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Executive Summary

The most recent stock assessments for South Atlantic and Gulf migratory group cobia, SEDAR 28, and Atlantic Cobia, SEDAR 58, established and maintained, respectively, a management boundary between the two groups at the Florida/Georgia border and recommended additional data collection including increased acoustic and PSAT tagging to provide greater resolution of the major stock boundary/mixing zone in the southeastern United States. We partnered with charter anglers to capture and place 124 acoustic transmitters and 27 satellite tags in cobia between North Carolina, South Carolina, Georgia, and the east coast of Florida, making use of the rapidly expanding network of receiver arrays in this region. We collected additional genetic samples in these areas to complement previous analyses and provide a more comprehensive view of cobia stock structure. Tagging occurred in multiple primary regions: North Carolina, South Carolina, Georgia, Northeast Florida, Central Florida, and Southeast Florida and analyses were informed by these initial tagging locations as well as continually collected acoustic data from our previous CRP study (NA15NMF4540105)

Combined with cobia tagged in previous CRP efforts, acoustically tagged cobia were detected on 24 separate arrays along the US Atlantic coast and eastern Gulf of Mexico with 30,171 detection events (including release, recapture, and harvest observations) from 255 cobia at 959 receiver stations. Time between first and last detection ranged from 1 – 1,782 days with a mean of 376 days, suggesting acoustic telemetry is an effective means for tracking cobia across years. In general, there was more mixing within the Atlantic stock compared to within the Gulf of Mexico stock. While less than within-stock mixing, mixing between stocks was evident. Cobia from each stock intermixed every month of the year to varying extents with mixing highest in the early fall to mid-winter. Thirty percent of tagged cobia (64 out of 219 tagged fish that were detected more than once) mixed in space and time with fish from a different stock. Because long-term acoustic tags were used, we expect to continue to collect additional migratory data from these cobia over the next several years.

Twenty-six PSAT tags for this project were deployed, however thus far only 12 have been deployed for greater than 30 days and popped-off with transmission of data, although multiple are still at-large and will add to this dataset. With limited long-term satellite tracking data, no consistent patterns have emerged with regards to movement within or between fish tagged in different regions or from the two primary stocks. Significant east-west migration however has been confirmed as has significant north-south movement while offshore, out of the range of the acoustic receiver networks. Temperature and depth data from these long-term deployments also confirm a preferential temperature range for cobia as well as novel data on the depth distribution of cobia when they migrate offshore.

Introduction

Statement of Problem:

While the research conducted under the previous CRP grant has provided a large volume of valuable data on cobia movement patterns, one inherent limitation of southeastern regional acoustic telemetry arrays is that siting typically occurs relatively close to shore and the east-west formation of acoustic gates are often more effective at detecting movements that occur in north/south direction. Collecting data on migratory patterns during spring-fall, when stocks are aggregating along shallower shelf areas is essential to understanding the dynamics of the fishery. However, a sound management scheme must account for the distribution of fish throughout the year. The acoustic telemetry data suggest that during late fall/winter, cobia tagged in SC and GA may move into deeper water or, at least, areas that are devoid of acoustic receivers. Determining overwintering locations and the extent to which cobia from different locations mix is necessary to properly allocate catch and make biological assessments of the fishery. Although some cobia potentially move into deeper areas out of the range of acoustic detection during cooler months, recreational harvest during these times are not uncommon (Captain Kirk Waltz, Captain Zack Bowen, personal communication). In central and southern Florida waters, where temperatures seldom drop below 20°C, cobia may utilize deeper offshore waters as thermal refugia during warmer months, as evidenced by their sporadic appearance in coastal arrays during upwelling events that push cooler water close to the coast.

As cobia management shifts to interstate management, it will be vital to the health of the fishery to identify the spatial and temporal nature of how harvest occurs on each stock. Understanding when and where potential subpopulations are available to anglers will improve our ability to define factors such as fishing mortality and provide more robust stock assessments. In order to build a more complete picture of cobia migratory behavior and stock structure as well as characterize habitat usage, we proposed to combine acoustic telemetry with pop-up satellite archival tags (PSATs) to build upon the data collected in our previous CRP project. The combination of tag types allows us to fill in gaps in location data that occur when cobia move beyond the range of the existing receiver arrays while also collecting detailed data on cobia temperature and depth profiles that have previously been unavailable. Our project specifically addressed **CRP Program Priorities:**

1.b. Developing methods to increase at-sea observations to obtain life history information and (e.g., otoliths for aging, gonads for maturity/fecundity), genetic material, or stomach contents for trophic level information and

1.j. Determining stock structure (stock boundaries) for currently assessed species.

Objectives:

The overall goal of our project was to combine additional acoustic telemetry with pop-up satellite tags to further refine the biological stock boundary as well as the potential extent of east-west and depth migration during fall – spring periods when few cobia are detected on existing, near-shore acoustic receiver arrays. Our specific objectives were to:

1. Employ local charter captains to capture 27 legal-sized cobia (914 mm fork length or greater). Fit each cobia with a MiniPAT PSAT tag and implant with a V16-4H acoustic transmitter.
2. Collect genetic samples from all cobia captured during the duration of the project.
3. Download acoustic receiver arrays within the management of collaborators at least twice a year and compile data on cobia detections from receivers within and outside these arrays.
4. Upon tag detachment, collect summary data from Argos satellite system on geolocation, temperature, and depth and, when possible, physically collect MiniPAT tag upon pop-off.
5. Synthesize results in concert with ongoing data collection from CRP project NA15NMF4540105 in order to provide a larger picture of cobia migratory patterns in the southeast United States and greater clarity of stock structure.

Methods

Acoustic Telemetry:

Passive acoustic telemetry utilizes an array of submerged acoustic receivers deployed to continuously and autonomously record the presence of fish implanted with acoustic transmitters. The acoustic telemetry portion of this project relied on the ever-expanding network of submerged acoustic receiver arrays throughout the study area and beyond. The Florida Atlantic Coast Telemetry (FACT) and Atlantic Coastal Telemetry (ACT) Networks are organized as part of a regional-scale cooperative network of passive acoustic receiver arrays maintained by several marine research organizations along the South Atlantic coast. As of 2022, the FACT Network consists of over 2,100 acoustic tracking stations deployed in a variety of habitats including coastal rivers, open estuarine waters, tidal inlets, beachfronts, offshore reefs, wrecks, and sand shoals (Figure 1). The core FACT array was established in 2008 and covers 875 km of all Florida's east coast from Jacksonville down into the Florida Keys. Membership in FACT has grown markedly in recent years with additional arrays now deployed in the Everglades, Florida Keys, Bahamas (Eleuthera, Andros Island, Bimini, and Grand Bahama), Jacksonville and Georgia. FACT currently has 93 partner groups including the Florida Fish & Wildlife Conservation Commission, Georgia Dept. of Natural Resources, Kennedy Space Center, US Navy, many research Universities along the East Coast, and several independent marine research organizations.

The ACT Network was established in 2006, primarily as a means for monitoring Atlantic and Gulf Sturgeon migration and extends from Georgia to Maine. As is the case with FACT, the ACT Network has expanded rapidly from 15 researchers at inception to currently include over 120 researchers working with over 100 different species. GADNR and SCDNR are currently each maintaining coastal arrays as part of the FACT and ACT networks with large clusters of receivers along the Georgia and South Carolina coasts, including but not limited to Brunswick, Gray's Reef, Port Royal Sound, Charleston, and northern South Carolina (http://dnr.sc.gov/marine/receiverstudy/methods.html). This network includes natural and artificial reef, shipping channel, and sand bottom locations. In addition to these coastal arrays, several hundred riverine and estuarine receivers are deployed throughout all major South Carolina waterways; including several areas in close proximity to identified cobia inshore aggregations.

Additional acoustic arrays exist in the Gulf of Mexico (integrated Tracking of Aquatic Animals of the GOM-iTAG) and Mid-Atlantic that are able to detect tagged cobia that leave our study area.

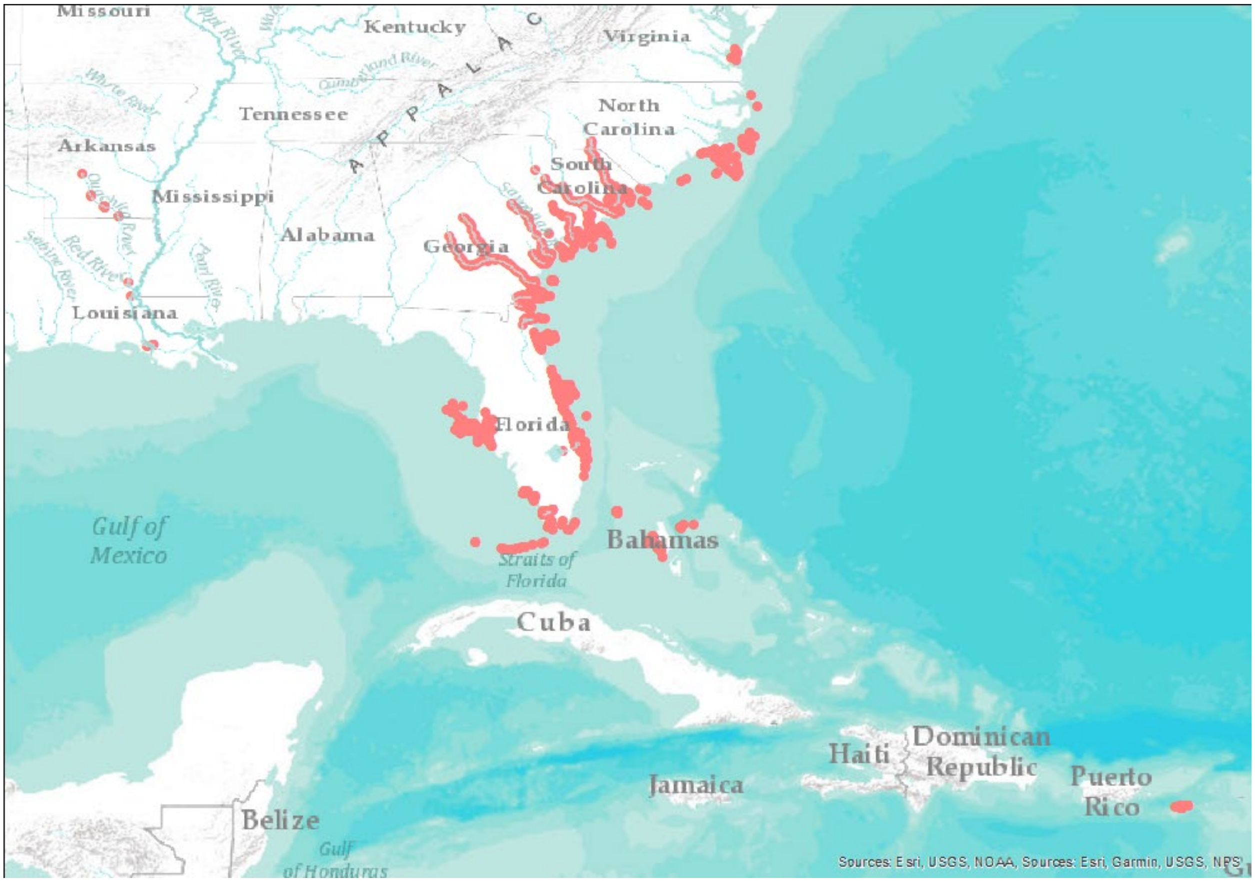


Figure 1. Overview of all current Florida Atlantic Coast Telemetry Network receiver arrays from VA-FL,the Caribbean and Mississippi River..

Cobia were captured, implanted with acoustic transmitters (V16-4H, Vemco Inc.) and released. The acoustic transmitters were programmed to emit a 69-kHz ultrasonic "ping" approximately every 90 seconds with a signal that is specific to the individual transmitter. If the animal passes within range (200-800 meters, depending on depth and oceanographic conditions) of a receiver, the ping is recorded (a detection) and therefore an animal's relative location at a specific point in time is known. By evaluating detections over time with multiple animals, we can evaluate migratory patterns of the overall tagged group. The size of the cobia involved allowed us to use a larger acoustic transmitter with a battery life of 4-5 years, meaning that each transmitting cobia will provide data well beyond the end of this specific project.

Acoustic and Satellite Tagging:

This project allows captains to play a role in data collection that will directly affect the fisheries management process. Captains involved in our previous CRP project remained engaged in our research and were hired along with additional charter captains from other areas to assist with cobia captures. Captains received a base charter fee of $400 for dedicated trips to collect and tag cobia and an additional $150 for each cobia tagged. The fee structure was similar to that used in our previous work. However, the base fee was increased by $100 to offset the smaller number of animals expected to be tagged on a per trip basis.

124 acoustic tags were released between the four states (5 NC, 52 SC, 10 GA, and 57 FL). A total of 26 satellite tags were deployed as follows: North Carolina (n=5), South Carolina (n=10), Georgia (n=2), Florida (n=9). Tagging efforts occurred in 10 major locations: Chesapeake Bay, VA; Cape Hatteras, NC; Cape Lookout, NC; Charleston, SC; Port Royal Sound and adjacent offshore locations, SC; Brunswick, GA; Jacksonville and St. Augustine, FL; Cape Canaveral, FL, and Jupiter, FL. Collaborators with the North Carolina Division of Marine Fisheries (NCDMF) tagged cobia in NC and VA as part of existing projects aimed at both conventional and acoustic tagging and supplemented the 5 allotted PSATs with additional tags from internal funding sources. South Carolina Department of Natural Resources (SCDNR) staff were responsible for all tagging in South Carolina, Georgia Department of Natural Resources were responsible for Georgia waters, Kennedy Space Center (NASA) Ecological Program staff were responsible for tagging in Central Florida and Florida Fish & Wildlife Conservation (FWC) staff were responsible for tagging in North and South Florida. Figure 2 shows the locations of all cobia tagged in this project.

Figure 2. Locations of all tagged cobia (acoustic and satellite) during the course of this project.

Cobia were landed via net and transferred, ventral side up, into a specially made V-shaped wooden fish cradle. The cradle and fish were placed into a cooler filled approximately ¼ full of seawater. A modified bilge pump and tubing apparatus were used to pump seawater out of the cooler, into the mouth and across the gills of the cobia, and back into the cooler to allow constant respiration during the surgical procedure (Figure 3). Fork and total length, as well as sex (when apparent) were recorded for each fish. A small (~30 mm) incision was made in the abdominal cavity just forward of the urogenital pore and off the centerline by 20-30 mm. The V16-4H acoustic tag was dipped in povidone iodine and inserted into the body cavity. The incision was then closed using one or two interrupted sutures. These methods were utilized in CRP project NA15NMF4540105 and typically allowed for quick recovery and robust condition at the point of release. Prior to tagging fish in the wild, a broodstock cobia from SCDNR's stock enhancement program was dummy tagged and observed over a six-month period. Based on these observations and in an effort to minimize negative effects on the fish from towing these tags, fish measuring 950 mm fork length and higher were implanted with a satellite tag. Following the surgical procedure, cobia were turned dorsal side up, at which time a stainless anchor (attached via short lead to the MiniPAT tag) was inserted into the dorsal pterygiophores of the fish approximately centered with the dorsal fin (Figure 4). An additional nylon dart tag was inserted into the pterygiophores on the opposite side in order to alert anglers to the additional tags and to ask them to release the cobia upon capture. Cobia was then transferred to the water, revived until able to swim off under their own power, and released (Figure 5). MiniPAT tags were programmed to provide pop-up timing ranging from 6-9 months depending on the month of tagging, resulting in additional verified locations during months when acoustic telemetry data is lacking based on tagging location.

Figure 3. Suture applied to cobia following insertion of acoustic transmitter.

The MiniPAT tag gathers depth, temperature, and light-level data while attached to the cobia. At either a preprogrammed date or upon a mortality event, which causes the animal to sink to depths where the tag may be crushed, the MiniPAT releases and floats to the surface. It begins transmitting its summarized data through the Argos satellite system until the battery is depleted. This usually takes 10 to 20 days. Should MiniPAT tags be recovered, the full data archive can be downloaded. The MiniPAT has the ability to send time series depth and/or temperature data through Argos. Sampling interval options range from 75 seconds to 10 minutes. Dawn and dusk light level curves, corrected for attenuation due to depth, are generated daily and geolocation calculations use these light curves to calculate animal horizontal habitat utilization and movement.

Figure 4. MiniPAT PSAT tagging location on cobia.

Once the tag is released from the animal, a recovery pinger provides transmissions that can be picked up via directional antenna and receiver. Project collaborators will again employ charter captains within our network to track down and physically collect tags. Our collaborator team encompasses a large geographic area along the southeast coast and can be quickly mobilized to respond when tags surface in offshore environments.

Figure 5. SCDNR Personnel with a cobia fitted with a MiniPAT PSAT tag and internal acoustic tag ready for release.

Cobia were primarily acoustically tagged during 2019-2020 and 2019-2021 for satellite tags (Table 1). Acoustic and satellite tagging in North Carolina occurred May/September but only included 5 satellite tagged cobia (Figures 6 & 7). Tagging efforts in South Carolina and Georgia primarily occurred in May/July however one fish was tagged off the coast of GA in December. In Florida, tagging occurred November through April or during summer upwelling events in July and September that brought cooler water and cobia into nearshore waters.

Table 1. Number of acoustic and satellite tags implanted in cobia in North Carolina, South Carolina, Georgia, and Florida during the project from 2018-2021.

Year	Acoustic Tagged Cobia (#)	Satellite Tagged Cobia (#)
2018	5	0
2019	57	12
2020	42	7
2021	20	7

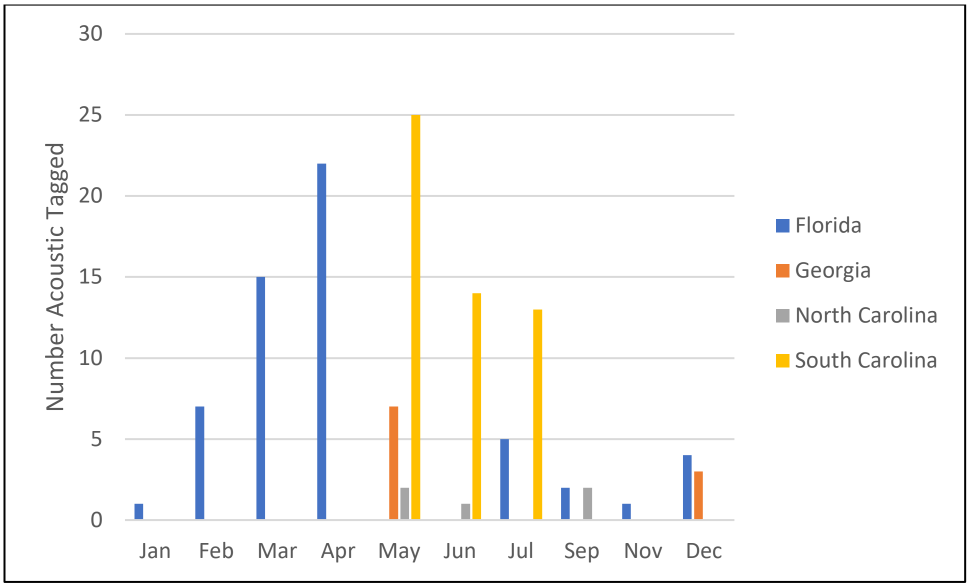


Figure 6. Acoustic tagging of cobia by state and month during 2019-2021.

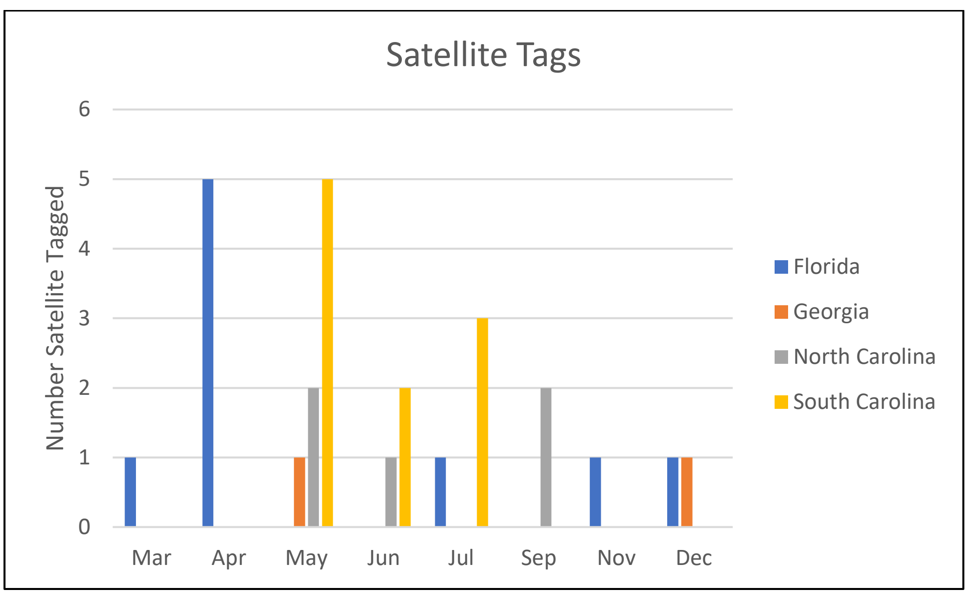


Figure 7. Satellite tagging of cobia by state and month during 2019-2021.

Overall, cobia tagged with acoustic tags had a mean FL of 845 mm (948 mm TL) with a minimum FL of 520 mm (615 mm TL) and a maximum of 1,230 mm FL (1,329 mm TL). A break down by state is displayed in Table 2. Cobia tagged with satellite tags had a mean FL of 1028 mm (1,156 mm TL) with a minimum FL of 890 mm (984 mm TL) and a maximum of 1,230 mm FL (1,329 mm TL). A breakdown by state is displayed in Table 3 and Figures 8 and 9 display the general tagging locations of all satellite tag deployments (Figure 8) and by northern or southern study region (Figure 9). Tagging locations were not evenly distributed throughout the region or throughout each individual state.

Table 2. Average fork length (FL), average total length (TL), and maximum and minimum FLs and TLs by state for all tags deployed during this study.

State	Fork Length (mm)	Minimum FL (mm)	Maximum FL (mm)	Total Length (mm)	Minimum TL (mm)	Maximum TL (mm)
Florida	821 ± 142.2	520	1230	912 ± 160.2	615	1328
Georgia	863 ± 78.3	760	1010	979 ± 97.0	850	1132
South Carolina	846 ± 124.3	617	1128	953 ± 138.4	691	1257
North Carolina	1062 ± 102.3	900	1161	1176 ± 127.3	984	1329
Grand Total	845 ± 136.4	520	1230	948 ± 153.5	615	1329

Table 3. Average fork length (FL), average total length (TL), and maximum and minimum FLs and TLs by state for all satellite tags deployed during this study.

State	Fork Length (mm)	Minimum FL (mm)	Maximum FL (mm)	Total Length (mm)	Minimum TL (mm)	Maximum TL (mm)
Florida	1037 ± 107.7	890	1230	1155 ± 127.9	990	1328
Georgia	981 ± 41.0	952	1010	1125 ± 9.9	1118	1132
South Carolina	1013 ± 64.0	942	1128	1153 ± 71.9	1072	1257
North Carolina	1062 ± 102.3	900	1161	1176 ± 127.3	984	1329
Grand Total	1028 ± 86.3	890	1230	1156 ± 97.3	984	1329

Figure 8. Locations of cobia fitted with MiniPAT PSAT tags throughout the study region.

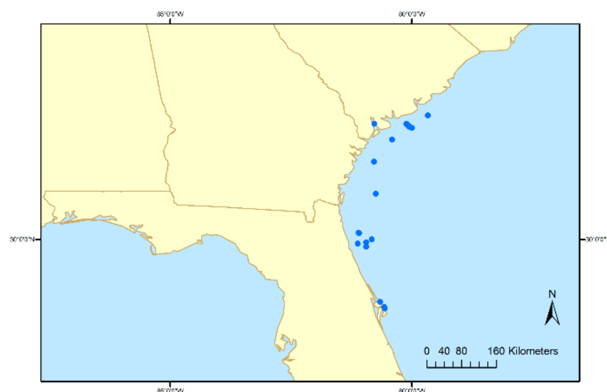


Figure 9. Locations of cobia fitted with MiniPAT PSAT tags in the northern region (left) and southern region (right).

As a cooperative research project, one of the primary goals was to involve charter guides in the data collection process. Because these guides spend countless hours on the water searching for cobia, their knowledge and experience helped us to increase our tagging sample size in an efficient manner. Over 2018-2021, a total of 16 charter guides in North Carolina, South Carolina, Georgia, and Florida participated in the study. Collectively, they were chartered for a total of 32 trips and were used to satellite tag 16 of 26 cobia (additional fish were tagged by project staff). Project funds were used to pay charter guides $12,200 for trip fees and an additional $2,400 for tagged fish. In total, $14,600 were transferred to the private sector for these services. Additionally, project staff have remained in contact with participating guides to provide ongoing updates on the results of this project. Each guide will receive a personalized summary of project results along with information specific to the fish that they helped tag. Through this outreach, we hope to maintain strong relationships with anglers who will remain vested in the science and management process into the future.

Receiver Downloads:

Receivers maintained by project partners in North Carolina, South Carolina, Georgia, and Florida were downloaded upwards to four times per year and made up the bulk of all cobia detections. In addition to our downloads, we received detection data from the United States Navy, Gray's Reef National Marine Sanctuary, Florida Atlantic University, the University of Miami, the University of Florida, The University of North Carolina, and the University of South Alabama. All data was provided to the FACT Network where data was QA/QC and distributed to researchers. Detection data is then maintained in a relational database (Microsoft access).

Several methods of validating data have been employed in telemetry-based studies to ensure the accuracy of detections (e.g. Bijoux et al. 2013; Young et al. 2016). In this study, detection data for tagged fish were validated before analysis by applying four rules: (1) removal of any detections before the date of surgery, (2) removal of any detections after a tag's published expiration date or after a known harvest date, (3) removal of detections that exceed a maximum swim velocity, specifically detections that occur within one hour at receiver stations over 10.5 km apart (2.9 meters/second), and (4) removal of continuous detections on a single receiver station for 2 months or more.

Results

Acoustic Detection Extent

Cobia tagged in this project were detected by acoustic receivers as far north as Delaware Bay, as far South as Key West, FL, and as far west as the eastern Gulf of Mexico near Tampa, FL (Figure 10).

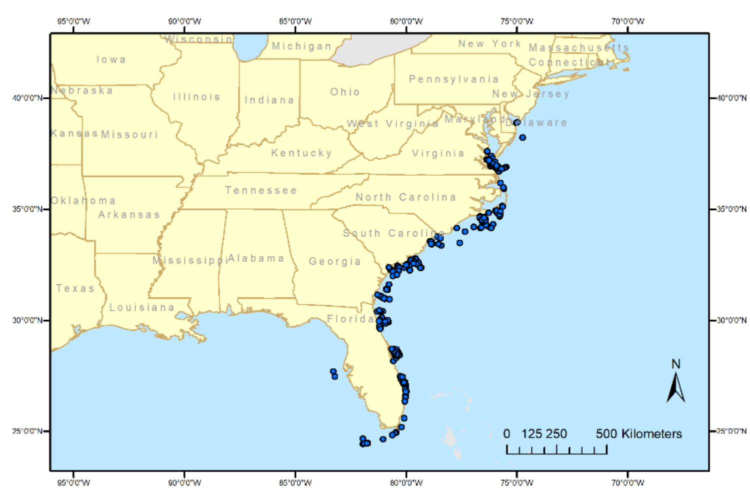


Figure 10. Geographic extent of all acoustic detections of cobia tagged during this study.

Breaking down the total detections to evaluate where fish that were tagged in each state were detected revealed (Figures 11-13) some directional movement or lack thereof depending on the state where cobia were tagged. However, the number of fish tagged in each state's waters appears to have an effect on distance of detections with states with more fish tagged (FL and SC) showing significantly broader geographic distributions of detections. Limited distribution of cobia tagged in Virginia and North Carolina waters are due to a small number of fish being tagged at the end of the 2021 seasons, with limited receiver downloads occurring since tagging.

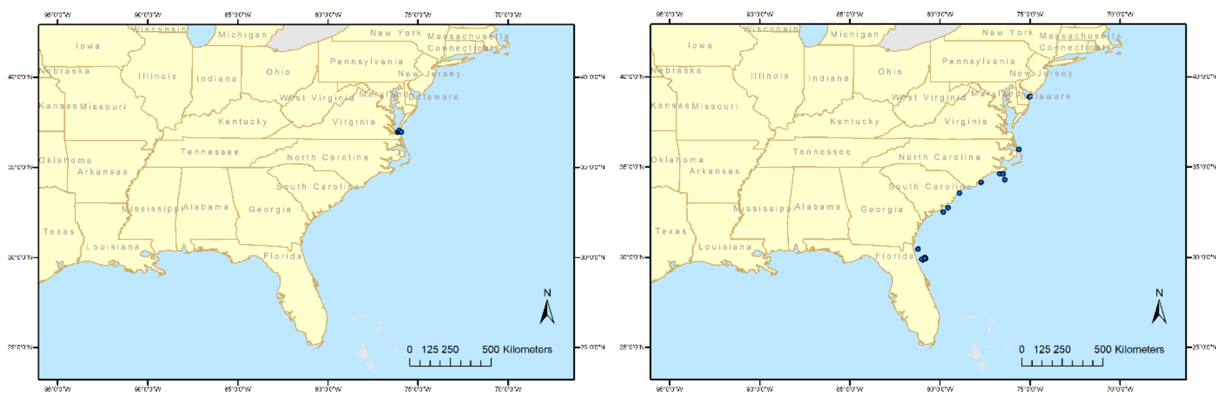


Figure 11. Detection extent of cobia tagged in Virginia (left) and North Carolina (right).

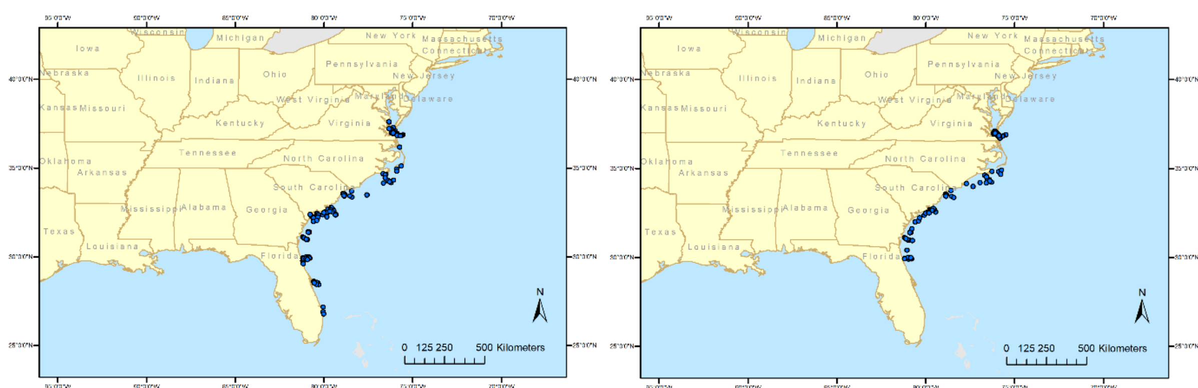


Figure 12. Detection extent of cobia tagged in South Carolina (left) and Georgia (right).

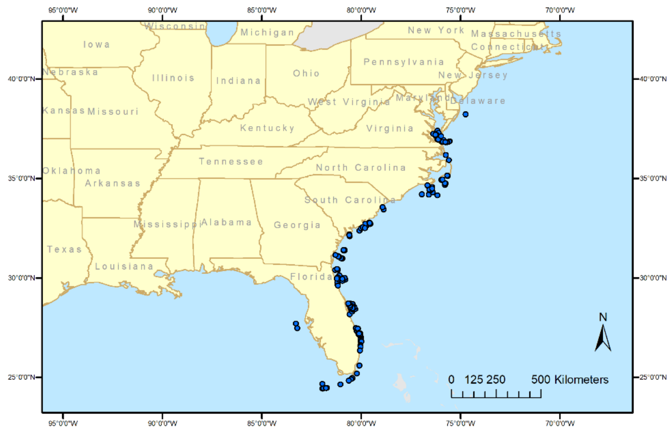


Figure 13. Detection extent of cobia tagged in Florida.

Fish tagged in South Carolina and Georgia exhibited broad detection ranges, with detections from fish tagged in South Carolina detected further south than any fish tagged in Georgia, but with similar northern detection limits (i.e., Chesapeake Bay). Since Florida was predicted for the majority of proposed mixing and denoted past and current population boundaries, we differentiated Florida detections among fish tagged in Northeast Florida (Figure 14), Central Florida (Figure 15), and Southeast Florida (Figure 16).

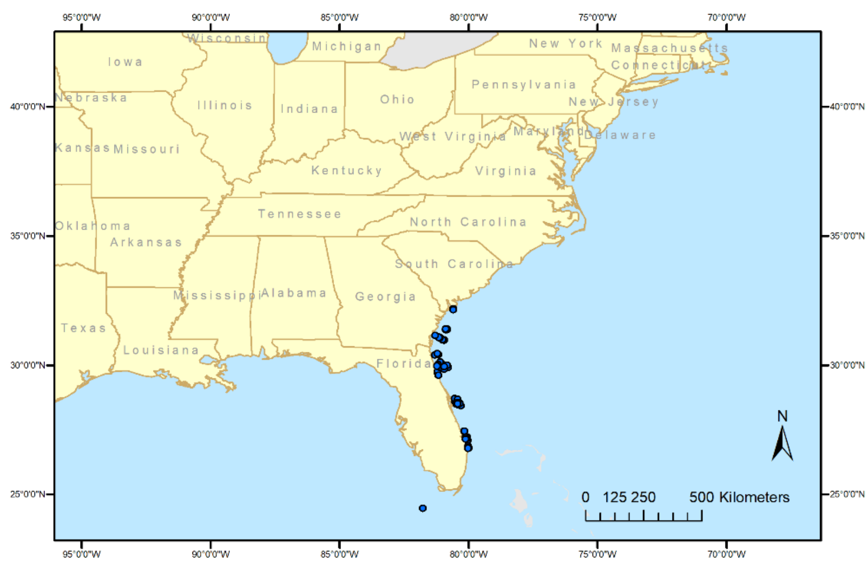


Figure 14. Detection extent of cobia tagged in Northeast Florida (St. Augustine and surrounding area).

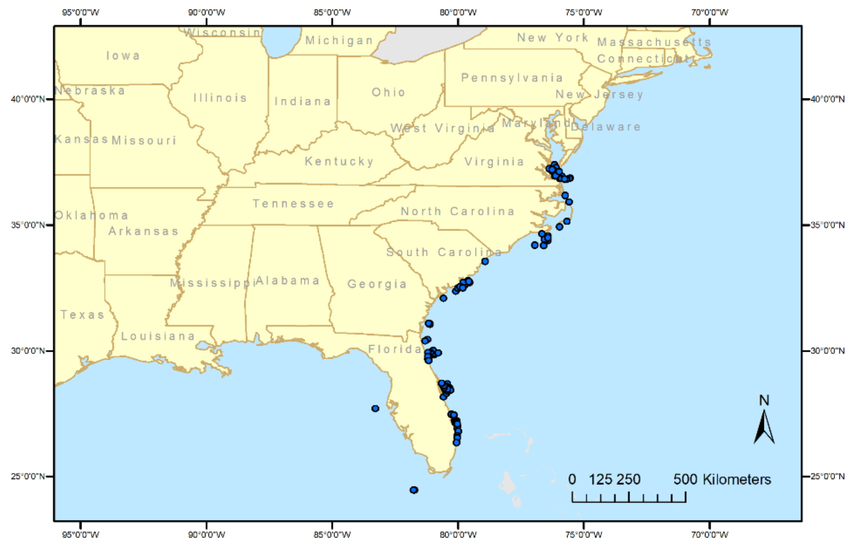


Figure 15. Detection extent of cobia tagged in Central Florida (Cape Canaveral area).

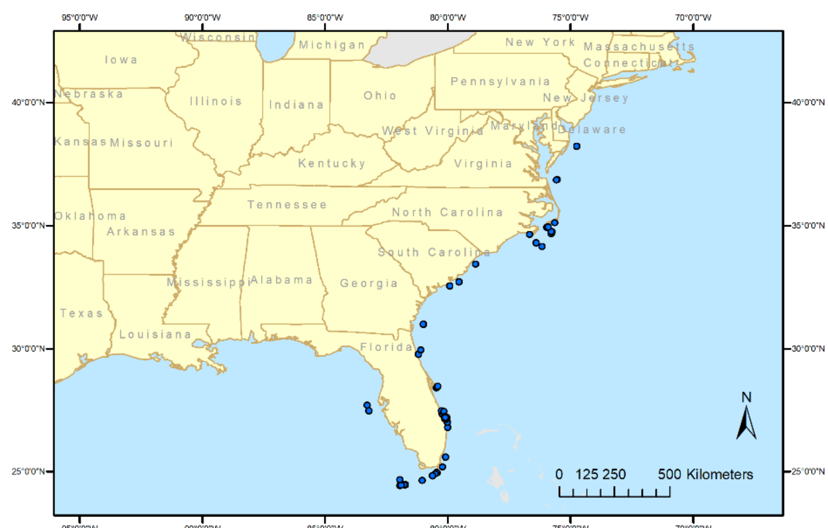


Figure 16. Detection extent of cobia tagged in Southeast Florida (Stuart/Jupiter area).

Of the Florida tagged fish, those tagged in the Northeast region had a smaller detection extent range than those tagged in central or Southeast regions of the state. Fish tagged in Southeast Florida had the greatest detection extent of any state or region and included the tags that were detected at Northern, Southern, and Western extremes of total detections. Combining data from previous tagging efforts and studies, including CRP NA15NMF4540105, for numbers of cobia tagged and detections of those individual animals in subsequent years, we find that many tags are viable for multiple years and continue to return valuable data (Table 4).

Table 4. Number of detected fish by year. "#Tagged" is the number of fish tagged that year and for each year along that row are the number of fish detected out of that cohort in the subsequent years.

		# Detected Each Year							
Year	#Tagged	2014	2015	2016	2017	2018	2019	2020	2021
2014	1	1	1	1	0	0	0	0	0
2015	5		4	3	4	3	3	1	0
2016	110			95	66	31	16	7	2
2017	28				23	10	8	0	0
2018	5					4	3	2	0
2019	56						49	24	11
2020	31							22	17
2021	19								13

Acoustic Telemetry

Data aggregation

Collaborators on the project deposited tag metadata, receiver deployment metadata, and detection files in the FACT online data processing system (aka the FACT node). From 2018 – 2021, project collaborators contributed data from 1,557 downloads and 255 tag deployments. Data were processed semi-annually where all tag and detection data are quality controlled and cross-matched within the FACT network and between networks using a compatible system. Most relevant to this project was the cross-matching between the ACT and OTN nodes. Raw and processed data are held in Research Workspace (www.researchworkspace.com). The data are held in a format as to be ingestible into the national-level Animal Telemetry Network Data Assembly Center (ATN DAC), where it will be archived. The collaborators are working with ATN staff to finalize the pathway into the DAC. The treatment and storage of data followed the FACT User policy (https://secoora.org/fact/resources/fact-user-agreement/). Summarized project data is accessible at: https://secoora.org/fact/data-visualization-tool/.

Methods- Quality control

Acoustic telemetry data contains erroneous detections due to the level of noise around a receiver caused by biotic and abiotic factors. Sufficient filtering of the data is required to produce a robust dataset reflective of the study animals. Telemetry data were quality controlled in two processes. The first process includes the quality control checks built into the FACT online data processing system (aka the node). Receiver deployments are checked for dual deployments, locations are checked against previously reported locations for the same stations, and tag detections from before deployment and battery expiration are discarded. This ensures the equipment is where the researcher said it was during the stated time period. Secondary sources of detections, specifically from arrays that do not use a compatible online system, do not undergo the same checks. The second process utilizes species level quality control rules implemented by the researcher. Detections matched to tags in the project were flagged if the velocity between locations exceeded 2 m/s (velocity filter from Resonate), locations were outside the species range of cobia (range filter), and if a tag was detected continuously on a single receiver for at least six hours a day for a week or more (fatality filter). Flagged detections were removed. Species level quality controls were applied using Jupyter notebooks.

Following Williamson et al. (2021), the recursion factor was calculated for the population. A recursion is when an animal leaves the detection range of a receiver, then is detected again at the same location. For recursion, detections less than six minutes were removed from the data to ensure that an animal had left the detection range based on tags that ping at a random with an interval of 120-160 seconds. Outliers, extremely long durations between detections at the same location, were trimmed and capped following the Inter-Quartile Range (IQR) rule whereby recursion times which fall below Q1-1.5 IQR or above Q3+1.5 IQR are considered outliers (Goyal, 2021). Time differences were log transformed to normalize the data and the Fisher-Jenks algorithm was used for ranking data into natural breaks (Moffit, 2019). Data were ranked using jenkspy in Jupyter notebooks. This resulted in a threshold of 31 minutes for cobia. Recursions were calculated in Jupyter notebooks with Python code.

Calculating detection events compresses the dataset, without losing information on individual movements. The recursion threshold was used to calculate detection events, if time between detections exceeded 31 minutes, it was considered a new detection event. Detections events were calculated using compress_detections from resonate.

Methods- Network analysis

To quantify spatial relationships between individuals, we developed undirected movement networks, where each node represents an individual and the tie between them an associative link. Undirected ties were defined as the presence of two individuals at the same receiver station within one week. The weight of the tie was the number of times two individuals were present at the same location. Presence was determined using the cohort analysis tool in resonATe.

Shared space between within the GOM and ATL stocks and between stocks were calculated by the number of edges and nodes per month. Stock was determined by the point of capture and tag implementation- a proxy for the stock assignment if the animal had been harvested. Stocks were divided at the Florida/Georgia border, animals tagged north of the Florida/Georgia border were assigned to the ATL stock and individuals tagged south of the Florida/Georgia border were assigned to the GOM stock. Areas of overlap were visualized on a map. Descriptive statics were calculated on the timing, specific place of original capture, and location of mixing between stocks. Network analyses were conducting using network in Jupyter notebooks.

Rationalized network visualization was achieved using hive graphs. Due to the number of tagged individuals, (nodes, n=255), a hairball layout was not informative. The resulting layout displays ties between individuals within each stock and between stocks overall and by month. Ties by month were summed across years. For ease of interpretation, nodes are colored by stock.

Results- Quality control and data processing

Tagged cobia were detected on 24 separate arrays along the US Atlantic coast and eastern Gulf of Mexico. Applying quality control rules resulted in a dataset with 184,604 detections (including release, recapture, and harvest observations) from 255 cobia. Of the 255 tagged individuals, 36 were only detected once and were removed from further analysis. Using the recursion factor of 31 minutes, 30,171 detection events at 959 receiver stations were calculated. Time between first and last detection ranged from 1 – 1782 days with a mean of 376 days, suggesting acoustic telemetry is an effective means for tracking cobia across years.

Results- Network analysis

The number of edges, or times two individuals were present at the same receiver station within a week, were calculated by month (Table 5). In general, there was more mixing within the ATL stock compared to within the GOM stock. While less than within-stock mixing, mixing between stocks was evident (Figure 17).

Cobia from each stock intermixed every month of the year to varying extents (Table 6, Figure 18). In general, mixing was highest in the early fall to mid-winter. Thirty percent of tagged cobia (64 out of 219 tagged fish that were detected more than once) mixed in space and time with fish from a different stock. Tagging locations of mixing fish were: Georgia- 13, North Carolina – 1, South Carolina – 25, Virginia – 1, Northeast Florida (NEFL) – 6, Central Florida (CEFL) – 9, and Southeast Florida (SEFL) – 8. The differences in the number of mixing fish by tagging area may not confer importance of that area as a source of mixing individuals. Rather, the proportion of mixing fish to the total number tagged in a specific area is more informative. The tagging area that yielded the highest number of mixing fish was NEFL (66%), followed by Georgia (48%), and South Carolina and CEFL (26% and 25%, respectively). Fish tagged in south Florida had the lowest rate of mixing at 16%.

To visualize where the mixing was occurring, we plotted the points of within stock mixture and between stock mixture. Stock mixing occurred from CEFL to South Carolina and Virginia (Figure 19). Mixing south of Canaveral was rare- only one fish tagged in Georgia was detected in SEFL. In total, nine fish tagged in Florida were detected north of the Florida/Georgia border, all of which were tagged in March (n=2, SEFL), April (NEFL=1, CEFL=3), and July (SEFL=1, NEFL=2). Nine tags deployed north of the Florida/Georgia border (GA-4, SC – 4, NC -1) were detected in Florida.

To visualize when the mixing was occurring, we plotted areas of mixing by month (Figure 20). Generally, the mixing pattern followed the paradigm of ATL cobia moving south into warmer waters during the winter months. The furthest extent of mixing in CEFL occurred Oct – March, while mixing in NEFL extended from July – Dec. Mixing in Virginia occurred from June- Sept and was attributed to two cobia tagged near Cape Canaveral on the same day (April 6th, 2019).

In summary, the results of the network analysis and description of the temporal and spatial extent of mixing suggest Cape Canaveral is an effective boundary between the ATL and GOM stocks. Further analysis pairing genetic profiles with movements would help better characterize the stock in central and northern Florida as well as identify migratory contingents from the ATL stock.

Table 5. Number of edges and nodes by month.

Month	N nodes total (individuals)	N edges	N nodes GOM stock	N nodes ATL stock
Jan	29	57	28	1
Feb	28	65	28	0
Mar	47	132	43	4
Apr	79	154	51	28
May	100	235	70	30
Jun	104	376	79	25
Jul	72	119	39	33
Aug	67	133	38	29
Sept	40	35	14	26
Oct	81	149	27	54
Nov	64	80	22	42
Dec	33	49	22	11

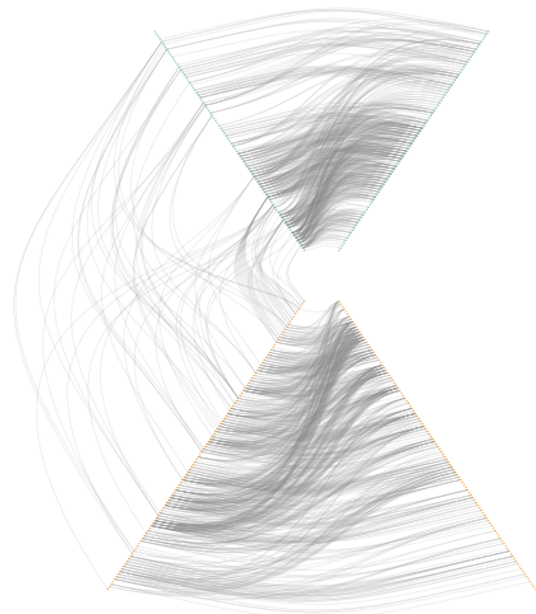


Figure 17. Hive graph of connections within and between stocks. Edges are grey, GOM nodes are blue and ATL nodes are yellow. Time is inclusive of all months throughout the study.

Table 6. Number of edges by month of mixing between stocks of cobia.

Month	N edges
Jan	3
Feb	0
Mar	4
Apr	13
May	10
Jun	6
Jul	6
Aug	15
Sep	19
Oct	40
Nov	11
Dec	13

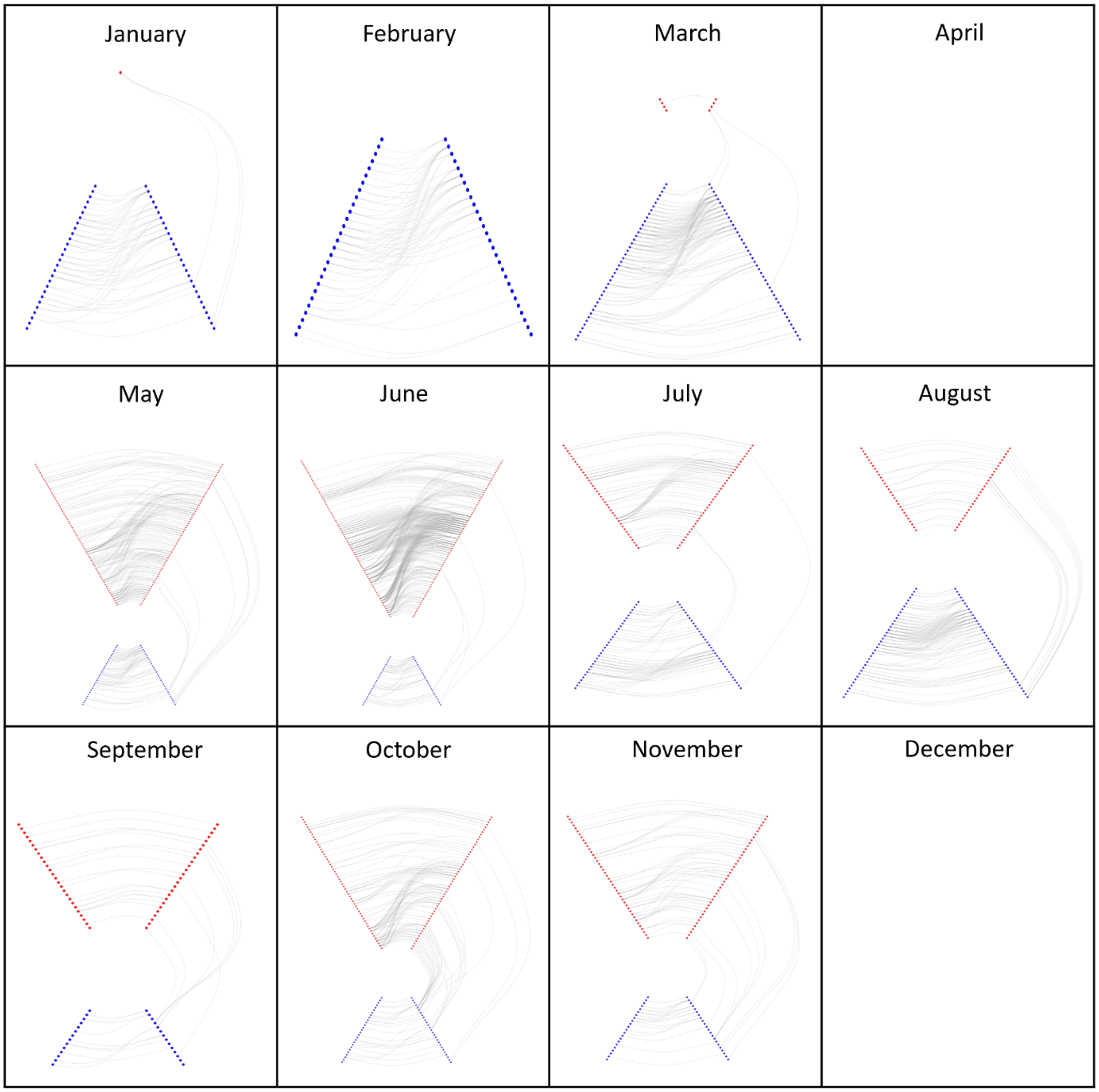


Figure 18. Hive graphs by month. Edges are grey, ATL nodes are red and GOM nodes are blue.

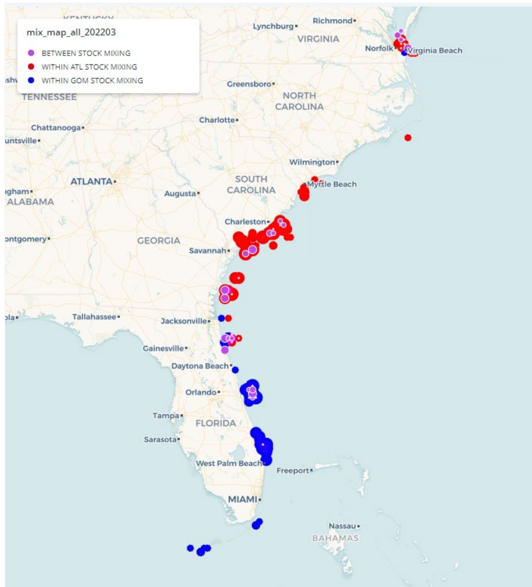


Figure 19. Locations of within stock mixing (ATL:red, GOM:blue) and between stock mixing (purple).

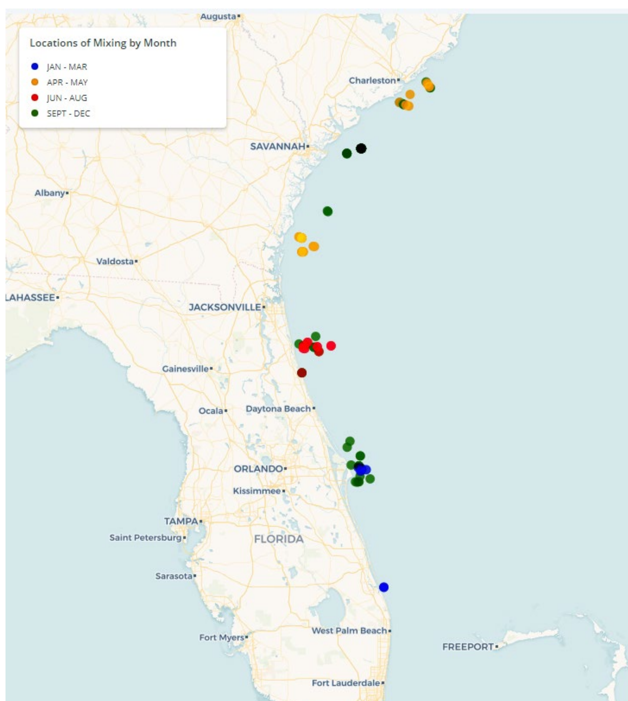


Figure 20. Areas of mixing by month. Circles are receiver stations where mixing occurred. Jan-Mar are blue, Apr - May are orange, Jun - Aug are red, and Sep - Dec are green.

Genetic Sample Collection

Non-lethal genetic samples (fin clip) were taken from all cobia captured during this study, regardless of size and whether they were fitted with an acoustic tag, satellite tag, or both. This is part of a larger and on-going effort to collect more genetic data to better understand the wild populations and potentially genetically unique sub-populations of cobia that utilize the southeast during various times of the year. In addition to adding to the population genetics dataset for modelling and increased understanding of populations and their interactions, the South Carolina Department of Natural Resources' population genetics group uses these fin clips to determine parentage and assess if any cobia caught are from the State's marine finfish stocking program for cobia, which releases juvenile (60-90mm TL) cobia annually into the Port Royal Sound, SC area to support a genetically distinct sub-population that utilizes that area for spawning in the late Spring and early Summer.

In 2018, one cobia fin clip was collected in Florida. In 2019, 148 fin clips were collected in North Carolina, 39 fin clips were collected in South Carolina, 9 fin clips were collected in Georgia, and 60 fin clips were collected in Florida. Two of the cobia captured in 2019 in South Carolina in the Broad River were cultured fish from the 2017YC releases from the South Carolina Department of Natural Resources' marine finfish stock enhancement program. In 2020, 42 fin clips were collected in North Carolina, 44 fin clips were collected in South Carolina, and 18 fin clips were collected in Florida. In 2021, 44 fin clips were collected in North Carolina, 21 fin clips were collected in South Carolina, and 21 fin clips were collected in Florida.

MiniPAT PSAT Tag Results

Twenty-six satellite tags were deployed or re-deployed during the course of this study with several still deployed and at-large as of March 2022 (Table 8). Multiple tags popped-off shortly after deployment, but without recovering many popped tags, the reasons for these are unknown. Post-release handling related mortality, post-release predation, insufficient anchoring of the tag in the animal, battery failure, and tags releasing prematurely are all potential explanations. Two of the deployed tags, which should have popped-off, have never communicated with the satellite communication system, four tags that were deployed were identified by Wildlife Computers to have battery issues. These tags, and several other undeployed tags at that point in the study, were replaced by the manufacturer for redeployment on other cobia. One tag popped off the same day as tagging, washed ashore and was able to be reprogrammed for redeployment and one tag never popped off or communicated with the satellite system but the fish was harvested by a recreational fisherman and gaffed before the tags were observed.

Table 8. Tagging information for 26 MiniPAT PSAT tags deployed during this study.

Tag	Tagged (Date)	Pop-off (Date)	Deployed Duration (Days)	State	Area	TL (mm)	FL (mm)
18P1287	5/26/2019	7/5/2019	40	SC	Betsy Ross HH	1189	1043
18P1288	4/6/2019	7/12/2019	97	FL	Cape Canaveral	nr	1110
18P1289[a]	4/6/2019	4/10/2019	4	FL	Cape Canaveral	nr	970
18P1290[b]	11/26/2019			FL	St. Augustine	1310	1230
18P1291[a]	5/22/2019	12/3/2019	195	SC	Edisto 60	1216	1068
18P1294	5/15/2019	5/28/2019	13	GA	St. Catherines Island	1118	952
18P1296[a,b]	4/25/2019			FL	St. Augustine	1150	1010
18P1305	5/28/2019	6/7/2019	10	NC	Cape Lookout - Moorehead	1149	1029
18P1309	6/18/2019	7/30/2019	42	FL	St. Augustine	1120	1010
18P1341[a]	4/24/2019	11/17/2019	207	FL	St. Augustine	1160	1020
18P1343	5/8/2019	10/15/2019	160	SC	Edisto 60	1230	1080
18P1345	5/6/2019	7/29/2019	84	SC	Edisto 60	nr	981
19P1030	6/6/2021			NC	Mouth of Chesapeake Bay	1181	1111
19P1068	6/26/2020	1/1/2021	189	SC	Edisto 60	1079	954
19P1130	7/6/2021	2/26/2022	235	SC	Charleston 60	1125	987
19P1236	9/13/2021			NC	Chesapeake Bay Bridge	1238	1110
19P1398	3/18/2020	3/20/2020	2	FL	Cape Canaveral	990	890
19P1504[c]	4/20/2021	4/20/2021	0	FL	St. Augustine	1328	1151
19P1507	12/22/2020	12/23/2020	1	FL	St. Augustine	1030	940
19P1601	7/1/2020	7/3/2020	2	SC	Edisto 60	1257	1128
19P1641	5/27/2021			NC	Nags Head Pier	984	900
19P1642	9/8/2021			NC	Chesapeake Bay Bridge	1329	1161
19P1691	6/10/2020	7/3/2020	23	SC	Edisto 60	1072	943
19P1692	7/15/2020	9/25/2020	72	SC	Edisto 60	1076	942
20P0260	12/10/2020	7/16/2021	218	GA	Brunswick GA	1132	1010
20P2664[d]	5/19/2021	6/18/2021	30	SC	Broad River Bridge	1129	1005

[a] Tags with reported battery issue by Wildlife Computers.

[b] Tag never popped off or communicated with satellite.

[c] Tag popped off and washed ashore without reporting to satellite, reprogrammed for reuse.

[d] Tag never popped off or communicated with satellite, fish was harvested by recreational angler off Hilton Head, SC.

To better understand the movement extent of individual cobia, Table 5 displays the minimum (10.1 °C) and maximum temperatures (31.4 °C) recorded by each tag, the minimum (0 m) and maximum (241.5 m) depth recorded by each tag, and the maximum and minimum latitudes and longitudes recorded by each tag. To limit the skewing of data by tags that were not deployed long enough for cobia to potentially leave the immediate tagging area, only tags which were deployed for at least 10 days are included in Table 9.

Table 9. Tag recorded temperature, depth, and location data for MiniPAT PSAT tags deployed at least 10 days.

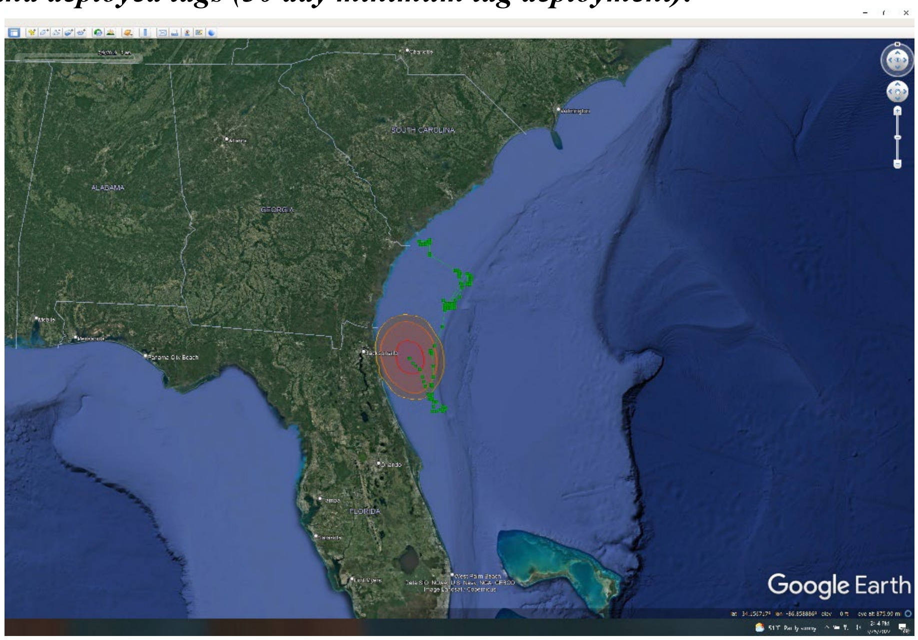
Tag	Deployed Duration (Days)	Min Temp (°C)	Max Temp (°C)	Min Depth (m)	Max Depth (m)	Avg Depth (m)	Max North	Max South	Max West	Max East
18P1287	40	20.6	29.7	0.5	70	28.3	32.125, -80.375	29.375, -80.35	32.1, -80.575	31.525, -79.6
18P1288	97	20.4	29.7	0.5	73.5	23.2	32.825, -78.125	28.625, -80.6	30.85, -81.1	32.825, -78.125
18P1291[a]	195	12.9	30.5	1.5	194.5	52.8	33.5, 76.575	29.925, -79.4	31.6, -80.8	32.875, -76.425
18P1294	13	21.9	27.3	0.5	31	17.7	32.775, -78.675	31.625, -80.775	31.625, -80.775	32.775, -78.675
18P1305	10	22.9	26.9	0.5	42	27.2	34.625, -76.4	33.675, -76.6	33.8, -76.65	33.875, -75.825
18P1309	42	22.4	29	2	76.5	28.1	29.875, -81.125	28.425, -80.125	29.875, -81.125	28.55, -79.875
18P1341[a]	207	17.4	29.8	0.5	56.5	21	31.625, -80.15	27.85, -80.075	30.125, -21.125	30.275, -77.325
18P1343	160	11.7	30.4	1	241.5	31.2	32.65, -79.55	27.6, -78.975	29.85, -80.925	27.625, -78.9
18P1345	84	15.1	30.8	0.5	142	29.3	32.675, -79.125	29.2, -80.325	29.625, -80.575	32.4, -78.95
19P1068	189	11.1	31.4	1	219.5	39	35.875, -75.1	30.725, -78.525	31.1, -80.825	33.675, -74.125
19P1130	235	11.9	30.4	2	174.5	44.5	32.625, -79.85	31.5, -79.85	32.15, -80.375	32.325, 78.875
19P1691	23	19.9	28.5	0.5	102	37.4	32.575, -78.725	30.625, -80.8	30.625, -80.85	31.675, -78.6
19P1692	72	10.1	31.1	1	179	57.1	32.35, -80.1	28.7, -80.125	32.1, -80.4	30.6, -79.1
20P0260	218	14.8	27.2	0.5	111.5	24.8	38.5, -73.875	30.15, -80.4	30.55, -80.925	38.5, -73.875
20P2664[b]	30	23.1	28.85	0	32.5	8.5	32.4, -80.625	31.275, -79.875	32.4, -80.625	31.275, -79.875

[a] Tags with reported battery issue by Wildlife Computers

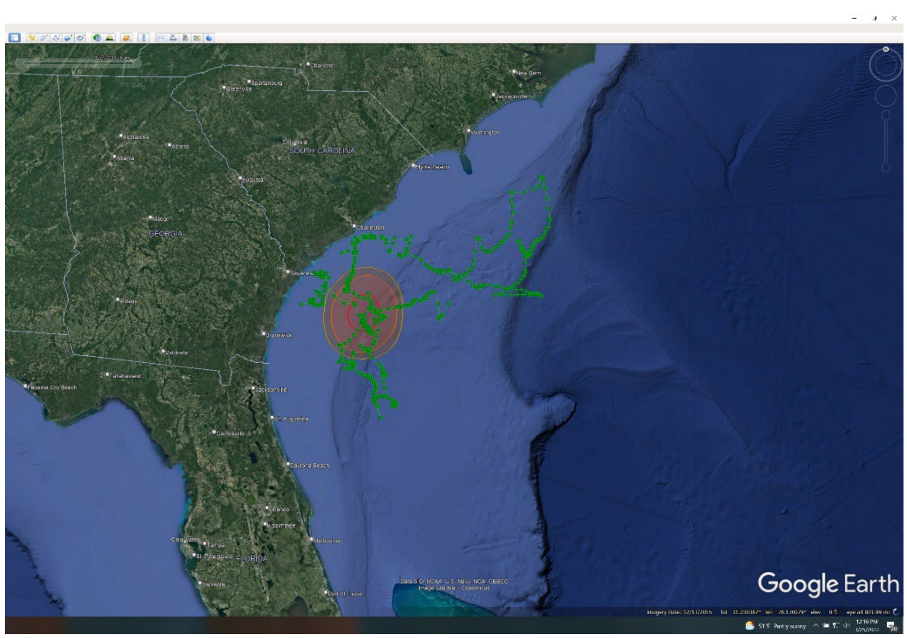
[b] Tag never popped off or communicated with satellite, fish was harvested by recreational angl

Detailed Satellite Movement Results

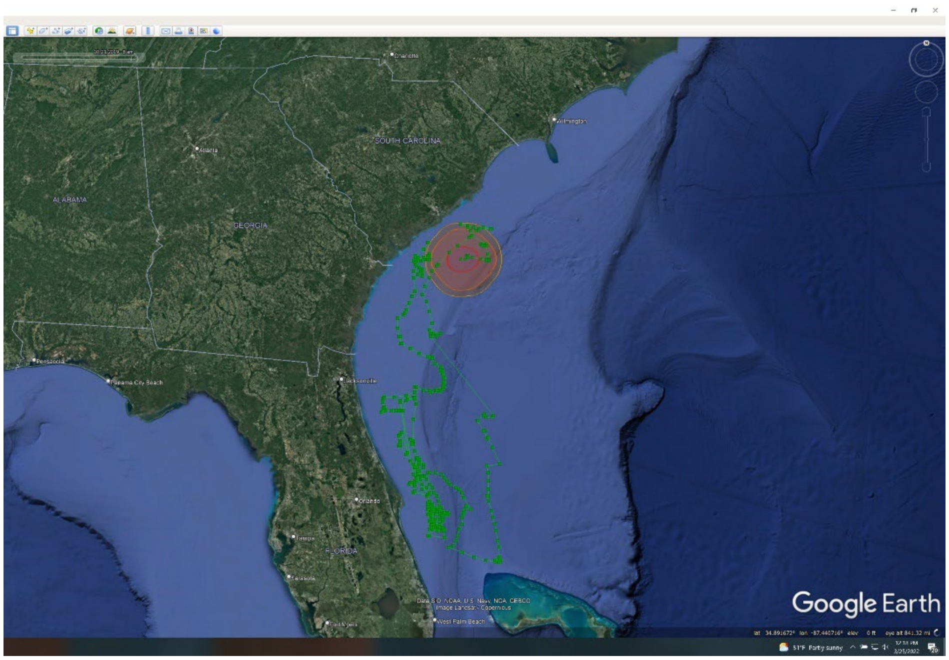
South Carolina deployed tags (30 day minimum tag deployment):



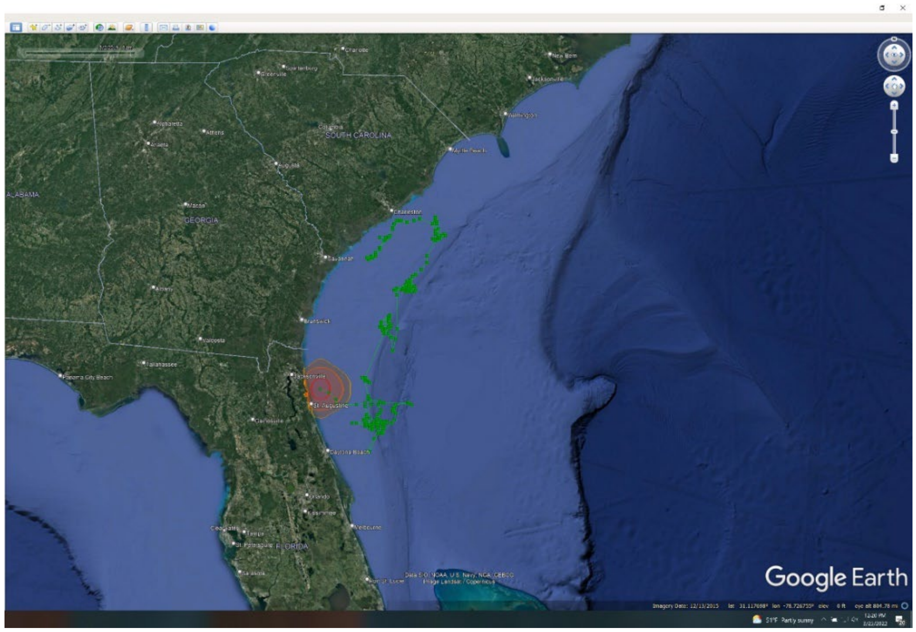
Satellite tag 18P1287 was deployed offshore of Hilton Head, SC on 05/26/2019 and remains within this area for approximately two weeks before traveling southwest into the Gulf Stream off the coast of GA. This fish continues as far south as Dayton Beach in the Gulf Stream then begins moving northwest before the tap releases off the coast of Jacksonville, FL on 7/5/2019, 40 days after deployment.



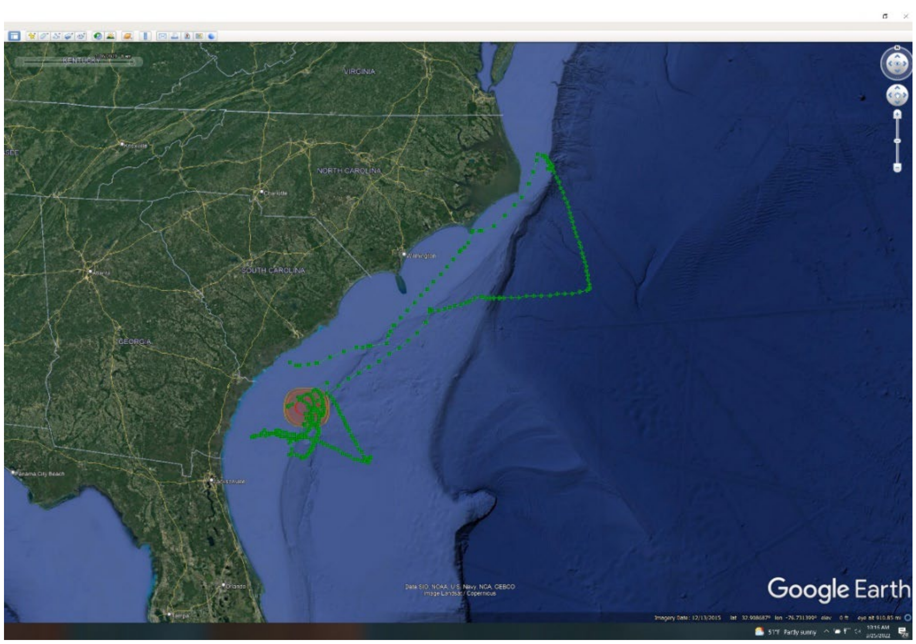
Satellite tag 18P1291 was deployed offshore of Edisto, SC on 5/22/2019 and begins moving southeast into waters off the GA coast and eventually into the Gulf Stream. The fish continues as far south as St. Augustine during late spring into early summer before moving back north, still within the Gulf Stream, until SC where it moves further offshore towards the ledge of the continental shelf where it spends the month of September. The fish begins an eastward track towards the coast of SC/GA getting within approximately 30 miles of the coast for the month of October. During early winter the fish moves back to the Gulf Stream off the GA before the tag releases on 12/3/2019, 195 days after deployment.



Satellite tag 18P1343 was tagged offshore of Edisto, SC on 5/8/2019 and remains in the area for a couple of weeks before traveling south into Florida waters during May. This fish then moved into the Gulf Stream offshore Jacksonville, FL for a brief period before moving west and south along the Florida coast. The fish remained landward of the Gulf Stream and as far south as Melbourne, FL until September when it moves east into the Gulf Stream and eventually close to the Bahama Islands. In late September, the fish begins moving north within the Gulf Stream and eventually west toward the coast of SC where it remains until the tag deploys on 10/15/2019, 160 days after release.

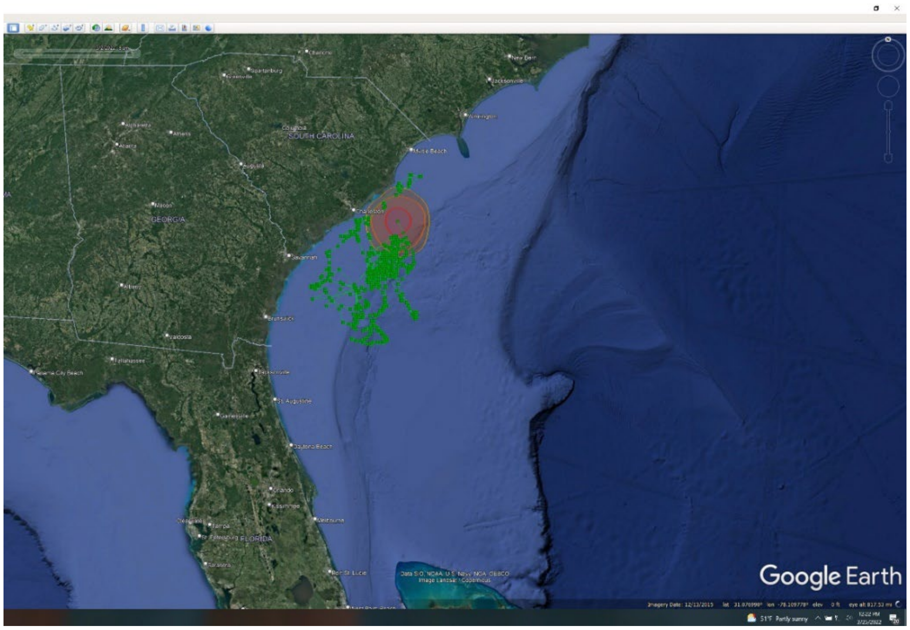


Satellite tag 18P1345 was tagged offshore of Edisto, SC on 5/6/2019 and remains nearshore SC until it moves westward into the Gulf Stream. During June, the fish begins moving south towards Daytona Beach while staying within the Gulf Stream before moving eastward towards the Northeastern Florida coast. The tag detaches from the fish on 7/29/2019 offshore of St. Augustine, FL, 84 days after deployment.

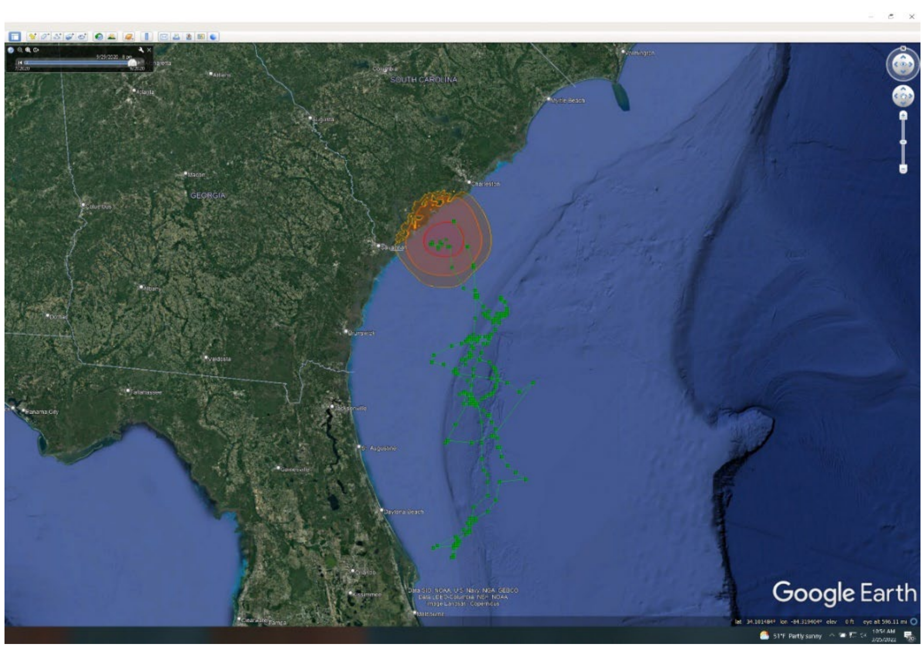


Satellite tag 19P1068 was tagged offshore of Edisto, SC on 6/26/2020 and begins an east, northeast track towards the Gulf Stream before turning north and making its way into NC waters in July. The fish travels up around the Outer Banks then moves southeast past the Gulf Stream and the ledge of the continental shelf during August. An eastward track is seen until the fish hits the Gulf

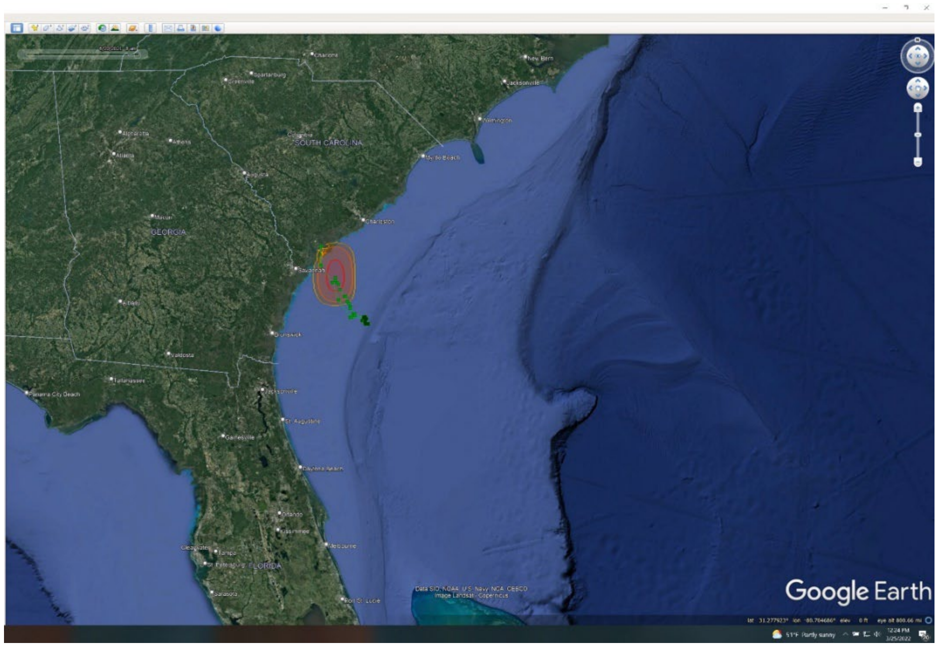
Stream before moving south offshore of GA where it remains until the tag pops off on 1/1/2021, 189 days after release. This fish is a good indicator that some overwintering of cobia is occurring around the warm Gulf Stream waters.



Satellite tag 19P1130 was tagged offshore of Charleston, SC on 7/6/2021 and travels south and east until the Gulf Stream off the coasts of GA and SC where it remains until the fall. During the early fall the fish moves landward and north back into SC coastal waters before returning to the Gulf Stream to overwintering. The tag deployment ended on 2/26/2022, 235 days after deployment making it the longest retained tag to date. This fish also shows that the Gulf Stream appears to be an import overwintering area for cobia off the eastern coast of America.

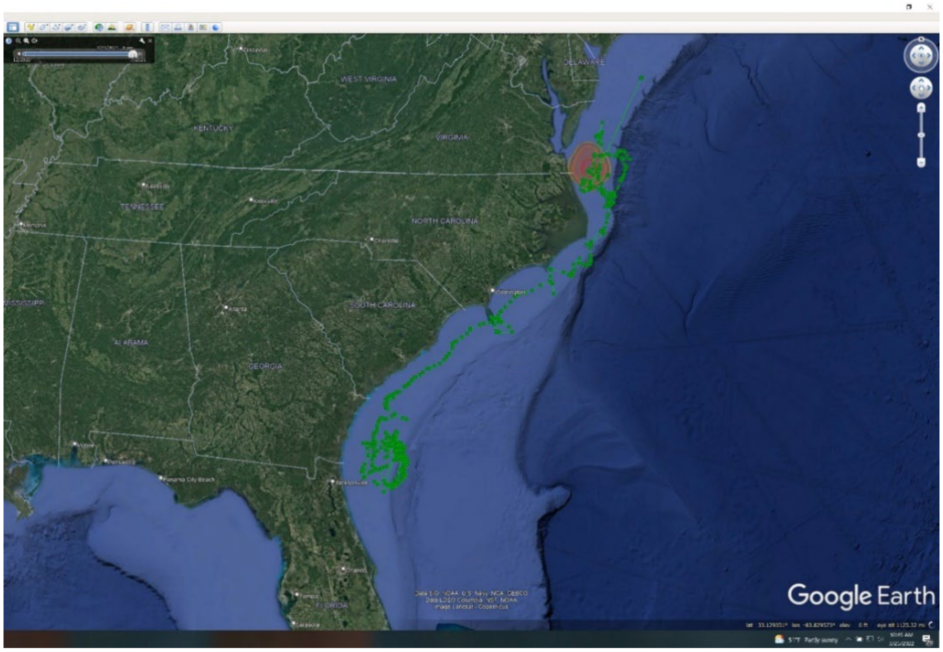


Satellite tag 19P1692 was tagged offshore Edisto, SC on 7/15/2020 and moves almost immediately south until it hits the Gulf Stream offshore GA. The fish continues its southward during the summer months until it reaches Cape Canaveral. In early September, the fish begins moving north within the Gulf Stream until it gets close to the GA/SC border at which point it moves westward toward shore before the tag pops off on 9/25/2020, 72 days after deployment.



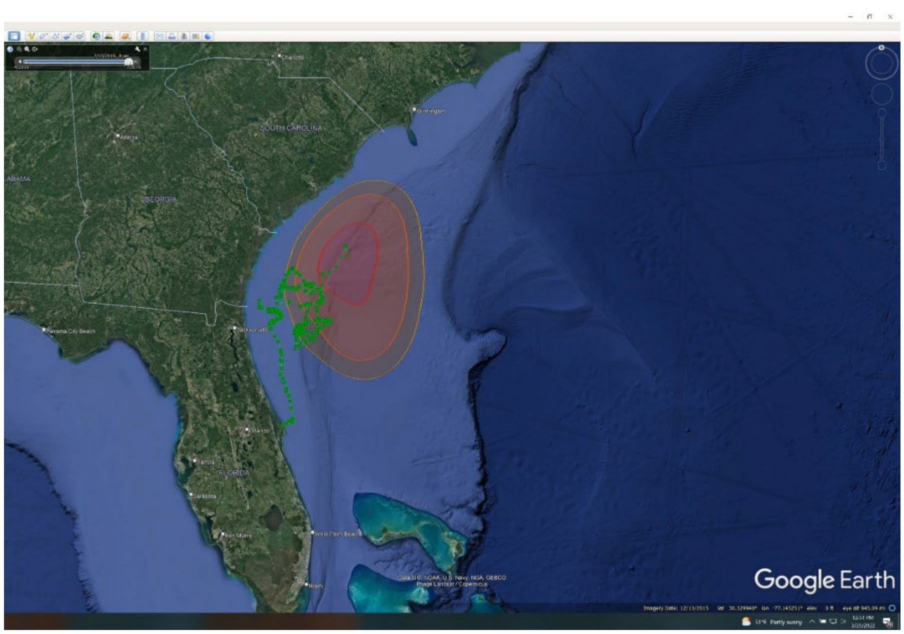
Satellite tag 20P2664 was tagged within the Port Royal Sound of SC where a know unique population segment has been identified. The fish begins moving southeast for the next two weeks until it enters the Gulf Stream and remains for a week. The fish follows a similar track back to its original tagging location before it was recaptured and harvested by an angler on a reef offshore of Hilton Head on 6/18/2021, 30 days after deployment.

Georgia deployed tags (30 day minimum tag deployment):

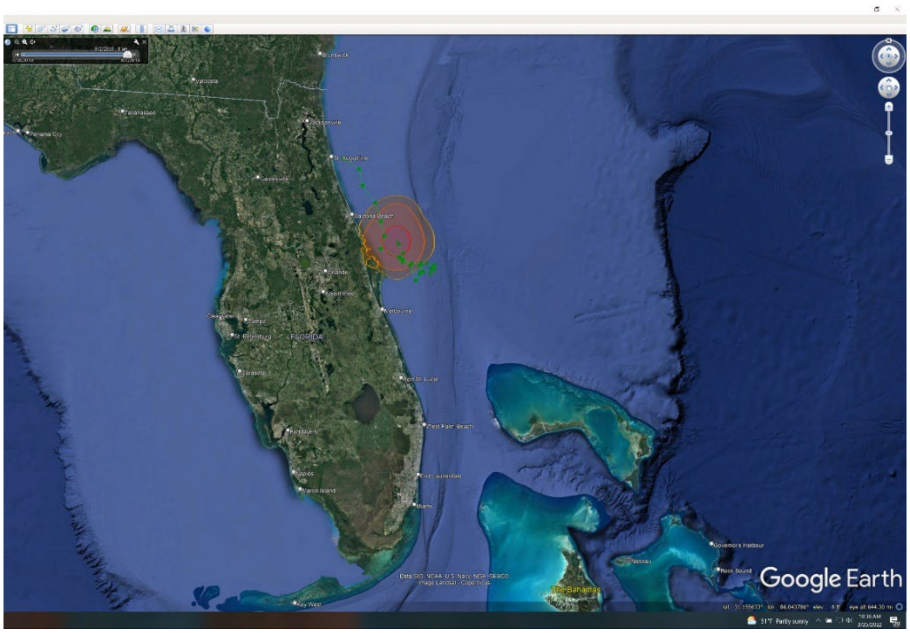


Satellite tag 20P0260 was tagged on 12/10/2020 off the coast of Brunswick, GA. This fish moved to the Gulf Stream off the coasts of GA and northern FL for the winter before moving nearshore and up the eastern seaboard beginning in April. The fish appears to spend some time around Cape Fear and Cape Lookout NC before moving off the coast of VA in June where it remained until the tag deployed on 7/16/2021, 218 days after initial release.

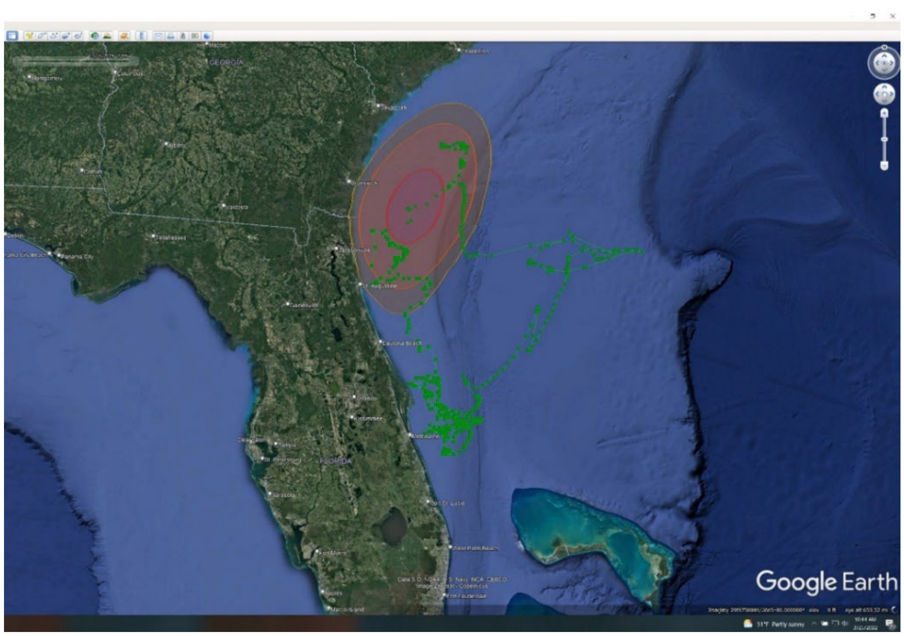
Florida deployed tags (30 day minimum tag deployment):



Satellite tag 18P1288 was tagged offshore Cape Canaveral on 4/16/2019. This fish shows a general northward track in offshore GA waters during the spring months. During the summer, the fish moves into Gulf Stream waters off the GA/FL coast until the tag pops off on 7/12/2019, 97 days after deployment.



Satellite tag 18P1309 was initially tagged on 6/18/2019 offshore of St. Augustine, FL. Based on geolocation data from the satellite tag, the fish moved south until it was offshore of Cape Canaveral where it made a brief trip to the Gulf Stream before the tag released on 7/30/2019, 42 days after deployment.

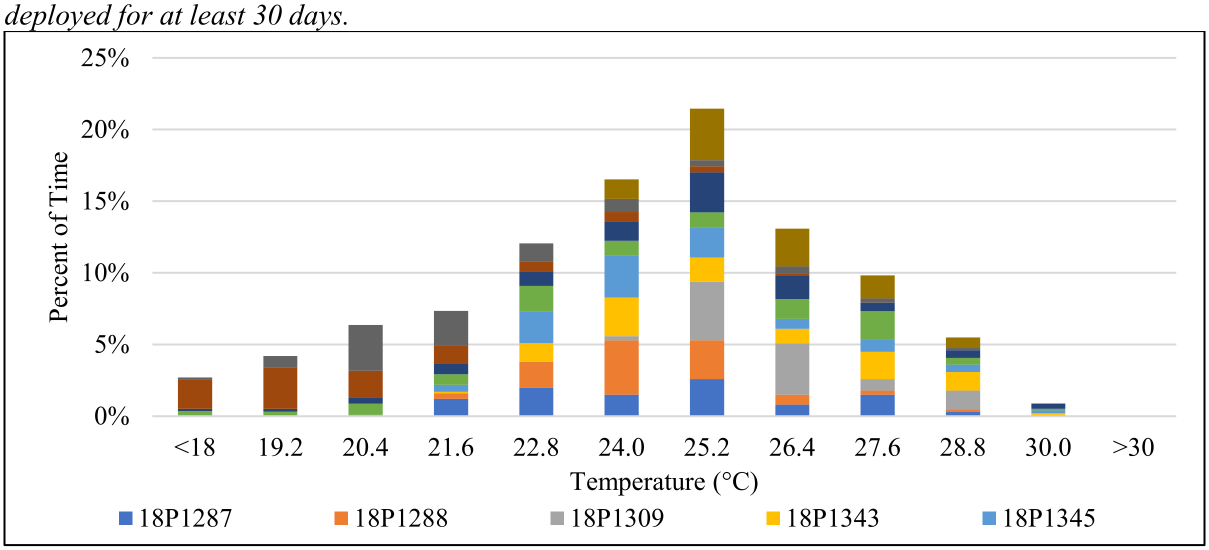


Satellite tag 18P1341 was tagged on 4/24/2019 offshore of St. Augustine, FL. The fish had a general southward track staying westward of the Gulf Stream and traveling as far south as Sebastian Inlet, FL during the summer months. In August, the fish moves west into the Gulf Stream where it moves slowly north until September when it moves northeast and out toward the ledge of the continental shelf off Jacksonville, FL. During October, the fish moves westward back to the Gulf Stream and north off the coast of GA before losing the tag on 11/17/2019, 207 post-release.

Temperature and Depth Distributions

For temperature distribution data, only data from tags deployed for 30 days or more were included. This prevents the skewing of data by tags that were deployed only for a short period of time where cobia may have not left surface waters or waters close to the tagging location. Figure 21 displays this data for the 10 tags deployed 30 days or more. The data is displayed as percent of time spend within each temperature bin with the displayed value (19.2, 20.4, 21.6, etc) representing the upper limit of that temperature bin. The first bin is all time spent below 18 °C and the last bin is all time spent above 30 °C. Eight of the ten fish had their highest percentage of time in either the 22.8, 24.0, 25.2, or 26.4 °C bins with an overall percentage of time in these four bins of 63%. The single highest bin was the 24.1-25.2 °C temperature range, which accounted for 21% of time for all ten fish combined. Interestingly, 8 of the 12 bins (19.3-28.8 °C) accounted for 5% or more time each, indicating a relatively wide range of temperature use by cobia, with excursions well above and below the preferred temperature ranges. Five of the 10 fish had multiple detections in the two bins below 19.2 °C, indicating these recordings are not likely to be anomalies, and likewise 7 of the 10 fish were detected above 30.0 °C however for a very short period.

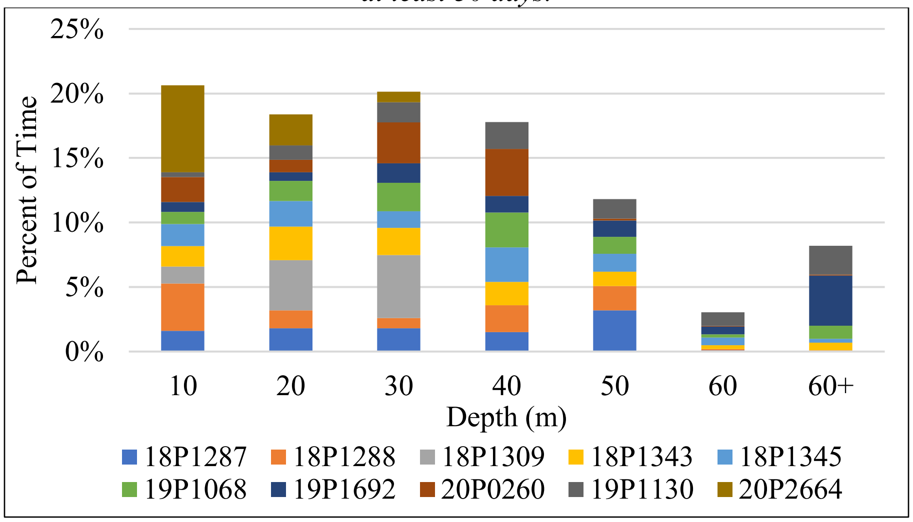
Figure 21. Histogram of temperature distribution for the 10 MiniPAT PSAT tagged cobia that were deployed for at least 30 days.



For depth distribution data, only data from tags deployed for 30 days or more were included. This prevents the skewing of data by tags that were deployed only for a short period of time where cobia may not have left surface waters or nearshore waters close to the tagging location. Figure 22 displays the data for the 10 tags that were deployed 30 days or longer. The data is displayed as percent of total time spent within each depth bin with displayed values (10, 20, 30 m, etc.) representing the upper limit of that depth bin. The first bin is time spent between 0 m (surface) and

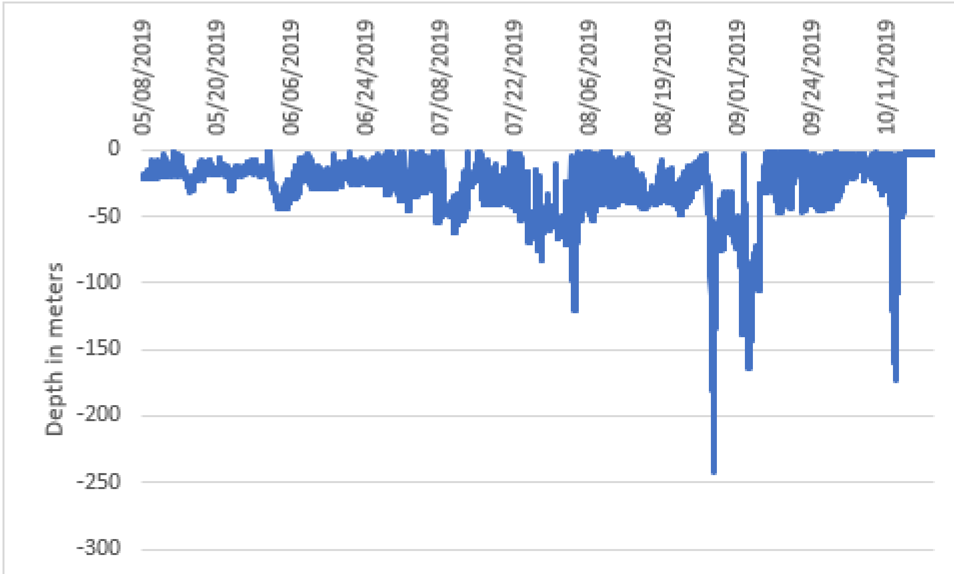
10 m and the final bin is percent of time spend at 70 m or greater depth. The data show a relatively uniform use of 10 m depth increments up until the 40.1-50 m bin with 18-20% of time spent in each of the 10, 20, 30, and 40 m bins. While there is a significant drop from the 40m bin to the 60 m bin, 8 of the 10 fish had recorded time spent in the 50.1-60 m bin and 7 of the 10 fish recorded time spent at deeper than 60 m with 8% of all time for all animals being recorded at this depth range.

Figure 22. Histogram of depth distribution for the 10 MiniPAT PSAT tagged cobia that were deployed for at least 30 days.



As an example of depth logging data, the detailed depth logging for one tag (18P1343) is shown in Figure 23. In general, most fish stayed in relatively shallow waters for several days to weeks after tagging, which makes sense given the nearshore locations, times of year, and water temperatures during tagging trips for most collaborators. Many of the cobia then have a period that corresponds to transit towards or to the edge of the continental shelf, with many having multiple excursions to depths >150m. Most tags then return to the surface at some point, presumably after pop-off and can be determined as popped off after significant time spent at 0m depth recordings.

Figure 23. Detailed depth profile logging from MiniPAT PSAT tag from an individual cobia (tag 18P1343).



Recaptures

To date, 14 of the 124 acoustically tagged cobia for this project which includes 2 satellite tagged cobia have been recaptured by anglers (Table 10). An additional 3 fish that were too small for acoustic tags but were tagged with conventional dart tags, were recaptured. Eleven of 17 fish were harvested, 2 fish were released, and the deposition of the final 2 fish was not provided by the angler. Ten of the 17 fish were recaptured in a different state than initially tagged with both Virginia and Florida having the most recaptures at 7. Days at large averaged 336 days with a minimum of 11 days and a max of 965 days. Distance from tagging location to recapture location was estimated to average 515 km with a minimum of 0 km and a maximum of 1,135 km. Fish tagged in Cape Canaveral, FL and recaptured in the Chesapeake Bay showed the highest amount of movement. Satellite tag 20P2664 was recaptured offshore of its original tagging location 30 days after initial tagging. The angler reported not seeing the satellite tag until after the fish was gaffed. Luckily the tag was returned to researchers and all the data from the deployment was downloaded. Satellite tag 18P1294 popped off after only 13 days at large, however the angler recapture was 775 days after initial tagging providing evidence that the satellite tag prematurely released from the fish. Regulatory changes and the Covid 19 pandemic over the last few years have likely changed the amount of effort and harvest that have occurred on cobia stocks in the southeastern US and affected the amount and source of returns from our tagged fish. These recaptures provide additional information about the movement of individual cobia. Anglers were provided a reward (either $25 or a t-shirt) and information about the tagged cobia.

Table 10. Reported recaptures of tagged cobia during grant period.

Acoustic Transmitter	Satellite Tag	Date	Initial Tagging Location	Recapture Location	Days at large	Distance in km
A69-9001-19095		10/21/2020	Stuart, FL	Jensen Beach, FL	965	0
A69-9002-11158		6/21/2019	Charleston, SC	Chesapeake Bay, VA	393	730
A69-9001-19008-2		8/22/2020	Cape Canaveral, FL	Poquoson, VA	504	1,135
A69-9001-20080		5/19/2019	Cape Canaveral, FL	Chesapeake, VA	353	75
A69-9001-15931		3/29/2020	Cape Canaveral, FL	Ormond Beach, FL	38	1,090
A69-9001-7096	18P1294	6/28/2021	Offshore GA	Chesapeake Bay, VA	775	855
A69-9001-7176		6/27/2020	Hilton Head, SC	Chesapeake Bay, VA	398	805
A69-9001-7177		10/13/2019	Charleston, SC	Charleston, SC	108	0
A69-9001-19126		12/7/2019	St. Augustine, FL	Jacksonville, FL	142	60
A69-9001-13167		5/4/2020	St. Augustine, FL	Offshore GA	291	138
A69-9001-7111		3/14/2020	Stuart, FL	Cape Canaveral, FL	23	145
A69-9001-19124		7/20/2021	Cape Canaveral, FL	Chesapeake Bay, VA	489	1,095
A69-9001-7118		4/2/2020	Cape Canaveral, FL	Jupiter, FL	11	175
A69-1303-45465	20P2664	6/19/2021	Broad River, SC	Charleston, SC	31	50
		2/21/2021	Offshore GA	St. Augustine, FL	635	200
		7/5/2021	Charleston, SC	Chesapeake Bay, VA	41	740
		12/11/2021	Charleston, SC	Cape Canaveral, FL	507	430

Discussion

Regulatory changes, seasonal closures, and the Covid-19 pandemic over the last few years have had negative economic and social impacts on anglers in the southeast United States (shortened seasons, loss of charter revenue, etc.) and have made cobia management a polarizing issue. An effective management scheme for cobia going forward will require a more complete understanding of cobia migratory behavior and interactions with fisheries in the southeast United States. We believe a coastwide collaborative effort is the best way to collect this data and this project utilized a multidisciplinary team of researchers from four state agencies (NC, SC, GA, and FL). This CRP project, NA15NMF4540105, produced large amounts of data on cobia movements along nearshore and offshore waters and revealed the potential for east-west migratory patterns extending past the continental shelf and well outside of existing acoustic arrays The extent of these movements had been previously undescribed. This project required the expert knowledge of a large and geographically diverse pool of charter captains to locate and capture cobia and, in the process, allowed them to become involved in the scientific process.

The project aimed to continue working with cooperating anglers, while incorporating new anglers to cover additional areas. There is currently a great need for better resolution of a potentially complex stock structure, especially as the regulatory framework moves toward interstate management and harvest allocations are potentially divided into smaller units. The holistic approach of utilizing satellite and acoustic telemetry together, especially when evaluated in concert with the telemetry and genetics data collected in our previous CRP project, will provide invaluable information on cobia overwintering grounds and stock structure that directly addresses program priorities. The combined deployment of acoustic and satellite tags proved to be valuable for the collection of detailed data on cobia locations, both during seasonal aggregations in nearshore waters as well as during winter, when locations have previously been unavailable. They also collected data on temperature and depth throughout the deployment period and these parameters can be used to infer habitat use and further validate geolocation data. Hopefully, this project will provide much needed data to the stock assessment process and help ensure that management decisions in a highly popular fishery are based on a sound understanding of population dynamics.

Acoustic telemetry data collected during this project add to the growing dataset that can be called upon by myriad researchers and stock assessment scientists to further define cobia movements, sub-population, and complex structure, as well as timing and locations of mixing between populations. Data from this study, our previous CRP study, as well as multiple regional collaborators was recently combined and synthesized for a manuscript entitled "Stock structure and site fidelity of cobia Rachycentron canadum on the U.S. east coast determined via acoustic telemetry and network analysis" (Gallagher et al. *In Review*). Satellite-based location of fish that leave nearshore waters and are no longer accessible to the acoustic receiver array networks reveal evidence that support the hypothesis of east-west migration of some cobia in addition to the known north-south migrations observed in near-shore acoustic data and recapture studies. Through the challenges of Covid-19 and tag manufacturer issues, as well as a significant method development phase for tag attachment and retention, the satellite data obtained so far is too limited for strong conclusions. The bulk of data from fish with deployed tags for 30 days or more are concentrated from fish tagged in South Carolina, with few tags being retained for lengthy periods of time from the other tagging locations and multiple tags still at large from North Carolina. Among these fish, consistent patterns of movement are difficult to determine other than to confirm the majority show some east-west movement as well as significant north-south movement while offshore, presumably following a relatively tight temperature preference range and predictable seasonal regional movements. Increased data from tags still at-large and tags that have been retrieved and can be reprogrammed and redeployed will significantly enhance the dataset and potentially allow more in-depth analysis of offshore movements. Coupling satellite movement data with increased population genetic sampling will enable a more accurate delineation of cobia populations or subpopulations for analysis of migratory patterns. These data represent a highly valuable data resource that will be important and immediately relevant in upcoming stock identification workshops and assessments, which will take place within the next few years. The continued incorporation of additional data tools into the evaluation of cobia life history is a positive and powerful direction for successfully management of this species and can potential be used for species with similar migratory and stock overlap.

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