSI-Cast Away system. In addition, the Lowrance system constantly measures temperature. We used the ciBiobase average temperature to populate Table 2 because the Lowrance system sampled constantly as we were taking SONAR samples.

Water temperatures were high, as we took the samples at the end of summer; the average temperature at all the site was 30.91. The temperature ranged from 28.75 to 31.88 °C.

The salinity ranged from 0 to 10.55 ppt, it was lower at the upstream sites. Rose Bay had the highest salinity because it is near Pamlico Sound. Most of the sites had salinities at or near zero ppt. Blount's Bay was the only other site with a slightly higher salinity at 4.16 ppt.

The salinity in the Pamlico River and its tributaries ranged from 0 to 14 ppt. The lowest salinities that we recorded were in the tributaries and upstream. Rose Bay and areas near Pamlico Sound had the highest salinities (Figure 5). In Figure 5**Error! Reference source not found.**, the long-term salinity data (median salinity from Salwise database, (Lindquist and Fegley 2015) for the river and sound are also shown.

The average secchi depth was 0.62 m, and it ranged from 0.35 to .88 m. Secchi was particularly low at Blount's Bay where salinity was 0.35 (Figure 6).

Pamlico River Rapid Assessment Survey video and SONAR sampling

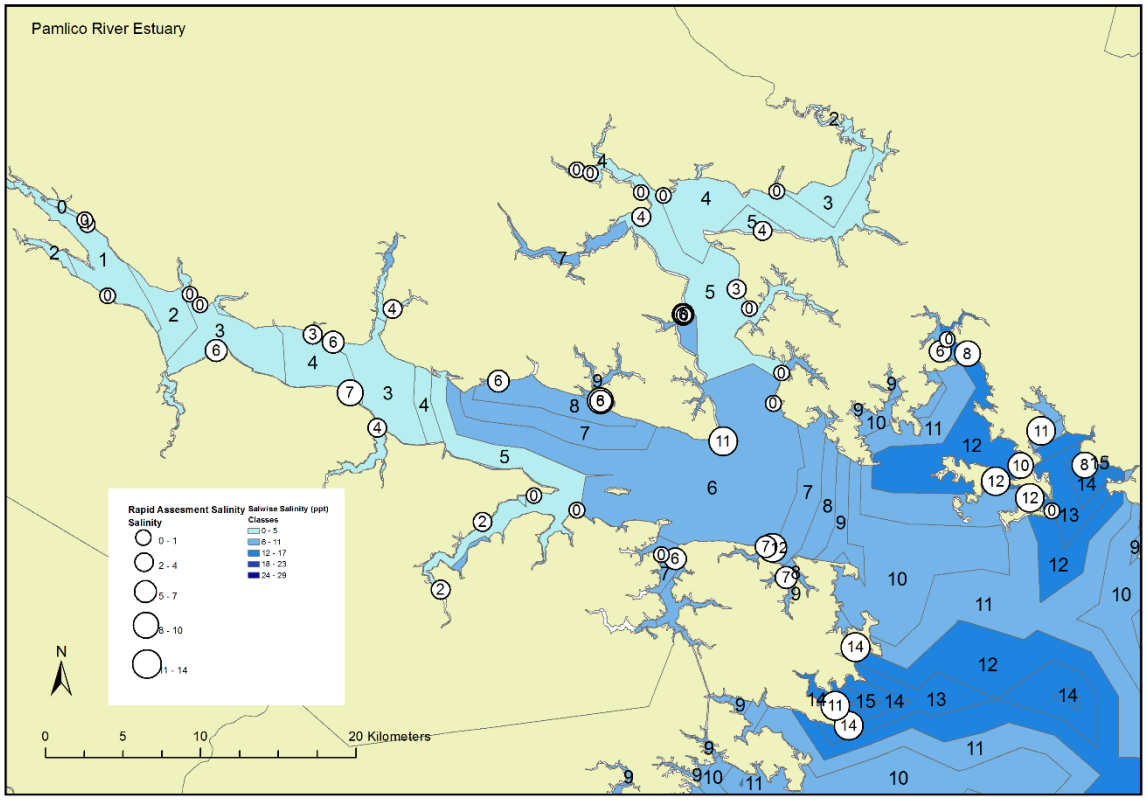


Figure 5 Salinity (ppt) along the RA transects of the Pamlico River. Graduated white circle symbols show surface salinity point samples taken at the start of each RA transect. Salinity point samples ranged from 0 to 14 ppt. Salinity contours are from an historical salinity data base called Salwise, a long-term salinity dataset for the NC rivers and sounds.

Pamlico River Rapid Assessment Survey video and SONAR sampling

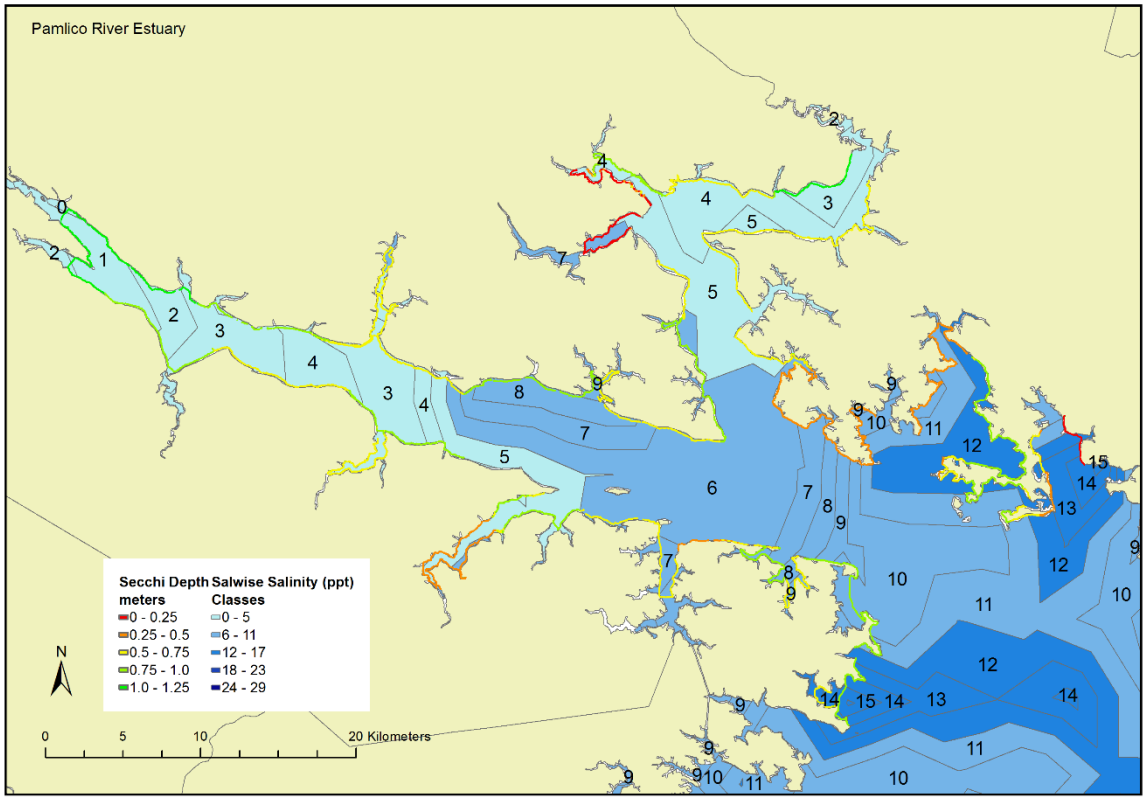


Figure 6 Secchi depth classes (m) are shown along each transect. Secchi depths were taken at the start of each transect. Salwise salinity (ppt) contours also shown.

Sonar and Video data

The SONAR data indicated that there is possible SAV along the entire shore of the Pamlico (Figure 7, Figure 8); however, the video confirmed only a few areas of SAV along the Pamlico River (Figure 10). The majority of SAV areas were located at the upstream areas of the river near Chocowinity Bay, and at some of the Pamlico River (e.g., Whichard's Beach, Durham Creek, and Bath Creek; Figure 7) and in the Pamlico River tributaries (e.g., North Creek, South Creek and St. Clair Creek; Figure 8).

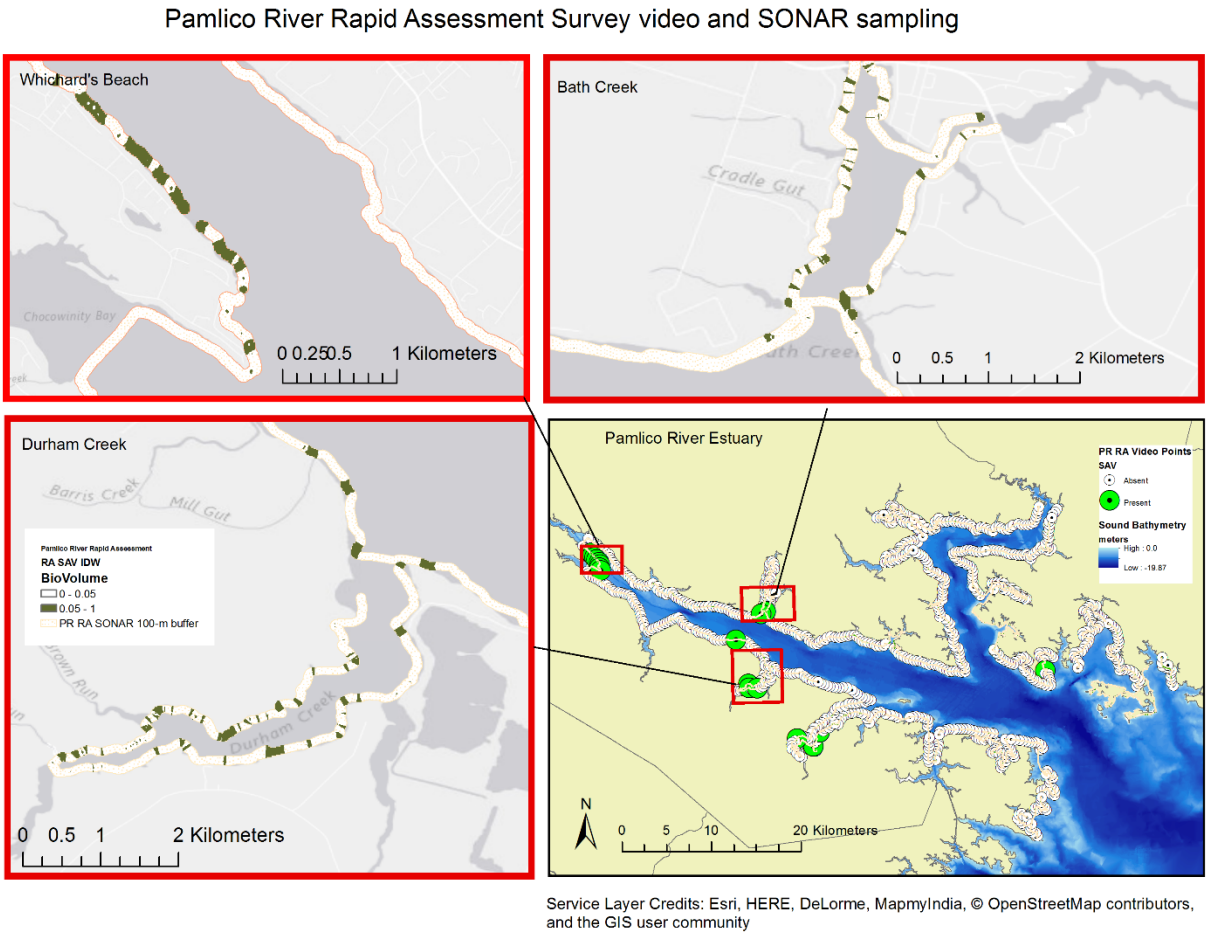


Figure 7 SAV presence in the Pamlico River along the 1-m isobath using underwater video and Lowrance echosounder and ciBiobase classification of SONAR data. Inset maps show SAV presence on underwater video and SONAR (biovolume > 0.2 shown in green) within three subareas (Whichard's Beach, Bath Creek, and Durham Creek). Underwater video points that were SAV-positive are also shown on the Pamlico River Estuary map in the lower right. Data were collected in the spring of 2015, spring and early summer of 2016. For this visualization, a 100-m band (50 m along each side of the SONAR track) is shown, although the SONAR beam swath is about 0.3 m at this depth and restricted to the area directly under the research vessel.

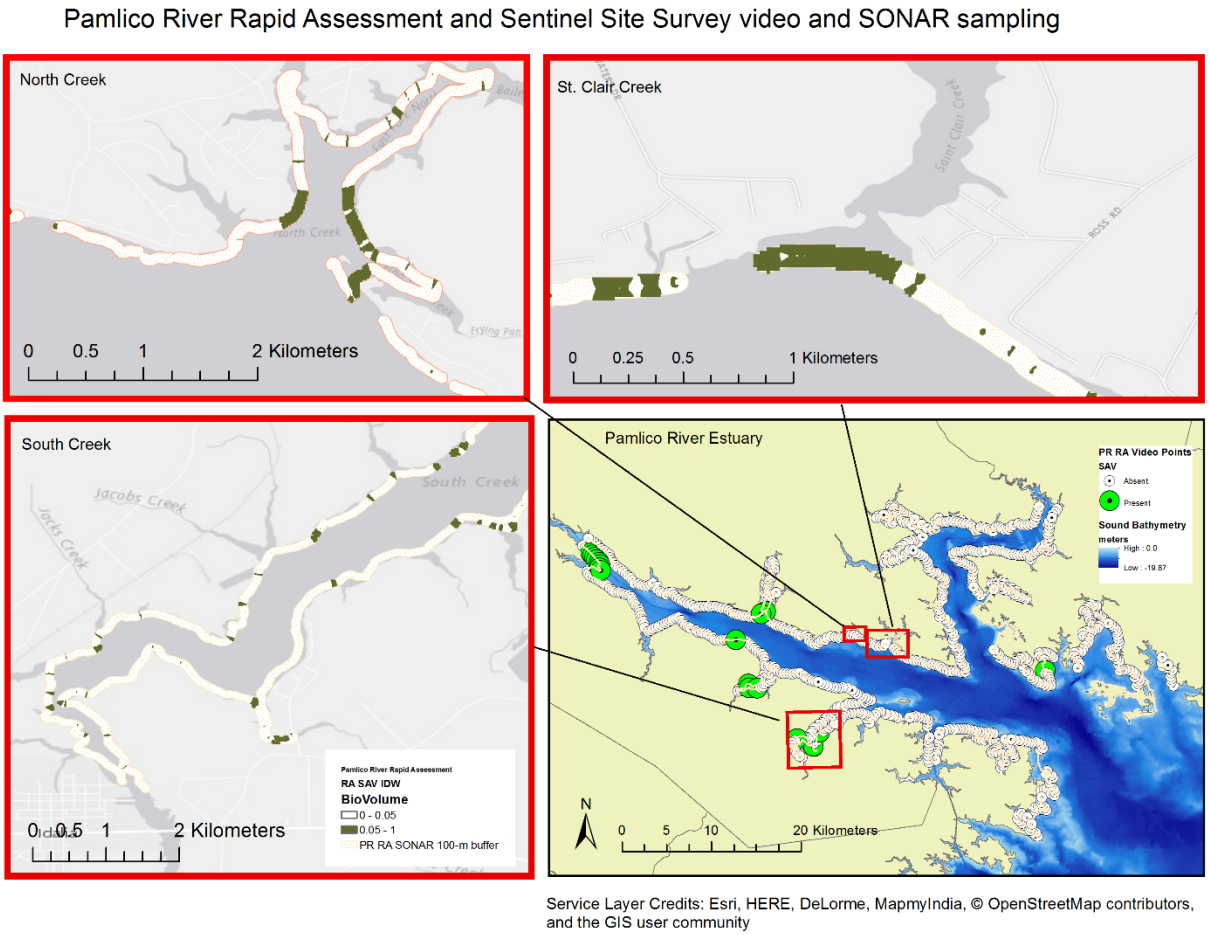


Figure 8 SAV presence in tributaries along the 1-m isobath using underwater video and Lowrance echosounder and ciBiobase classification of SONAR data collected in the Pamlico River. Inset maps show SAV presence on underwater video and SONAR (biovolume > 0.2 shown in green) within three subareas (North Creek, South Creek, and St. Clair Creek). Underwater video points that were SAV-positive are also shown on the Pamlico River Estuary map in the lower right. Data were collected in the spring of 2015, spring and early summer of 2016. For this visualization, a 100-m band (50 m along each side of the SONAR track) is shown, although the SONAR beam swath is about 0.3 m at this depth and restricted to the area directly under the research vessel.

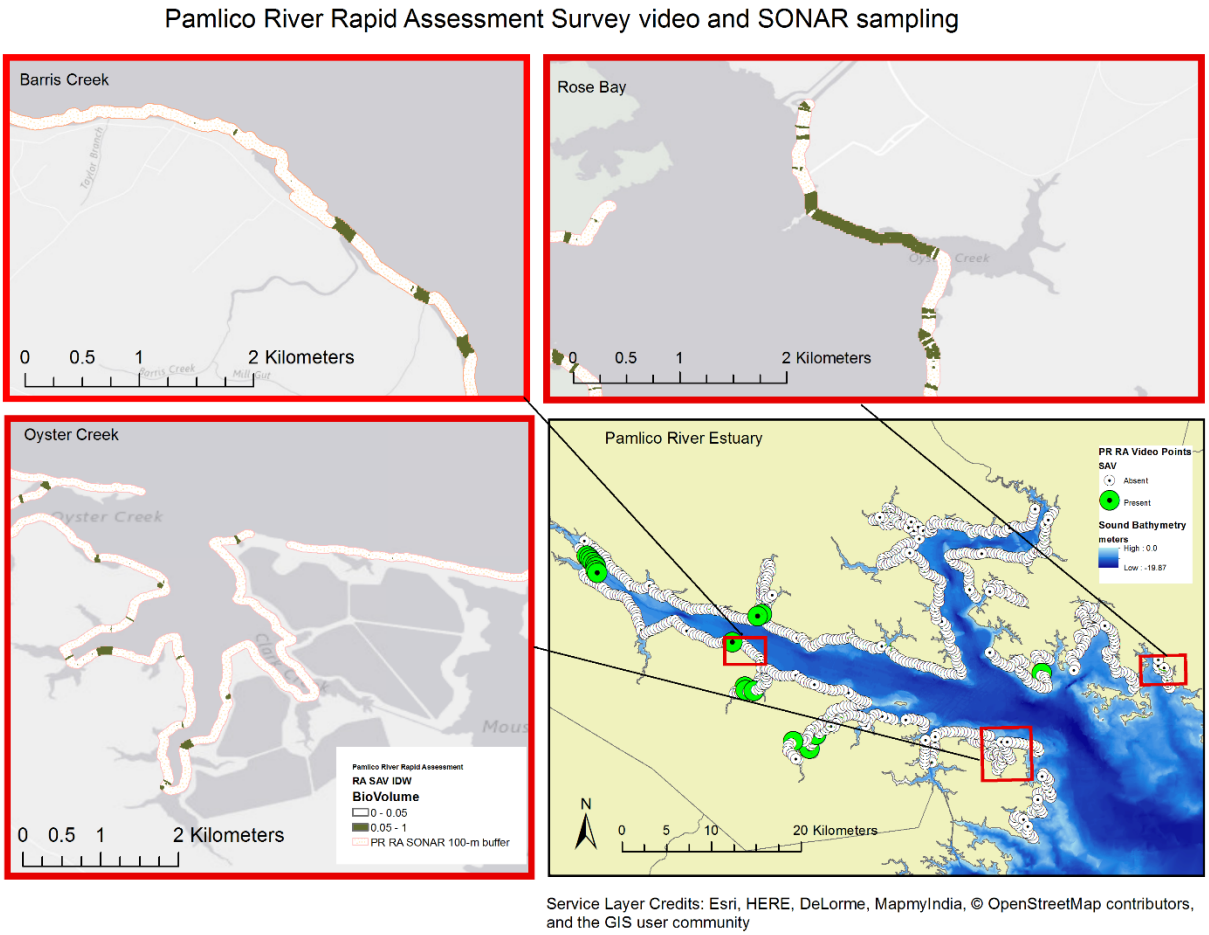


Figure 9 SAV presence in tributaries along the 1-m isobath using underwater video and Lowrance echosounder and ciBiobase classification of SONAR data collected in the Pamlico River. Inset maps show SAV presence on underwater video and SONAR (biovolume > 0.2 shown in green) within three subareas (Barris Creek, Rose Bay, and Oyster Creek). Underwater video points that were SAV-positive are shown on the inset maps and the Pamlico River Estuary map in the lower right. Data were collected in the spring of 2015, spring and early summer of 2016. For this visualization, a 100-m band (50 m along each side of the SONAR track) is shown, although the SONAR beam swath is about 0.3 m at this depth and restricted to the area directly under the research vessel.

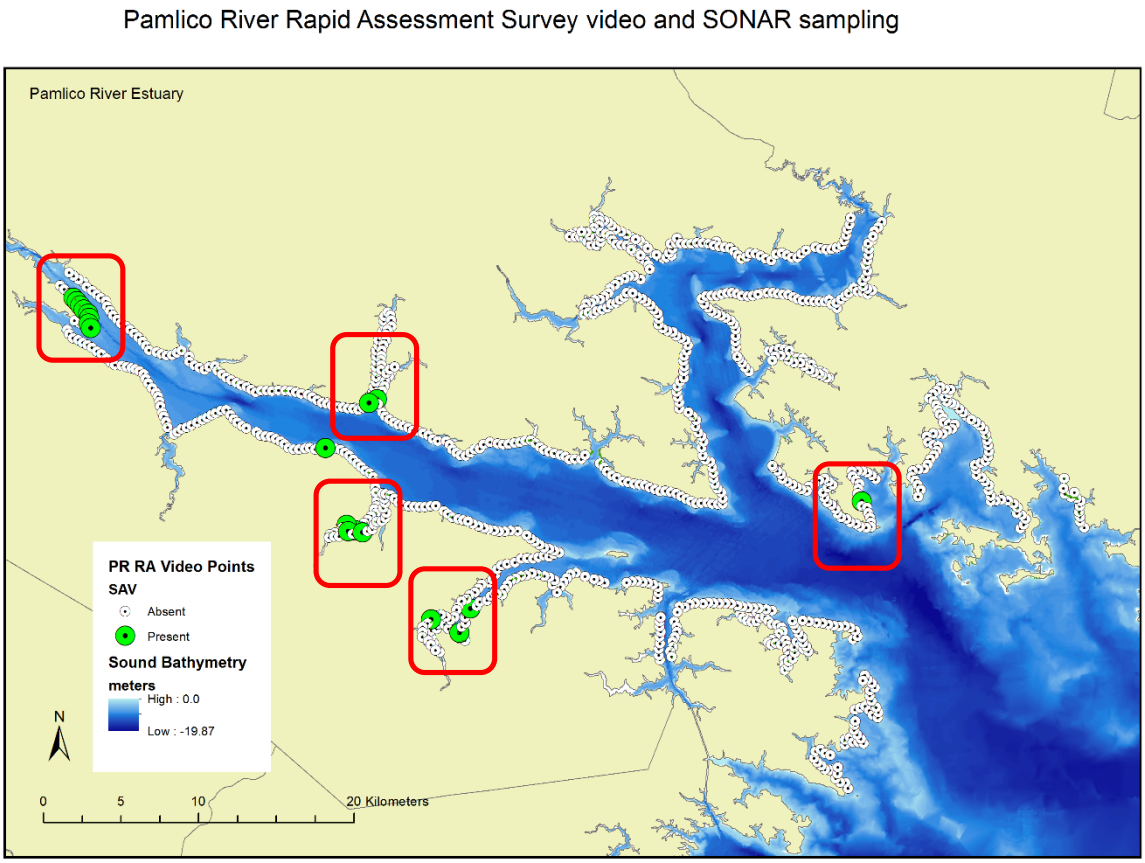


Figure 10 SAV presence using underwater video in the Pamlico River, NC. Data was collected in the 2015 spring and 2016 spring/summer.

Video-verification points

Each video point was compared to the closest SONAR point for the entire sound, and the average accuracy for the Rapid Assessment transects was estimated to be 93.88%, which is slightly higher to what was reported in Kenworthy et al. (2012), and a previous report for the Albemarle Sound (Luczkovich and Zenil 2015). The accuracy for the Pamlico River ranged from 75% to 100%. Accuracy was higher in areas where there was no SAV; however, areas with SAV showed lower accuracy. These decline in accuracy can be attributed to the patchiness of SAV. SONAR sampling had a much higher sampling rate than that of the underwater vide, so it is possible that the video is not good at detecting SAV where SAV is patchy. The diagram in Figure 11 can help illustrate this scenario.

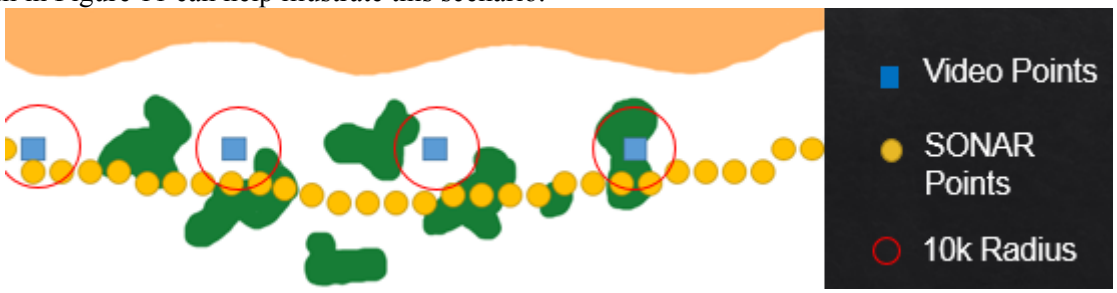


Figure 11 Diagram representing SONAR and underwater video sampling rate; although not at scale, it's clear that video is likely to miss SAV areas when SAV is patchy (green areas).

Sentinel Sites

Quadrat, SONAR, and video, data

The quadrat data indicates that SAV was present at only three of the six sentinel sites (Figure 14, Figure 15, and Figure 17): Whichard's Beach, Riverside, and Rose Bay. Nonetheless, the amount of SAV found at Rose Bay was very small, and it was not picked up by the Biosonics system. The Biosonics data cokriging indicates that there are patchy SAV beds at Whichard's Beach and River side, but the other sites do not appear to have any SAV. These results were confirmed by the video and quadrat data.

The ciBiobase system found larger areas of SAV, but they were not confirmed with underwater video or quadrat data. The cloud base program generates SAV Percent Area Cover (PAC) and kriging maps of SAV distribution from the SONAR files collected; however, we have little control on how this data was analyzed. Percent Area Cover is defined as the percent of the coordinate points that had a vegetation signal within component pings that resulted in 5% biovolume or greater (Navico 2014a). Table 1 shows the ciBiobase vegetation kriging layer for each of the 6 sentinel sites. PAC is also reported in this table.

Environmental variables

Salinity, temperature, and secchi (proxy for transparency) were measured at each of the sentinel sites the days that we sampled with video and SONAR. The salinity and temperature were collected *in situ* using the YSI-Cast Away system. In addition, the Lowrance system constantly measures temperature. We used the ciBiobase average temperature to populate Table 2 because the Lowrance system sampled constantly as we were taking SONAR samples. The salinity ranged from 0 to 10.55 ppt, it was lower at the upstream sites. Rose Bay had the highest salinity because it is near Pamlico Sound. Most of the sites had salinities at or near zero ppt. Blount's Bay was the only other site with a slightly higher salinity at 4.16 ppt. The average secchi depth was 0.62 m, and it ranged from 0.35 to .88 m. Secchi was particularly low at Blount's Bay where salinity was 0.35. Water temperatures were high, as we took the samples at the end of summer; the average temperature at all the site was 30.91. The temperature ranged from 28.75 to 31.88 °C.

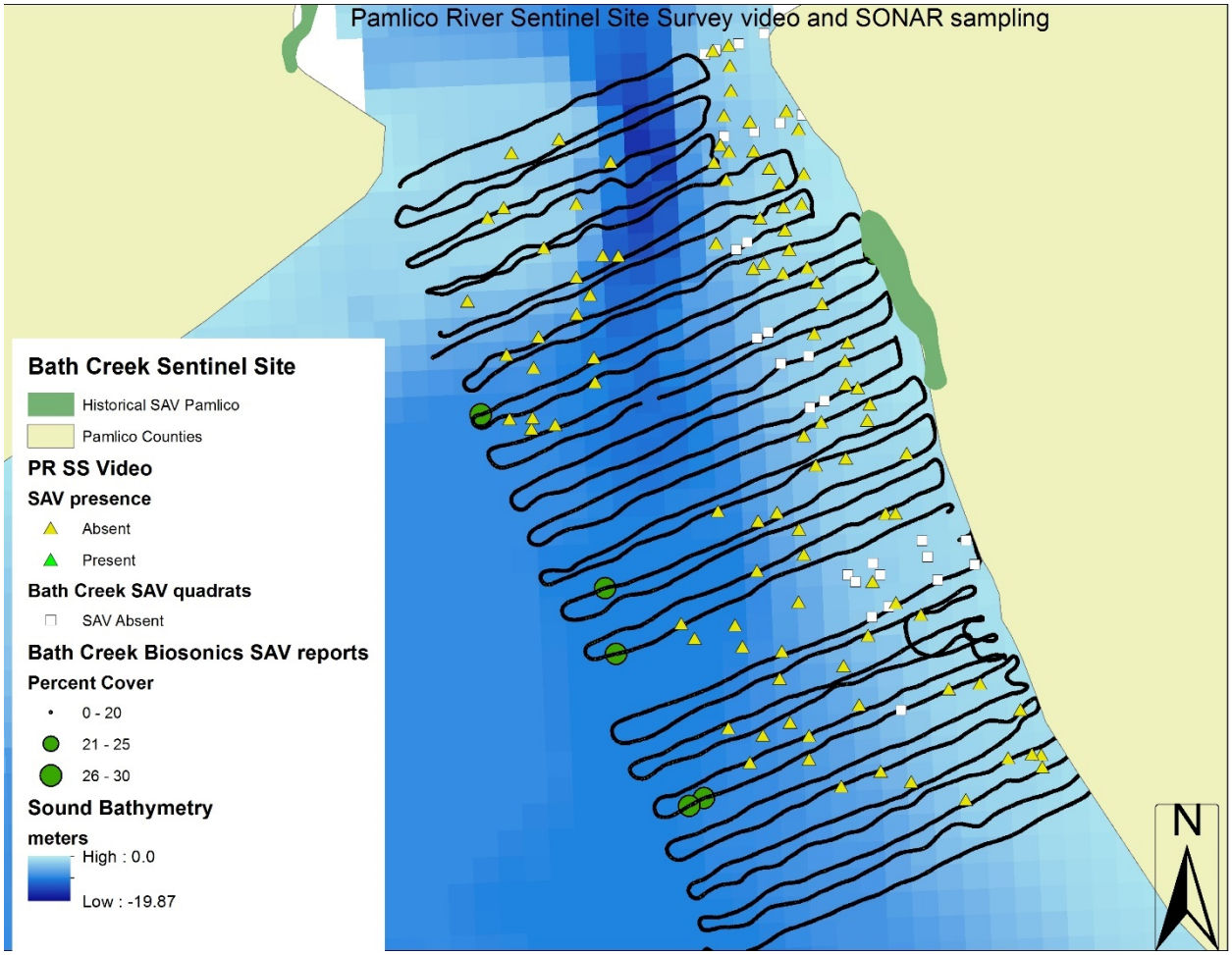


Figure 12 Bath Creek Biosonics system SONAR sampling. Underwater video is also reported. Sampling took place on summer/fall 2016. Quadrat data is also reported.

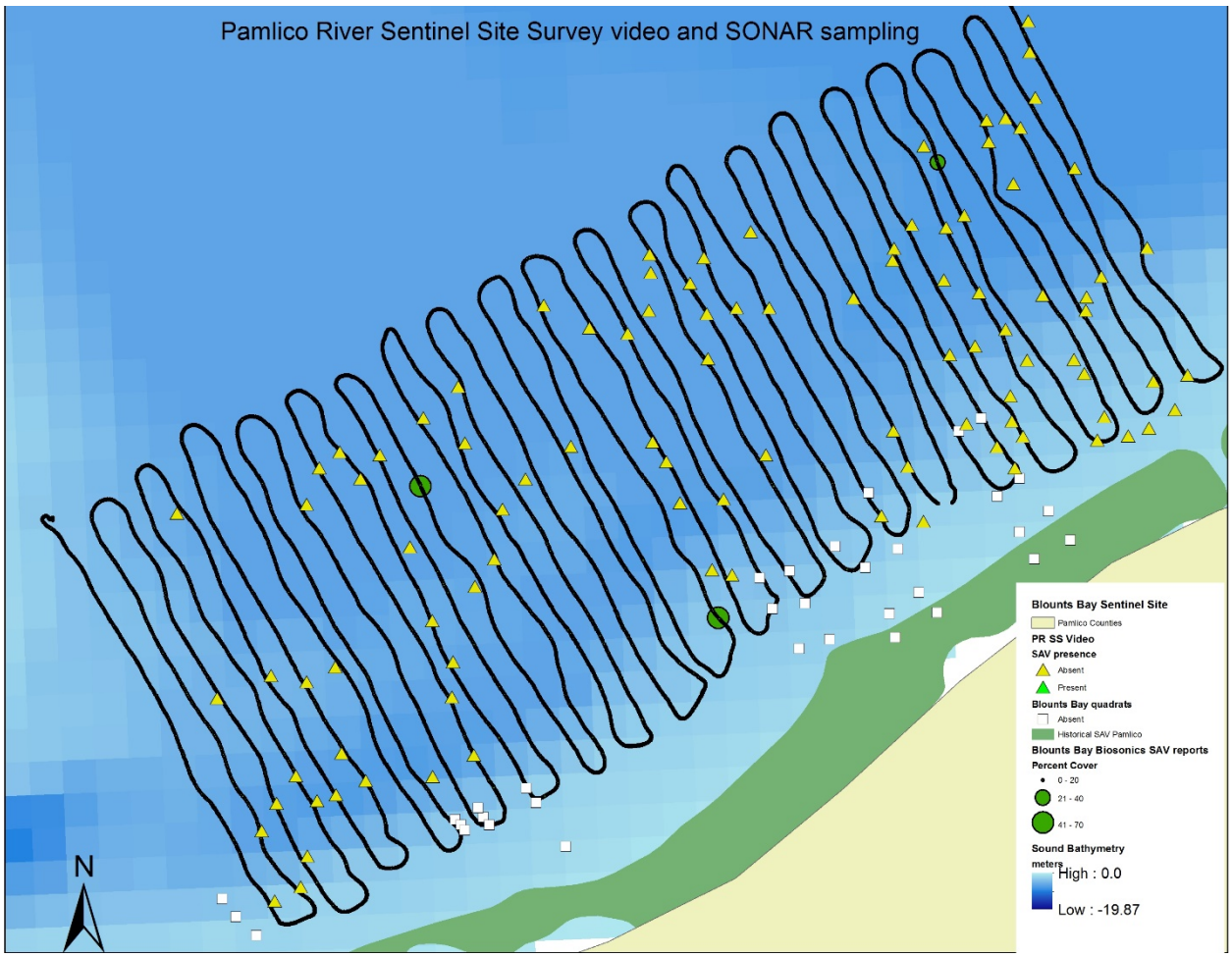


Figure 13 Blounts Bay Biosonics system SONAR sampling. Underwater video is also reported. Sampling took place on summer/fall 2016. Quadrat data is also reported.

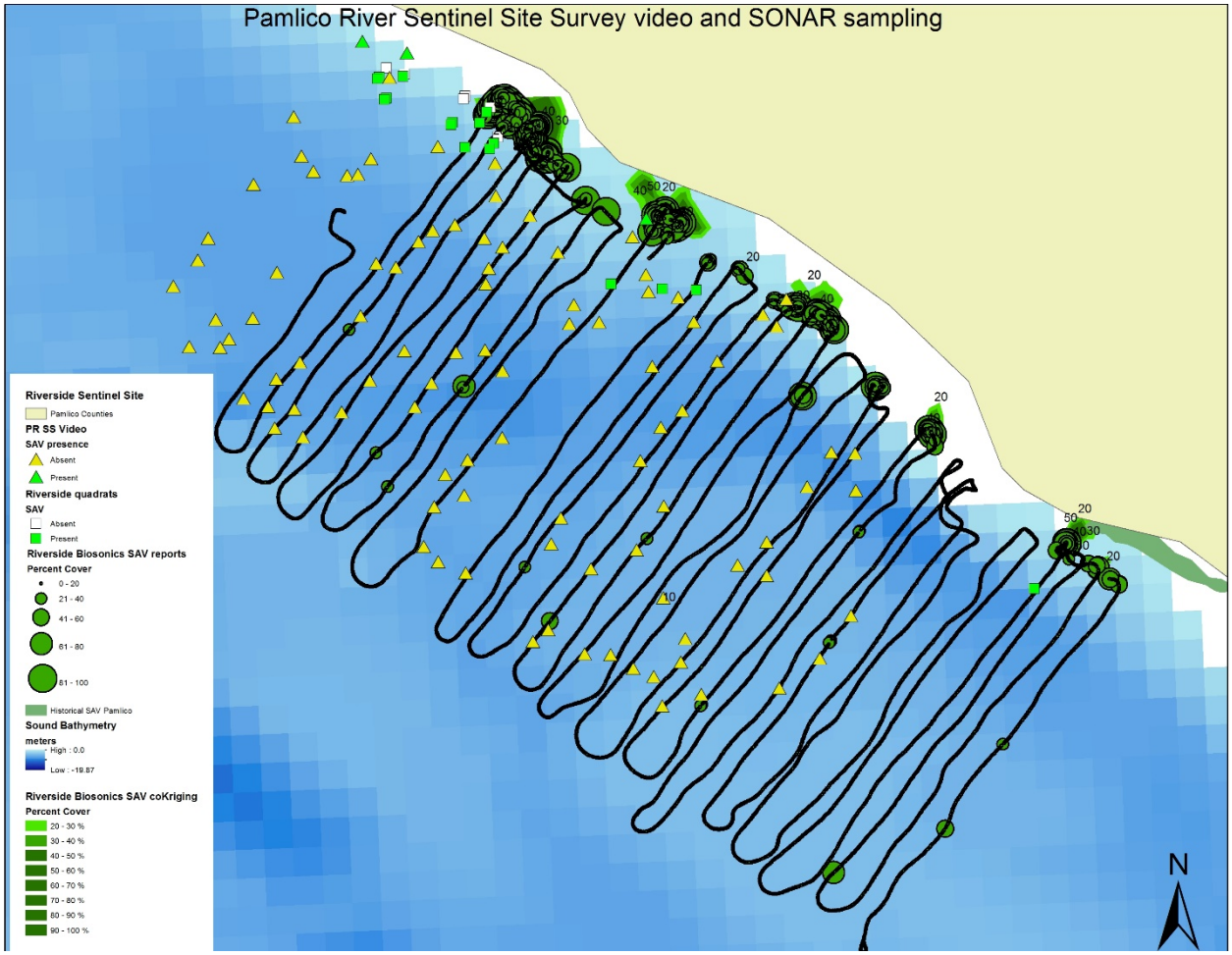


Figure 14 Riverside Biosonics system SONAR sampling. Underwater video is also reported. Sampling took place on summer/fall 2016. Quadrat data is also reported.

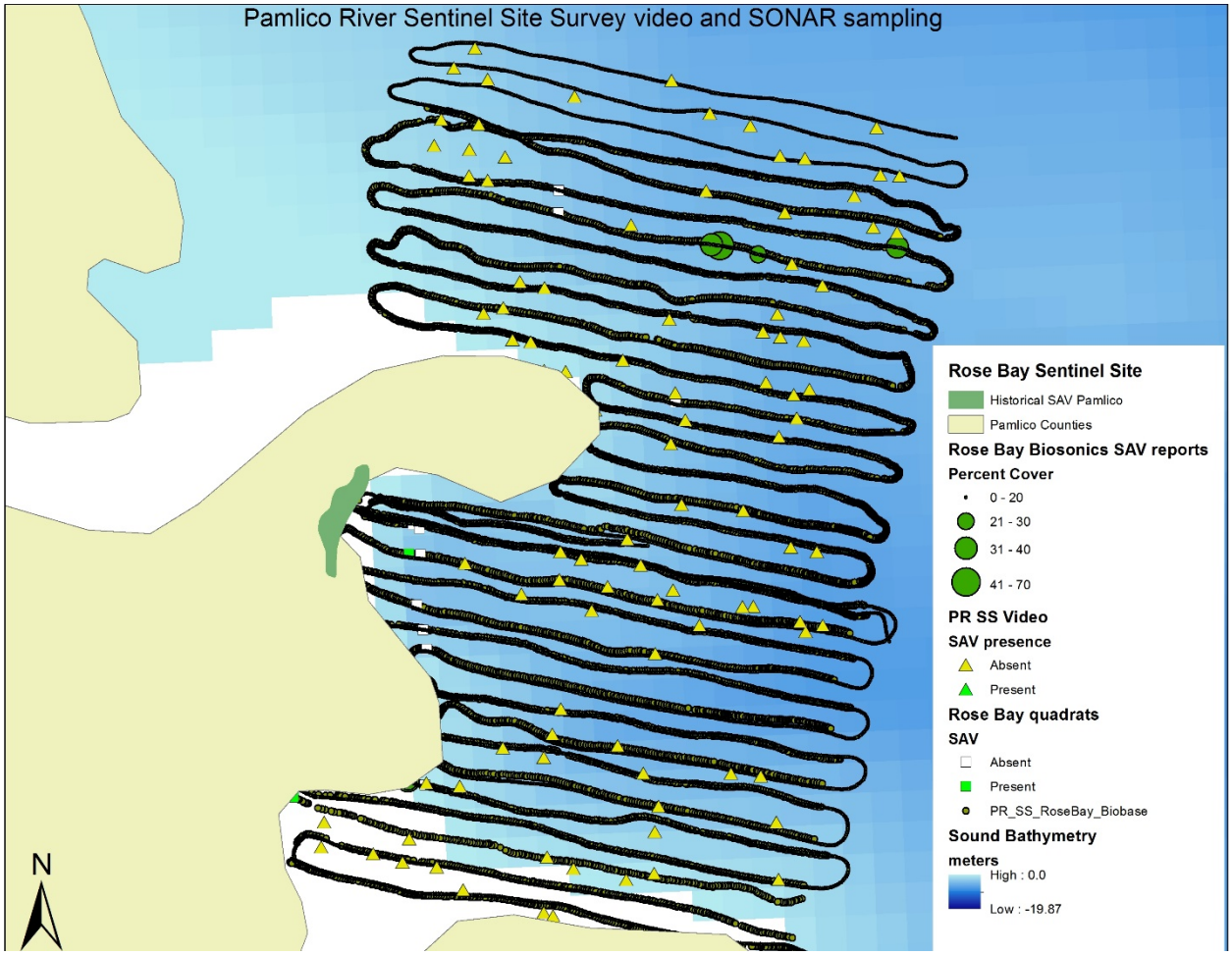


Figure 15 Rose Bay Biosonics system SONAR sampling. Underwater video is also reported. Sampling took place on summer/fall 2016. Quadrat data is also reported.

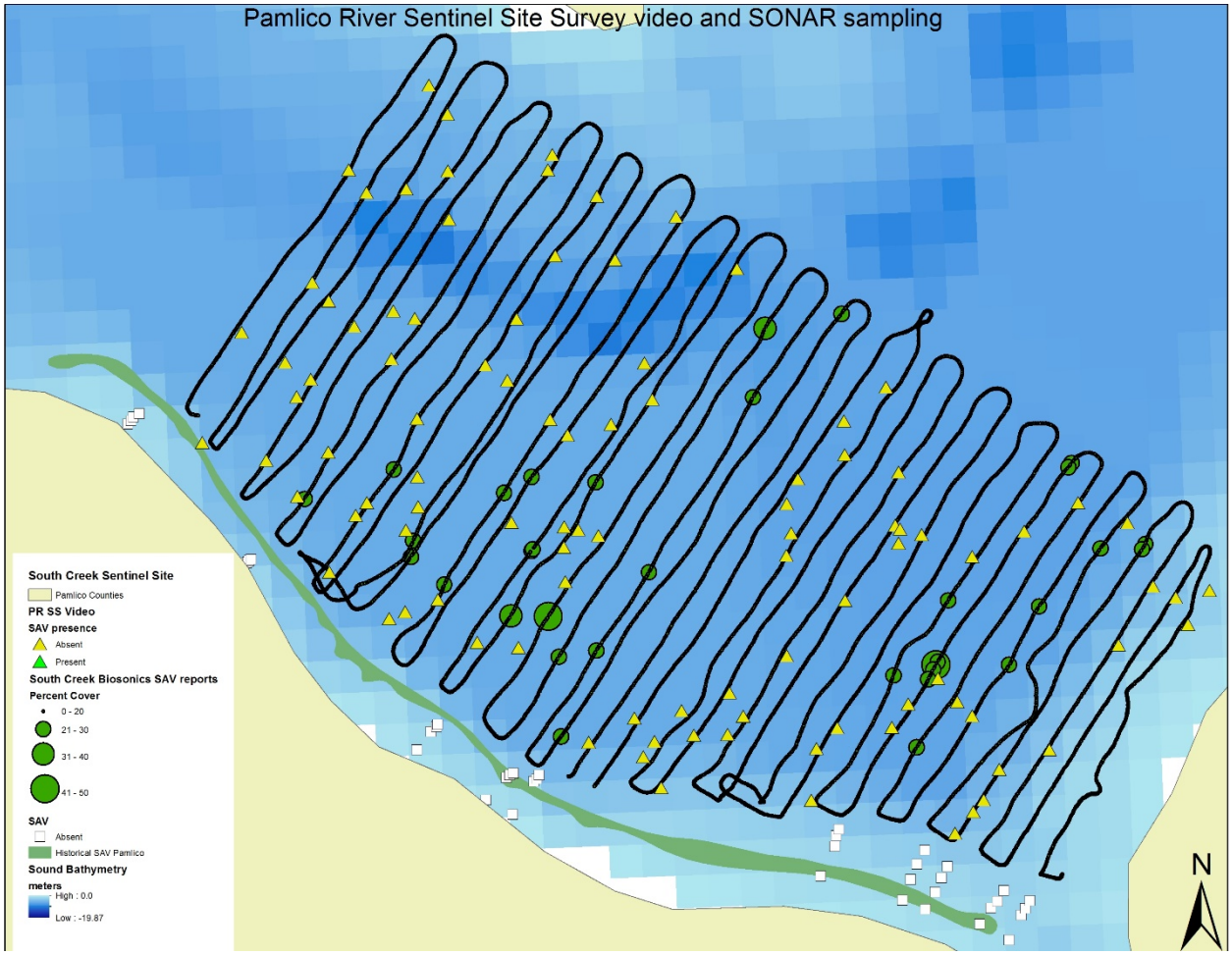


Figure 16 South Creek Biosonics system SONAR sampling. Underwater video is also reported. Sampling took place on summer/fall 2016. Quadrat data is also reported.

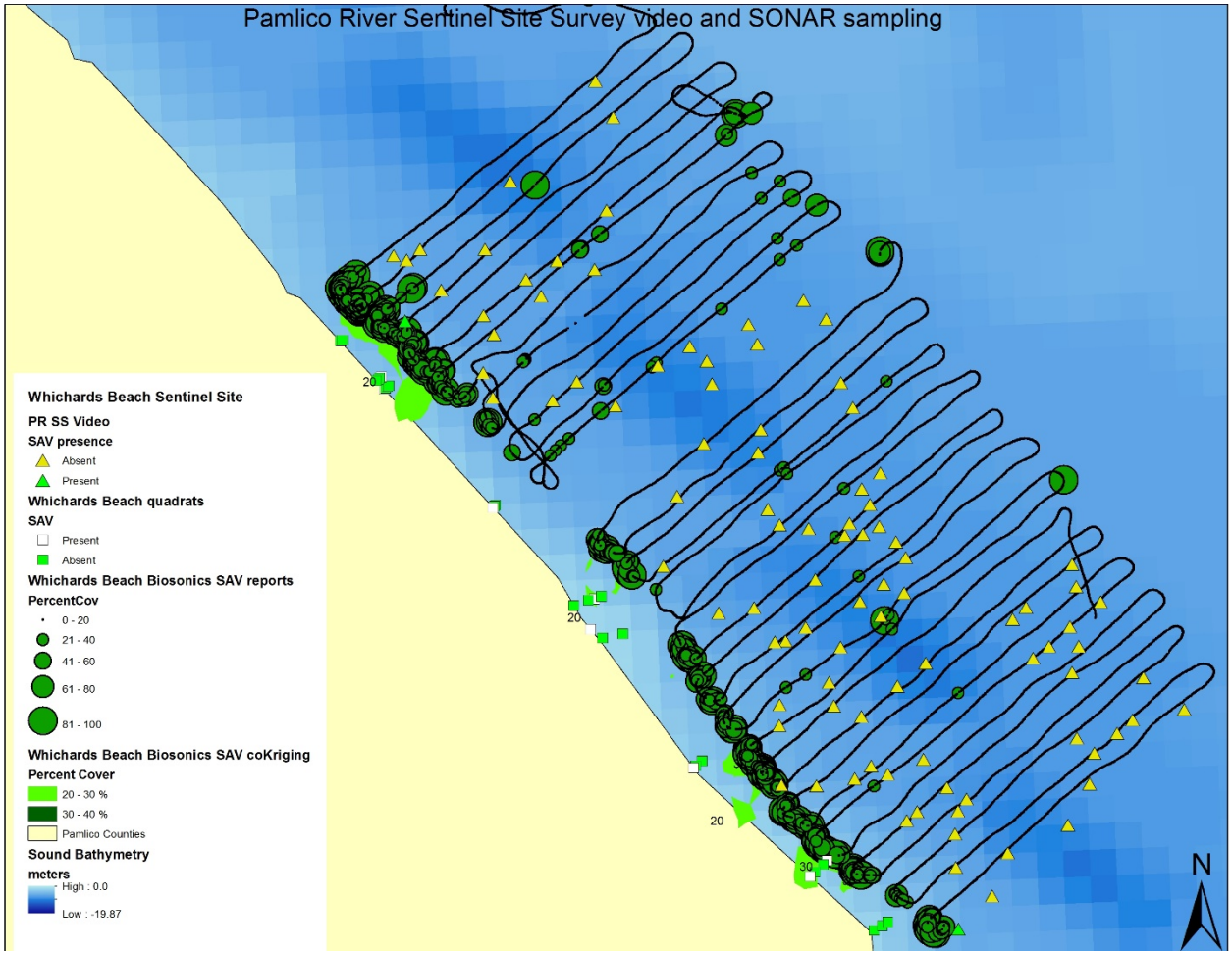
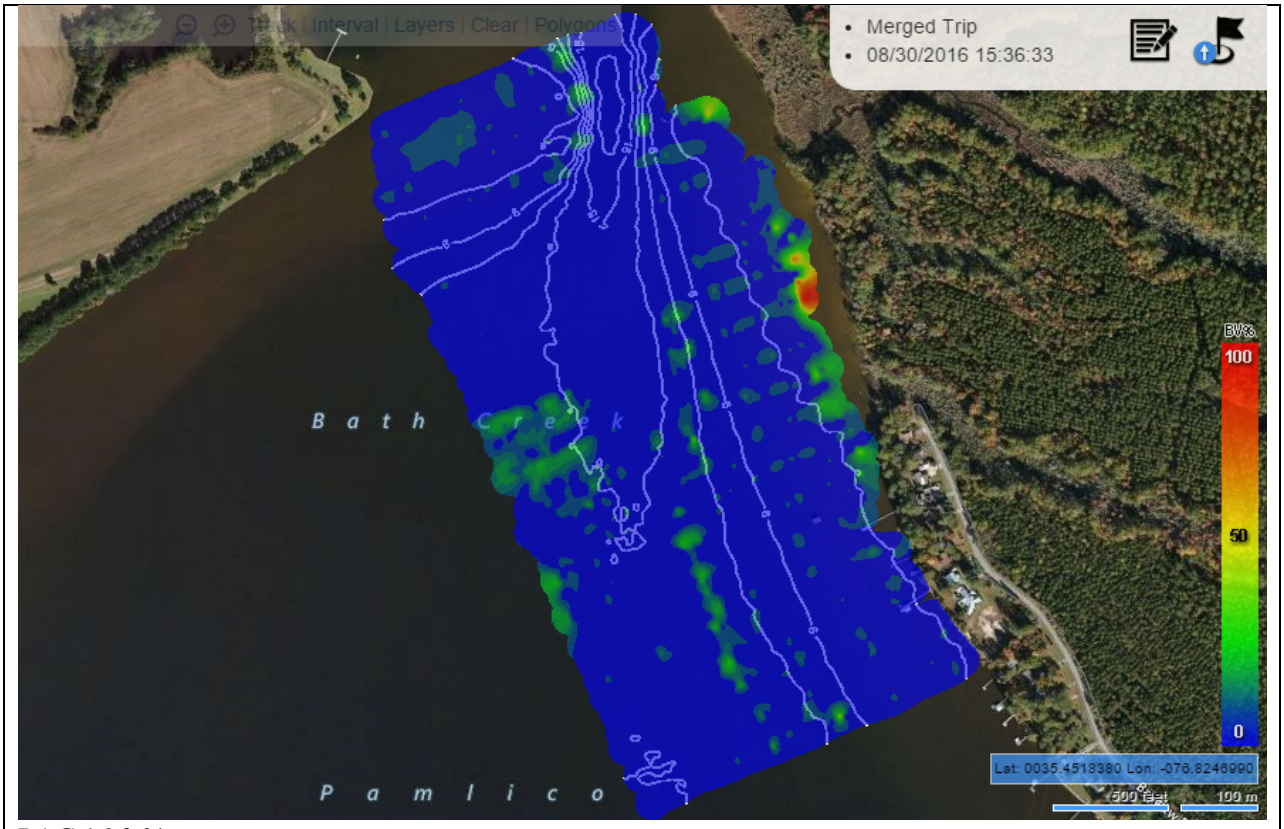


Figure 17 Whichards Beach Biosonics system SONAR sampling. Underwater video is also reported. Sampling took place on summer/fall 2016. Quadrat data is also reported.

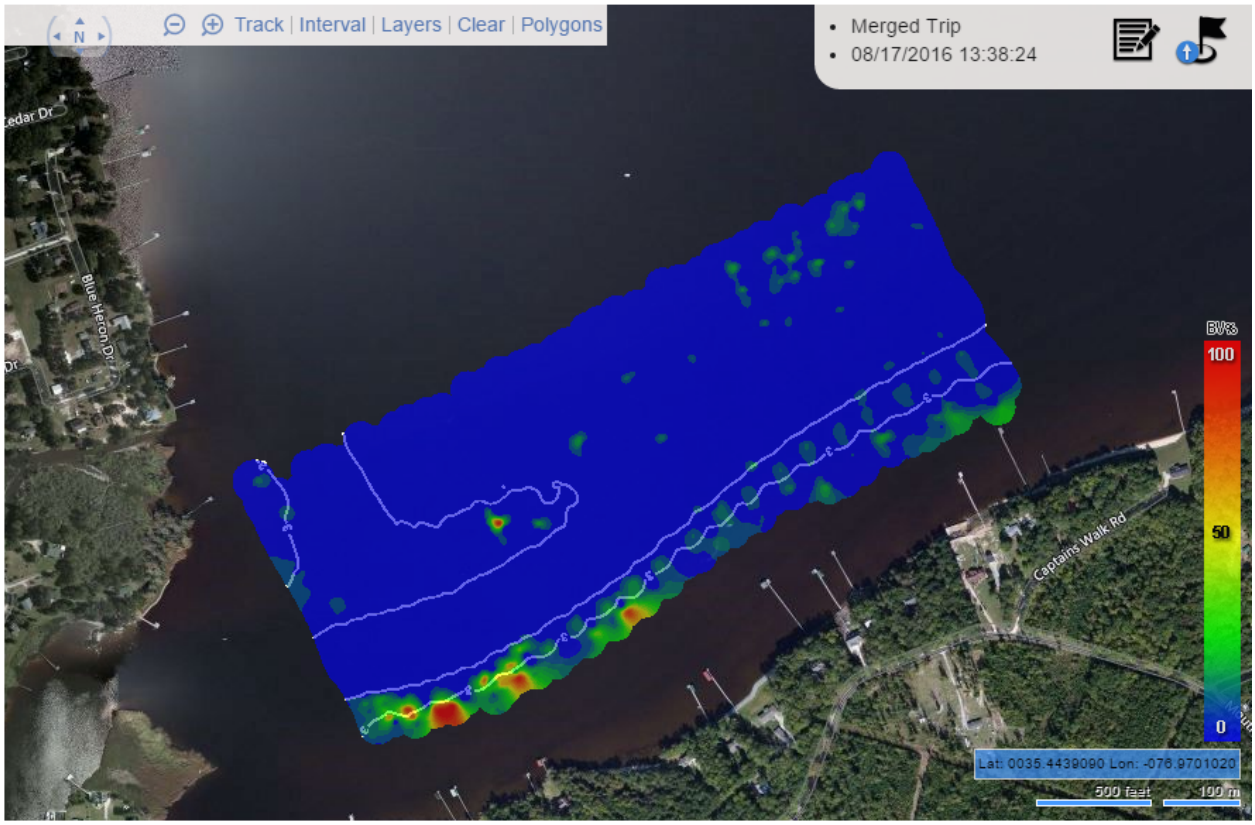
Table 1 CiBiobase vegetation layers at each of the sentinel sites in the Pamlico River and some tributaries. The sampling was done in the 2016 late summer/fall.

PR SS Bath Creek



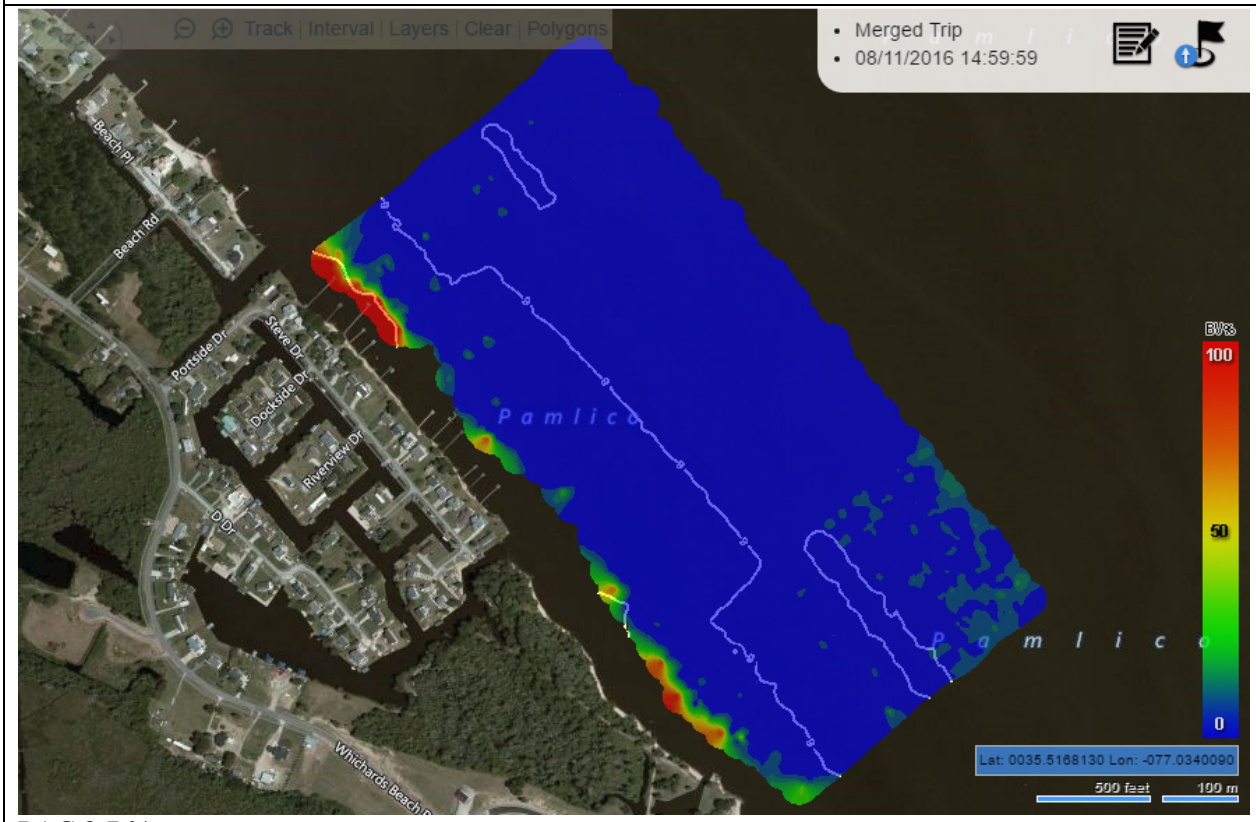
PAC 16.9 %

PR SS Blounts Bay



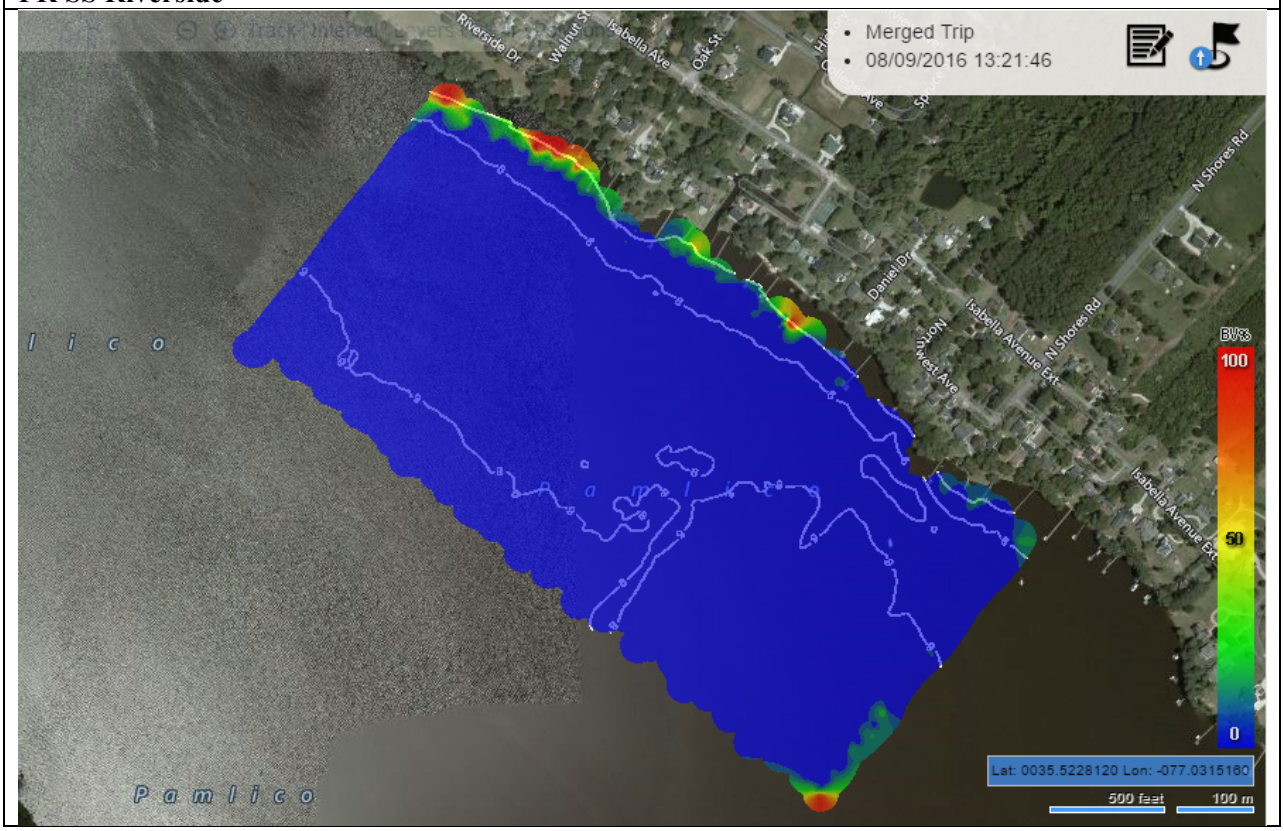
PAC 6.8%

PR SS Whichards Beach



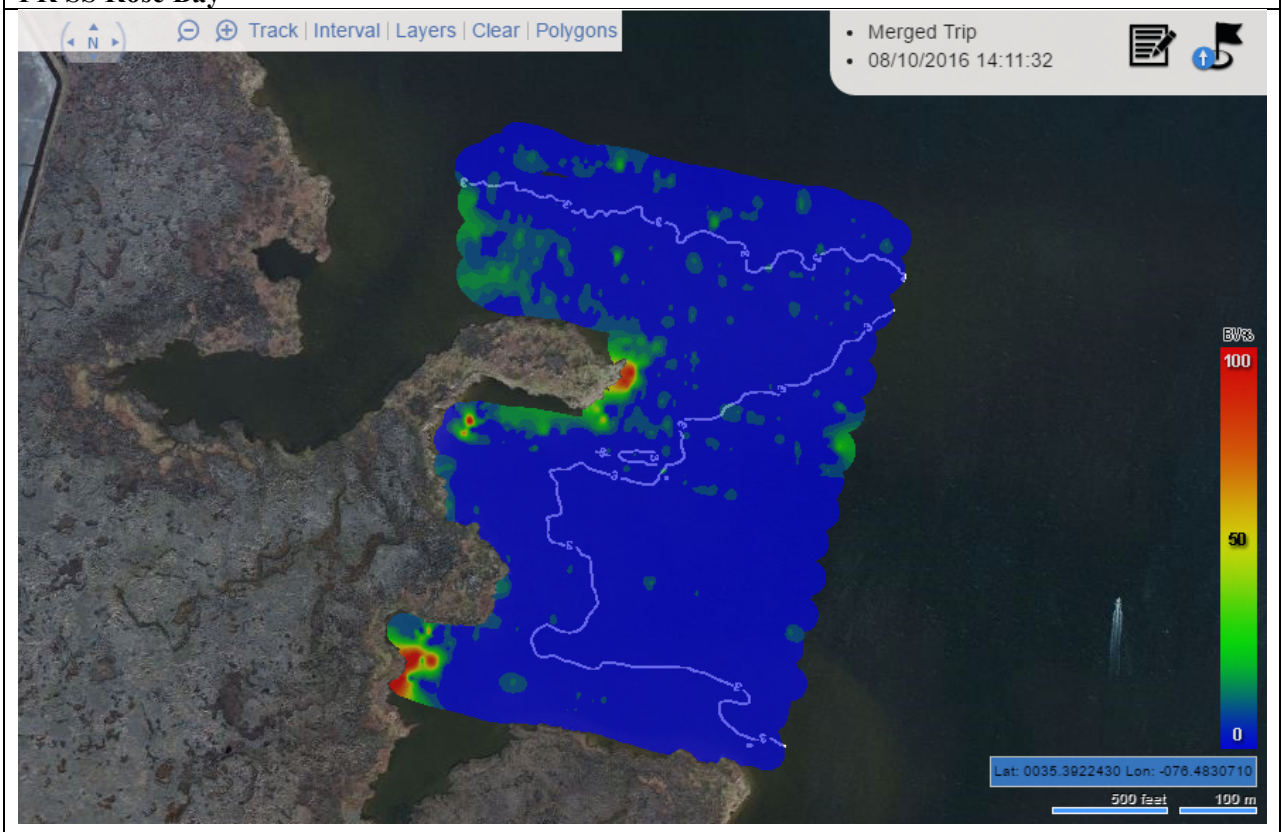
PAC 8.7 %

PR SS Riverside



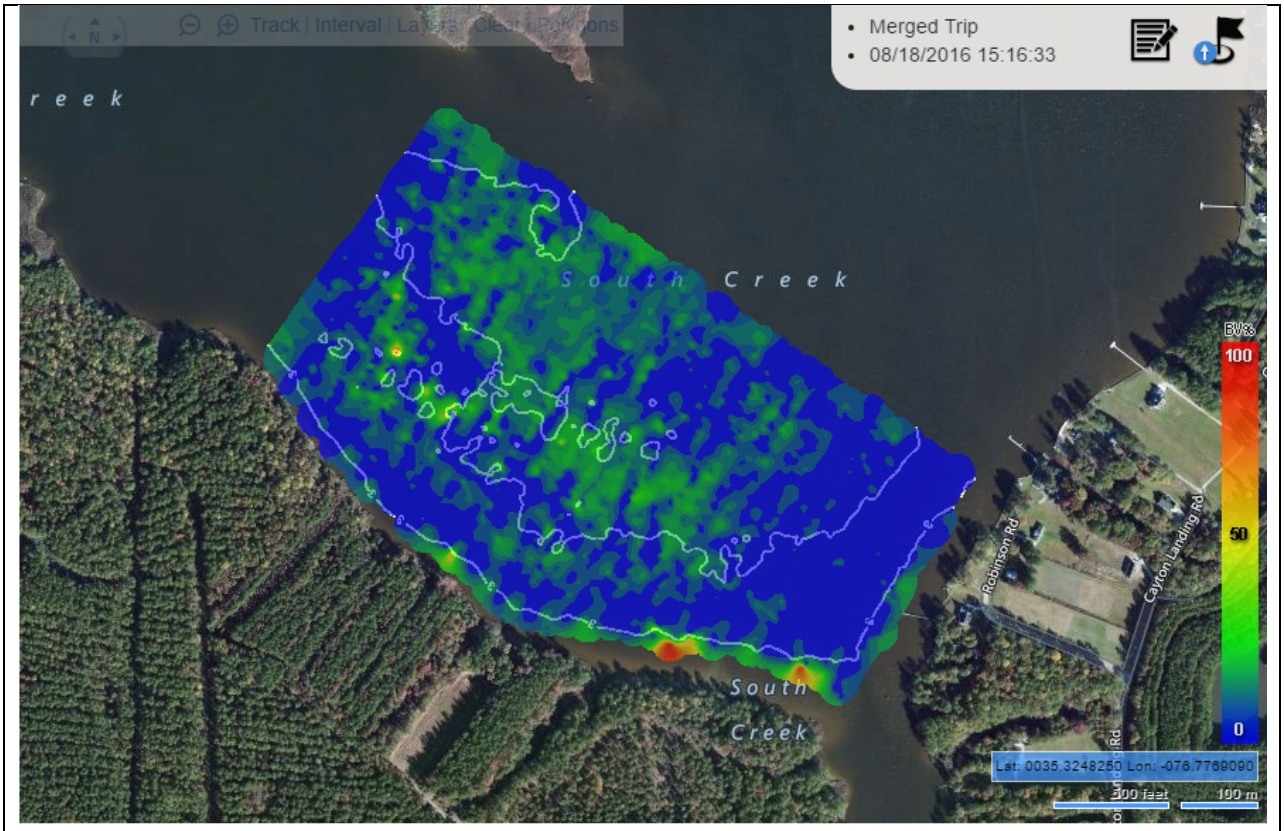
PAC 2.4 %

PR SS Rose Bay



PAC 17%

PR SS South Creek



PAC 16.9 %

Table 2 Environmental parameters and PAC measured at each sentinel site in the late summer/fall of 2016 in the Pamlico River.

Sentinel Site (PR-SS)	PAC (%)	Area surveyed (ha)	SAV area (ha)	Avg. Depth (m)	Water Temp (C)	Salinity (ppt)	Secchi (m)
Bath Creek	16.9	50.56	8.54	2.66	28.75	0	0.64
Blount's Bay	6.8	43.84	2.98	1.8	31.66	4.16	0.35
Whichard's Beach	8.7	49.82	4.33	2.95	31.6	0.08	0.63
Riverside	2.4	50.63	1.22	1.88	31.37	0	0.88
Rose Bay	17	41.46	7.05	0.92	30.2	10.55	0.53
South Creek	44.1	44.17	19.48	1.75	31.88	0	0.67
Average	15.8	46.0	7.0	1.9	31.3	3.0	0.6
Totals		229.92	35.06				

Video-verification points

The SONAR accuracy was calculated for each sentinel site, and the overall accuracy for the 6 sentinel sites was estimated to have an average of 94% for the Biosonics system and 87% for the ciBiobase system. The accuracy for Biosonics ranged from 88 to 100%. The high accuracy is highly attributed to low SAV abundance, areas with higher SAV abundance tend to have lower accuracy.

Table 3 SONAR accuracy compared to the video accuracy. SONAR sampling took place in the Pamlico River sentinel sites at the end of the 2016 summer.

Site	True positive	True negative	Total video points	Accuracy (%)
PR SS Bath Creek	0	70	74	94.59
PR SS Blounts Bay	0	82	89	92.13
PR SS Whichards Beach	0	96	100	96
PR SS Riverside	2	76	78	100
PR SS Rose Bay	0	75	79	94.94
PR SS South Creek	0	88	100	88
Average Accuracy				**94.28**

The accuracy for ciBiobase ranged from 69.79% to 100% (

Table 4). The low accuracy took place at the South Creek site, the SONAR detected la large amount of SAV (i.e. 44.1 PAC), but the video did not detect any SAV in this area. Usually false positives are attributed to SAV patchiness or substrate that have a SONAR signal that resembles that of SAV.

Table 4 SONAR accuracy compared to the video accuracy. SONAR sampling took place in the Pamlico River sentinel sites at the end of the 2016 summer.

Site	True positive	True negative	Total video points	Accuracy (%)
PR_SS_BathCreek	0	68	78	87.18
PR_SS_BlountsBay	0	76	85	89.41
PR_SS_Washington	1	81	89	92.13
PR_SS_Tyler	1	90	91	100.00
PR_SS_RoseBay	0	65	77	84.42
PR_SS_SouthCreek	0	67	96	69.79
Average Accuracy				**87.16**

Discussion

Changes in SAV Distribution

A special case to consider is Blount's Bay sentinel site. The ECU SAV team has sampled that area for several years now. It was first sampled in 2010 as part of a previous CRFL grant. During this sampling a large SAV bed as identified (Figure 18). A significant part of the bed corresponded with historical SAV distribution. We sampled the Blount's Bay area again in 2015 as part of this CRFL grant. During this time, the ciBiobase sonar system reported a few areas with positive SAV presence; however, there was no positive confirmation with the video. We return to the area in 2016 because we established a sentinel site in this area. We increased the area that was monitored in 2010, and we did not find SAV with video nor quadrat samples, only some positive reports with the Biosonics sonar system (Figure 20). When we looked at all the 2010, 2015, and 2015 data (Figure 21 and Figure 22), it is evident that presence of SAV in Blount's Bay has decreased, by 2016 there was no evidence of SAV on the video or quadrats.

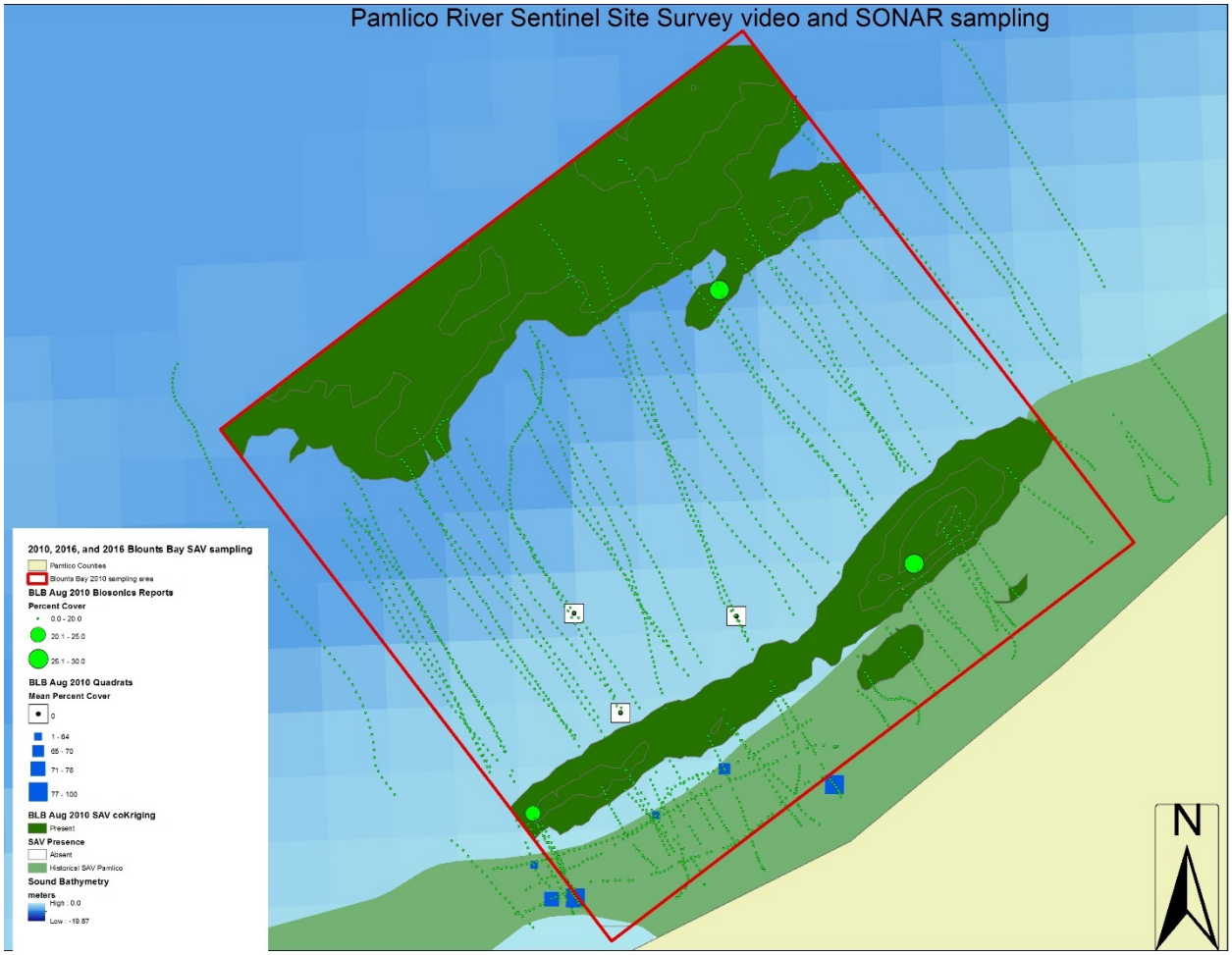


Figure 18 Blounts Bay video and SONAR monitoring in August 2010.

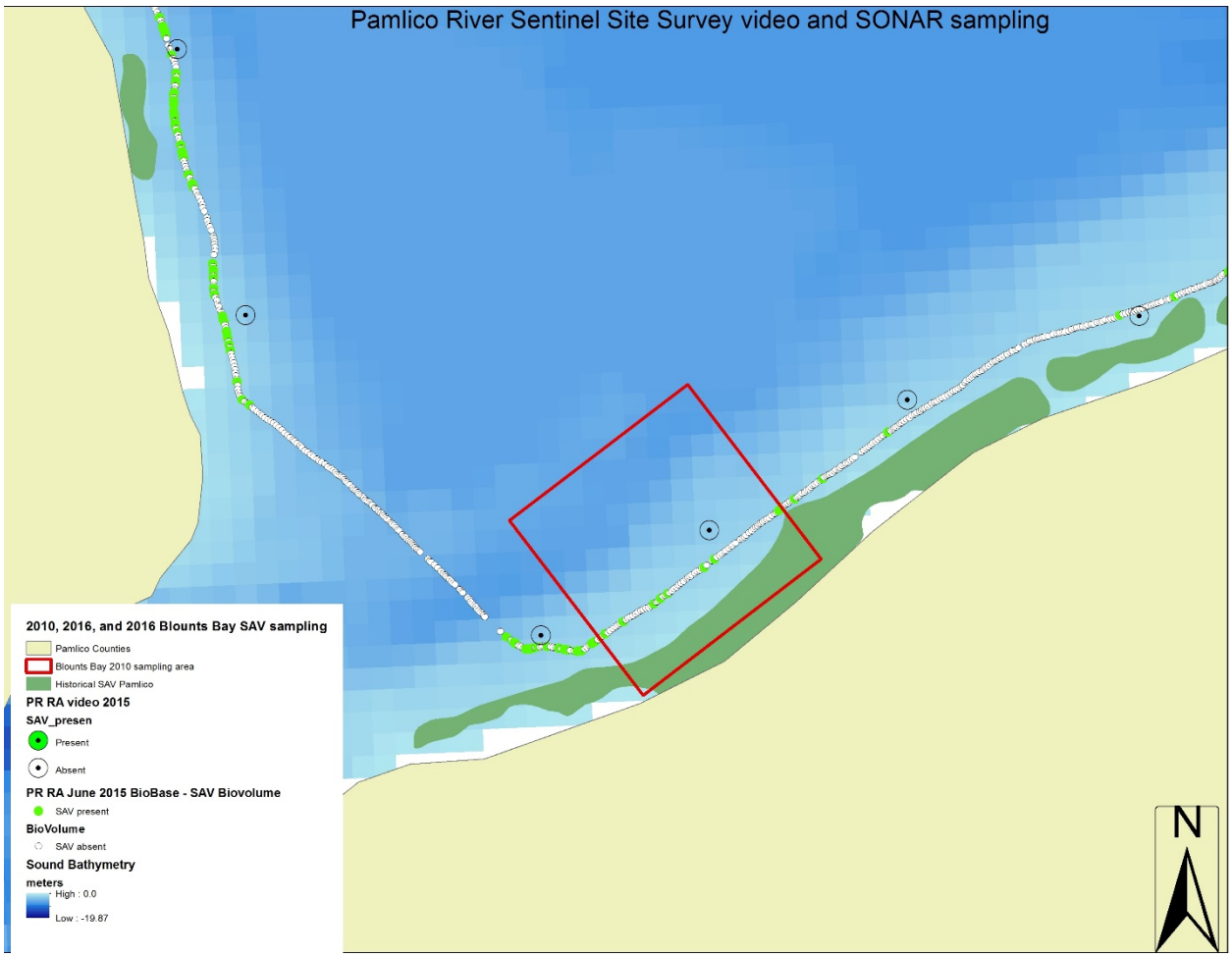


Figure 19 Blounts Bay video and SONAR monitoring in June 2015. Part of SAV rapid assessment monitoring.

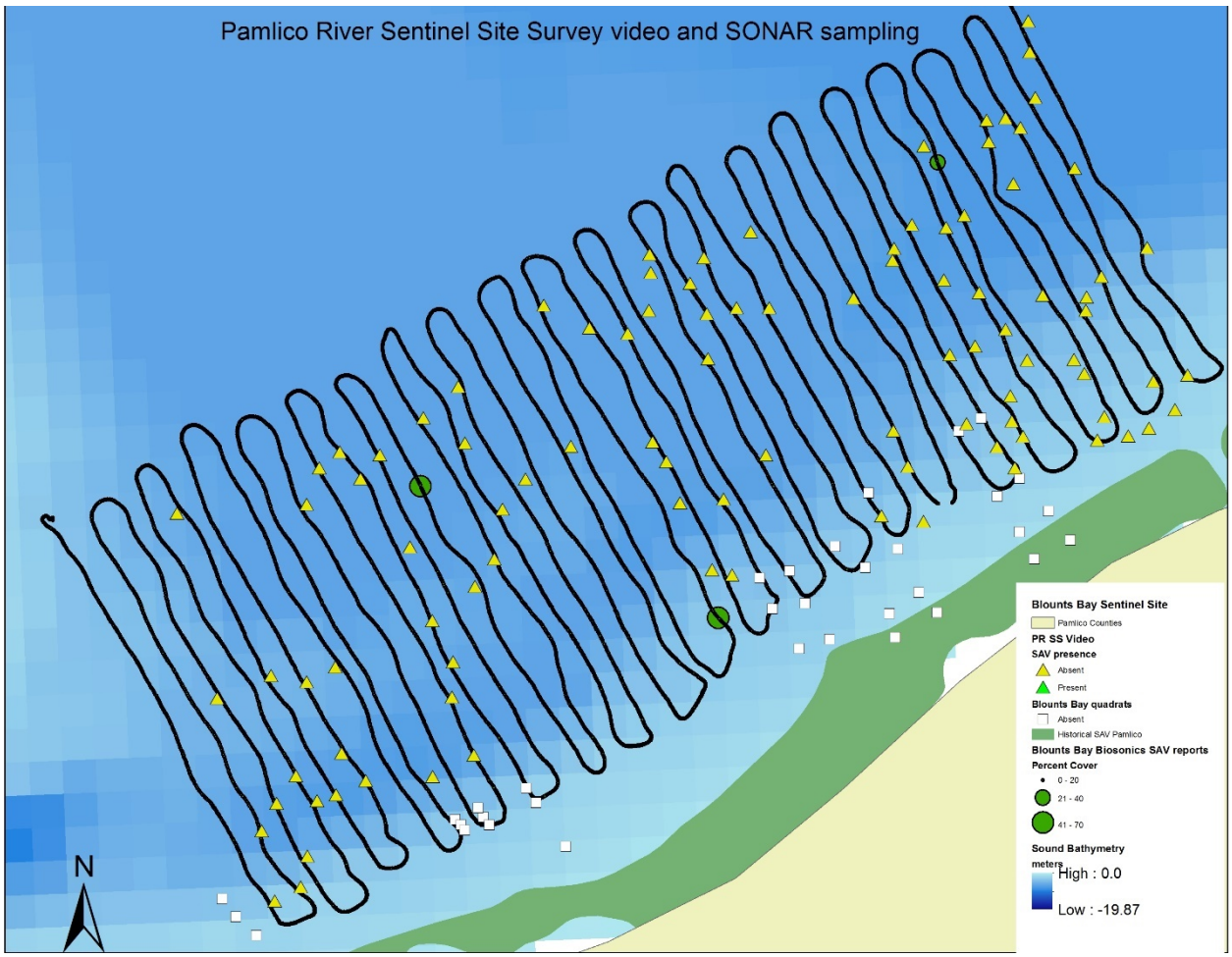


Figure 20 Blounts Bay video and SONAR monitoring in August 2016. A sentinel site was established in this area.

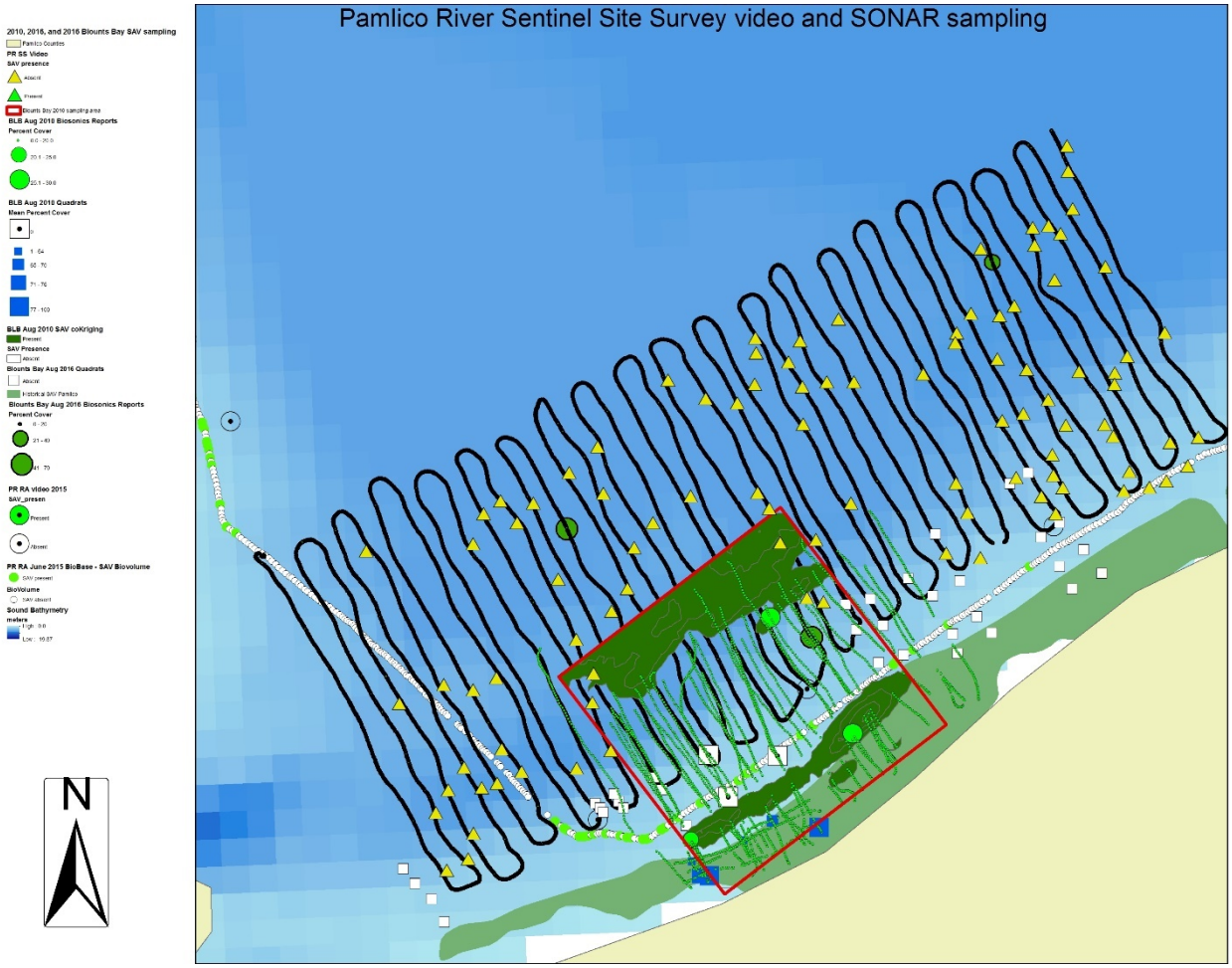


Figure 21 Blounts Bay video and SONAR monitoring in August 2010, rapid assessment in 2015, and sentinel site in 2016.

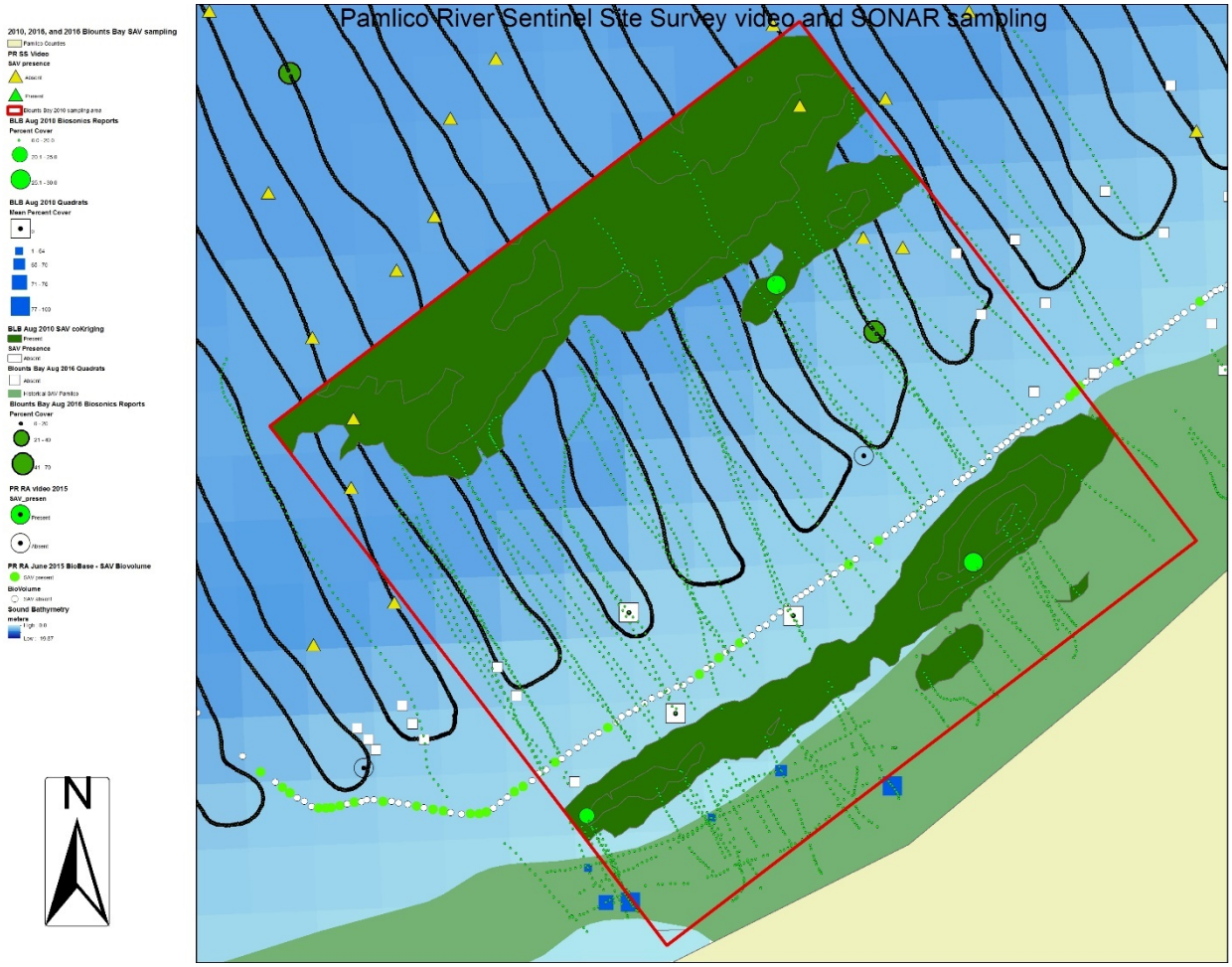


Figure 22 Blounts Bay video and SONAR monitoring in August 2010, rapid assessment in 2015, and sentinel site in 2016. Zoom in the 2010 sampled area.

Comparisons of Lowrance and Biosonics SONAR systems

SONAR accuracy was calculated for the Biosonics system. We compared the SONAR accuracy to the video data the same way we did for the Lowrance/Biobase system. The comparison between the two systems is shown on Table 5. The Biosonics seems to have a much greater accuracy; however, both systems had high accuracy.

Table 5 Percent Accuracy in comparison to video for the CiBiobase and Biosonics systems.

Site	CiBiobase	Biosonics
PR SS Bath Creek	87.18	94.59
PR SS Blounts Bay	89.41	92.13
PR SS Whichards Beach	92.13	96.00
PR SS Riverside	100.00	100.00
PR SS Rose Bay	84.42	94.94
PR SS South Creek	69.79	88.00
Average	**87.16**	**94.28**

Further statistical comparisons between the two SONAR systems were done using a zero-inflated poisson (ZIP) regression model of SAV presence-absence data using depth (m) and Sonar system (ciBiobase/Lowrance or Biosonics DTX/Visual habitat) as predictor factors. We also considered a logistic regression model to predict SAV presence or absence in acoustic reports from the SONAR systems, but this logit model proved inadequate, under-predicting SAV probability in shallow water (< 1m) due to excessive counts of zero SAV in deeper water. A zero-inflated logit model was appropriate for these data because there are an excess number of zeros when compared to that expected by a Poisson distribution (Hall and Shen 2010). Also, there are likely to be two processes generating zero counts in the data (SAV will not occur if the water is too deep due to light limitation; also, SAV can be lost or fail to occur in shallow water due to a number of factors, such as strong winds, low water levels (air exposure), disturbance, or lack of seeds). The zero-inflated poisson (ZIP) regression model output from the **zeroinfl** regression model from the R statistics package **pscl** is shown below for the Riverside Sentinel Site location. There are two parts to the outputs: the poisson count model and the zero-inflated model. The coefficients for each factor (depth and Sonar type) in the poisson count model refer to the change in the log odds of the outcome *SAVprob* for a one unit increase in each predictor variable. The **predict()** command was used to generate data at various depths for each SONAR system.

Outcome or response variables:
SAVprob = is the predicted probability of SAV positive acoustic report at that location from the ZIP model
SAV = the SAV presence or absence (binary response data)
Predictors:
z = depth in m
SONAR = 1 for BioSonics, 2 for ciBiobase

This is the output from the **zeroinf ( )** regression model in the **pscl** package in R:

```
Call:
zeroinfl(formula = SAV ~ depth_m + SONAR2, data = Riverside.BB.BS.SAV)

Pearson residuals:
     Min       1Q   Median       3Q      Max
-0.85911 -0.18487 -0.10241 -0.02522 32.65074

Count model coefficients (poisson with log link):
            Estimate Std. Error z value Pr(>|z|)
(Intercept)  2.32377    0.12183  19.074   <2e-16 ***
depth_m      2.95306    0.09238  31.966   <2e-16 ***
SONAR22     -0.13788    0.08864  -1.555     0.12

Zero-inflation model coefficients (binomial with logit link):
            Estimate Std. Error z value Pr(>|z|)
(Intercept) -11.2966     1.1191 -10.095   <2e-16 ***
depth_m      -7.7561     0.6884 -11.267   <2e-16 ***
SONAR22     -21.9436    42.4935  -0.516    0.606
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Number of iterations in BFGS optimization: 40
Log-likelihood: -3453 on 6 Df
```

The zero-inflation poisson (ZIP) model suggested that there was no significant difference between the two SONAR systems (P=0.12 for the count model; P = 0.606 for the zero-inflation model). This can be observed better in a plot of the *SAVprob* as a function of depth (Figure 23). The BioSonics DTX/Visual Habitat system overestimates *SAVprob* slightly (but not significantly) relative to the Lowrance/ciBioBase

system at depths below 1.25 m.

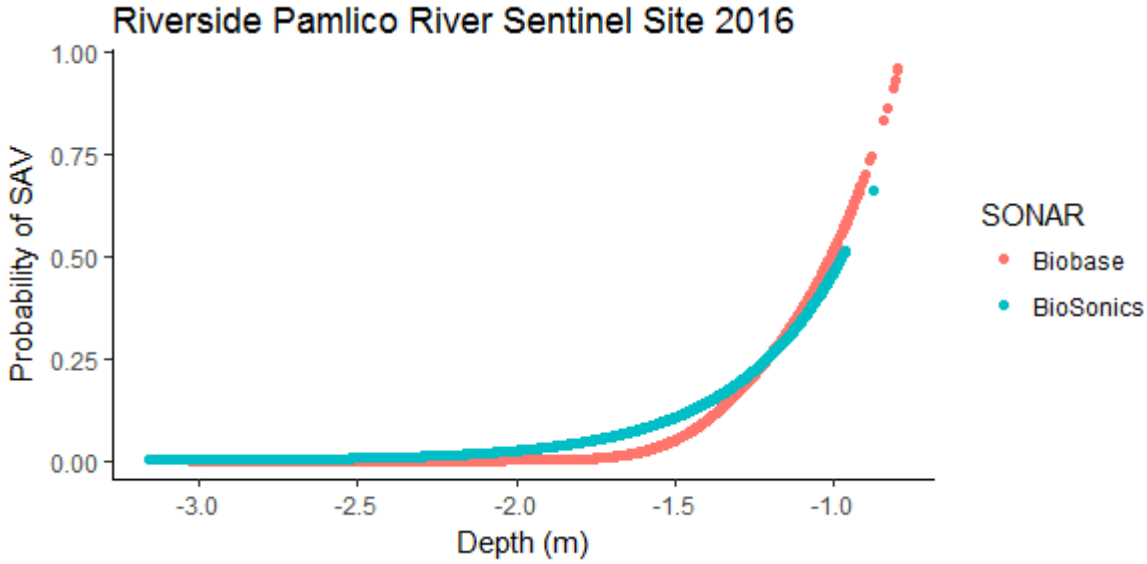


Figure 23 The SAVprob predictions from a zero-inflated poisson (ZIP) regression model of acoustics reports from the two SONAR systems (ciBiobase and BioSonics) as a function of depth.

Finally, we use the ZIP regression model to plot the probability of observing SAV using SONAR *SAVprob* along each SONAR transect taken at the Riverside SS, showing the probabilities as a gradient of colors (Figure 24). The results show the probability of an SAV bed (*SAVprob* > 0.5) is greatest close to shore, in depths >1 m. These results were confirmed using the BioSonics SONAR by video observation and quadrat surveys (Figure 14) and for the Biobase system (Table 1).

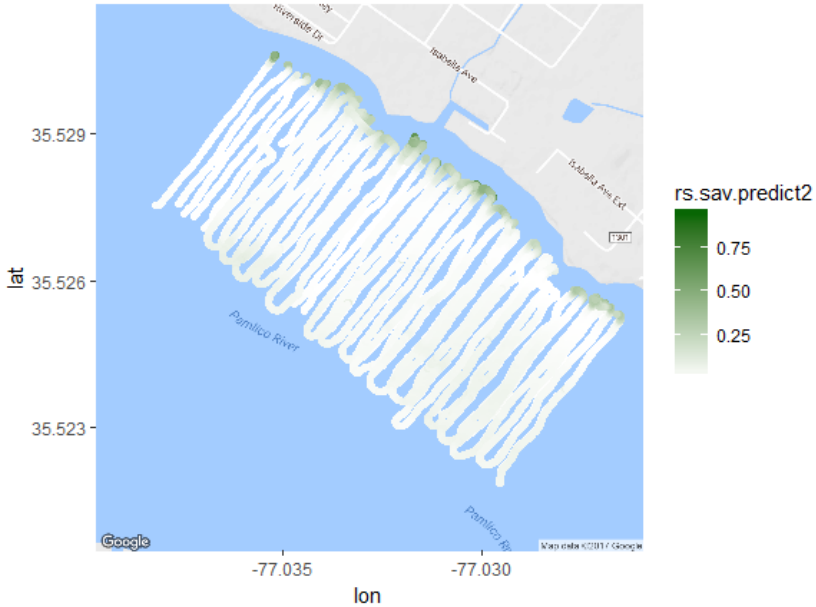
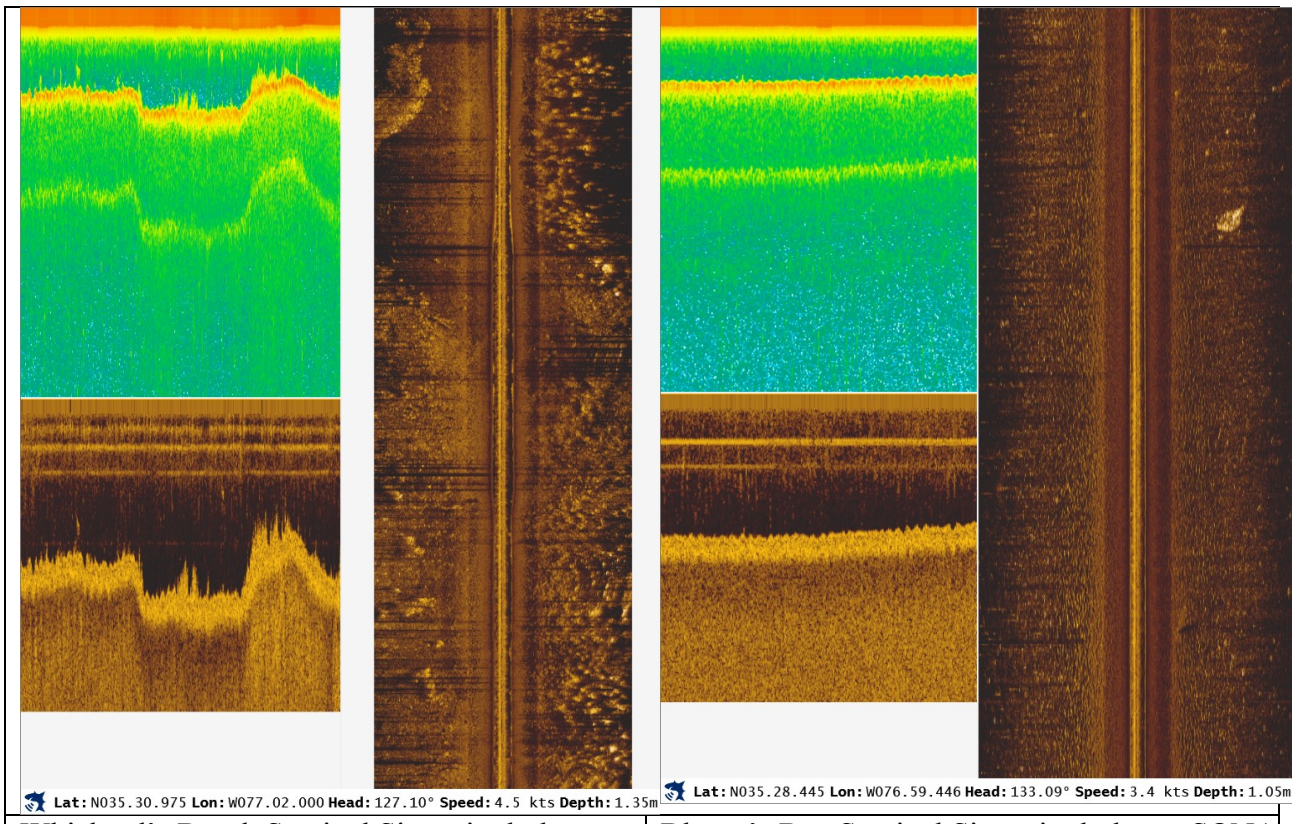


Figure 24. A map of PR-SS Riverside showing the SAVprob predicted by the ZIP model along each SONAR transect.

Future Directions

In the future, we will revisit this Pamlico River Estuary for survey SAV again at these sentinel sites. The APNEP protocol suggests that these sentinel sites should be revisited on an annual basis, but we have not proposed to do that in the coming year (2017). It might be possible to do this in 2018-2020. The protocol suggested a rotational plan with each estuary to be re-surveyed on a 5-year rotation at the minimum. We recommend more frequent (annual) surveys for the sentinel sites here, as NCDMF and CRFL budgeting permits.

Finally, there are new developing technologies for SAV monitoring using side-scan SONAR. We have used side-scan sonar (Lowrance Structure Scan with 455/800 kHz transducer) as part of the echosounder system, and such data were collected at the same time as the down-looking single beam SONAR during this survey (**Figure 25**). The side-scan data that was collected in this Pamlico River SAV survey was used to confirm SAV beds where they occurred. Side-scan SONAR is not currently being used to quantify SAV biovolume or percent cover in any automated way along a SONAR track, although such a classification an algorithm is being developed for such quantification of SAV by the experts at Navico/ciBiobase.



Whichard's Beach Sentinel Site: single-beam SONAR (left panels) and side-scan SONAR (rig track) showing lots of SAV beds in this area	Blount's Bay Sentinel Site: single-beam SONA (left panels) and side-scan SONAR (right track) showing absence of SAV beds in this area

Figure 25. The single beam SONAR echogram compared with the side-scan (455 kHz looking out 12.5 m to each side) SONAR track at two sentinel site areas, Whichard's beach (left) and Blount's Bay (right). Side-scan SONAR will look out a variable distance on either side of the vessel, 12.5 on each side in this case, but will have little information beyond this distance in 1 m of water.

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Appendices

Appendix 1 – Data Sources and Metadata

Pamlico River Sentinel Sites

Site Name_corner	UTM coordinates Zone 18 N Easting	Northing
PR_SS_BathCreek_NE	807579.2	191209.9
PR_SS_BathCreek_NW	807126	191001.2
PR_SS_BathCreek_SE	808008.1	190311.4
PR_SS_BathCreek_SW	807551.1	190094.8
PR_SS_BlountsBay_NE	795005.1	189644.8
PR_SS_BlountsBay_NW	794130.5	189161.1
PR_SS_BlountsBay_SE	795246	189205.5
PR_SS_BlountsBay_SW	794371.3	188723.7
PR_SS_Riverside_NE	788606.7	198755.7
PR_SS_Riverside_NW	787833.9	199353.4
PR_SS_Riverside_SE	788299.1	198366.1
PR_SS_Riverside_SW	787532.2	198958.2
PR_SS_RoseBay_NE	839343.4	184927.7
PR_SS_RoseBay_NW	838859.3	185022.6
PR_SS_RoseBay_SE	839161.8	183942.2
PR_SS_RoseBay_SW	838675.9	184033.2
PR_SS_SouthCreek_NE	812238.2	176861.8
PR_SS_SouthCreek_NW	811968.6	176440.1
PR_SS_SouthCreek_SE	813081.6	176320.7
PR_SS_SouthCreek_SW	812812.2	175895.1
PR_SS_Whichards_NE	788522.6	197794.4
PR_SS_Whichards_NW	788149.3	197477.5
PR_SS_Whichards_SE	789168.4	197036.4
PR_SS_Whichards_SW	788791.3	196715.4

Appendix 2 – the SONAR and underwater video SAV protocols as used in this survey

Submerged Aquatic Vegetation Monitoring Protocol Developed for North Carolina

Rapid Assessment – Along-shore sampling

Rapid assessment sampling consists of shore parallel transects that follow a specific depth near the shoreline. The objective of the rapid assessment is to quickly cover large areas and identify areas with SAV beds. This method is better for identifying larger SAV beds (>330 m in length).

Rapid Assessment Sampling

SONAR data was collected using the Lowrance HDS-7 and the Biosonics DTX from a small boat following pre-programed GPS points that determine the beginning and end of the 10-km transect. The vessel followed one-meter isobaths along the shore of the river. The transects were created by dividing the county shoreline at 10-km intervals with the split tool in ArcGIS. Water quality readings (temperature, salinity, and secchi disk depth) were taken at each 10-km transect, and underwater video samples were taken every 330 meters (approximately 30 video samples per transect).

Equipment and Software – Pre-field sampling

- ArcGIS license
- Subscription to CiBiobase
- SD memory cards
- Waterproof paper

Equipment and Software – Field sampling

- Small monitoring vessel with a shallow draft, it needs to be operated in shallow waters (>0.5 m)
- Lowrance HDS depth finder with 200 kHz SONAR transducer
- Biosonics DTX echosounder with with a 420-kHz single-beam transducer with a 6° beam angle. A Garmin 17X HVS WAAS-enabled unit is integrated with the SONAR for highly precise and accurate geo-referenced data (accuracy 0.7 to 2.5-m; Contour Innovations 2013).
- Panasonics Tough Book CF-31
- Visual Acquisition software available for free at biosonicsinc.com
- SONAR transducer mount or transducer mounted to monitoring vessel
- Underwater video camera (Sartek model #SDC-MSS)
- Digitial HD Videocassette recorder (Sony GV-HD7001/1)
- Mini DV Cassette
- Video pole, a pool cleaning pole can work
- Dry Erase board with markers
- SD memory cards
- Field sheets printed on waterproof paper
- YSI Castaway – CTD
- Secchi Disk

Tasks – pre-field sampling

1. Create 10-km transects along shore.
2. Export transects lines into GPX files and load them into and SD card. Make sure that the HDS finder can read the files that you load into the SD card before going into the field.

3. Generate field sampling sheets. See Appendix 1 – Field sampling sheet (example).

Tasks – field sampling

1. Fill out basic information on Field Sheet: transect name, date, Lowrance offset (distance of lowrance transducer to water surface), Biosonics offset, SD card name, and mini DV tape name.
2. Take and record water quality readings when arriving to area within the 10-km transect: YSI Castaway salinity and temperature readings, and secchi disk depth readings. Record readings in Field Sheet.
3. Start Lowrance SONAR system data collection:
    a. Turn on HDS fish finder
    b. Load transect lines and random video points from the files menu into the fish finder by selecting Files → Memory Card → "name of file" → Import
    c. Find desire survey starting transect
    d. Start SONAR by selecting Advanced → Log sonar → Record. Make sure that the SONAR files are logged into the SD card memory and not the HDS internal memory; otherwise, the HDS will run out of memory. Ensure that the pinging rate is set to 10 pings per second and frequency to 200 kHz.
    e. Begin survey sampling.
    f. The boat should run at an average of 8 or 9 kmh^{-1}
    g. Stop SONAR by selecting Advanced → Log sonar → Stop. Create a new SONAR file per transect run. The SONAR file gets saved into the SD card as an sl2 file. Make sure to stop SONAR every time you take a video sampling point to avoid noise in the SONAR caused by dropping the camera. This may lead to false positives.
    h. Record the file name for each of the transects you sample. The default naming system is usually Sonar0000, Sonar0001, and so on. You can give more meaningful names to these files when you get back at lab or office (e.g. PR_RA_Spring_2016_0001).
    i. Turn off SONAR at the end of the survey.
4. Start Biosonics DTX SONAR system data collection:
    a. Connect cables to DTX transducer box:
        i. Mount GPS antenna on a pole on deck and connect
        ii. DC power or AC power (12V)
        iii. Tough Book with blue Ethernet cable
        iv. Transducer and make sure is securely attached to transducer and submerged underwater.
        v. Make sure all connections are tight
    b. Open Visual Acquisition on the computer:
        i. Start computer.
        ii. Start Visual Acquisition software.
        iii. Click on Configuration Menu.
        iv. Set the environmental parameters: temperature and salinity (from YSI readings).
        v. Set threshold at -130 db, ping duration (15 pings per second).
        vi. Set depth range (0 m – 4 m).
        vii. Click Start All to begin survey.
        viii. The boat should run at an average of 8 or 9 kmh-1.
        ix. Click Stop all to End survey.

x. File name is given as date and time stamped on hard drive - record on datasheet.
xi. Turn off equipment and raise transducer before moving to a new area.

5. Start underwater video sampling:
    a. Connect video camera to video recorder.
    b. Connect video camera and video recorder to AC power.
    c. Turn video recorder and camera on.
    d. Take a video sample at the beginning of 10-km transect.
    e. Take video sample every 330 meters.
        i. Use HDS to navigate to the last waypoint where you took a video sample. When you are 330 m away from the waypoint you can take another sample. Repeat until you covered the 10-km transect. This will help you determine how far to travel before each video sample.
    f. When approaching 6 to 10 m distance from sampling point, turn the boat gear to neutral.
    g. Lower the video pole when boat speed is almost neutral (camera should be 13 cm above the bottom).
    h. Log waypoint where camera was lowered.
    i. Record way point where camera was dropped, presence or absence of SAV in video, and depth on Field Sheet.

Tasks – post-field sampling

1. Enter field notes into an excel file.
2. Analyze Lowrance SONAR data:
    a. Copy sl2 sonar files from SD into a computer or hard drive and assign them new meaningful names.
    b. Upload sl2 files to CiBiobase. CiBiobase will analyze each file and send an email when analysis is complete.
    c. Review each analyzed SONAR file to ensure CiBiobase algorithm worked appropriately.
    d. Export CiBiobase files as .csv files by selecting desired transect → Analyze/edit button → Export data → Vegetation → Point →Export → Save file
    e. Important csv files into ArcGIS by selecting Add data → select .csv file → Display x,y → select WGS 1984 as coordinate system.
3. Analyze Biosonics SONAR data:
    a. Load desire SONAR file into Visual Habitat, free software provided by Biosonics.
    b. Follow the following settings for bottom detection and plant detection:
        i. Bottom detection: rising edge -55 dB with 5 cm length criterion
        ii. Plant detection: plant detection threshold -60 dB and 7 cm plant detection criterion
    c. Run analysis for each of the SONAR files you want to analyze.
    d. Review analysis with echogram display and make manual edits of bottom and vegetation where you dim necessary.
    e. Export final report into a .csv file.
    f. Important csv files into ArcGIS by selecting Add data → select .csv file → Display x,y → select WGS 1984 as coordinate system.

4. Analyze underwater video:
    a. Review video and make sure that field notes match the SAV presence or absence that was recorded.
    b. Create an excel file with latitude and longitude for the video points recorded in HDS system. Enter the presence as 1 and absence as 0 in a column for each of the video points.
    c. Save file as .csv
    d. Important csv files into ArcGIS by selecting Add data → select .csv file → Display x,y → select WGS 1984 as coordinate system.

Sentinel Sites – Intensive assessment areas

These sites involve more intensive monitoring with SONAR, underwater video, and in some case near-shore quadrat transects. The objective of these sentinel sites is to be able to detect small inter-annual change in SAV abundance at specific locations (Kenworthy et al. 2012).

Sentinel Site Selection

We selected sentinel sites based on rapid assessment (alongshore sampling) of the river. After the rapid assessment, the shoreline was divided into 1000 X 500-m bins. This can be done by the split feature in edit mode or ArcGIS. Then, the sentinel sites were selected per the following criteria:

1) SAV present on the NC SAV historical layer
2) SAV present in the rapid assessment SONAR and underwater monitoring.

Each of these sentinel sites are defined by an area of 1000 m X 500 m (50 ha).

Sentinel Site Sampling

Each sentinel site is defined by an area of 1000 m X 500 m (50 ha). The base for this sentinel site is 1,000 m of shoreline, and we monitored 40 transect lines that extend 500 m perpendicular to the shoreline (Figure 1). The lines are selected *a priori* using the systematic approach described in (Kenworthy et al. 2012). The lines were a maximum of 25 m apart to maximize SAV presence interpolation. In addition, 100 random verification points were collected to compare the SONAR accuracy to the video data.

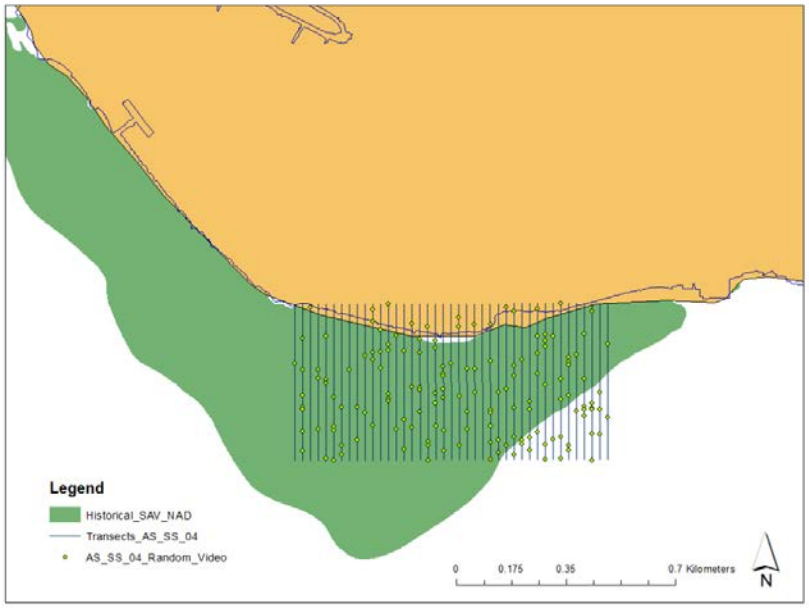

Figure 1 Edenton Sentinel Site in the Albemarle Sound. Transects, video, and historical SAV are shown.

Equipment and Software – Pre-field sampling

- ArcGIS license
- Digital Shoreline Analysis System (DSAS) plug in for ArcGIS – available for free through USGS
- Subscription to CiBiobase
- SD memory cards
- Waterproof paper

Equipment and Software – Field sampling

- Small monitoring vessel with a shallow draft, it needs to be operated in shallow waters (>0.5 m)
- Lowrance HDS depth finder with 200 kHz SONAR transducer
- Biosonics DTX echosounder with with a 420-kHz single-beam transducer with a 6° beam angle. A Garmin 17X HVS WAAS-enabled unit is integrated with the SONAR for highly precise and accurate geo-referenced data (accuracy 0.7 to 2.5-m; Contour Innovations 2013).
- Panasonics Tough Book CF-31
- Visual Acquisition software available for free at biosonicsinc.com
- SONAR transducer mount or transducer mounted to monitoring vessel
- Underwater video camera (Sartek model #SDC-MSS)
- Digitial HD Videocassette recorder (Sony GV-HD7001/1)
- Mini DV Cassette
- Video pole, a pool cleaning pole can work
- Dry Erase board with markers
- SD memory cards
- Field sheets printed on waterproof paper
- YSI Castaway – CTD
- Secchi Disk

Tasks – pre-field sampling

4. Select Sentinel Site.
5. Create transects in ArcGIS utilizing the Digital Shoreline Analysis System (DSAS) tool available for free through USGIS. The transects should be a maximum of 25-m for optimal SAV presence interpolation.
6. Generate 50 random video sampling points per sampling strata (i.e. deeper than 1 m, and shallower than 1-m).
7. Export transects lines into GPX files and load them into and SD card. Make sure that the HDS finder is able to read the files that you load into the SD card before going into the field.
8. Generate field sampling sheets. See Appendix 1 – Field sampling sheet (example).

Tasks – field sampling

6. Fill out basic information on Field Sheet: site name, date, Lowrance offset (distance of lowrance transducer to water surface), Biosonics offset, SD card name, and mini DV tape name.
7. Take and record water quality readings when arriving to area within the sentinel site: YSI Castaway salinity and temperature readings, and secchi disk depth readings. Record readings in Field Sheet.
8. Start Lowrance SONAR system data collection:
    a. Turn on HDS fish finder
    b. Load transect lines and random video points from the files menu into the fish finder by selecting Files → Memory Card → "name of file" → Import
    c. Find desire survey starting transect
    d. Start SONAR by selecting Advanced → Log sonar → Record. Make sure that the SONAR files are logged into the SD card memory and not the HDS internal memory; otherwise, the HDS will run out of memory. Ensure that the pinging rate is set to 10 pings per second and frequency to 200 kHz.
    e. Begin survey sampling.
    f. The boat should run at an average of 8 or 9 kmh^{-1}
    g. Stop SONAR by selecting Advanced → Log sonar → Stop. Create a new SONAR file per transect run. The SONAR file gets saved into the SD card as an sl2 file. Make sure to stop SONAR every time you take a video sampling point to avoid noise in the SONAR caused by dropping the camera. This may lead to false positives.
    h. Record the file name for each of the transects you sample. The default naming system is usually Sonar0000, Sonar0001, and so on. You can give more meaningful names to these files when you get back at lab or office (e.g. PR_SS_Spring_2016_0001).
    i. Turn off SONAR at the end of the 40 transects.
9. Start Biosonics DTX SONAR system data collection:
    a. Connect cables to DTX transducer box:
        i. Mount GPS antenna on a pole on deck and connect
        ii. DC power or AC power (12V)
        iii. Tough Book with blue Ethernet cable
        iv. Transducer and make sure is securely attached to transducer and submerged underwater.
        v. Make sure all connections are tight
    b. Open Visual Acquisition on the computer:

i. Start computer
ii. Start Visual Acquisition software
iii. Click on Configuration Menu
iv. Set the environmental parameters: temperature and salinity (from YSI readings)
v. Set threshold at -130 db, ping duration (15 pings per second)
vi. Set depth range (0 m – 4 m)
vii. Click Start All to begin survey
viii. The boat should run at an average of 8 or 9 kmh-1
ix. Click Stop all to End survey
x. File name is given as date and time stamped on hard drive - record on datasheet.
xi. Turn off equipment and raise transducer before moving to a new area.

10. Start underwater video sampling:
    a. Connect video camera to video recorder
    b. Connect video camera and video recorder to AC power
    c. Turn video recorder and camera on
    d. Utilize HDS system as GPS to guide you to desire sampling points.
    e. When approaching 6 to 10 m distance from sampling point, turn the boat gear to neutral.
    f. Lower the video pole when boat speed is almost neutral (camera should be 13 cm above the bottom).
    g. Log waypoint where camera was dropped
    h. Record way point where camera was dropped, presence or absence of SAV in video, and depth on Field Sheet.

Tasks – post-field sampling

5. Enter field notes into an excel file.
6. Analyze Lowrance SONAR data:
    a. Copy sl2 sonar files from SD into a computer or hard drive and assign them new meaningful names.
    b. Upload sl2 files to CiBiobase. CiBiobase will analyze each file and send an email when analysis is complete.
    c. Review each analyzed SONAR file to ensure CiBiobase algorithm worked appropriately.
    d. Export CiBiobase files as .csv files by selecting desired transect Analyze/edit button → Export data → Vegetation → Point →Export → Save file
    e. Important csv files into ArcGIS by selecting Add data → select .csv file → Display x,y → select WGS 1984 as coordinate system.
7. Analyze Biosonics SONAR data:
    a. Load desire SONAR file into Visual Habitat, free software provided by Biosonics.
    b. Follow the following settings for bottom detection and plant detection:
        i. Bottom detection: rising edge -55 dB with 5 cm length criterion
        ii. Plant detection: plant detection threshold -60 dB and 7 cm plant detection criterion
    c. Run analysis for each of the SONAR files you want to analyze.

   d. Review analysis with echogram display and make manual edits of bottom and vegetation where you dim necessary.
   e. Export final report into a .csv file.
   f. Important csv files into ArcGIS by Add data → select .csv file → Display x,y → select WGS 1984 as coordinate system.
8. Analyze underwater video:
   a. Review video and make sure that field notes match the SAV presence or absence that was recorded.
   b. Create an excel file with latitude and longitude for the video points recorded in HDS system. Enter the presence as 1 and absence as 0 in a column for each of the video points.
   c. Save file as .csv
   d. Important csv files into ArcGIS by selecting Add data → select .csv file → Display x,y → select WGS 1984 as coordinate system.

Appendix 1 – Field sampling sheet

Site/Transect		Water Temp			
Date		Salinity			
Time		Secchi depth (m)			
Lowrance File		Notetaker			
Lowrance offset		miniDV tape			
Lowrance SD card					
BiosSonics offset					

Video	Lowrance file	Wpt	Depth (m)	No SAV = 0 SAV = 1	Video	Lowrance file	Wpt	Depth (m)	No SAV = 0 SAV = 1
1					32				
2					33				
3					34				
4					35				
5					36				
6					37				
7					38				
8					39				
9					40				
10					41				
11					42				
12					43				
13					44				
14					45				
15					46				
16					47				
17					48				
18					49				
19					50				
20					51				
21					52				
22					53				
23					54				
24					55				
25					56				
26					57				
27					58				
28					59				
29					60				
30					61				
31					62				

Video	Lowrance file	Wpt	Depth (m)	No SAV = 0 SAV = 1	Video	Lowrance file	Wpt	Depth (m)	No SAV = 0 SAV = 1
63									
64									
65									
66									
67									
68									
69									
70									
71									
72									
73									
74									
75									
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Additional Information: