Examining the Movement Ecology and Habitat Utilization of Black Sea Bass (*Centropristis striata*) in Chesapeake Bay Using Telemetry Techniques

Final Report
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General Information

Report Title: Examining the Movement Ecology and Habitat Utilization of Black Sea Bass (*Centropristis striata*) in Chesapeake Bay Using Telemetry Techniques

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Executive Summary

This project was designed to examine the movement ecology and habitat utilization of black sea bass (BSB; *Centropristis striata*), a commercially and recreationally valuable species in the Chesapeake Bay. Through dedicated rod and reel sampling surveys and tagging the proposed project addressed **NCBO Fisheries Research Program Priority #1 – Examining the role of inshore habitat in offshore productivity for Black Sea Bass**. Researchers from Coonamessett Farm Foundation (CFF) collected biological data from all BSB captured during rod and reel surveys and subsequently affixed all individuals with an appropriate tag (passive, acoustic, or pop-up satellite archival tag [PSAT]). Environmental data (i.e. depth, temperature, and location) were recorded at each of the sites surveyed within Chesapeake Bay and offshore at known congregation sites, to capture individuals that may be migrating in and out of the Bay and nearshore to offshore habitats. To ensure the successful outcome of this project, we networked with existing establishments, including advisors from the Chesapeake Bay Interpretive Buoy System (CBIBS), existing acoustic telemetry networks along the United States (US) east coast (e.g. Mid-Atlantic Acoustic Telemetry Observation System [MATOS] and the Atlantic Cooperative Telemetry Network [ACT]), citizen science volunteers from the Ocean Research Project Fish Finder mobile acoustic receiver program, and local recreational boat captains.

1 Purpose

1.1 Description of Problem

BSB are a widely distributed species in the US, ranging from the Bay of Fundy to the Gulf of Mexico. They are known to congregate around structures such as reefs, shipwrecks, and pilings (Able et al. 1995, Steimle et al. 1999, Drohan et al. 2007). Seasonally, BSB tend to move nearshore, including into estuaries, in the spring and summer and offshore towards the continental shelf in the autumn and winter. Within the Northwest Atlantic, from North Carolina to Maine, BSB are vital to commercial fishermen, grossing over ~$12 million and catching ~3.5 million pounds in 2019 alone (ASMFC 2021). Recent data indicates that north of Hudson Canyon, BSB catch has substantially increased, while in more southern waters, the catch has remained stable (ASMFC 2021).

Interestingly, BSB found north of Cape Hatteras are a distinct genetic population from those in the Southern Atlantic Bight (SAB) and in the Gulf of Mexico (GoM; Roy et al. 2012). As a result, studying the unique habitat conditions for each genetic stock can help improve local scale management. Identifying the habitat of concern or designating Essential Fish Habitats (EFHs) is crucial to determining where species and/or localized stocks of species depend on to survive, including habitat they use to spawn, breed, feed or grow to maturity (NOAA 2018a). Delineating

EFHs for other species has helped to rebuild depleted fish stocks in the US, by protecting over 800 million acres of fish habitat, while simultaneously supporting the $200 billion US fishing industry (NOAA 2018a). The most recent EFH for BSB was designated in 2007 (NOAA 2007).

Estuaries are designated EFHs for many commercially and ecologically important species along the US east coast, serving as important breeding, feeding, and nursery grounds. This includes the Chesapeake Bay (NOAA 2018b), a designated EFH for species such as red hake (*Urophycis chuss*), windowpane flounder (*Scopthalmus aquosus*), summer flounder (*Paralicthys dentatus*), scup (*Stenotomus chrysops*), and BSB. Chesapeake Bay is the largest estuarine system on the US east coast, spanning over 11,000 km^2, with an average depth of 6.4 m. The Chesapeake Bay watershed encompasses an estimated 166,000 km^2, including six states (New York (NY), Pennsylvania, Delaware, Maryland, West Virginia and Virginia (VA)) stretching from Cooperstown, NY in the north to Norfolk, VA in the south. Nine major rivers (Susquehanna, Potomac, Patuxent, Choptank, Rappahannock, Mataponi, Pamunkey, James, and Appomattox) also drain into the Bay, bringing runoff with it that could potentially alter how fish utilize this habitat (Childs et al. 2008). There are concerns that degradation of or limitations in available habitat will perpetuate additional negative impacts to the ecosystem (i.e., decrease in forage species, nutrient enrichment, shoreline alterations and climate-driven changes) (Kahn and Kemp 1985, ASMFC 1997, Sheaves 2009). To mitigate effects from the loss of critical habitats, including EFHs, efforts have focused on the restoration and protection of sensitive habitats in Chesapeake Bay critical to BSB.

While Chesapeake Bay has been designated as an EFH for BSB, there are still large data gaps regarding how these fish utilize and move in and out of the Bay. Traditional fisheries survey techniques for the region have not accurately accounted for BSB abundance due to the nature of this species as structure-oriented (VIMS 2018). Tagging fish with passive and electronic devices has been a successful method for assessing populations, including specifically in the Chesapeake Bay with the heavily managed striped bass (Dorazio et al. 1994, Jiang et al. 2007, Graves et al. 2009, Wingate et al. 2011). However, due to limited sample sizes, studies like these can on occasion also end up having useful yet limited results (Fabrizio et al. 2017). As technology has become more affordable, modern studies can now cover larger sample sizes and make use of a variety of highly synergistic tagging and telemetry techniques to determine how, when and where a fish species uses a habitat and the overlapping environmental conditions.

1.2 Objectives

1) Conduct seasonal (spring and summer) rod and reel surveys inshore and offshore to collect inhabitance, abundance, and relevant biological parameters of captured BSB.
2) Develop a better understanding of BSB movement patterns and habitat usage by affixing conventional spaghetti tags, acoustic telemetry tags, and pop-up satellite tags.
3) Determine relationships between environmental data and movement patterns, using CBIBS oceanographic buoy data, ancillary data from satellite tags, and data loggers.
4) Utilize a network of citizen science volunteers from FishFinder (www.oceanresearchproject.org/programs/science/citizen-science/) to deploy additional mobile receivers within the Bay and along the east coast.

2 Project Outcomes

2.1 Objective 1: Conduct seasonal (spring and summer) rod and reel surveys inshore and offshore to collect inhabitance, abundance, and relevant biological parameters of captured BSB.

Over the course of the project we conducted four fishing trips (**Figure 1**). All trips took place aboard the F/V Playin Hookey captained by William Pappas and departing from Rudee Inlet, Virginia Beach, VA. Two trips occurred in April and the other two occurred in August. The first year of sampling occurred in 2019, and due to COVID, we had to skip a year, resulting in the second year of sampling occurring in 2021. In 2019, we took the approach of prioritizing offshore sampling in the spring and inshore sampling in the summer to match the expected trend of inshore movement by BSB in summer months for spawning (NMFS 2007). Due to high catch of extremely small BSB within nearshore sites we shifted effort in 2021, focusing mainly on offshore fishing to capitalize on the availability of larger fish that could carry the various electronic tags.

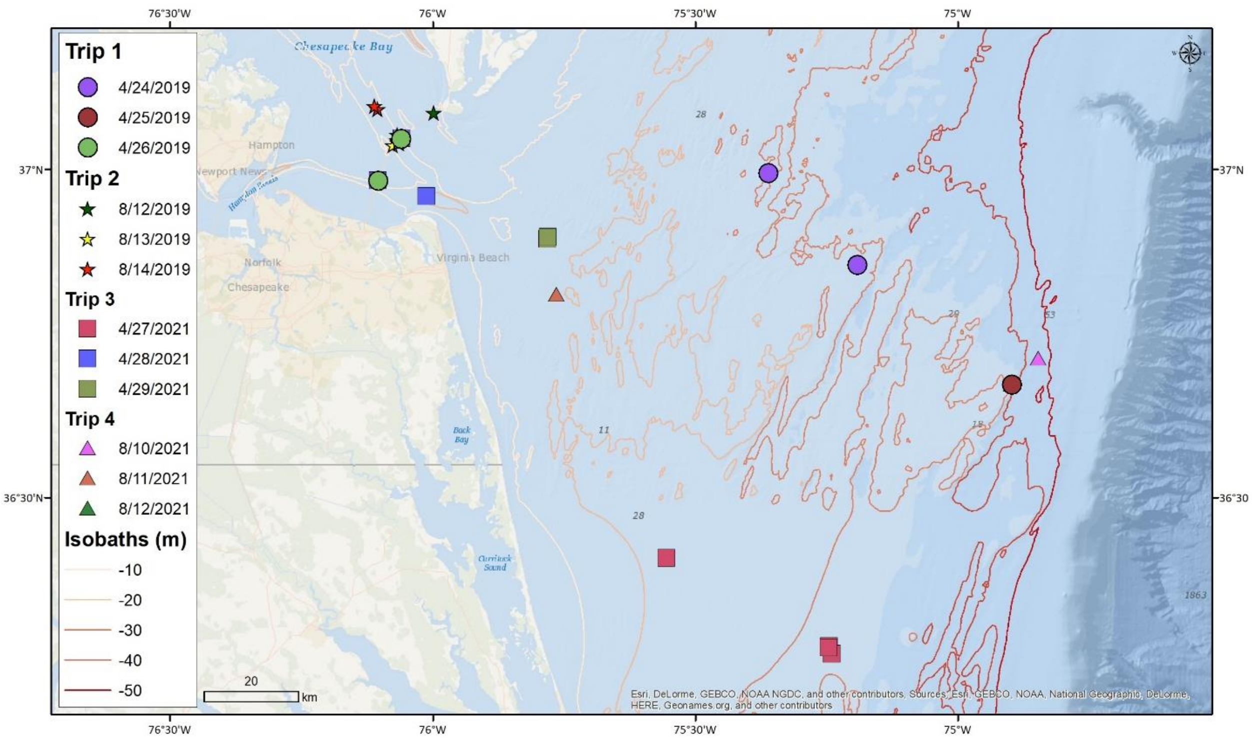

Figure 1: *Trip locations throughout the entire project.*

Trip #1

Trip #1 occurred from April 24 – 26, 2019. On day one of fishing, we traveled ~90 km offshore, directly east of VA Beach to fish at an established site used by the charter boat captain. There we caught and tagged 21 BSB, with a mean (± SD) total length (TL) of 34.7 ± 6.1 cm (**Table 1**). This site had a depth of 27.7 m and sea surface temperature (SST) was 13.9° C. The second site we fished on day one was 20 km closer to shore, and slightly north of site one. Here, the depth was 30.5 m and SST increased slightly to 16.7° C. We spent an hour fishing at this site and caught seven BSB with a mean (± SD) TL of 37.7 ± 8.3 cm. Fish collected here were slightly larger than those caught at the first site.

On day two, of Trip #1, we fished at a site ~125 km from VA Beach, that was also slightly south of fishing site one on day one. At this site we caught 20 fish that were on average (± SD) 39.0 ± 6.6 cm TL. The depth at this site was 33 m and SST was 14.4°C. On day three, we were forced to remain inshore due to inclement weather. As a result, we fished two of the islands of the Chesapeake Bay Bridge-Tunnel. We did not catch any BSB within the Chesapeake Bay, likely due to reduced effort resulting from poor weather conditions and, potentially, inappropriate seasonality for this area. However, we did catch two tautogs (*Tautoga onitis*) (58.5 and 40.5 cm TL) at the islands.

Table 1: *Summary data of BSB catch per trip.*

Date	Sample Size	Length (Mean ± SD)
4/24/2019	21	34.7 ± 6.1 cm
4/24/2019	7	37.7 ± 8.4 cm
4/25/2019	20	39.0 ± 6.6 cm
8/12/2019	72	15.0 ± 1.6 cm
8/13/2019	40	15.0 ± 1.1 cm
8/14/2019	2	15.0 ± 1.4 cm
4/27/2021	24	33.3 ± 7.3 cm
4/28/2021	0	N/A
4/29/2021	28	25.1 ± 3.6 cm
8/10/2021	6	36.0 ± 5.7 cm
8/11/2021	4	27.5 ± 1.9 cm
8/12/2021	18	26.8 ± 3.0 cm
TOTAL	242	23.9 ± 10.1 cm

Trip #2

Trip #2 took place from August 12 – 14, 2019. During all three days, we fished at the mouth of the Chesapeake Bay. This was our second research trip of four, and we planned for more intensive inshore sampling to balance the heavy offshore sampling performed during Trip 1. Overall during Trip 2, we tagged and measured 114 fish from three primary spots. We only tagged fish larger than 12 cm. We caught and released many more fish that were too small to handle the tagging needle. The majority of sampling occurred adjacent to the Fourth Island and we fished directly off the island and then near it at the channel marker. On day one, we also moved farther north along the bridge to fish near Fisherman's Island, which was generally unsuccessful. Overall on day one, we caught 72 fish and those that were tagged and measured averaged (±SD) 15.0 ± 1.6 cm. On day two, we again focused on fishing at the Fourth and Third Islands. Overall, we caught 40 fish on day two and they were on average (±SD) 15.0 ± 1.1 cm. The tagged fish from the Third Island were actually slightly smaller (14.7 ± 1.02 cm) than those caught at the Fourth Island (15.5 ± 1.1 cm). On day three, we returned to the Fourth Island to conduct ROV surveys. We also tried to fish farther within the Bay, where the VIMS trawl survey had observed BSB during the 2019 survey. We caught two fish at this site, but the strong current made it difficult to hold at the site. Fish caught during this trip were much smaller than those caught offshore during Trip 1. Mean length was 15.0 cm for all three days, which was less than half the mean length for the fish caught during Trip 1.

Trip #3

Similar to Trip #1 in 2019, Trip #3 occurred in late April from the 27th – 29th, 2021, and we sampled from BSB fishing spots within offshore waters adjacent to the Chesapeake Bay to tag fish prior to their inshore migration for spawning. On day one we traveled ~120 km south east of VA Beach to fish for larger BSB. In the morning we stayed at the farthest offshore site, and caught 48 fish with an average (±SD) TL of 32.7 ± 6.9 cm. This site was ~30 m deep and SST was 12.8° C. Then on the way back to the inlet, we fished a spot ~80 km southeast of VA Beach. Here we caught one large BSB measuring 46 cm. Due to poor weather on day two, we remained in the Chesapeake Bay to sample near the Second and Fourth Islands of the Bay Bridge-Tunnel and the Cape Henry Chilore Wreck; however, we did not catch any BSB at these sites. The currents were strong making it hard to stay on site. On day three, we fished offshore again, but much closer to shore at a locally known recreational fishing site, the Santore Wreck. Fish at Santore were slightly smaller than those caught on day one, averaging (± SD) 25.1 ± 3.6 cm. We caught 28 BSB at Santore, and one previously tagged Tautog measuring 34 cm. The tautog was returned alive and the tag was reported.

Trip #4

Trip #4 took place from August 10 – 12, 2021. Unlike, the previous August trip (Trip #2), we decided to fish at offshore sites on all three days. On day one we traveled ~125 km east of VA Beach to fish at two sites. The first site was much deeper (47.5 m) than our previous fishing excursions and we only caught one fish measuring 36 cm TL. SST at this site was 24.7° C. The next site was only 8 km away and was much shallower (32.9 m) and slightly warmer (SST = 25.1° C). At this site we caught five BSB with a size range of 29 – 45 cm TL. On day two we tried a site ~25 km from shore, as weather conditions were not favorable for a full day of fishing. This site was 15.8 m deep and SST was even warmer at 26.6° C. We caught four fish ranging in size from 26 – 30 cm TL. Then on day three we fished at the Santore wreck, again to ensure a high catch on a day with a small weather window. We caught 18 fish with an average (±SD) TL of 26.8 ± 3.0 cm. This set of fish were slightly larger than those caught at Santore in April during Trip #3.

2.2 Objective 2: Develop a better understanding of BSB movement patterns and habitat usage by affixing conventional spaghetti tags, acoustic telemetry tags, and pop-up satellite tags.

To track the movement patterns of BSB within Chesapeake Bay and adjacent offshore waters, we deployed 241 T-bar tags on BSB throughout the region. Of those fish 40 also received an internal Vemco acoustic tag, 28 received an external Star-Oddi temperature, depth, and conductivity recorder, and 4 received a pop-up satellite archival tag (PSAT; **Table 2; Figure 2**). In

***Table 2**: Summary data for electronic tag deployments*

Tag Type	Trip #	Sample Size	Length (Mean ± SD)
Vemco	1	6	36.8 ± 8.3 cm
	2	2	19.0 ± 2.8 cm
	3	24	31.8 ± 6.9 cm
	4	8	31.4 ± 6.4 cm
TOTAL		40	31.2 ± 7.0 cm
Star Oddi	1	6	40.2 ± 3.2 cm
	3	2	32.0 ± 1.4 cm
	4	18	26.7 ± 3.0 cm
TOTAL		26	30.3 ± 6.4 cm
PSAT	1	1	46.0 cm
	3	3	46.0 ± 2.0 cm
TOTAL		4	46.0 ± 1.6 cm

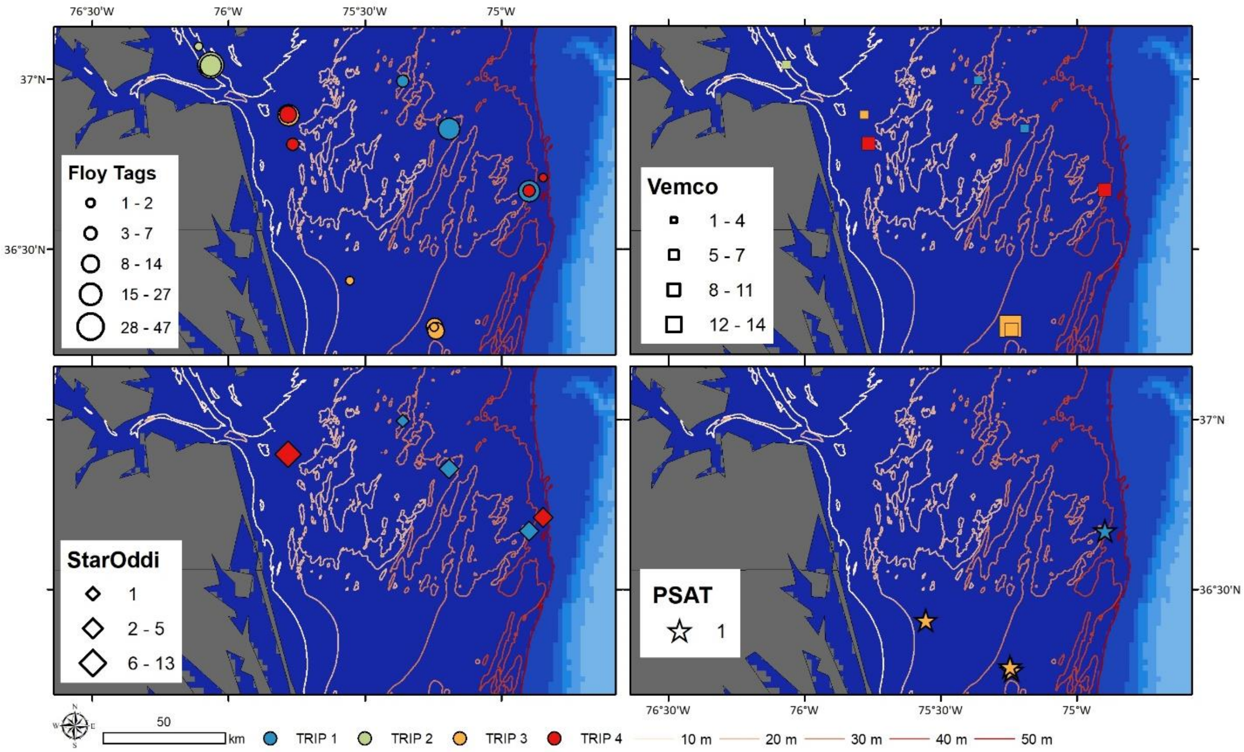

Figure 2: *Deployment locations for the various tags implanted or affixed to BSB.*

addition, five Vemco receivers were placed along the shoreline of the Chesapeake Bay, both close to the mouth of the Bay and farther inland.

Figure 3: *Tagging workstation on the F/V Playin Hookey.*

The overall procedure for tagging fish started with first capturing the animal using hook and line. Then fish were immediately vented using a hypodermic needle to puncture the swim bladder adjacent to the pectoral fin to increase survival especially when caught from deeper sites (Zemeckis et al. 2020). After the swim bladder was deflated, the fish was immediately placed into a live well, with an aerator. The water was regularly replaced in the warmer months or if there was an excess of surface scum build-up. Once the live well had 3 – 5 fish, we began measuring and tagging procedures. Fish were first measured, then given a passive external tag if larger than 12 cm TL. T-bar tags were attached to the fish using a retail tagging gun, with the tag placed adjacent to the dorsal fin, in the dorsal musculature (Fabrizio et al. 2013).

If the fish was of an appropriate size (>17 cm), we placed the animal, upside down, into a V shaped holding container, wrapped in a very wet towel for implantation of the acoustic tag (**Figure 3**). For implantation, we used a scalpel to first remove 2-3 scales from the site. Then we made a 1-2 cm incision on the ventral mid-line anterior to the cloaca. We coated the tag in triple antibiotic, and then placed it into the body cavity. The incision was then closed using 1 – 3 sutures, triple antibiotic was applied to the incision, along with a layer of liquid bandage to help seal the site. Fish were implanted with a Vemco V9T tag emitting a signal at 69 Hz for 233 days.

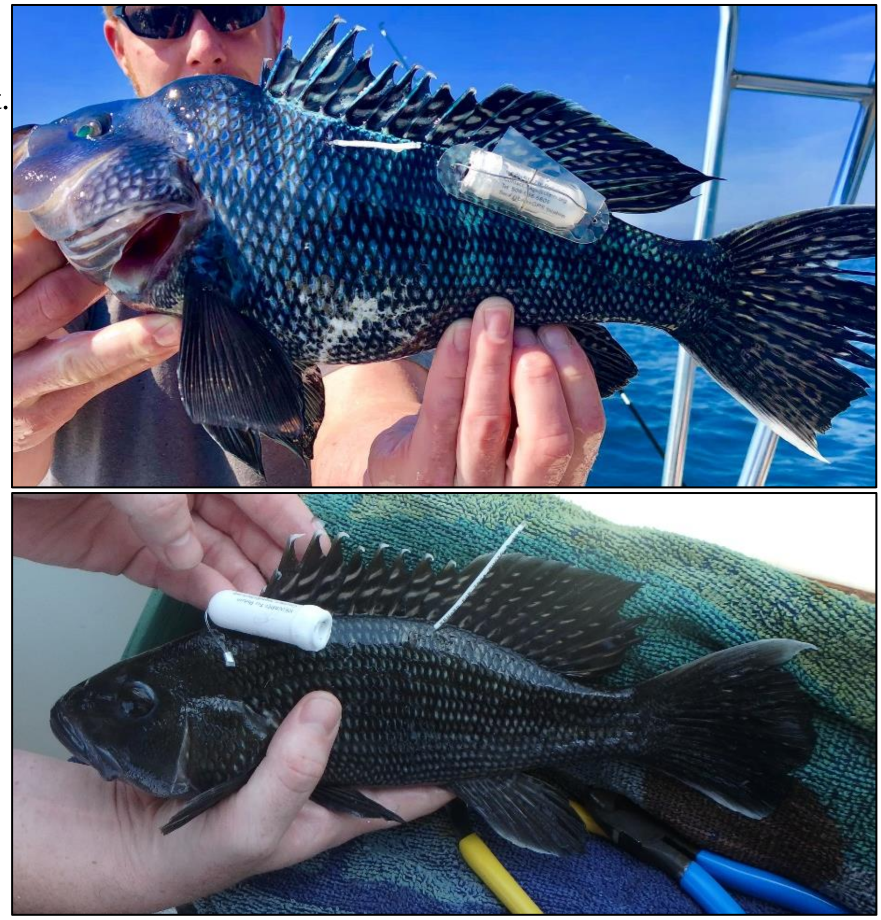

Figure 4*: Top: Star Oddi tag attached using the harness technique. Bottom: Star Oddi tag attached using the look technique.*

For fish receiving a Star-Oddi, we also measured and attached a T-bar tag first. If the fish was over 31 cm TL, then we deemed it of an appropriate size for the Star-Oddi tags while using the saddle technique for attachment. Star-Oddi tags recorded temperature, depth, and conductivity, and were meant to last for several hundred days. However, these tags need to be recovered in order to obtain the data. For the first three trips, we used the saddle technique to deploy the Star-Oddi tags as prescribed by the manufacturers (**Figure 4**). This technique involved placing a plate on the side of the fish, anterior to the caudal peduncle, running two thin metal wires through the plate, then through the flesh of the fish to the opposite side, then through another plate and housing for the Star-Oddi tag. Then the wire was twisted tight. Due to the slow process, this technique was difficult on BSB, and difficult to accomplish while handling a BSB particularly with their sharp dorsal fin spins. As a result, for Trip #4, we adjusted to the loop technique and instead threaded thin monofilament through the tag, then through the muscle anterior of the dorsal fin, leaving the tag dangling from the fish. This technique was adapted from Sweezey et al. (2020) and further tested in Runde et al. (2022) for external attachment of electronic tags on fish. Instead of using a spaghetti tag to secure the electronic tag, we altered the technique to use smaller gauge monofilament passing through the animal, and a crimp instead of a simple overhand knot. This process required a much shorter handling time and left fish in a better condition when returned to the sea. Due to lower impact to the animals, we also shifted our size limit for the Star Oddi tags when using this technique to fish larger than 23 cm TL.

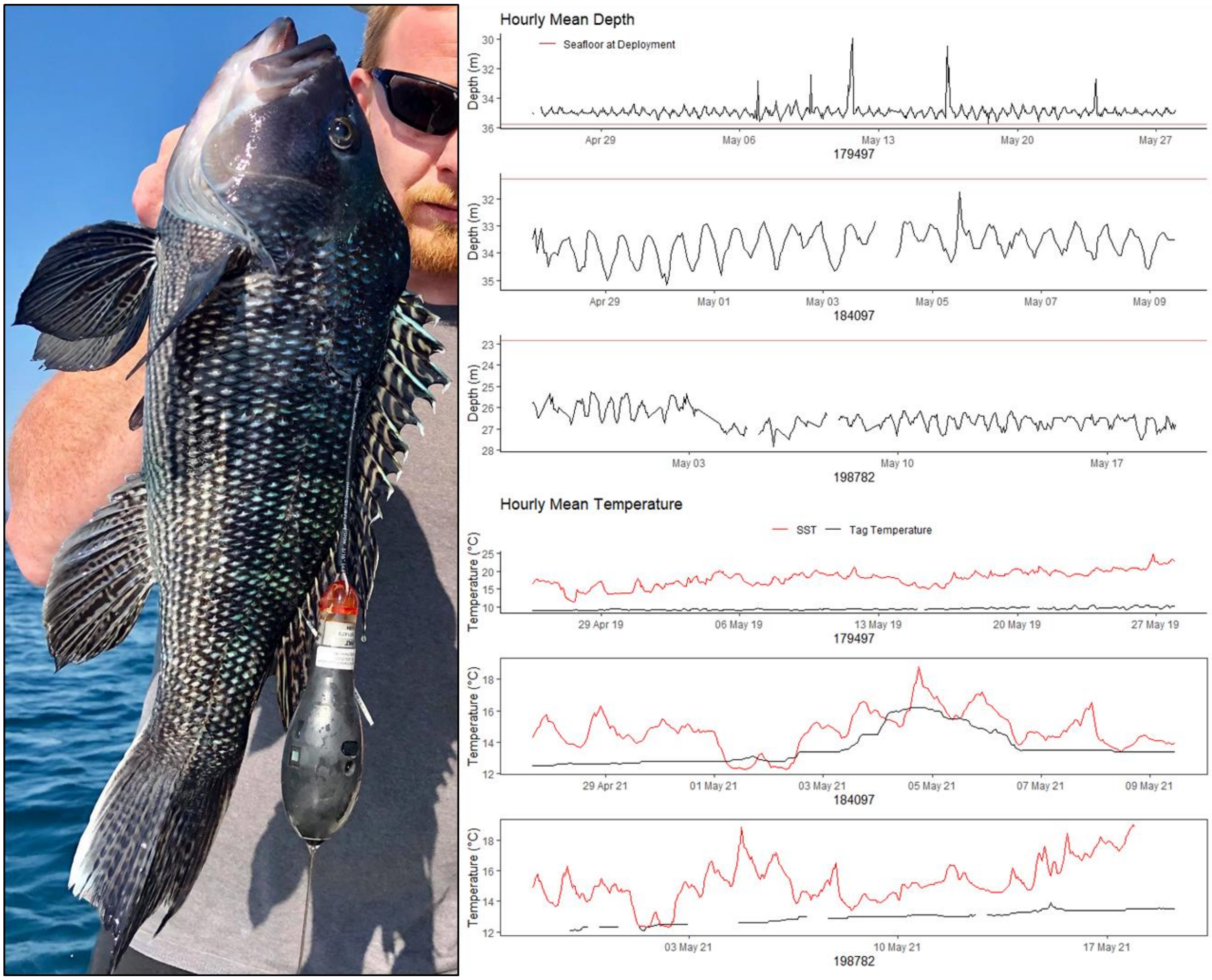

Figure 5: *Image: PSAT attachment to BSB during Trip #1. Top graph: Hourly mean depth data from three PSATs. Bottom graph: Hourly mean temperature data recorded by the PSATs overlaid with SST at the deployment site.*

For fish receiving a PSAT, we also measured and attached a T-bar tag first. Four fish measuring 44 – 48 cm TL received a PSAT (**Figure 5**). The tags were placed into the fish near the dorsal fin using a small titanium anchor designed by Wildlife Computers. These anchors are placed superficially into the muscle. All PSAT tags were programmed to remain attached for 250 days. After all tagging was complete, fish were either returned to the live well or returned directly to the sea if we were still floating over the wreck. We made sure to release fish as close to the location of capture as possible. All fish immediately swam down once released.

Trip #1

During Trip #1 we deployed a total of 47 T-bar tags, 6 Vemco tags, 6 Star-Oddi tags, and 1 PSAT. At the first fishing site on day one we deployed 21 T-bar tags, two Vemco tags and two Star-Oddi tags. We chose larger fish for the Star-Oddi tags, placing them on fish sized 37 and 41 cm TL. The Vemco tags were deployed in fish sized 28 and 30 cm TL. At the second fishing site on day one, we deployed 6 T-bar tags, one Vemco and one Star-Oddi. We also attempted a PSAT deployment, however, the fish (50 cm TL) did not appear to be handling it well, so we removed it before releasing the fish. One day 2, we deployed 20 T-bar tags, 3 Vemco, 3 Star-Oddi tags and 1 PSAT (ID #179497). The Vemco tags were deployed on one fish 35 cm TL, and two fish both 47 cm TL. The Star-Oddi tags were deployed on fish with TL of 36, 43, and 44 cm. The PSAT was deployed on a fish 46 cm TL.

Trip #2

During Trip #2, caught fish were much smaller than during the offshore sampling. As a result, we primarily deployed T-bar tags (n = 114) and only deployed 2 Vemco tags. On day one, all tagging occurred adjacent to the Fourth Island. This included 72 T-bar tags and the 2 Vemco tags. The acoustic tags were implanted in fish 17 and 21 cm TL. On day two, we fished first at the Third Island, deploying 11 T-bar tags, before switching to the Fourth Island and deploying an additional 29 T-bar tags. Caught fish on day two were all smaller than 17 cm TL, making them too small to handle the internal acoustic tag. On the third day, we only caught two fish, both smaller than 17 cm, as a result they were outfitted with only a T-bar tag.

Trip #3

During Trip #3, the return to offshore waters, meant we could tag larger fish. During this trip we deployed 52 T-bar tags, 24 Vemco tags, 2 Star-Oddi tags and the 3 remaining PSATs. At the first site on day one, we tagged 23 fish. Of these, 21 fish received a Vemco tag and ranged in size from 23 – 45 cm TL. At this site, we also deployed PSATs (ID #198781 and 184097) on two fish measuring 44 and 48 cm TL respectively. At the second site on day one, we caught one larger fish, 46 cm TL, and deployed a PSAT (ID #198782) on it. On day two, due to poor weather, we fished inshore and did not catch any fish. On day three, we fished at the Santore Wreck and deployed 28 T-bar tags, 3 Vemco tags and 2 Star-Oddi tags. The Vemco tags were deployed on fish measuring 22, 27, and 27 cm TL, while the Star-Oddi tags were deployed on the largest fish measuring 31 and 33 cm TL.

Trip #4

During Trip #4, we again fished offshore, deploying 28 T-bar tags, 8 Vemco tags and 20 Star-Oddi tags. On day one, at the farthest offshore site, we deployed 6 T-bar tags. On the first two caught fish, we also attached Star-Oddi tags using the saddle technique. These fish were 36 and 39 cm TL. The remaining four fish received an internal tag, and their size ranged from 29 – 45 cm TL. On day two, we fished closer to shore, and only caught four fish. All of them received a T-bar tag and an internal acoustic tag. On day three, we fished at Santore Wreck again, and caught 18 fish. All of these fish received both a T-bar tag and the Star-Oddi attached using the loop technique.

2.3 Objective 3: Determine relationships between environmental data and movement patterns, using CBIBS oceanographic buoy data, ancillary data from satellite tags, and data loggers.

Tag Returns

We received eight tag returns. Seven tagged fish were caught at Santore wreck and one was caught at a far offshore site we fished during Trip #3. We received three tag returns on May 31, 2021 at Santore Wreck, approximately a month after we had tagged those fish. These three fish did not have an electronic tag, and TL measurements were approximately the same as when we caught them. The fourth recovered fish was caught 2 months after we released it at Santore. It also was approximately the same size and did not have an electronic tag. The fifth recovered tag was caught in August 2021 by the captain of the charter boat used for this project, William Pappas, at the offshore location we fished at on day one of Trip #3. This recovered fish did have a Vemco tag implanted and seemed healthy three months after it was originally tagged. When we measured this fish it was 10.2 inches; however, upon recovery it was measured as 12 in. Then the final three recovered tags were all caught at Santore wreck in early September, after having been tagged during Trip #4. Two fish measured the same as when we caught them, and one fish was 0.75 inches larger when measured during the recapture. All three fish were equipped with a Star-Oddi tag attached using the loop attachment technique. However, upon recovery, none of the fish had retained the Star-Oddi and there were no clear signs of where the tag had been attached. In Runde et al. (2022), BSB outfitted with electronic tags using the loop technique retained the tag for the full 60-day treatment. As a result, we are unsure of how the tag could have been lost from the fish after only a month of deployment. However, Runde et al. (2022) conducted tank experiments, and fish in the wild likely behave differently.

Satellite Telemetry

Four fish received satellite tags, and this accounts for the first ever deployment of satellite tags on BSB. Tag retention was quite short, ranging from 8 – 32 days. We suspect the tags detached from the fish and then started floating, rather than fish mortality. The sat tag deployed on Trip #1 (179497) lasted 32 days. This fish remained at ~35 m throughout the duration of the deployment, with an occasional swim up the water column 2 – 3 m, perhaps moving over the wreck or structure. Water temperature steadily rose ~1°C, from 9° to 10°C, through the duration of the tag deployment. Based on the bottom depth at the capture site, we suspect this fish remained at the same site throughout the duration of the sat tag deployment.

Tag 184097 was deployed during Trip #3, and this tag was retained for 11 days. This fish consistently swam between 33 – 35 m depth, which was slightly deeper than the bottom depth at the release site (30 m), indicating that this fish may have swam to a new site. For the first few days of the deployment, water temperature was under 13°C; however, this fish ventured into warmer water or a warm front moved through the region, as temperature warmed to 16°C for two days (May 4 – 6), before returning to and remaining ~13°C until the transmitter released from the fish. This corresponded to a mini-heat wave, where air temperature rose ~5°C from May 3rd to May 4th, before dropping again on May 6th.

Tag 198781 was deployed near tag 184097 on the same day, however, the tag only lasted 8 days and transmitted a small portion of the data. This fish remained in the deepest water, between 40 – 50 m, which was much deeper than the depth at release site (30 m), again indicating that this fish likely moved to a new site immediately after tagging. Temperature at the start of the deployment was 12.5°C and rose to 16.3°C just prior to the tag releasing from the fish. This rise in water temperature corresponded to the rise in temperature experienced by 184097 on May 4.

The last sat tag (198782) was also deployed on Trip #3, slightly inshore of the two also deployed on the same trip. This tag lasted 22 days. The fish seemed to also move to a new site after release with bottom depth at the deployment site being shallower (~23 m) than recorded from the tag (26 – 28 m). Water temperature also increased by ~1°C through the duration of the deployment from 12.5° to 13.5°C. Unlike the other two tags deployed on this trip, this fish did not record the rise in water temperature on May 4 – 6, even though the warm front also moved over this location.

We used data from Buoy 44099, located offshore from the mouth of the Chesapeake Bay to identify the SST for the region during the satellite tag deployments. The Nearest CBIBS buoy, First Landing, unfortunately went offline in 2021, providing only data from the 2019 season. Buoy 44099 did document a rise in SST from May 4 – 6, and this rise clearly impacted bottom temperatures in certain parts of the ocean.

Remotely Operated Vehicle (ROV) Deployments

Through the course of the project we used an ROV to film the habitat and fishing sites during every trip. We didn't have the opportunity to film all fishing locations; however, we filmed several of them over the course of the four trips. Overall, we filmed a total of ~97 minutes of footage during which fish were present. There were some ROV dives into habitats where we couldn't identify fish, and this was due to low light or high currents making flying the ROV difficult. At sites with manageable currents and good visibility, we would fly the ROV to the ocean bottom searching for BSB. Once at the bottom at either a reef or wreck, we would fly the ROV over the area and both follow fish when possible or stay still in order to document the fish that pass through the frame of the camera. Due to the nature of the sites, to avoid entanglements of the ROV tether, dives were kept short (mean ± SD = 5.1 ± 2.3 min) and we would typically take several dives per site to also reset location to gain a broader perspective of the area. For each ROV video, we conducted analyses using BORIS event logging software to calculate the MaxN and frequency of counts with BSB and other fish species documented in the footage. For each video, we annotated every other minute of footage, and recorded the maximum number of fish counted in a single frame across that minute. The frequency of counts is equal to the number of times in a video during which at least one fish of a unique species is counted. MaxN is a common value used to determine the number of fish documented in video surveys (Stobart et al. 2015).

During Trip #1, we deployed the ROV at the second site fished on day one and at the only site fished on day two to film the habitat and measure temperature at the depths fish were residing. One day one we filmed the site for ~15 minutes across two dives. We flew the ROV to a depth of 25 m to film the wreck, and water was 8.7° C at this depth. The sections of the wreck we filmed were flatter surfaces with less dynamic structure. However, the wreck was covered in encrusting organisms and BSB were present on the surface of the wreck. Over the course of the footage, we conducted 9 counts of adult BSB, 3 counts of juvenile BSB and 5 counts of tautog (*Tautoga onitis*). The MaxN was 15 adult BSB, 2 juvenile BSB, and 2 tautog. On day two of trip one, we accrued ~18 minutes of footage of the site. This wreck was far more dynamic with a more complicated structure. We also documented a large portion of a fishing net that, although was several meters away from the main structures, was likely caught on the wreck. The first dive primarily documented the net and the MaxN was 8 for adult BSB and 2 for juvenile BSB both with a frequency of one. During the second dive we filmed the ship and the MaxN was 199 adult BSB, 6 juvenile BSB and 3 tautog (**Figure 6**). Adult BSB were counted 10 times, juvenile BSB were counted once and tautog were counted twice.

During Trip #2, we deployed the ROV on the third day at the Fourth Island and the nearby channel marker to document the habitat where we tagged BSB (**Figure 7**). At the channel marker, the current was too strong to pilot the ROV effectively; however, at the fourth island, we were able to document many fish, particularly juvenile BSB. At the fourth island, water depth was ~6 m and bottom temperature was 24.5° C. Near the channel marker, the depth was ~16 m and the bottom temperature was 20.0° C. SST during the ROV dives was 25.2 °C. We obtained footage of smaller BSB than what we were able to catch, and noticed that this artificial reef seemed to be dominated by BSB and a few larger tautog. At the fourth island, across four dives, the MaxN for adult BSB was 4, for juvenile BSB it was 18, for tautog it was 2 and for a *Sparidae* species (pinfish [*Lagodon rhomboids*] or scup [*Stenotomus chrysops*]) it was 14 fish. The frequency of counts for adult BSB was 5, for juvenile BSB it was 7, and for tautog and *Sparidae sp* it was 4 each. Similar to the findings from the rod and reel effort, juvenile BSB were most commonly documented in the footage; however, although we did not catch a *Sparidae*, they also ended up being prevalent within this structure.

Figure 6*: Over one hundred BSB counted at the wreck filmed on day two of Trip #1.*

Figure 7: *Fish filmed at the Bay-Bridge Island during Trip #2. White circles are BSB, red circle is a tautog and the purple circle is a school of* Sparidae sp.

During Trip #3, we spent a considerable amount of time using the ROV on day two to document the environment due to the poor fishing conditions. We deployed the ROV at the second island and near the Chilore wreck. At the second island, the current was extremely strong making flying the ROV difficult. In addition, the water clarity was very poor. During three dives, we did document a MaxN of 2 adult BSB, 1 juvenile BSB and 1 tautog. Adult and juvenile BSB were counted once and tautog were counted three times. At Chilore, we documented fish near the wreck in the sandy bottom during one dive, this included two blenniformids and 1 juvenile BSB. The fish were associated with clumps of sponge likely encrusting over a rock. During day three, we deployed the ROV at Santore Wreck and filmed for ~13 minutes (**Figure 8**). The wreck was fairly shallow at only ~16 m deep and SST was 14.1° C. Unfortunately, during the dive the temperature-depth logger failed and we did not get a recording of the environmental conditions at the wreck. At this wreck, we recorded a MaxN of 10 for adult BSB, 7 for juvenile BSB, 2 for tautog, 4 for cunner (*Tautogolabrus adspersus*), and 2 for clearnose skate (*Raja eglanteria*). Frequency of count was 5 for adult BSB, 4 for juvenile BSB, 5 for tautog and cunner, and 3 for clearnose skate.

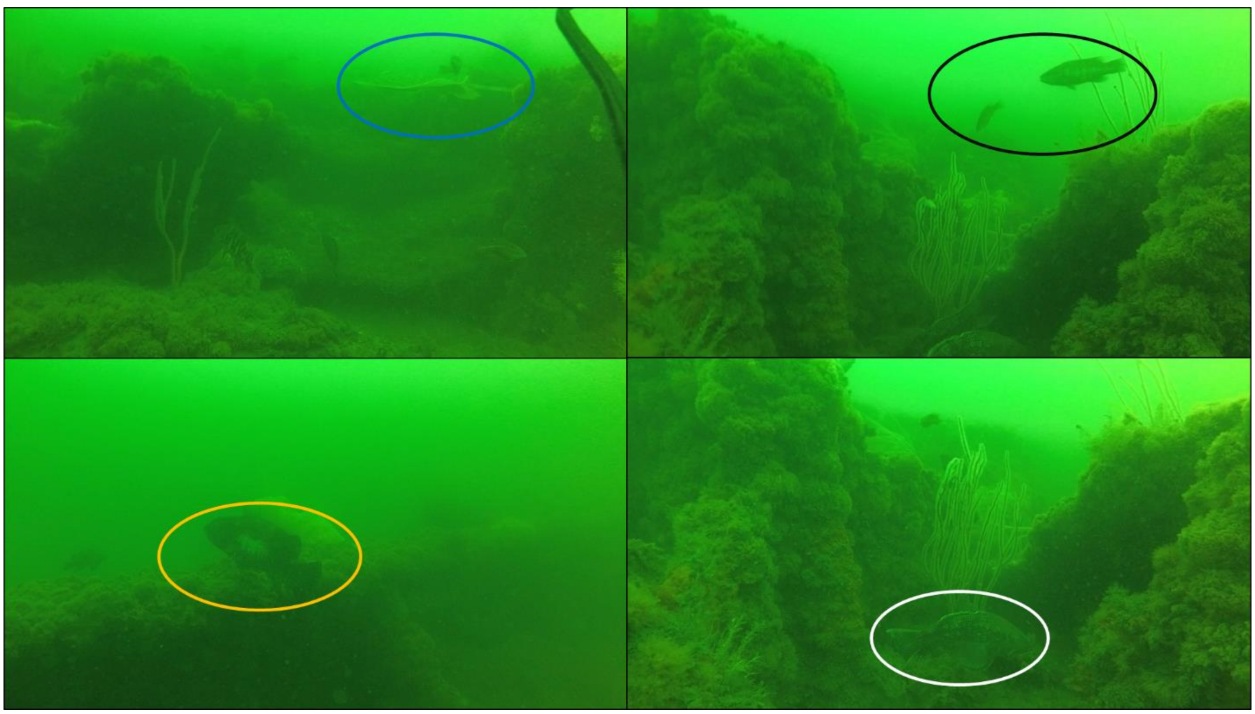

Figure 8: *Footage from Santore wreck taken during Trip #3. The blue circle is a clearnose skate, the black circle contains cunners, the orange circle is a tautog and the white circle is a BSB.*

During Trip #4, we again used the ROV to film Santore Wreck to identify any seasonal changes (**Figure 9**). We filmed for ~15 minutes across three dives, and seemed to be documenting a slightly different portion of the wreck than during Trip #3. During this trip, water clarity was greatly improved, and we filmed the broadest range of species, but again primarily BSB. The MaxN for adult BSB was 4, for juvenile BSB it was 6, for tautog it was 2, for cunner it was 3, for spadefish (*Chaetodipterus faber*) it was 4, for triggerfish (*Balistes capriscus*) it was 7, and for sheepshead (*Archosargus probatocephalus*) and scup it was 1 each. The frequency of count was 5 for adult BSB, 3 for juvenile BSB, 2 for tautog and scup, 3 for cunner, and 1 for spadefish, triggerfish and sheepshead each. The ROV reached a depth of 17 m and temperature at the wreck was 20.0° C, while SST reached 26.4° C.

Figure 9*: Footage from Santore wreck during Trip #4. The white circles are BSB, the orange circle is a scup, the blue circle is a sheepshead, the red circle is a grey triggerfish and the yellow circle contain a group of spadefish.*

Fishing Site Comparisons

We compared fishing locations based on catch and ROV footage. We fished at two sites twice. During Trip #1 and Trip #4 we fished at the same offshore site (**Figure 10**). This site was the farthest offshore for all trips. During Trip #1, which occurred in April, we fished at the site for ~2.5 hours, and caught a total of 20 fish with a mean (± SD) TL of 39.0 ± 6.6 cm. During Trip #4, in August, at the same site, we fished for ~3 hours and only caught six fish, averaging 36.0 ± 5.7 cm TL. During Trip #1, we also deployed the ROV at this site and documented the highest MaxN values (n = 199), indicating an extremely dense population of BSB at the site in April. The density may have declined between years or seasons. Due to weather, we may have also been drifting over the wreck too quickly during the August trip to fish the site most effectively. Unfortunately, the conditions were not favorable to ROV at this site during Trip #4 preventing the ability to confirm a shift in BSB density.

During Trip #3 and Trip #4, we fished at the same nearshore wreck, Santore, which is also a popular site for other recreational fishing boats (**Figure 11**). During Trip #3, in April 2021, we caught 28 fish and the TL mean ± SD was 25.1 ± 3.6 cm. During Trip #4, we caught 18 fish and the mean size was 26.8 ± 3.0 cm. Fish were slightly larger during Trip #4, and this was also consistent in the ROV footage and tag return information. In the ROV footage we documented more juveniles at the wreck during Trip #3, and from the tag returns, smaller fish were caught in

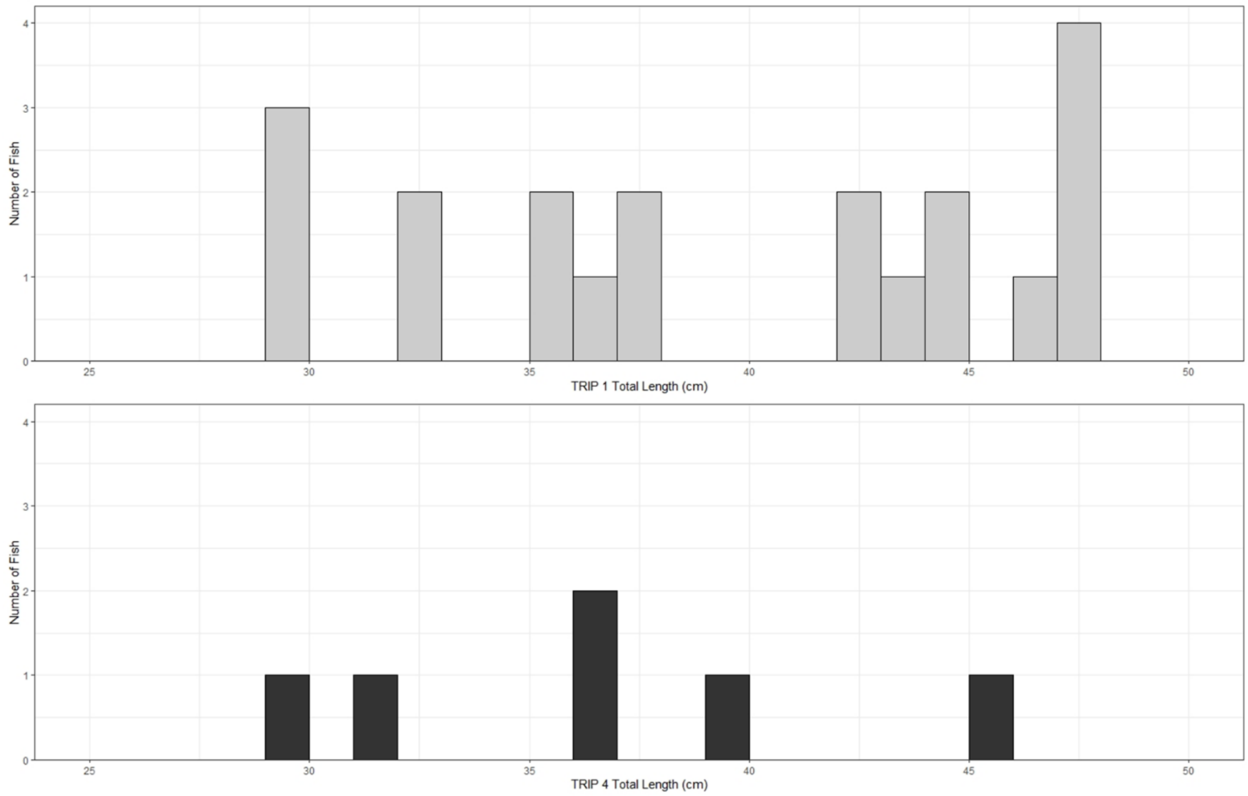

Figure 10: *Length-frequency histograms (1 cm bins) for fish caught during Trip #1 (top) and Trip #4 (bottom) at the same offshore fishing site.*

May, while larger fish were caught in September. This slight increase in TL could be the resident BSB growing between fishing trips.

We also compared fishing sites based on distance from shore (**Figure 12**). We fished at a total of 13 unique sites, with five considered inshore (at the mouth of the Chesapeake Bay), three nearshore (within 20-30 km of shore) and five offshore (>60 km from shore). Size of fish caught in each region varied significantly ($p < 0.001$). At the inshore sites, we caught 114 fish, specifically during Trip #2, and TL mean ± SD was 15.0 ± 1.4 cm. At the nearshore sites, we caught 51 fish and the mean size was 26.3 ± 4.3 cm. Those sites were fished during Trips #3 and #4. At the offshore sites we caught 77 fish during Trips #1, #3, and #4 and they were the largest, with a mean size of 35.6 ± 7.0 cm; a potential indicator that as BSB grow, they may move offshore as a result of intraspecific competition and do not engage in spawning migrations to inshore waters. We did not identify larger fish moving inshore for spawning, and perhaps BSB spawn offshore, and the young-of-the-year make their way inshore to find safer habitat where they do not need to compete with the large BSB. Additionally, this size variation between the nearshore and offshore sites could be from fishing pressure. Boats are less likely to fish in the farthest offshore sites for BSB, while nearshore sites seem to be heavily fished as indicated by the tag returns. The mean size of fish we caught at Santore was ~10.5 inches, just under the legal size limit of 12 inches for keeping fish. Although, when we fished this site during the offseason for BSB, the average size was less than the legal size limit.

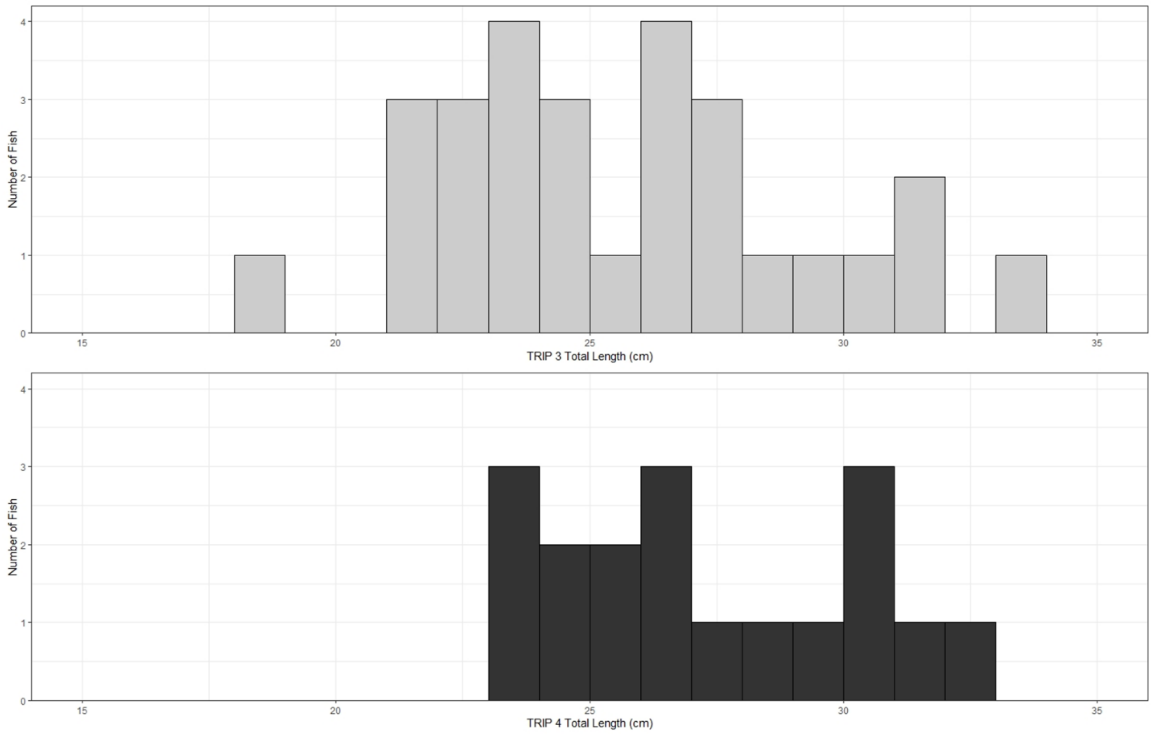

Figure 11: *Length-frequency histograms (1 cm bins) for fish caught during Trip #3 (top) and Trip #4 (bottom) at the same nearshore fishing site, Santore Wreck.*

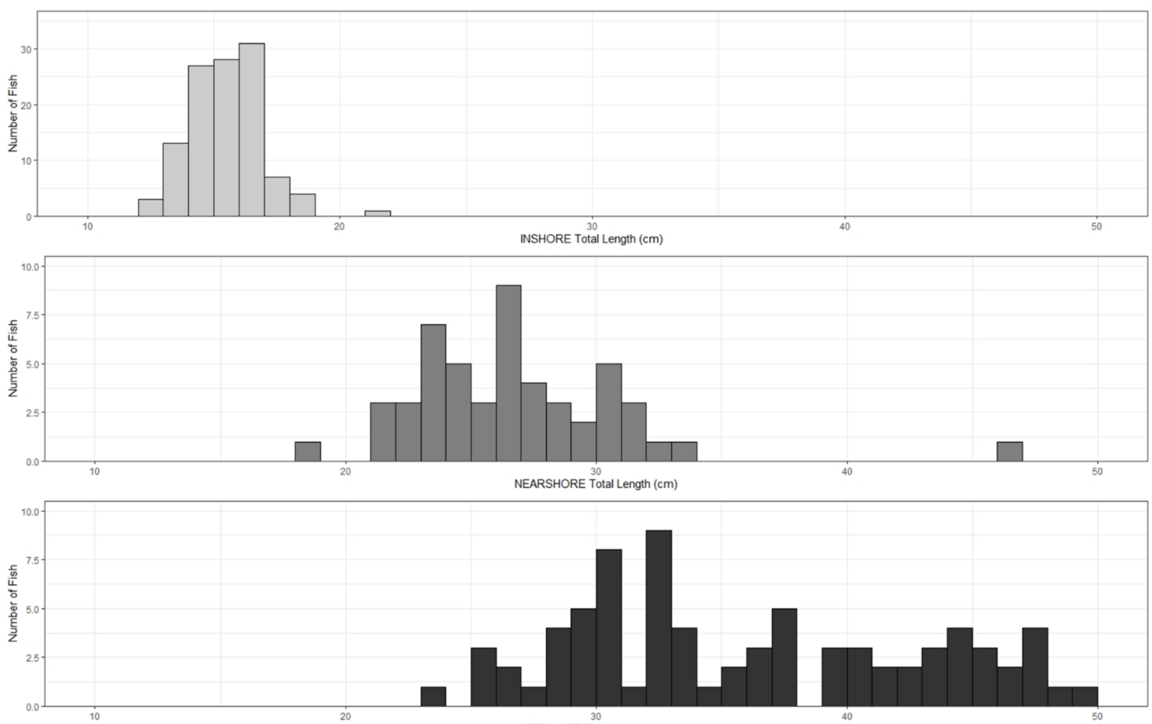

Figure 12: *Length-frequency histograms (1 cm bins) for fish caught at inshore sites (top), nearshore sites (middle) and offshore sites (bottom).*

2.4 Objective 4: Utilize a network of citizen science volunteers from FishFinder to deploy additional mobile receivers within the Bay and along the east coast.

Over the project period from spring 2018 and then extended through fall 2021, six acoustic receiver stations were mostly operational to detect tagged species within the Chesapeake Bay watershed (**Figure 13**). Two additional receivers replaced two lost receivers. These instruments were internally logging, battery powered VR2W VEMCO receivers. This project's BSB tag id's were carefully screened for during data upload events.

Figure 13*: Locations for the deployed acoustic receivers.*

The Ocean Research Project Inc. 501c3 citizen science cruising network and partner Chesapeake Bay Foundation were supportive of the receiver array activity to the best of the multiple parties restricted capacity as the COVID pandemic became an on obstacle to overcome during the project evolution. Two volunteer sailboat owning parties participated as FishFinders, a project associated with Ocean Research Project's sailing citizen science program. They intended to deploy a receiver at anchorage during cruising trips then at the dock upon their return from trips over the 2010-2020 period. The FishFinding volunteers had major plans for Chesapeake Bay southern bay cruising areas where Black Sea Bass juveniles may inhabit and where there are minimal to no receiver arrays in operation to detect them. However, both parties kept their vessels at the dock in tributary bays in southern and northern Chesapeake Bay relative to personal and pandemic related setbacks. The southern bay sailing party deployed their assigned receiver at a dock at Fishing Bay Yacht Club off the Piankatank River but the receiver was pulled and sent back early during COVID due to the inability to monitor the unit. Instead of the continued recruiting of bay sailing parties for the tagged species observation period conflicting with the pandemic, the Ocean Research Project coordinated receiver deployments with Chesapeake Bay Foundation waterfront locations at the end of their piers and bulkheads in both Maryland and Virginia. Monitoring and accessing the locations at Bishops' Head, Tilghman Island, Smith Island, and Virginia Beach proved to be challenging during COVID restrictive periods. Two instruments were lost and brief periods of gaps in observing occurred if a battery needed replacement and COVID restrictions limited receiver access. Efforts were made to recover the missing receivers with a remotely operating vehicle and grapple anchor. Receiver replacement was conducted regardless of COVID access complications at these sites. Continued efforts to recover the instruments are considered during the summer period with warmer water and more vessel activity.

Nonetheless, receivers stationed at Chesapeake Bay Foundation waterfront sites proved to be worthwhile spots for tagged species detection. The Karen Noonan Center's Bishop Head, Tilghman and Smith Island receiver stations proved to make great locations for fish detections. There were twenty-four independent fish detected at mid-bay stations. There was one fish detection at Brock Port Center in Virginia Beach's Lynnhaven Inlet and three independent fish detections in the South River at Glebe Bay.

The MATOS repository is populated with the detection data from this project which is also available to the Animal Telemetry Network to ensure any species detection data recorded is shared with parties who have registered their tags associated with regional acoustic telemetry projects. Some fish detection tags were confirmed to belong to the University Maryland Center for Environmental Science and Smithsonian Environmental Research Center of juvenile striped bass associated with researchers Mike O' Brien and Kimberly Richie.

While the field period of this project overlapping with COVID complications restricted volunteer organization and citizen science participation to act as temporary or mobile receiver arrays, the potential to utilizing these parties to advance monitoring BSB and other tagged species in the Chesapeake Bay watershed and eastern seaboard is still a promising supplemental methodology for expanding observations of key living resources.

3 Conclusions

Overall, we identified basic information on the demographics of BSB within waters at the mouth of the Chesapeake Bay and adjacent offshore sites. Although we deployed 66 Vemco and Star Oddi tags in total, we did not receive a single recovery or transmission from either device. The lack of data from the Vemco tags indicates that the fish were unlikely to move from their near/offshore sites into the Chesapeake Bay, where the acoustic receivers were placed. Unfortunately, due to the limited number of trips, we did not feel comfortable deploying acoustic receivers at the offshore sites without consistent tending. As a result, we could not verify that fish remained resident based on electronic tagging, however, the consistent size variation between sites and the T-bar tag recoveries 2.5 months after deployment indicate that BSB likely remain at a specific wreck long-term. This appeared to match tag return data from Moser and Shepherd (2009) that found BSB in the southern MAB had the shortest mean distance (15 km) between tag recaptures (mean days at liberty = 227). In addition, when examining historical fisheries survey data of the NW Atlantic (https://oceanadapt.rutgers.edu/), BSB catch varied seasonally from inshore (fall) to offshore (spring); however, in recent years with the increases in ocean temperatures, as well as, evident increases in the BSB population, seasonal habitat variation may be breaking down. Consequently, these alterations could lead to resident populations at the various wrecks and reefs within the region.

Although the more traditional electronic tags provided limited success, this is the first study to deploy PSATs on BSB. There can be a high variation in the success rate of these types of tags, and being the first deployment for a species, we were expecting the tags to release earlier than programmed (Lutcavage et al. 2015). However, even with the short deployment durations, we still identified some unique occurrences, specifically fish likely remaining resident away from the original site of capture/deployment and extreme bottom temperature fluctuations based on short term weather events. From previous data logger deployments on BSB, it has been identified that 10-11°C bottom temperature tends to initiate the seasonal migration to overwintering sites (Moser and Shepherd 2009). One of our tagged BSB transmitted bottom temperatures lower than 10°C, indicating that this species may have a lower temperature tolerance than previously established (Atwood et al. 2001). However, this may be a function of the size of the fish (Miller et al. 2016), as the PSAT tagged fish was particularly large compared to those tested by Atwood et al. (2001). Although currently the costs of deploying PSATs on BSB may outweigh the benefits, as attachment techniques improve and technology prices go down, this option could provide important movement information on a species clearly increasing in population and potentially expanding their range as there is still limited understanding on their inshore/offshore migrations. Furthermore, with the limited likelihood of tag returns from far offshore fishing sites, PSATs can transmit critical data otherwise extremely difficult to recover.

We suggest future research to include deployments of electronic tags on fish within Chesapeake Bay. This would likely require either smaller tags or larger fish, but would help gain more insight on fish movement and ecology beyond simply passive tag returns. From our experience and from Moser and Shephard (2009), tagging fish outside of Chesapeake Bay did not provide information on the ecology of BSB directly associated with the estuary. Due to the short migrations taken by BSB in the southern MAB, it doesn’t seem as though BSB in offshore waters enter or exit the Bay (Moser and Shephard 2008). As a result, the large population of juvenile BSB among the Bay-Bridge Islands requires further investigation to determine where these smaller fish are spawned and how they arrive at these reefs. Furthermore, tagging is required to determine if these juveniles then contribute to the population of adults in offshore wrecks. Overall, BSB were extremely easy to catch regardless of fish size or hook size, some of the smallest BSB caught were barely twice the size of the hook. Based on the ROV footage BSB also tended to dominate fishing sites. Given how aggressive and abundant BSB were at the fishing sites they may outcompete other reef fish. As BSB populations adapt to climate change, an increase in the duration of BSB residency on reefs and wrecks could have serious impacts on species diversity around these structures. To ensure appropriate levels of diversity of relevant species in the region, fishing effort for BSB may have to be increased to account for population shifts due to climate change.

Literature Cited:

Able KW, Fahay MP, Shepherd GR. 1995. Early life history of black sea bass, *Centropristis striata*, in the mid-Atlantic Bight and a New Jersey estuary. Fishery Bulletin 93: 429-445

Atlantic States Marine Fisheries Commission (ASMFC). 1997. Atlantic Coastal Submerged Aquatic Vegetation: A Review of its Ecological Role, Anthropogenic Impacts, State Regulation, and Value to Atlantic Coastal Fish Stocks.

Atlantic State Marine Fisheries Commission (ASMFC). 2021. Addendum xxxiii to the summer flounder, scup, and black sea bass fishery management plan.

Atwood HL, Young SP, Tomasso Jr JR, Smith TI. 2001. Salinity and temperature tolerances of black sea bass juveniles. North American Journal of Aquaculture. 63(4):285-8.

Childs AR, Cowley PD, Naesje TF, Booth AJ, Potts WM, Thorstad WB, Okland F. 2008 Do environmental factors influence the movement of estuarine fish? A case study using acoustic telemetry. Estuarine Coastal and Shelf Science 78: 227-236.

Dorazio RM, Hattala KA, McCollough CB, Skjeveland JE. 1994. Tag recovery estimates of migration of striped bass from spawning areas of the Chesapeake Bay. Transactions of the American Fisheries Society. 123(6):950-63.

Drohan AF, Manderson JP, Drinkwater DB. 2007. Essential fish habitat source document: black sea bass, *Centropristis striata*, life history and habitat characteristics, 2nd ed. NOAA Tech. Memo. NMFS-NE-200, 68p.

Fabrizio MC, Manderson JP, Pessutti JP. 2013. Habitat associations and dispersal of black sea bass from a mid-Atlantic Bight reef. Marine Ecology Progress Series. 482:241-53.

Fabrizio MC, Tuckey TD, Musick S. 2017. A Brief Guide to Striped Bass Ecology & Management in Chesapeake Bay.

Graves JE, Horodysky AZ, Latour RJ. 2009. Use of pop-up satellite archival tag technology to study postrelease survival of and habitat use by estuarine and coastal fishes: an application to striped bass (*Morone saxatilis*). Fishery Bulletin. 107(3):373-83.

Jiang H, Pollock KH, Brownie C, Hoenig JM, Latour RJ, Wells BK, Hightower JE. 2007. Tag return models allowing for harvest and catch and release: evidence of environmental and management impacts on striped bass fishing and natural mortality rates. North American Journal of Fisheries Management. 27(2):387-96.

Kahn JR, Kemp WM. 1985. Economic Losses Associated with the Degradation of an Ecosystem: The Case of Submerged Aquatic Vegetation in Chesapeake Bay.

Lutcavage ME, Lam CH, Galuardi B. 2015. Seventeen years and $3 million dollars later: performance of PSAT tags deployed on Atlantic bluefin and bigeye tuna. Col Vol Sci Pap ICCAT. 71:1757-65.

Miller AS, Shepherd GR, Fratantoni PS. 2016. Offshore habitat preference of overwintering juvenile and adult black sea bass, *Centropristis striata*, and the relationship to year-class success. PloS one. 11(1):e0147627.

Moser J, Shepherd GR. 2008. Seasonal Distribution and Movement of Black Sea Bass (*Centropristis striata*) in the Northwest Atlantic as Determined from a Mark-Recapture Experiment. Journal of Northwest Atlantic Fishery Science. 40.

NOAA. 2007. Black sea bass, *Centropristis striata*, Life History and Habitat Characteristics. NOAA Technical Memorandum NMFS-NE-200.

NOAA. 2018a. "Essential Fish Habitat." NOAA Fisheries, www.fisheries.noaa.gov/national/habitat-conservation/essential-fish-habitat.

NOAA. 2018b. "Summary of Essential Fish Habitat (EFH) Designation: Major Estuaries, Bays, and Rivers alng the Northeast United States Coast." NOAA Fisheries, https://www.greateratlantic.fisheries.noaa.gov/hcd/est.htm.

Roy EM, Quattro JM, Greig TW. 2012. Genetic management of Black Sea Bass: Influence of biogeographic barriers on population structure. Marine and Coastal Fisheries. 4(1):391-402.

Runde BJ, Buckel JA, Bacheler NM, Tharp RM, Rudershausen PJ, Harms CA, Ben-Horin T. 2022. Evaluation of six methods for external attachment of electronic tags to fish: assessment of tag retention, growth, and fish welfare. Journal of fish biology.

Sheaves MS. 2009. Consequences of ecological connectivity: the coastal ecosystem mosaic. Marine Ecology Progress Series 391: 107-115.

Steimle FW, Zetlin CA, Berrien PL, Chang S. 1999. Essential Fish Habitat Source Document: Black sea bass, *Centropristis striata*, life history and habitat characteristics. NOAA Technical Memorandum NMFS-NE-143

Stobart B, Díaz D, Álvarez F, Alonso C, Mallol S, Goñi R. 2015. Performance of baited underwater video: does it underestimate abundance at high population densities? PLoS One. 10(5):e0127559.

Sweezey BB, Capizzano CW, Langan JA, Benoît HP, Hutchins EW, Mandelman JW, Koh WY, Dean MJ, Anderson BN, Sulikowski JA. 2020. Estimating the discard mortality of Atlantic cod in the southern Gulf of Maine commercial lobster fishery. North American Journal of Fisheries Management. 40(5):1252-62.

VIMS Multispecies Research Group. (2018, April, 24). Chesapeake Bay Multispecies Monitoring and Assessment Program (ChesMMAP) Abundance Indices: Black Seabass. http://fluke.vims.edu/mrg/chesmmap_abundance/BlackSeaBass

Wingate RL, Secor DH, Kraus RT. 2011. Seasonal patterns of movement and residency by Striped Bass within a subestuary of the Chesapeake Bay. Transactions of the American Fisheries Society. 140(6):1441-50.

Zemeckis DR, Kneebone J, Capizzano CW, Bochenek EA, Hoffman WS, Grothues TM, Mandelman JW, Jensen OP. 2020. Discard mortality of black sea bass (*Centropristis striata*) in a deepwater recreational fishery off New Jersey: role of swim bladder venting in reducing mortality. Fishery Bulletin. 118(2).