Use of Pop-Up Satellite Archival Tags (PSATs) to Investigate the Movements, Habitat Utilization, and Post-Release Survival of Cobia (*Rachycentron canadum*) that Summer in Virginia Waters

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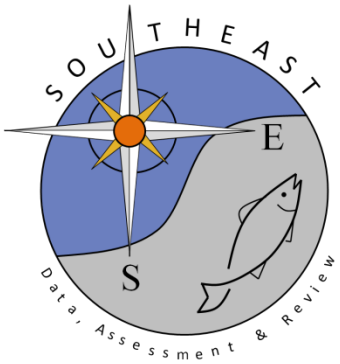

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Use of Pop-Up Satellite Archival Tags (PSATs) to Investigate the Movements, Habitat Utilization, and Post-Release Survival of Cobia (*Rachycentron canadum*) that Summer in Virginia Waters

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Abstract

The most recent stock assessment of U.S. Atlantic cobia was completed in 2012 and concluded that cobia were not overfished, nor was overfishing occurring. The stock assessment concluded with recommendations to study cobia stock structure, life history, movement patterns, and post-release survival. To address some of these data deficiencies, we deployed 36 PSATs on cobia in Virginia coastal waters during the summer months to assess movements, habitat utilization, and post-release survival. From the 24 tags that reported, no mortalities were inferred. Movements were noted as far south as Daytona Beach, Florida, but most tags reported from waters offshore of North Carolina and South Carolina, near the continental shelf break, indicating that this may be essential habitat for overwintering cobia.

Introduction

Cobia (*Rachycentron canadum*) is a finfish species of recreational and economic importance to Virginia, other U.S. Atlantic coast states, and throughout much of their nearly circumglobal range. Recent recreational fishery closures along the U.S. eastern seaboard resulting from harvests estimated to have greatly exceeded the allowable catch limit, combined with uncertainty of stock structure and amended stock definitions, have turned cobia management into a topic of ever-growing controversy (Cochran, 2016). This study intends to inform management decisions by increasing our understanding of movements, habitat utilization, and post-release survival of cobia that summer in Virginia coastal waters.

Management Controversy

The current cobia stock boundary, implemented in 2015, uses the Georgia – Florida state boundary to define the Atlantic and Gulf Migratory Groups of cobia. Prior to 2015, United States' cobia were still managed as two stocks, but the demarcation line between stocks was at the Florida Keys. The 2015 re-designation of stock boundaries is one aspect of cobia management caught in controversy.

The implementation of new cobia management (stock) boundaries would not likely have been controversial if it were not for the reallocation of catch limits and estimates of significant overharvests from the Atlantic Migratory Group stock. When the Atlantic Migratory Group of cobia included the east coast of Florida, the annual allowable catch limit (ACL) was 1.44 million pounds (NMFS, 2017). When the new management boundaries were put in place in 2015, the recreational ACL was split, with 620,000 pounds allocated to the states from Georgia northward and 840,000 pounds allocated to the east coast of Florida (NMFS, 2017). 2015 was designated as a transition year with ACLs of 630,000 pounds and 830,000 pounds for the respective management zones (GoMFMC, 2014). This ACL allocation noticeably differs from the average harvests from those areas for the prior decade (2005-2014). Over this 10-year period, the average recreational harvests from Georgia northward were estimated to be 706,000 pounds while the east coast of Florida averaged 413,000 pounds (NMFS, 2017; ASMFC, 2016). Over this period, only in 2011 and 2014 did the east coast of Florida have higher estimated recreational harvests than the states from Georgia northward (NMFS, 2017). Furthermore, 2011 was an anomalous year with the lowest and highest decadal harvest estimates for Georgia northward and the east coast of Florida, respectively (NMFS, 2017).

The primary source for estimating cobia harvests is the Marine Recreational Information Program (MRIP), a collection of fishery survey data compiled by the National Oceanic and Atmospheric Administration that is used for species assessment, monitoring, and management. It provides time series data about annual cobia landings using catch intercepts. Intercept data is extrapolated using effort data from mail or telephone surveys to estimate total annual harvest.

The most recent MRIP harvest estimates are also focus points of the cobia management controversy. Total Atlantic Migratory Group harvest estimates in 2015 and 2016 were 1.57 and 1.34 million pounds, respectively. Virginia was the single greatest contributor to these totals with back-to-back record catches of 882,000 and 915,000 pounds, far in excess of the entire regional ACL. These record figures were obtained using 38 and 37 cobia catch intercepts extrapolated with effort data. Harvest estimates from the east coast of Florida for the same years were 425,000 and 447,000 pounds (NMFS, 2017).

As a result of the overharvest estimates, the recreational cobia season in federal waters was closed early for the first time on 20 June 2016 following the 2015 estimate of 248% of the

ACL (Daniel, 2016). Southeast Atlantic states with cobia fisheries reacted by tightening regulations (size and bag limits) and seasons in their state waters to prevent a complete fishery closure. Despite area closures and tighter state-by-state restrictions, the 2016 estimated recreational harvest exceeded 1.3 million pounds, 217% of the ACL (NOAA Southeast Regional Office, 2017). As a result, the 2017 season was completely closed in federal waters (Federal Register, 2017). This is perhaps the aspect of cobia management that has received the most attention as recreational anglers been very vocal about new restrictions.

Federal recreational regulations, applicable in waters greater than 3 miles from shore, historically set a minimum cobia harvest size of 33 inches fork length and a limit of 2 fish per angler, up to 6 fish per vessel, without season restrictions (Federal Register, 2016). Within their waters, states largely enforced the same size and possession limits set by federal regulators until the first early season closure in federal waters. Since that time, disputes over the accuracy of harvest estimates and desires to protect state interests have led to a diverse set of restrictions across states whose waters are frequented by cobia.

Objectives

Much of the scrutiny on cobia management is a direct result of the lack of thorough understanding of cobia stocks and how they are influenced by recreational angling. The 2012 stock assessment made several recommendations to gain better insights into cobia dynamics. To achieve some of those goals, this project used pop-up satellite archival tags (PSATs) to help inform management decisions by studying movements, post-release survival, and habitat utilization of cobia that summer in Virginia coastal waters. Knowledge of migration and seasonal movement patterns is needed to ensure accurate stock definitions, and PSATs can provide a timely assessment of migratory behaviors. PSATs in in this study also assess post-release mortality of cobia caught in the recreational fishery. These data are needed to better estimate recreational fishing mortality of cobia, an estimate which has heightened importance given recently amended regulations that are likely to increase regulatory discards. The habitat utilization data collected by PSATs will allow for better understanding the impacts of management measures and may provide anglers with knowledge to enhance their effectiveness.

Materials and Methods

This study used three models of pop-up satellite archival tags (PSATs) to assess cobia movements, habitat utilization, and post-release survival following capture in the recreational fishery. All angling and tagging was completed within the Chesapeake Bay and surrounding coastal Virginia waters. Fish tagged for this study are representative of the size classes targeted by recreational fishermen (greater than 37 inches total length).

PSATs attached to fish collect environmental data such as water temperature, pressure (depth), and light levels for programmed durations ranging from days up to two years. These data can be studied to infer habitat utilization, movements, and post-release survival of fishes. Following release from a fish after the specified data-gathering period, a PSAT floats to the surface and transmits archived data to the ARGOS (Advanced Research Global Observation Satellite) network. In addition to receiving and retransmitting data, ARGOS satellites can determine the location of PSAT transmitters with 1.5-kilometer accuracy using the Doppler frequency shift of received transmissions.

There are a handful of PSAT manufacturers offering a variety of tag models with prices ranging from as low as $600 to exceeding $4,000. The non-trivial expense of these tags

necessarily limits sample size of studies conducted with them. This study procured 41 PSATs, the largest possible sample size with available resources. 30 of the 41 tags were comparatively simple, transmitting daily maximum and minimum environmental temperatures and average daily inclination in addition to pop-up location, useful for assessing migrations and temperature range of the water occupied. The other 11 tags have additional capabilities and were used opportunistically (left over or recovered from other studies) to study movements and post-release survival and to make habitat utilization inferences by transmitting light, pressure, and temperature measurements summarized at 15-30 minute intervals.

The three different model PSATs used in this study are the mrPAT by Wildlife Computers (WC) (n=30), and the X-Tag (n=7) and PTT-100 (n=4) models by Microwave Telemetry, Inc. (MTI). All PSATs were programmed for six-month (Microwave Telemetry tags) or 180-day (Wildlife Computers) duration. X-tags and PTT-100 tags from Microwave Telemetry record light, pressure, and temperature observations at 2-minute intervals, summarized into 15- or 30-minute intervals for data transmission. Mark Report Pop-Up Archival Tag (mrPAT) tags from Wildlife Computers report only final location at release, recorded daily minimum and maximum temperatures, and average daily inclination. The two different models of Microwave Telemetry tags were used because they were available from previous studies and could be reprogrammed or refurbished at a minimal cost. The mrPAT tags were selected because of their relatively low cost ($1,500 each), allowing the greatest possible sample size with the available resources to investigate overwintering locations.

All three PSAT models have default conditional release settings. The Microwave Telemetry tags have constant pressure releases in which a tag begins its release/transmit sequence if the pressure sensor registers a constant depth for 4 consecutive days (pressure equivalent to constant depth ±3 meters for the X-tags and ±10 meters for the PTT-100s). The mrPAT conditional release is a wet-dry conductivity sensor that triggers the release/transmit sequence if the top of the tag is out of the water for 6-minutes in any rolling 2-hour period, sampled every 3 seconds. The conditional release feature was disabled on PTT-100 tags due to the probability of cobia maintaining a constant depth ±10 meters for days at a time.

Tag Deployment

Tags were attached to cobia exceeding a minimum length threshold set for each tag model. Minimum fish length for Wildlife Computers mrPATs and Microwave Telemetry, Inc. X-Tags was at least 37 inches in total length. This length was determined semi-arbitrarily to be a safe minimum size such that fish survival will be negligibly impacted by the presence of a towed PSAT. It also corresponded with the federal minimum size of 33-inch fork length, deemed equivalent to 37-inch total length. Fish tagged with the PTT-100 tags were at least 45 inches in total length to ensure ability to accommodate the resistive forces of the larger tags. Total length in inches was used for this study because it is the measurement method dictated by Virginia state regulations and is commonly used by the anglers assisting with the study. Although the effects of PSATs on teleost fish physiology has not been studied, cobia of these sizes should carry the PSATs with negligible impact on their swimming kinematics and metabolism. This inference is drawn from a study on juvenile sandbar sharks (*Carcharhinus plumbeus*) smaller than the cobia tagged in this study, in which researchers noted less than a 5% change in metabolic rate when sharks were fitted with a Microwave Telemetry X-Tag (Lynch et al., 2017).

Cobia for this study were caught by recreational anglers, both private and charter, using methods of their choice which are assumed to be representative of typical recreational practices.

The most common methods of fishing for cobia were chumming or sight-casting using live or artificial baits rigged with J-hooks, or lures rigged with J-hooks. Fish were hooked, landed, netted, and brought into the boat for measurement and tag attachment. Data recorded for each fish included total length in inches, estimated weight in pounds, fight time, air exposure time, bait, hook type, release location, and any observational notes. Tags were attached to fish using standard methods developed by Graves et al. (2002). Each PSAT was tethered to an intramuscular anchor that was inserted into the fish musculature below the posterior dorsal fin and well above the coelomic cavity, ideally with the dart interlocking with the pterygiophores. Each specimen was released as quickly as possible. The tether linking the intramuscular anchor to the PSAT was 80-pound test monofilament line secured with stainless steel crimps; total tether length was approximately 16 centimeters.

Data Analysis

Data received from transmitting tags were used to analyze movements, habitat utilization, and post-release survival. The minimum straight line distance between the point of fish release and the first location report of the transmitting tag shall be used to define net travel distance. Light-based location estimate algorithms are not used in this study, as the error for estimating location would be greater than net travel distance for many specimens. Pressure and temperature data are examined to describe habitat utilization within the water column to assess activity associated with seasonality. Data are summarized to show percentage of time spent at different depths.

Tagged cobia were considered to have survived capture and release if the tag collected data indicating specimen activity for at least ten days after release. The ten-day duration was selected as a time period short enough to minimize observations of natural mortality but long enough to detect mortality resulting from capture events. It is usually impossible to distinguish natural mortalities from catch-related mortalities that occur several days after release, so this study assumed that any mortality occurring within 10 days of release as fishing mortality (resulting from the processes of capture, tagging, and release). A deceased fish will sink to the ocean floor, so mortality should be indicated by a drop in measured water temperature, constant depth below the surface (in the case of MTI pressure-sensing tags) or a nearly vertical tag (in the case of WC tags with an inclinometer).

Results

36 of 41 tags were deployed on cobia meeting the minimum size requirements (7 of 7 X-Tags, 3 of 4 PTT-100s, and 26 of 30 mrPATs). The remaining five tags were not deployed due to availability of fish meeting the minimum size. The size distribution of fish tagged is shown in Figure 1.

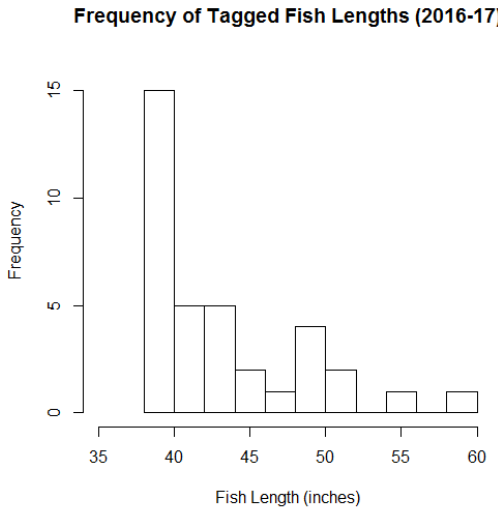

Figure 1. Distribution of the size of cobia tagged for this study in August and September 2016 and 2017. Fish size was measured as total length in inches.

Tag Reporting and Locations

The Microwave Telemetry X-tags were deployed in August 2016. One X-tag reported early after collecting data for 85 days, and 70% of the transmissible data were received. Three X-tags reported five to nine days after their scheduled release date and 21 – 45% of the transmissible data were received. Data from these three tags indicate that all release mechanisms triggered on schedule, but the tags remained attached to the fish for an extended period. The tags were attempting to transmit data while still attached to the fish, under water, hence the great reduction in data received. No transmissions were ever received from three of the X-tags.

The PTT-100s were deployed in August and September 2017. As the conditional release function was disabled, no tags reported early. One tag reported as scheduled from the middle of the North Atlantic. Preliminary data from the tag indicate that it was attached to the fish for 76 days and then floated in the ocean until its scheduled report date. The second PTT-100 transmitted very few, sporadic messages that were insufficient to determine a location or acquire useable data. This tag likely detached from the fish prematurely and was beached and partially covered, inhibiting successful data transmission. The third PTT-100 reported 16 days past its scheduled report date. It is still transmitting its data at the drafting of this report.

The 26 mrPAT tags were deployed in August and September 2017. Of these, 17 tags reported prematurely, with total deployment durations ranging from 1 to 99 days. All of these early reports categorized the tags as "floaters," meaning that each tag initiated its release/transmit protocol due to the "dry" threshold being reached for the conductivity sensor (6 minutes in any rolling 2-hour window). One tag reported as scheduled, after its full 180-day deployment. Zero transmissions were received from the remaining eight tags. Of the 18 tags that reported, 16 reported usable location data (ARGOS location classes 1, 2, or 3). Table 1 summarizes tag deployment and reporting. A map of tag report locations is shown in Figure 2.

Table 1. A summary of tags deployed on cobia in coastal Virginia waters, including tag type, deployment date, fish size (total length in inches), deployment duration (days), net displacement (kilometers) and number of days for which data was reported. * Indicates estimated displacement using approximate pop-up location. A dash represents no usable data.

#	Tag Model	Deployment Date	Fish TL (inches)	Deployment duration (# days)	Net displacement (kilometers)	Data days
1	X-Tag	8/12/2016	43	-	-	-
2	X-Tag	8/14/2016	46	192	982	92
3	X-Tag	8/17/2016	51	188	203	142
4	X-Tag	8/17/2016	50	-	-	-
5	X-Tag	8/17/2016	55	-	-	-
6	X-Tag	8/20/2016	38	189	312	124
7	X-Tag	8/30/2016	49	85	250*	84
8	PTT-100	8/25/2017	48	79	-	TBD
9	PTT-100	9/04/2017	50	194	444	TBD
10	PTT-100	9/04/2017	51	-	-	-
11	mrPAT	8/03/2017	42	-	-	-
12	mrPAT	8/03/2017	38	40	59	40
13	mrPAT	8/03/2017	38	-	-	-
14	mrPAT	8/05/2017	49	-	-	-
15	mrPAT	8/06/2017	38	-	-	-
16	mrPAT	8/09/2017	55	13	24	13
17	mrPAT	8/09/2017	43	55	34	55
18	mrPAT	8/10/2017	42.5	-	-	-
19	mrPAT	8/10/2017	45	9	20	9
20	mrPAT	8/13/2017	38	-	-	-
21	mrPAT	8/17/2017	40	99	721	99
22	mrPAT	8/17/2017	42	96	418	96
23	mrPAT	8/19/2017	40	11	48	11
24	mrPAT	8/20/2017	38	6	23	6
25	mrPAT	8/25/2017	42	180	459	100
26	mrPAT	8/26/2017	40	30	21	30
27	mrPAT	8/26/2017	39.5	-	-	-
28	mrPAT	8/27/2017	44	5	25	5
29	mrPAT	8/27/2017	43	1	3	1
30	mrPAT	8/27/2017	42	4	43	4
31	mrPAT	9/03/2017	38.5	66	232	66
32	mrPAT	9/04/2017	42	32	175	32
33	mrPAT	9/08/2017	39	-	-	-
34	mrPAT	9/09/2017	39	57	-	10
35	mrPAT	9/09/2017	38	33	-	33
36	mrPAT	9/17/2017	39	22	260	22

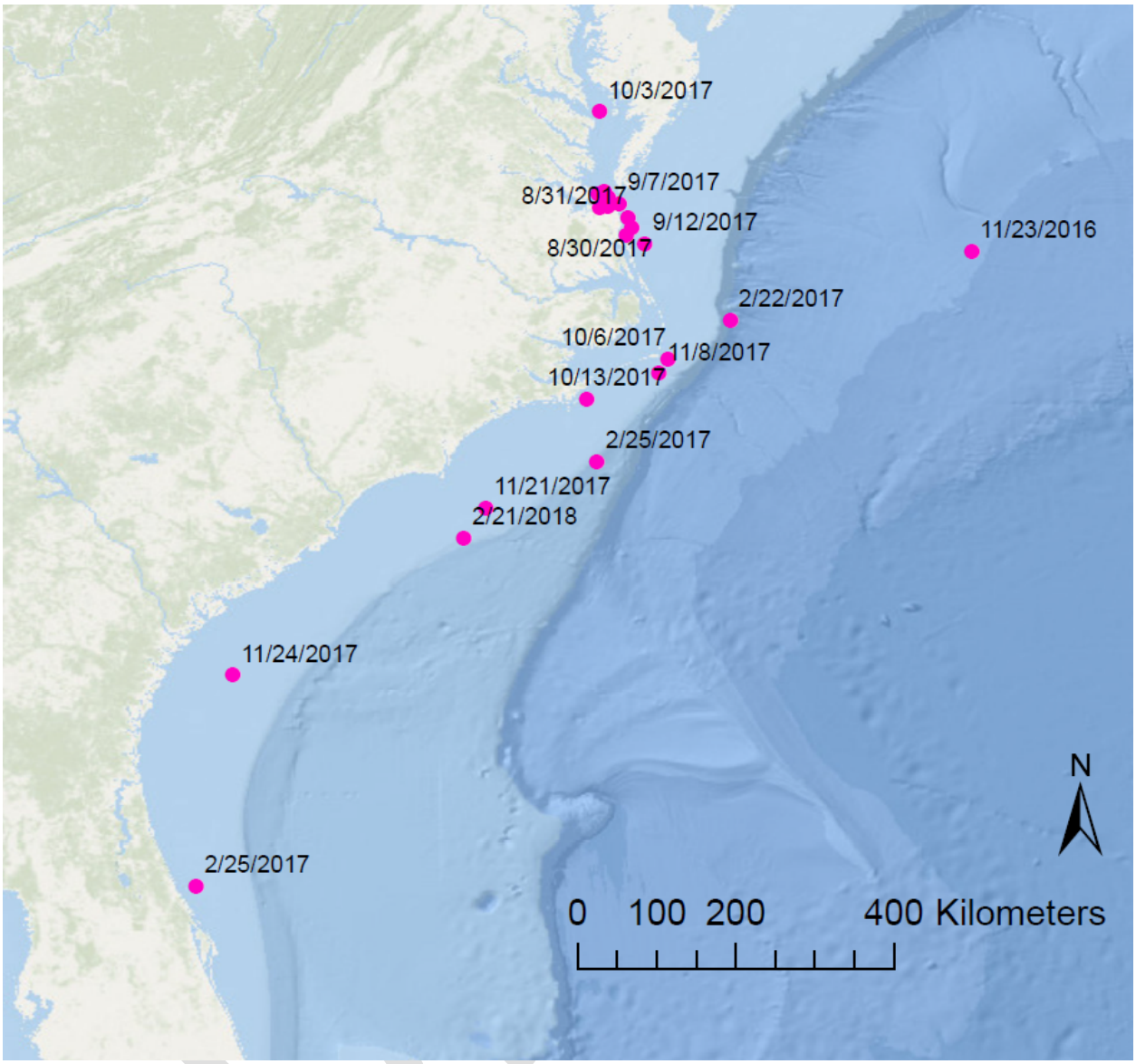

Figure 2. Map showing tag reporting locations. All tags were deployed in Virginia state waters (in the Cheseapeake Bay or within 3 miles of the Virginia shoreline) in the months of August and September in 2016 and 2017. The point furthest from shore labeled 11/23/2016 was the tag's first location reported after floating on the surface for 4 days; it was likely south of Hatteras, NC when it released from the fish based on comparisons with other tag drift trajectories. All other locations are assumed to be actual within hours of releasing from the fish.

Cobia Mortality

None of the 24 successful tags reported data consistent with fish mortality for the duration of tag attachment. The MTI X-tags all reported data indicating fish moving up and down in the water column. The two MTI PTT-100s have not had their data fully processed yet, but the preliminary data shows fish activity consistent with survival. All reporting WC tags (mrPATs) reported tag tilt data representative of a swimming fish prior to tag release. No

conclusions can be made regarding the 12 tags from which no useable transmissions were received.

Habitat Utilization

The temperature of water occupied by cobia ranged from 12.13 to 29.33 degrees Celsius. Only a handful of data points, however, showed cobia in waters less than 15 degrees. The depths utilized by cobia ranged from 0.0 meters to 86.1 meters. Very few data points showed cobia in depths greater than 50.0 meters.

Preliminary analysis of the pressure data from the four X-tags shows marked differences in water depths occupied with warm and cool seasonal changes (Figure 2). Data for this preliminary analysis include all data points received, so the interpretation may be biased by those tags which reported more data. It is worth noting that approximately 25% of all depth observations received for August and September report the tagged cobia to be in the top 1 meter of the water column. Nearly 40% of the total depth observations in these warmer months represent a specimen in the top 3 meters of the water column. In contrast, less than 5% of all depth observations received indicated a cobia in the top 3 meters of the water column in the cooler months of October through February.

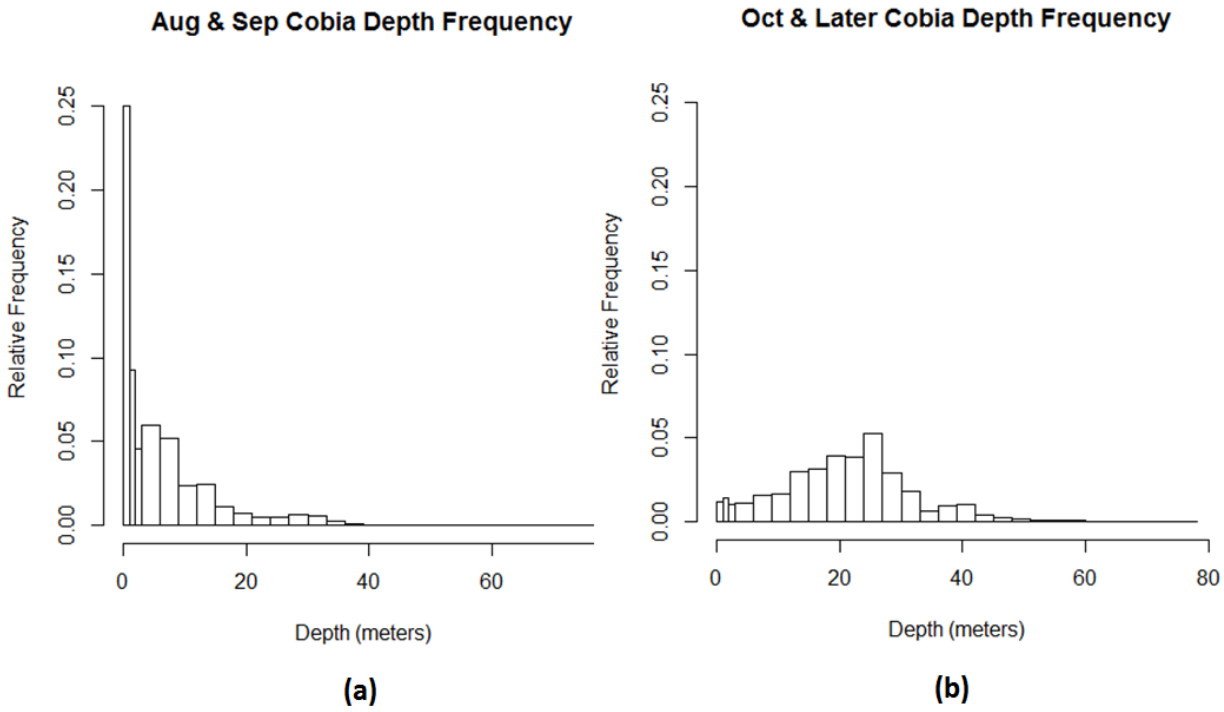

Figure 2. Histograms of all reported depth observations from four MTI X-tags attached to cobia. Depth observations are separated seasonally, with observations from August and September (a) grouped together to represent warm months, while observations October through February (b) are grouped together to represent cooler months. Distributions were compared statistically with a Chi-Square Goodness of Fit Test, $p < 0.05$.

Cobia Movement

Five tags successfully reported after being attached to cobia for the entire programmed 6-month deployment duration. One of these fish traveled as far south as Daytona, Florida, but the other four indicated fish offshore of North Carolina and South Carolina at the time of their release in February and early March.

One tag shows that cobia occupy waters of the Chesapeake Bay, as far north as Maryland, as late as October.

All tags that reported prior to 15 November were within 10 kilometers of shore, whereas all tags that reported after 15 November were more than 15 kilometers away from shore, up to 77 kilometers from the nearest shoreline.

Discussion

Cobia Movement

A major objective of this study was to assess cobia over-wintering locations. All tags were deployed in August and September, near the end of the season when cobia are common in Virginia waters, and programmed for 6-month deployments with the aim to discover cobia locations in February and early March. While the preponderance of reporting tags were premature, their location data are useful in illustrating the migratory nature of the species. Not only do cobia migrate south from Virginia waters in the fall and winter, but they tend to occupy waters further from shore in the cooler months. These findings show that waters offshore of North Carolina and South Carolina may be important habitat for overwintering cobia. Additionally, one of the five full-term tags reported from Florida waters, demonstrating that some fish from Virginia waters do travel at least as far south as Florida. This was a single event, however, and larger sample sizes will be needed to estimate the degree of connectivity. It is possible that the fish with the tag that reported from waters offshore of Savannah, Georgia in November 2017 was on its way to waters farther south.

All tags that popped up after 15 November were at distances greater than 15 kilometers from the nearest shoreline. This observed offshore movement of cobia may explain the greatly reduced reports of acoustic tags during the cooler months as most receivers are located inshore.

Habitat Utilization

The seasonal change in water depths utilized indicate that cobia likely occupy waters near the Virginia coasts in the months of August and September, but the increased frequency at greater depths corroborate evidence that cobia spend more time in locations farther from the coast in the cooler months. Additionally, the large proportion of time spent near the surface in warm months may signal high susceptibility to sight fishing methods in the summer.

Cobia Mortality

The notable absence of a single observed mortality substantiates claims that cobia are a hardy species. It further evidences that the assumed post-release mortality rate of approximately 5% used in previous SEDAR assessments is not unreasonable. The somewhat high rate of non-reporting tags (average 33% non-reporting), however, makes it difficult to make any conclusive statements about cobia mortality rates. No conclusions can be made regarding the 12 tags from which no usable data were received.

Tag Performance

Tag performance in this study was imperfect, but it was not significantly below average performance rates of similar studies conducted using PSATs with other species (Musyl et. al, 2011).

We speculate the three X-Tags whose data were never received may have remained attached to the fish, evidenced by the three late releasing tags. It is also possible the tags may have been physically damaged or sustained any number of malfunctions throughout the tag's deployed lifespan. All tags are marked with contact information should they be discovered by a passerby in the future.

The early reporting mrPATs were all classified as "floaters." We speculate, based on the high number of premature reports combined with the approximately 0.25 frequency of time reported in the top meter of the water column from the X-Tag depth data in warm months (Figure 2a), that some premature reports may be the result of cobia basking near the surface such that the dry release criteria is met. We cannot rule out that some premature mrPAT reports are a result of the tag physically separating from the fish, as this is confirmed for 2 of the MTI tags. We learned after deploying the mrPAT tags that the default conditional release settings can be modified. If mrPATs, or similar wet/dry release tags, are used to study cobia in the future, we recommend using shorter tethers (6-10cm), and doubling the required dry time (to 12 minutes in any 2-hour window) to initiate the conditional release feature to minimize the likelihood of premature tag release due to basking cobia.

Conclusion

PSATs are useful, and expensive, but imperfect tools to study cobia movements, habitat utilization, and post-release survival. Cobia spending summer months in Virginia waters are hardy fish with low mortality incurred from catch-and-release recreational hook-and-line angling when handled quickly and respectfully. They exhibit clear behavioral differences with seasonal progression, spending substantial time near the surface and near coastlines in warm months, but moving farther from shore, and to the south, with more time spent at greater depths in the cooler months. These new insights into cobia ecology should be considered when implementing further studies and when making management decisions to ensure continued sustainability of cobia populations.

Literature Cited

ASMFC, 2016. Cobia management: How the Atlantic States Marine Fisheries Commission could take part in the management of the cobia fishery, August 2016, 56 pp.

Cochran, B., 2016. Cobia season controversy has anglers angry. *Bristol Herald Courier*, Bristol, 23 January 2017. Electronic publication, http://www.heraldcourier.com/outdoor/cobia-season-controversy-has-anglers-angry/article_40d36df0-0767-11e6-af45-9fac35cfa550.html.

Daniel, L., 2016. For the Interstate Fishery Management Plan for Cobia. Atlantic States Marine Fisheries Commission Public Information Document, November 2016, 19pp.

Federal Register, 2016. Docket No. 101206604-1758-02. Federal Register Rules and Regulations, 81 (47), pp. 12601.

Federal Register, 2017. Docket No. 101206604-1758-02. Federal Register Rules and Regulations, 82 (15), pp. 8363-8364.

GoMFMC, 2014. Final Amendment 20B to the Fishery Management Plan for the Coastal Migratory Pelagic Resources in the Gulf of Mexico and Atlantic Region, a publication of the Gulf of Mexico Fishery Management Council, 255 pp.

Graves, J.E., Luckhurst, B.E. and Prince, E.D., 2002. An evaluation of pop-up satellite tags for estimating postrelease survival of blue marlin (*Makaira nigricans*) from a recreational fishery. *Fishery Bulletin*, *100*(1), pp.134-142.

Lynch, S.D., Marcek, B.J., Marshall, H.M., Bushnell, P.G., Bernal, D. and Brill, R.W., 2017. The effects of pop-up satellite archival tags (PSATs) on the metabolic rate and swimming kinematics of juvenile sandbar shark *Carcharhinus plumbeus*. *Fisheries Research*, *186*, pp.205-215.

Musyl, M.K., Domeier, M.L., Nasby-Lucas, N., Brill, R.W., McNaughton, L.M., Swimmer, J.Y., Lutcavage, M.S., Wilson, S.G., Galuardi, B. and Liddle, J.B., 2011. Performance of pop-up satellite archival tags. *Marine Ecology Progress Series*, *433*, pp.1-28.

NMFS, 2017. Recreational Fisheries Statistics Queries. Electronic publication, http://www.st.nmfs.noaa.gov/recreational-fisheries/data-and-documentation/queries/index, 02 June 2017.

NOAA Southeast Regional Office, 2017. Annual Catch Limit Monitoring. Electronic publication, http://sero.nmfs.noaa.gov/sustainable_fisheries/acl_monitoring/index.html, 02 June 2017.