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Final report

Assessment of Critical Habitats for Recovering the Chesapeake Bay Atlantic Sturgeon Distinct Population Segment

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Introduction

Atlantic Sturgeon *Acipenser oxyrinchus oxyrinchus* are found in waters from Newfoundland and Labrador, Canada to Florida, United States (Hildebrand and Schroeder 1928). They are a long-lived, late maturing, anadromous species which spend most of its life in saltwater. These fish enter freshwater rivers and large creeks to spawn before running back to the Atlantic Ocean. Juveniles spend several years in brackish water, then migrate to nearshore coastal waters before making their first trip to the Atlantic Ocean where they mature (Dovel and Berggren 1983).

The Atlantic Sturgeon was once abundant in Chesapeake Bay and was an important food source to Native Americans and European colonists alike (Bowen and Andrews 2000). At the end of the 19th century, the Atlantic Sturgeon was heavily fished for caviar and flesh. The peak coastal harvest of Atlantic sturgeon, 3,355,000 kg, occurred in 1890. Annual harvest declined to 295,000 kg by 1901, and was less than 45,000 kg by the 1920s (Hildebrand and Schroeder 1928).

In addition to overfishing, habitat degradation has also had a major impact on Atlantic Sturgeon spawning success. These anadromous fish spawn in tidal freshwater below the fall line, usually over hard bottom substrates. Such areas in most major rivers along the Atlantic coast have been altered severely by dredging, dam construction, or siltation due to urbanization and agricultural practices.

Atlantic Sturgeon in Maryland waters of the Chesapeake Bay indicated declining populations similar to other Atlantic stocks. By 1928, sturgeon north of the Potomac River were rare (Merritt 1992) and in 1996, Maryland closed the fishery. In the same year, the United States Fish and Wildlife Service (USFWS) and the Maryland Department of Natural Resources (MD DNR) implemented an Atlantic Sturgeon Reward Program. The program, which paid commercial waterman for reporting live captures of Atlantic Sturgeon bycatch in Maryland, ran until 2012 and resulted in 1,710 (1,592 first-time) Atlantic Sturgeon reports. These reports provided important information on movement, distribution, growth, habitat and bycatch.

The Atlantic Sturgeon fishery closures continued. In 1998, the U.S. fishery was closed to harvest by the Atlantic States Marine Fisheries Commission. In 2012, the National Marine Fisheries Service (NMFS) listed each of the five Distinct Population Segments (DPS) as threatened or endangered under the Endangered Species Act. Presently the Chesapeake Bay DPS of Atlantic Sturgeon is federally protected as endangered.

Despite being considered biologically extinct in the Chesapeake Bay (Secor et al. 2000), numerous sightings of breaching Atlantic Sturgeon were reported in the Nanticoke River and its largest tributary, Marshyhope Creek, beginning in 2011 (S. Minkkinen, USFWS, personal communication). In 2013, an Atlantic Sturgeon jumped into a fisherman's boat on the

Marshyhope Creek. The present research was to determine if there was a population of Atlantic Sturgeon in the Nanticoke River and Marshyhope Creek, and to determine if they were migrants moving through the system or if they were present for the purpose of spawning. This would be the only known spawning population of Atlantic Sturgeon in Maryland waters.

Methods

Site Description

The Nanticoke River watershed is dominated by agricultural areas and forested land. The towns of Vienna and Sharptown are located on the river within Maryland. Several other small towns are also located within the watershed. The salinity in the Nanticoke River ranges from 0.1 ppt near Sharptown to 7-15 ppt at the mouth near Roaring Point. The entire Maryland portion of the Nanticoke River is tidal. The Nanticoke River is frequently used for commercial barge traffic.

The river is characterized by deep holes around river bends and large sandy flats. A habitat mapping study by National Ocean Atmospheric Administration Fisheries, Chesapeake Bay Office (NCBO), indicated that the substrate is sand interspersed with cobble to the north near the MD/DE border at Sharptown, and sandy in the lower reaches (Bruce et al. 2016). Several large creeks feed the Nanticoke River including, Marshyhope Creek in Maryland, and Broad Creek and Deep Creek in Delaware.

The majority of sampling occurs in the upper Marshyhope Creek from August through early October. The Marshyhope Creek watershed consists mostly of agricultural and forested lands. Several small towns are located within the watershed. Federalsburg is the largest, and is the only large town located directly on the banks of the creek (Figure 1).

The tidal portion of Marshyhope Creek occurs from the mouth to the confluence with Faulkner Branch in the Idylwild Wildlife Management Area (WMA) upstream of Federalsburg, MD. The tidal portion upstream of Federalsburg becomes narrow and shallow, with substrates dominated by mud. Therefore, Marshyhope Creek Atlantic sturgeon habitat probably extends only as far as Federalsburg.

The NCBO habitat study indicates that substrates downstream of Federalsburg are dominated by sand and mud mixtures. In areas of scour around bends and in deep holes, gravel and sand are the dominant substrate, with several areas of cobble located two miles south of Federalsburg. Further downstream, towards the confluence of the Nanticoke River, the riverbed transitions to mostly sand/gravel and sand/clay mixes.

Gill Netting

Gill net sizes were chosen based on successful sampling of Atlantic Sturgeon in the James River (Balazik et al. 2012). In 2013, gill nets with 25.4 – 30.5 cm stretch mesh, 3.7 m in height, 91.4 m in length were used. After sampling unsuccessfully in the Marshyhope Creek, it was decided that smaller nets may be necessary. In 2014, gill nets 15.2- 30.5 cm stretch mesh, 3.1 m in height, 91.4 m in length were fished. After successfully landing Atlantic Sturgeon in the largest mesh size, project biologists decided to again fish the larger gill nets. In 2015, gill nets with 25.4-35.6 cm stretch mesh, 3.7 m in height, 91.4 m in length were used.

Regardless of size, all gill nets were sinking, with 29.5 kg lead core line attached to the bottom. A 9.5 mm float line attached to the top of the net, with numerous various sized plastic and foam floats spaced approximately 1 m apart, kept the net open in the water column. Each net was anchored at either end with a 4.5 kg Danforth anchor. Orange bullet floats were attached to each anchor to help dislodge the anchor from substrates, and to help mark the net to passing boaters. Due to heavy recreational boat traffic, 5-8 additional large bullet floats were attached to the float line to aid in net visibility.

In 2013, gill nets were initially set parallel to the current. After zero Atlantic Sturgeon captures, in 2014 it was decided to change net set configuration from parallel to perpendicular to the current. Nets continued to be set perpendicular to the current in 2015. In accordance with NMFS Permit No. 16547-01 (NMFS Permit, hereafter) protocols, gill netting for Atlantic Sturgeon only occurred when water temperature did not exceed 27.0 °C to allow for acoustic transmitter implantation.

In 2013-2014, gill net sites were selected based on water depth and anecdotal evidence from local fisherman. After Atlantic sturgeon were successfully captured in 2014 and continuing in 2015, these fish were manually tracked with a VEMCO, VR-100 general purpose acoustic receiver (Bedford, Nova Scotia, Canada). Detected fish were used as sentinels to locate other untagged fish in the vicinity, under the assumption that they would utilize similar habitats, or follow other sturgeon. When no Atlantic Sturgeon transmitters were detected, nets were set in areas that successfully captured sturgeon previously.

Gill nets were checked for Atlantic Sturgeon by lifting the nets across the bow and sliding the boat along the net. This was done without changing the location of the net. Occasionally an anchor would become dislodged by strong river currents. On these occasions, the net was pulled into the boat and reset in the same location. On average, the nets were set and allowed to soak in the water for two slack tides. During this period, the nets were checked every hour to ensure that captured Atlantic Sturgeon were not overstressed.

When an Atlantic Sturgeon was captured in the net, it was first tied by the tail and anchored to the boat. This prevented premature release if the fish were to break free from the net. The sturgeon was then gently and rapidly removed from the net and lifted aboard the boat with the aid of hoop net. The hoop nets help support the fish, and aid the biologists in controlling the fish to reduce the possibility of physical injury.

Once on the boat, the fish was placed into a 340 L tank (2.4 m x 0.9 m x 0.5 m) containing fresh river water supplemented with pure oxygen (Figure 2). The fish were worked up immediately according to the NMFS Permit protocols. Each fish was measured to total length (2015 only) and fork length (mm), weighed (kg), and a fin clip was taken for DNA analysis. Sex was determined by expressing gametes. The fish were then internally tagged with a Passive Integrated Transponder (PIT) tag and externally tagged with a Floy T-bar tag below the dorsal fin, on the left side of the fish.

Water temperature permitting (< 27 °C), the Atlantic Sturgeon were then anesthetized with 150 mg/L tricaine methane sulfonate (MS-222) in 2014 or electronarcosis (EN; Henyey et al. 2002; Balazik et al. 2013; Balazik 2015) in 2015. An internal acoustic transmitter (VEMCO model V16-6H, battery life 10 years; Bedford, Nova Scotia, Canada) was inserted via a 5.0-7.0 cm incision made ventrally, just anterior to the vent. The incision was closed by the interrupted suturing technique with sterile, absorbable sutures that are undyed and braided (Coated Vicryl, Ethicon, Inc. 2007). If the sex could not be determined by manual expression, sex was visually determined through the incision. The closed incision was dressed with iodine.

Before implantation, each acoustic tag was tested manually with a VR-100 acoustic receiver to ensure that the tag was functioning properly. These acoustic tags aid in tracking the movements of the fish throughout Marshyhope Creek, Nanticoke River, Chesapeake Bay and Atlantic Ocean.

Once the fish was tagged successfully, and all metrics were taken, the fish were lifted overboard and placed back into the river. Maryland DNR biologists remained with the fish until it exhibited signs that it was fully recovered from the MS-222 or EN and surgery and swam away from the boat on its own.

Receiver Arrays

In order to track the movements of fish that are tagged with acoustic transmitters, acoustic monitoring receivers (VEMCO model VR2W; Bedford, Nova Scotia, Canada) were placed throughout river systems. The first receivers were placed in Marshyhope Creek in 2013, with additional receivers added to the array each year (Figure 3). Initially, once the receivers were deployed, they remained deployed for the entire year, and were maintained monthly. After a severe icing event that occurred in the winter of 2014, project biologists decided it would be best to remove all receivers in December once all detected Atlantic Sturgeon have left the river systems, to prevent potential loss of assets.

Receiver locations were initially determined based on anecdotal evidence of sightings by local fishermen. Later, receiver locations were determined by locating private piers or U.S. Coast Guard (USCG) navigational buoys that were close to the channel in areas where Atlantic Sturgeon are known to occur. Locations that maximize the distance the receivers will be able to detect transmitters are on long straight sections of river, and on the outsides of bends where the receiver can detect transmitters on either side of the bend.

The easiest method for receiver deployment was to obtain permission to access a private pier. Pier owners were contacted by phone and general mail. Once permission was granted, stainless steel cable was looped through two holes drilled into tube steel and crimped into place with two zinc-plated copper crimps. The length of cable needed was determined by lowering the tube steel to the bottom of the river. The cable was looped around a lower beam on the pier, cut and crimped into place with two crimps. A length of hydraulic tubing was slid over the cable inside the loop to prevent the cable from wearing on the wooden beams. The receiver was attached to the cable with two hose clamps and two heavy duty zip ties approximately 1.0 m from the riverbed (Figure 4).

Another method for receiver deployment was to attach the cable to a USCG navigational buoy. An official request package was sent to Commander, U.S. Coast Guard, Fifth Coast Guard District Portsmouth, VA with a project description, an E-mail stating compliance with the Coastal Zone Management Act, and a letter to certify that the State of Maryland is self-insured.

The USCG granted a license to use USCG real property (HSCG83-14-6-0026) for all requested assets. Receiver attachment to USCG assets was similar to that of a private pier. Tube steel attached to stainless steel cable was lowered to the riverbed. Once an appropriate length was determined, the cable was cut and crimped as close to the waterline as possible, usually by looping the cable around a step. The receiver was attached in the same manner as with the private piers.

If a private pier or USCG asset was not available in the desired area, a MD DNR Jim-Buoy (Figure 5) was deployed. Each buoy was white and lined with orange reflective tape, with the words UMD (University of Maryland) STURGEON REASEARCH (UMD is a project partner), painted on the side. Galvanized chain was then shackled from an eye bolt on the bottom of the buoy to two 22.0 kg cinder blocks. The chain was several meters longer than the maximum depth at high tide to ensure the buoy will float. A 2.0 m length of steel cable that held the receiver, was also shackled to the eye bolt on the bottom of the buoy and weighed down with tube steel at the opposite end. The receiver was attached in the same manner as with the private piers and USCG navigational buoys or pilings.

Receivers were coated with a thin layer of zinc oxide cream to prevent fouling by algae and barnacles. The cream also aided in the removal of any growth that did occur, but did not damage or affect the functionality of the receiver.

Receivers were maintained monthly. Each receiver was retrieved, activated, and all data were downloaded to a computer with the VEMCO User Environment (VUE) software. The receivers were then cleaned of debris and algae and returned to the water. Once all tagged Atlantic Sturgeon were detected leaving Nanticoke River in late fall, the receivers and all related equipment were removed from the private piers, USCG buoys and all MD DNR Jim Bouys, and anchors were removed from the rivers and creeks.

Every Atlantic Sturgeon implanted with an acoustic tag was registered into the Atlantic Cooperative Telemetry (ACT) network. Through this network, researchers who detect a MD DNR tagged Atlantic Sturgeon on one of their receivers can share this information with MD DNR biologists. In return, data collected on MD DNR receivers from fish tagged by other researchers are returned to them.

Statistical Analysis

Maryland DNR biologists wanted to determine if there was a diurnal difference in movement in Atlantic Sturgeon. The time of first detection was determined for each tagged Atlantic Sturgeon on receivers within the Marshyhope Creek and Nanticoke River. It was assumed that the first time an Atlantic Sturgeon was detected by a receiver, the fish was moving. Each day was broken in to “day” and “night” time periods. The “day” time period was from 0700-1859 and the “night” period was from 1900-0659. The number of times an Atlantic Sturgeon was detected at the receiver in each of those time periods was counted. A paired two-sample t-test was run in Excel (Microsoft Office 2013) to test for differences.

Results

Gill Netting

Maryland DNR biologists gill netted for Atlantic Sturgeon for a total of 709.87 hours over 40 fishing days (Table 1). Catch per unit of effort (CPUE) was calculated as the total number of fish captured, divided by the total number of hours fished per year. The CPUE was higher (0.033) in 2014 than in 2015 (0.019). In 2015, gill netting started in mid-July, most likely before the sturgeon entered Marshyhope Creek, leading to a lower CPUE. Each year, fishing ceased each season when tagged Atlantic Sturgeon were no longer detected in the Marshyhope Creek.

To date, 15 individual Atlantic Sturgeon have been captured in Marshyhope Creek (Table 2). Eight adult Atlantic Sturgeon were captured and tagged in Marshyhope Creek from August 27 to September 16, 2014. Fish ranged from 135-203 cm FL. Bottom water temperature ranged from 21.5-26.6^{o}C when fish were captured in the fall. All fish were captured within a one hour window of slack tide. Seven adult male Atlantic Sturgeon were captured and tagged in Marshyhope Creek from August 31 to September 29, 2015. Fish ranged from 132-163 cm FL (147-183 cm TL). Bottom water temperature ranged from 22.1-25^{o}C when fish were captured. Zero Atlantic Sturgeon were captured in 2013.

One of the Atlantic Sturgeon tagged in 2014, ATS 27543, was recaptured in 2015 by Delaware Division of Fish and Wildlife (DE DFW). The fish was reportedly in good condition and the incision where the transmitter was implanted was fully healed (Figure 6). The fish was identified by its PIT tag and had lost the external Floy tag. The Floy tag was replaced by DE DFW biologists.

In 2014, one female and one male Atlantic Sturgeon were captured in the same gillnet. The male and the female were both in spawning condition (presence of flowing milt in the male, and loose, black eggs in the female). The male fish indicated wear on the ventral scutes and base of the caudal fin. The other five male Atlantic Sturgeon that were captured in 2014 were flowing milt, and the second female Atlantic Sturgeon was full of eggs (observed during surgery to implant the acoustic tag). Four of the seven male Atlantic Sturgeon captured in 2015 expressed milt when gentle pressure was applied to the abdomen. The other three fish had testes that were visible during surgery.

Atlantic Sturgeon Movement

In 2014, five of the eight sampled Atlantic Sturgeon left Marshyhope Creek and traveled within the Nanticoke River for up to a month after tagging, generally moving back and forth between Ferry Point and Chapter Point (Table 3). One fish traveled downstream to Chapter Point, where he lingered for more than a month before finally leaving the river. Two fish left the Marshyhope Creek and swam farther upstream in the Nanticoke River to Sharptown, MD. The majority of fish left the system by the beginning of October. One fish was not detected leaving until the end of October.

In 2015, only four of the seven tagged fish traveled throughout the river system for a few weeks (Table 4). Two fish left the Nanticoke River within a week and another in two weeks, without making a return trip upstream. These fish were all tagged late in the season. The remaining four fish traveled throughout the Marshyhope Creek and Nanticoke River for up to a month before leaving the system. One fish traveled upstream in the Nanticoke River and crossed into Delaware, where it was detected by receivers in Broad Creek. All the 2015 tagged Atlantic Sturgeon exited the Nanticoke River by mid-October.

In addition to the seven fish captured and tagged in 2015, three Atlantic Sturgeon tagged in 2014 returned to the Nanticoke River (Table 5). Two of these fish were detected entering the river at the end of June (ATS 27545 and ATS 26352) and one fish in mid-August (ATS 27543). The two fish arriving earlier staged in the lower reaches of the Nanticoke River until mid to late August, when they started to make their way upstream to the Marshyhope Creek and headwaters of the Nanticoke River. The fish that entered the Nanticoke River later in the season did not stage in the lower reaches of the river. This fish immediately migrated upstream to the Delaware waters of the Nanticoke River, and was detected on receivers by interagency partners, DE DFW.

At the time of this writing, eight of MD DNR's tagged Atlantic Sturgeon (and one sturgeon tagged by a partner) have returned to the Nanticoke River and Marshyhope Creek in 2016. Two of the 2014 sturgeon that returned in 2015 have also returned in 2016. These sturgeon exhibited the same behaviors as the fish who returned in 2015. They staged in the lower reaches of the Nanticoke River and made brief trips to Marshyhope Creek and the upper reaches of the Nanticoke River, before returning to the staging area (no table will be included due to incomplete data).

ATS 27543

After tagging, ATS 27543 originally swam upstream, where he stayed for a week before exiting the Nanticoke River in late September (Figure 7). After exiting the Chesapeake Bay, he was detected on receivers in the Delaware Bay in October and the offshore array maintained by the U.S. Navy in the Atlantic Ocean in December to April. The fish returned to the Chesapeake Bay in April 2015 but was not detected entering the Nanticoke River until Mid-August (Figure 8). Instead of staging in the lower reaches of the river near Chapter Point, this fish swam immediately upstream into Delaware waters of the Nanticoke River and Broad Creek. He stayed in these upper areas of the river until the beginning of October when he made a brief trip into Marshyhope Creek. He lingered near the mouth of the Nanticoke River before leaving two weeks later. From December through April 2016, ATS 27543 was detected on three receivers 26-70 km offshore of Virginia Beach, Virginia. He then returned to the mouth of the Chesapeake Bay in April and again in June 2016. At the time of this writing, he was detected on receivers in the Nanticoke River (not depicted graphically).

ATS 27544

Atlantic Sturgeon ATS 27544 was never detected leaving the Nanticoke River system in 2014. MD DNR biologists manually tracked for the sturgeon between the last two receivers where it was detected. The transmitter was tracked to a deep hole 6 km downstream from Vienna, MD. The area was search thoroughly using a directional hydrophone to triangulate the exact position on several occasions. For the remainder of the year, the transmitter never moved from the initial position. There were no Atlantic Sturgeon observed and no deceased Atlantic Sturgeon reported in the area. Since no carcass was observed, this fish likely shed its tag and is assumed to be alive.

ATS 27545

Fish ATS 27545 was tagged in 2014 and returned to the Marshyhope Creek in 2015 (Figure 9). After exiting the Chesapeake Bay undetected in 2014, he was detected by receivers in the Delaware Bay in November 2014. In April 2015, he returned to the Chesapeake Bay, bypassed the Nanticoke River, and entered the Choptank River. He traveled all the way upstream to Bow Knee Point in the Choptank River before he was detected leaving the river two weeks later. He was then detected entering the Nanticoke River six days later. He staged in the lower Nanticoke River for two months and then swam up river to the Marshyhope Creek in late August. He exited Marshyhope Creek in mid-October. He exited the Chesapeake Bay one week later. In December 2015 and March through April 2016, ATS 27545 was detected on receivers 30-60 km offshore of Virginia Beach, Virginia. Four days later he was detected at the mouth of the Chesapeake Bay.

ATS 27546

This Atlantic Sturgeon is the only female sturgeon captured by MD DNR that retained an operational tag. This fish exited the Marshyhope Creek (Figure 10) one week after she was tagged in late-August, and moved between Chapter Point and Ferry Point for a few weeks before leaving the system. She left the Chesapeake Bay in November 2014 and was detected near the mouth of the Chesapeake Bay in April of 2015 but never entered the bay. Instead, she was detected moving up the Atlantic coast of Delaware to the mouth of the Delaware Bay in late May 2015. She was detected again in the mouth of the Chesapeake Bay in December 2015. She was detected approximately 10 km off shore of Virginia Beach, Virginia in January 2016 then back at the mouth of the Chesapeake Bay the next day. Fish ATS 27546 was detected again at the mouth of the Chesapeake Bay in April and May. At the end of May and early June, she was detected in Sandy Hook Bay, New Jersey.

ATS 27547

Fish ATS 27547 is perhaps MD DNR's most well-traveled male sturgeon (Figure 11). He was tagged in September 2014 and exited the Chesapeake Bay in November. He was detected again by South Carolina Department of Natural Resources receivers in Charleston, South Carolina in December 2014. In April of 2015, he returned to the Chesapeake Bay and was detected by U.S. Navy receivers in the mouth of the James River. He was then detected moving up the Atlantic Coast in May, and frequented the mouth of the Delaware Bay though September 2015. In October 2015, he returned to the mouth of the James River and then exited the Chesapeake Bay in late-November. One week later, he was detected by North Carolina State University receivers in Beaufort, North Carolina. In mid-January 2016, he was again detected on receivers off the coast of South Carolina. In April he was detected at the mouth of the

Chesapeake Bay. By June, he made his way to the York River and was detected as far upstream as the lower Pamunkey River.

ATS 26350

Atlantic Sturgeon ATS 26350 was tagged in mid-September 2014 and exited the Marshyhope Creek, but continued to move throughout the Nanticoke River for almost two weeks. It swam upstream to Sharptown, Maryland before exiting the system, and eventually the Chesapeake Bay, in early November (Figure 12). This fish was detected coming into the Chesapeake Bay in April 2015, and detected again entering the mouth of the Rappahannock River at the end of August. Three weeks later, the fish left the Rappahannock River and arrived at the mouth of the York River. He went as far upstream as 4 km above Horseshoe, Virginia in the Pamunkey River (a tributary to the York River) and stayed there for three weeks, constantly moving between the receivers before exiting York River in mid-October (Figure 13). The next day he was detected at the mouth of the Chesapeake Bay. Fish ATS 26350 was detected on receivers 30-40 km offshore off of Virginia Beach, Virginia. He returned to the mouth of the Chesapeake Bay in April of 2016 and again to the York River in May 2016.

ATS 26351

Fish ATS 26351 was a male tagged in the Marshyhope Creek in mid-September 2014. He left Marshyhope Creek, but moved around within the Nanticoke River for a few days, including running upstream to Sharptown, Maryland, before exiting the river (Figure 14). He spent a few weeks around the mouth of the Chesapeake Bay before leaving in mid-November 2014. This fish was again detected at the mouth of the bay in April 2015 but was not detected in any Chesapeake Bay tributaries. He returned again to the mouth of the Chesapeake Bay in April 2016, and was detected again in the Nanticoke River in early May 2016. He was detected on receivers all the way up to Sharptown, Maryland. He has since left the Nanticoke River and in late June, he was detected on receivers at the mouth of the Rappahannock River in Virginia (not depicted graphically).

ATS 26352

Atlantic Sturgeon ATS 26352 was a male tagged in mid-September 2014 that immediately left the Nanticoke River system. A few weeks later, he was detected leaving the Chesapeake Bay (Figure 15). He returned to the Chesapeake Bay in April 2015 and was detected in the suspected staging areas of the Nanticoke River in late June (Figure 16). This fish moved around in the lower reaches of the Nanticoke River until August when he moved upstream into the Marshyhope Creek for the first time. Fish ATS 26352 moved between the Nanticoke and Marshyhope in mid-August. He eventually exited the system in October and the mouth of the Chesapeake Bay in November. Fish ATS 26352 has again returned to the Nanticoke River in 2016, and so far has been detected as far upstream as Ferry Point.

ATS 26353

Fish ATS 26353 was the first sturgeon tagged in 2015 at the end of August. He continued to frequent the Marshyhope Creek for several weeks, making a trip to the Nanticoke River as far downstream as Lewis Wharf and upstream to Sharptown, Maryland before returning to Marshyhope Creek (Figure 17). He left the Marshyhope Creek for the final time at the end of September and exited the Nanticoke River in early October. He left the Chesapeake Bay in November. Fish ATS 26353 has returned to the Nanticoke River in 2016 in early June, and to date was detected as far upstream as Chapter Point.

ATS 26354

Atlantic Sturgeon ATS 26354 left the Marshyhope two days after being tagged in 2015 (Figure 18). He remained in the Nanticoke River, moving between Ferry Point and Roaring Point for a month before leaving the river. This fish exited the bay in early November. He was detected on receivers off the coast of North Carolina in late March 2016. This fish has since returned to the mouth of the Chesapeake Bay in 2016. He was first detected at the Chesapeake Bay mouth in May and traveled briefly upstream to the mouth of the Rappahannock and York Rivers (not depicted graphically). He then returned to the mouth of the Chesapeake Bay, and at the time of this writing was in the Nanticoke River.

ATS 23900

Male sturgeon ATS 23900 was captured in 2015. This fish was previously captured in the Altamaha River in Georgia by University of Georgia researchers in 2006 (M. Mangold, USFWS, personal communication). This fish had no external tags and was only identified as a recapture when it was scanned for PIT tags. He was tagged with a Floy tag and an internal acoustic telemetry tag before release. Fish ATS 23900 moved around in the Marshyhope Creek for a week post-surgery (Figure 19). He then traveled upstream in the mainstem Nanticoke River and made several trips to Broad Creek in Delaware. He was detected on receivers in Delaware until early October, then exited the Nanticoke River a few days later. He exited the Chesapeake Bay in mid-October. Fish ATS 23900 was detected in late December off the coast of South Carolina, and again in May 2016. He was last detected at the mouth of the Chesapeake Bay in June 2016.

ATS 23901

Sturgeon ATS 23901 was tagged in early September 2015. He slowly made his way out of the system within the next three weeks without returning back upstream (Figure 20). He left the mouth of the Chesapeake Bay in November. He returned to the Nanticoke River in 2016 and swam as far upstream as Ferry Point.

ATS 23902

Atlantic Sturgeon ATS 23902 was tagged in mid-September 2015. He made several trips between Brookview and Ferry Point before leaving the Marshyhope Creek for the last time at the end of September (Figure 21). Two weeks later, he exited the Nanticoke River system and left the Chesapeake Bay by the end of October 2015. He came back to the mouth of the Chesapeake Bay in April 2016. In early June, he was detected at the mouth of the York River in Virginia (not depicted graphically).

ATS 23903 and ATS 23904

Male Sturgeons ATS 23903 and ATS 23904 exhibited similar behavior. Both fish were tagged in late September. Both fish left the Nanticoke River system less than two weeks after capture (Figure 22; Figure 23). Fish ATS 23903 was never detected leaving the Chesapeake Bay. Fish ATS 23904 was detected leaving the Chesapeake Bay in mid-November. Both fish returned to the Nanticoke River in 2016. ATS 23903 was detected upstream to Chapter Point and ATS 23904 made his way to Lewis Wharf.

Additional Atlantic Sturgeon

An Atlantic Sturgeon that was previously tagged in the Pamunkey River, a tributary to the York River (Virginia) was detected in the Nanticoke River in 2015. This fish staged in the lower Nanticoke River for over three months before moving upriver past Sharptown, Maryland. It was detected on receivers in Seaford, Delaware and Deep Creek, another tributary to the Nanticoke River, before leaving the system in mid-October. This behavior is similar to the behavior exhibited by Atlantic Sturgeon captured and tagged in Marshyhope Creek.

Similar to 2015, Atlantic Sturgeon tagged by other researchers were detected in the Nanticoke River in 2016. One fish, originally tagged in the Pamunkey River, entered the river in early May, and migrated upriver as far as Ferry Point twice before exiting the system. Another Atlantic Sturgeon, originally tagged in the Delaware River, entered the river in early June. This fish moved upriver to Riverton before returning to the staging area at Chapter Point where he remained for two weeks.

Two fish tagged by collaborators, one from the James River, and one from the Pamunkey River, were detected in the Pocomoke River in 2014 and 2015, respectively. The fish from the James River was detected near the mouth of the river for a week before leaving. The fish from the Pamunkey River moved around in the lower reaches of the Pocomoke River before moving upstream to Pocomoke City in September. He stayed in this location until exiting the river in mid-October.

Receiver Arrays

From 2013 to 2016, the MD DNR receiver array expanded from two to 30 receivers (Table 6; Figure 24). All are located in eastern shore Maryland tributaries to the Chesapeake Bay. The majority of receivers are located in Marshyhope Creek (16 receivers; Figure 25) and mainstem of the Nanticoke River (7 receivers; Figure 26). The number of receivers in this system has grown from two receivers in 2013 to 24 receivers in 2016 (Figure 3). Another receiver is located in Broad Creek, a tributary to the Nanticoke River. Additional receivers are located on the Choptank (3 receivers; Figure 27) and Pocomoke (3 receivers; Figure 28) rivers. The receiver located at the Dover Bridge on the Choptank River was removed due to the lack of

Atlantic Sturgeon detections. No receivers were lost when deployed using the attachment methods described.

Each receiver has a detection distance of approximately 1,000 m line-of-sight. Unfortunately, the receivers are unable to detect transmitters around bends in the river. Based on this information, the distance each receiver could detect a transmitter was estimated on a map of the Marshyhope Creek (Figure 29). Approximately 75-90% of Marshyhope Creek downstream of Federalsburg, Maryland has receiver coverage.

To date, over 150 individual fish from six different species and 16 different researchers, were detected on MD DNR receivers. In addition to the 15 Atlantic Sturgeon tagged by MD DNR, 15 Atlantic Sturgeon, tagged by other agencies were detected on MD DNR receivers.

After the data were downloaded, codes were identified and data were returned to the owner if possible. However, all researchers are not registered through the ACT network, so not all transmitters can be identified. Thirty fish detected on MD DNR receivers to date are unidentified.

Some stations, specifically on the Nanticoke and Pocomoke rivers, indicate a large number of detections within a single year, while other receivers indicate only a small number of detections (Table 7; Figure 30). The Chapter Point receiver on the Nanticoke River had more than 12,000 detections in 2014 and 20,000 detections in 2015. This is more than twice the number of detections at any other single receiver on the Nanticoke River or Marshyhope Creek. This is also seen on the Pocomoke River in 2015. The Pocomoke City receiver had over 3,000 detections while the other two receivers had only 564 detections, combined.

Statistical Analysis

Atlantic Sturgeon arrived at receivers significantly more often during the "night" hours than during the "day" hours (t = -3.83, df = 13, p = 0.001). The total number of first time detections was 206 with 72 occurring during the "day" hours and 134 occurring during the "night" hours. The number of first time detections was determined for 14 of the 15 tagged Atlantic Sturgeon. Fish ATS 27544 was excluded for only having two first time detections.

Discussion

Fall Spawning in Nanticoke River system

In 2014, one male and one female adult Atlantic Sturgeon were captured in the same net. Both fish were found to be in spawning condition; flowing milt in the male and loose black eggs in the female. The male sturgeon also had wear on the ventral scutes and at the base of the caudal fin (Randall and Sulak 2012; Hager et al. 2014). Being in such close proximity to each other, it is possible that these fish were actively spawning when caught. All of the fish in this study were captured between 20-25^{o}C. This is within the range of temperatures that others have reported fall spawning populations, or capturing fish in spawning condition (Collins et al. 2000; Balazik et al. 2012; Hagar et al. 2014; Smith et al. 2015)

It is possible that a fall spawning population of Atlantic Sturgeon exists in Marshyhope Creek. Fall spawning populations of Atlantic Sturgeon have been reported in several tributaries to the Chesapeake Bay. Balazik et al. (2012) documented evidence of a fall spawning population of Atlantic Sturgeon in the James River based on the seasonal presence of spawning condition fish, tracking data, and the seasonal frequency of vessel strikes. Similarly, Hager et al. (2014) reported a fall spawning population of Atlantic Sturgeon in the York River watershed in Virginia after capturing reproductively active fish in the Pamunkey River.

Smith et al. (2015) confirmed fall spawning in the Roanoke River in North Carolina when researchers collected Atlantic Sturgeon eggs from egg mats placed near putative sturgeon spawning areas. Research partners from the University of Maryland Center for Environmental Science (UMCES) have placed egg mats in the Marshyhope Creek downstream of putative spawning areas (Richardson and Secor 2016). To date no eggs have been collected.

All of the Atlantic Sturgeon tagged by MD DNR in the Marshyhope Creek (2014-2015) were detected on receivers in 2016 with the exception of ATS 27544. Maryland DNR believes this sturgeon shed her tag shortly after implantation (Table 8). Thirteen of the fourteen remaining fish were detected in June. The remaining fish, ATS 27545, was last detected entering the Chesapeake Bay in April 2016. This extremely important information indicates that these fish have all retained their transmitters, and the transmitters are still functioning. Most importantly, these 14 Atlantic Sturgeon are still alive and were not adversely affected by capture and the surgical procedure to insert the acoustic transmitter.

One Atlantic Sturgeon (ATS 27543) that was captured and tagged in 2014 was recaptured by interagency partner DE DFW in 2015. The fish appeared to be healthy and the incision where the transmitter had been inserted, was healed (Figure 6). However, the previously applied Floy tag was lost. Delaware DFW tagged this fish with a new Floy tag before he was released. Floy T-bar tag retention in sturgeons appears to be initially high (>90%), then falls in later years. Rien et al. (1994) tagged White Sturgeon *Acipenser transmontanus* and found that T-bar retention was reduced to <83% after one year at-large. Clugston (1996) found similar results in tagged Gulf Sturgeon *Acipenser oxyrinchus desotoi.* He found that after the one year, external tag retention was reduced to 60%, but the retention of PIT tags remained >90% after the first year of the study. For long term studies research into alternative external tags may be necessary.

Anesthetization techniques

Atlantic Sturgeon captured in 2014 were anesthetized with MS-222, while fish captured in 2015 were anesthetized with EN. All of the fish anesthetized with MS-222 left Marshyhope Creek within a few days of capture. Most of the fish remained in the Nanticoke River for several weeks, typically travelling the lower reaches of the Nanticoke River. Only two of the fish swam upstream past the Marshyhope Creek to Sharptown, Maryland and none returned to the Marshyhope Creek.

The fish anesthetized with EN also left the Marshyhope Creek, usually within a few days of capture. Several of the fish returned to the Marshyhope Creek at a later date (ATS 26353 and ATS 23902), and one fish (ATS 23900) even continued to move upstream in the Nanticoke River to Broad Creek in Delaware. Two fish travelled the lower Nanticoke River (ATS 26353 and ATS 26354). Two Atlantic Sturgeon captured in 2015, both captured in late September, left the Marshyhope Creek and completely exited the Nanticoke River within days of their initial capture. Maryland DNR biologists believe this was due to their late season capture.

Electronarcosis is the current preferred method used by MD DNR to anesthetize Atlantic Sturgeon in the field. The fish anesthetized with EN succumbed to the effects of the electricity rapidly, remained motionless during surgery and recovered instantly once the electricity was turned off. There were no ill effects to the biologists during surgery. Fish that were anesthetized with MS-222 (150 mg/L) took >5 minutes to succumb to the effects of the drug and frequently took >10 minutes to fully recover. After release, MS-222 anesthetized sturgeon remained disoriented at the surface of the water rather than swimming to the bottom.

Balazik et al. (2013) found no significant differences in cortisol levels 1 h post treatment between juvenile Atlantic Sturgeon anesthetized with MS-222 and EN. Balazik (2015) also demonstrated that the use of EN did not appear to affect the behavior of male Atlantic Sturgeon if they are captured and treated during the spawning season. Maryland DNR biologists will continue the use of EN to anesthetize Atlantic Sturgeon. The only time MS-222 will be used in the future is if the EN machine becomes unserviceable or the power source fails.

Telemetry arrays

Receivers within the Marshyhope Creek were placed to maximize transmitter detections (Figure 29). This limits missed detections. It also has the potential to help biologists narrow down the location of spawning habitat within the creek. Many of the receivers were placed in the vicinity of hard bottom which is preferred Atlantic Sturgeon spawning substrate (Collins et al. 2000)

Some of the receivers indicate a large number of detections in comparison to other receivers within the Nanticoke and Pocomoke rivers (Figure 30). Fish potentially use these areas for staging before they move further upriver to spawning habitat. Further research needs to be conducted to identify conditions that determine staging area preference. It may be beneficial to attempt to capture these sturgeon while they are congregated before they spread throughout the river system. Capturing fish in the staging area could indicate the impact capture has on the potential spawning run of a fish or allow more fish to be captured in a shorter period of time.

The areas that the Atlantic Sturgeon pass through between staging and spawning habitats are thought to be transition areas (Figure 31), and the sturgeon spend little time in these areas. The addition of 12 receivers to Marshyhope Creek in 2016 may also help to determine spawning locations if one receiver indicates a much larger number of detections than other receivers in the area.

Atlantic Sturgeon entered the Nanticoke River as early as May or June, but remain in the lower reaches of the Nanticoke River in the staging area. Due to heavy commercial vessel traffic, sampling in the mainstem Nanticoke River was difficult. Only fish that reached the upper Marshyhope Creek were encountered, and these fish were usually in active spawning condition.

The acoustic receiver data also indicate a strong preference for evening, night and early morning movement. Wrege et al. (2011) found similar results with Gulf Sturgeon in the Pensacola Bay system in Florida. They describe a significant diurnal difference in sturgeon movement during the fall through spring months. The data from the current analysis come primarily from late summer through early fall.

To date, MD DNR biologists have only attempted to capture sturgeon during daylight hours. Even though some fish were moving and captured during the day, it may be advantageous to attempt to gill net in the evening and nighttime hours when the fish are more active. It could also reduce gill net avoidance, and reduced boat traffic would minimize encounters between vessels and sampling gear.

The Atlantic Sturgeon were observed to return to the Nanticoke River at the same time each year. In 2015, two sturgeon tagged by cooperators arrived at the end of May, followed by two more sturgeon previously tagged by MD DNR in June. An exception to this is, Atlantic Sturgeon ATS 26543 did not arrive in the Nanticoke River until August. In 2016, five of MD DNR's tagged sturgeon arrived in the river within eight days of each other in early June, and another arrived one week later. One fish tagged by a collaborator arrived in mid-May.

Similarly, in the fall the fish all seem to exit within a few days of each other. In 2014, MD DNR tagged sturgeon all left the river within 1.5 weeks of each other at the end of September, with the exception of one fish that lingered at Roaring Point. This fish left in late October. In 2015, all of the fish MD DNR tagged that year left within a week in mid-October, with the exception of one fish that left in the beginning of October. Of the three 2014 returning fish, two of these fish also left in the beginning of October. The remaining previously tagged fish left in late October. Interestingly, this was the same fish that left in late October in 2014.

It appears that the rapid departure of the fish in 2015 was due to a large rain event in the Nanticoke River watershed. It is possible water temperature plays a key role in determining when fish enter and exit the river system. Future studies on the Nanticoke River should include long-term water quality monitoring to help biologists to more precisely determine when fish are entering and exiting the system.

Pamunkey Connection and DNA assessment

Several of the Atlantic Sturgeon (ATS 26350 and ATS 27547) that were captured in Marshyhope Creek were later detected by interagency partners as they entered the York River and migrated up into the Pamunkey River tributary in Virginia. Several others were detected near the mouth of the York River. Conversely, numerous sturgeon that were tagged by researchers in the Pamunkey River were later detected in the Nanticoke River during putative spawning seasons. Evidence exists that the Pamunkey River Atlantic Sturgeon and the Nanticoke River Atlantic Sturgeon populations are more closely related to each other than they are related to other Chesapeake Bay spawning populations such as the James River. It is suspected that these two populations from the Nanticoke and Pamunkey rivers may be part of a larger metapopulation. As of 2015, 16 samples were analyzed for river of origin and DPS assignments. Twenty-five samples are the minimum sample size needed for statistical significance (T. King, United States Geological Survey, personal communication).

Conclusion

Interestingly, MD DNR tagged Atlantic Sturgeon all exhibited similar behaviors upon entering the river, regardless of where they were tagged and which river they were detected in. Fish tagged in the Marshyhope Creek that returned to the Nanticoke River typically staged in lower areas of the river near Chapter Point, making occasional transits to the upper areas of the Nanticoke River and Marshyhope Creek. During these upstream movements, they often remained for only a short time before returning to the staging area. As the season progressed, the fish traveled further upstream eventually remained there for a few days to weeks. Once the tagged Atlantic Sturgeon decided to leave the river, they exited the system within a couple of days. This same behavior was exhibited by Atlantic Sturgeon tagged in the Nanticoke River and detected on the York, Pamunkey, and Pocomoke rivers.

Substantial information was collected since the recent discovery of mature Atlantic Sturgeon in the Marshyhope Creek and Nanticoke River. Fish are migrating up the rivers and creeks in the fall months, and appear to be in spawning condition. Additionally, some fish return on an annual basis and fish from other rivers are frequenting the area. There is so much more to learn:

1. How large is this population of Nanticoke River Atlantic Sturgeon and are they genetically similar to the Pamunkey River population?
2. Are the fish successfully spawning in Marshyhope Creek?
3. Is there acceptable habitat and water quality for spawning, egg, larval and juvenile production?

Future studies and monitoring of Atlantic Sturgeon on Marshyhope Creek and Nanticoke River should be directed towards answering these questions and others, in an effort to restore this biologically and economically important and ancient species to river systems and the Chesapeake Bay.

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Tables

Table 1. Total time fished for Atlantic Sturgeon and annual CPUE. The highest CPUE occurred in 2014 when more Atlantic Sturgeon were captured in a shorter period of time. The increase in hours fished in 2015 occurred because sampling started several weeks before sampling started in previous years.

Year	Hours Fished	# Fish Captured	Catch per Hour	Start Date	End Date
2013	94.60	0	0.000	08/29/2013	10/09/2013
2014	245.50	8	0.033	08/07/2014	10/08/2014
2015	369.63	7	0.019	07/21/2015	10/01/2015
Total	709.87	15	0.021	-	-

Table 2. Date and time of capture and biological information for the 15 Atlantic Sturgeon captured in Marshyhope Creek from 2014-2015.

VEMCO ID	Date Tagged	Time	Mesh Size (cm)	Sex	Total Length (cm)	Fork Length (cm)	Weight (kg)
27544	08/27/2014	1430	25.40	F	-	203.00*	70.00
27545	08/27/2014	1430	25.40	M	-	142.00*	32.00
27543	09/05/2014	1600	25.40	M	-	176.00*	43.00
27546	09/11/2014	0740	25.40	F	-	168.00	43.00
27547	09/11/2014	0850	20.30	M	-	135.00	20.00
26350	09/11/2014	1520	20.30	M	-	135.00	19.00
26351	09/16/2014	1245	25.40	M	-	135.00	21.00
26352	09/16/2014	1400	25.40	M	-	182.00	33.00
26353	08/31/2015	0638	30.48	M	147.32	142.24	30.16
26354	08/31/2015	0745	30.48	M	149.86	132.08	23.60
23900	09/15/2015	1105	30.48	M	149.86	132.72	22.22
23901	09/15/2015	1515	25.40	M	168.28	154.94	30.76
23902	09/17/2015	1330	35.56	M	172.09	154.94	34.04
23903	09/29/2015	1005	30.48	M	183.52	162.56	37.24
23904	09/29/2015	1505	30.48	M	175.26	154.94	34.56

*Fork length was estimated based MD DNR captive wild broodstock.

Table 3. 2014 Atlantic Sturgeon movements for fish captured in 2014. The date and time of the initial and final detection for a receiver was recorded. The first detection for each sturgeon was the first time it was detected after the transmitter was implanted and the direction of movement was determined by the release location. Only the furthest upstream and furthest downstream movement was indicated as a fish moved in that direction. For example, ATS 27545 moved downstream from Fook's Pier to Chapter Point. There are four receivers in between these two locations that are not mentioned.

VEMCO ID	Date Tagged	Receiver Detected	Date of Initial Detection	Time of Initial Detection	Date of Last Detection	Time of Last Detection	Waterbody	Direction Moved
27544	08/27/2014	Brookview	08/28/2014	0904	08/28/2014	1001	Marshyhope	Downstream
		Ferry Point	08/29/2014	1128	08/29/2014	1445	Nanticoke	Downstream
27545	08/27/2014	Fook's Pier	08/28/2014	0321	08/28/2014	0814	Marshyhope	Upstream
		Chapter Point	09/13/2014	0156	10/25/2014	1312	Nanticoke	Downstream
27543	09/05/2014	Brookview	09/06/2014	1037	09/07/2014	0503	Marshyhope	Downstream
		Fook's Pier	09/08/2014	2353	09/16/2014	2321	Marshyhope	Upstream
		Chapter Point	09/28/2014	0123	09/28/2014	0223	Nanticoke	Downstream
27546	09/11/2014	Brookview	09/12/2014	0521	09/16/2014	0554	Marshyhope	Downstream
		Chapter Point	09/21/2014	2259	09/23/2014	0446	Nanticoke	Downstream
		Ferry Point	09/24/2014	0644	10/01/2014	0117	Nanticoke	Upstream
		Chapter Point	10/02/2014	1318	10/02/2014	1846	Nanticoke	Downstream
27547	09/11/2014	Brookview	09/15/2014	0503	09/15/2014	1217	Marshyhope	Downstream
		Ferry Point	09/18/2014	0316	09/19/2014	0606	Nanticoke	Downstream
		Brookview	09/19/2014	1439	09/19/2014	1654	Marshyhope	Upstream
		Chapter Point	09/21/2014	0446	09/22/2014	0302	Nanticoke	Downstream
		Ferry Point	09/22/2014	1712	09/24/2014	0638	Nanticoke	Upstream
		Chapter Point	09/25/2014	0039	09/28/2014	0435	Nanticoke	Downstream
26350	09/11/2014	Brookview	09/12/2014	0357	09/12/2014	0418	Marshyhope	Downstream
		Chapter Point	09/15/2014	0707	09/16/2014	2355	Nanticoke	Downstream
		Sharptown	09/17/2014	2246	09/17/2014	2349	Nanticoke	Upstream

		Chapter Point	09/18/2014	2059	09/19/2014	2031	Nanticoke	Downstream
		Ferry Point	09/20/2014	1626	09/20/2014	2117	Nanticoke	Upstream
		Chapter Point	09/21/2014	0919	09/21/2014	1010	Nanticoke	Downstream
26351	09/16/2014	Brookview	09/16/2014	2052	09/17/2014	0938	Marshyhope	Downstream
		Chapter Point	09/19/2014	0001	09/20/2014	0219	Nanticoke	Downstream
		Sharptown	09/21/2014	0503	09/21/2014	1240	Nanticoke	Upstream
		Chapter Point	09/23/2014	0158	09/23/2014	0324	Nanticoke	Downstream
26352	09/16/2014	Brookview	09/17/2014	2213	09/29/2014	1138	Marshyhope	Downstream
		Chapter Point	10/01/2014	0004	10/01/2014	0501	Nanticoke	Downstream

Table 4. 2015 Atlantic Sturgeon movements for fish captured in 2015.

VEMCO ID	Date Tagged	Receiver Detected	Date of Initial Detection	Time of Initial Detection	Date of Last Detection	Time of Last Detection	Waterbody	Direction Moved
26353	8/31/2015	Palmer's Mill	8/31/2015	1723	8/31/2015	1946	Marshyhope	Upstream
		Sharptown	9/18/2015	0352	9/18/2015	0430	Nanticoke	Down/Upstream
		Lewis Landing	9/19/2015	0343	9/19/2015	0516	Nanticoke	Downstream
		Brookview	9/20/2015	1953	9/22/2015	1339	Nanticoke	Upstream
		Roaring Point	10/1/2015	0425	10/1/2015	0500	Nanticoke	Downstream
26354	8/31/2015	Brookview	9/2/2015	0054	9/4/2015	1316	Marshyhope	Downstream
		Lewis Landing	9/11/2015	0059	9/11/2015	1810	Nanticoke	Downstream
		Ferry Point	9/21/2015	0235	9/24/2015	0730	Nanticoke	Upstream
		Roaring Point	9/25/2015	2317	9/30/2015	2102	Nanticoke	Downstream
		Ferry Point	10/1/2015	1945	10/3/2015	1718	Nanticoke	Upstream
		Roaring Point	10/8/2015	1830	10/8/2015	1919	Nanticoke	Downstream
23900	9/15/2015	Brookview	9/16/2015	0754	9/16/2015	1626	Marshyhope	Downstream
		Palmer's Mill	9/17/2015	0452	9/18/2015	0915	Marshyhope	Upstream
		Brookview	9/18/2015	2110	9/19/2015	1653	Marshyhope	Downstream
		Palmer's Mill	9/20/2015	0500	9/20/2015	0532	Marshyhope	Upstream

		Ferry Point	9/21/2015	0805	9/21/2015	2329	Nanticoke	Downstream
		Broad Creek	9/22/2015	1008	10/4/2015	1152	Broad Creek	Upstream
		Ferry Point	10/5/2015	1115	10/5/2015	1407	Nanticoke	Downstream
		Broad Creek	10/6/2015	0107	10/6/2015	1714	Broad Creek	Upstream
		Roaring Point	10/8/2015	1534	10/8/2015	1632	Nanticoke	Downstream
23901	9/15/2015	Palmer's Mill	9/17/2015	0143	9/22/2015	0400	Marshyhope	Upstream
		Roaring Point	10/1/2015	2152	10/7/2015	0122	Nanticoke	Downstream
23902	9/17/2015	Brookview	9/17/2015	2321	9/18/2015	1055	Marshyhope	Downstream
		Ferry Point	9/19/2015	0123	9/19/2015	0225	Nanticoke	Downstream
		Brookview	9/21/2015	0902	9/21/2015	1026	Marshyhope	Upstream
		Ferry Point	9/22/2015	0349	9/22/2015	0506	Nanticoke	Downstream
		Brookview	9/23/2015	1150	9/29/2015	0630	Marshyhope	Upstream
		Roaring Point	10/7/2015	2005	10/13/2015	0453	Nanticoke	Downstream
23903	9/29/2015	Brookview	9/29/2015	2108	9/30/2015	1000	Marshyhope	Downstream
		Roaring Point	10/5/2015	2300	10/10/2015	0543	Nanticoke	Downstream
23904	9/29/2015	Brookview	9/29/2015	2348	9/30/2015	0313	Marshyhope	Downstream
		Roaring Point	10/6/2015	1323	10/13/2015	0852	Nanticoke	Downstream

Table 5. 2015 Atlantic Sturgeon movements returning fish originally captured in 2014. Shown here are movements for tagged sturgeon returning to the Nanticoke River and Marshyhope Creek after one year at-large. Each Atlantic Sturgeon's movement starts and ends when they entered or exited the Chesapeake Bay. Two consecutive upstream/downstream movements indicate the sturgeon entered a new river system. Due to the large number of acoustic receivers at the Chesapeake Bay mouth, these receivers were combined into a single line.

VEMCO ID	Date Tagged	Receiver Detected	Date of Initial Detection	Time of Initial Detection	Date of Last Detection	Time of Last Detection	Waterbody	Direction Moved
26350	9/11/2014	Chesapeake Bay Mouth	04/14/2015	0351	04/14/2015	0420	Chesapeake Bay	Upstream
		Rappahannock River	08/29/2015	0410	09/09/2015	2058	Rappahannock	Upstream
		Pamunkey 01	09/19/2015	0006	09/19/2015	0026	Pamunkey	Down/Upstream
		Pamunkey 22	09/21/2015	2055	09/21/2015	2227	Pamunkey	Upstream
		Pamunkey 06	09/24/2015	0010	09/24/2015	0957	Pamunkey	Downstream
		Pamunkey 22	10/02/2015	2359	10/03/2015	0314	Pamunkey	Upstream
		York River Mouth	10/20/2015	0343	10/20/2015	0352	York	Downstream
		Chesapeake Bay Mouth	10/25/2015	2304	11/05/2015	1750	Chesapeake Bay	Downstream
26352	9/16/2014	NavyCBBT2	04/20/2015	0842	04/20/2015	0926	Chesapeake Bay	Upstream
		Chapter Point	06/22/2015	1405	06/24/2015	0632	Nanticoke	Upstream
		Ferry Point	06/26/2015	0108	06/27/2015	0120	Nanticoke	Upstream
		Chapter Point	06/29/2015	1035	07/21/2015	0238	Nanticoke	Downstream
		Brookview	07/31/2015	0538	07/31/2015	2137	Marshyhope	Upstream
		Lewis Landing	08/01/2015	2303	08/09/2015	0634	Nanticoke	Downstream
		Sharptown	08/11/2015	1556	08/11/2015	0000	Nanticoke	Upstream
		Ferry Point	08/13/2015	0800	08/13/2015	0907	Nanticoke	Downstream
		Woodland Ferry	08/14/2015	0815	08/15/2015	1515	Nanticoke	Upstream
		Ferry Point	08/16/2015	1034	08/16/2015	1303	Nanticoke	Downstream
		Palmer's Mill	08/19/2015	1937	08/31/2015	1456	Marshyhope	Upstream
		Sharptown	09/11/2015	1851	09/14/2015	0007	Nanticoke	Down/Upstream
		Phillip's Landing	09/30/2015	0503	09/30/2015	0520	Broad Creek	Upstream
		Woodland Ferry	09/30/2015	808	10/01/2015	0031	Nanticoke	Down/Upstream
		Lewis Landing	10/01/2015	1521	10/01/2015	1928	Nanticoke	Downstream
		Ferry Point	10/02/2015	2159	10/02/2015	0110	Nanticoke	Upstream
		Roaring Point	10/03/2015	0405	10/03/2015	1231	Nanticoke	Downstream
		Chesapeake Bay Mouth	10/12/2015	1557	11/09/2016	2306	Chesapeake Bay	Downstream
27543	9/5/2014	Chesapeake Bay Mouth	04/14/2015	0828	04/14/2015	1904	Chesapeake Bay	Upstream

		Roaring Point	08/18/2015	1545	08/18/2015	1932	Nanticoke	Upstream
		Woodland Ferry	08/20/2015	1925	08/20/2015	2141	Nanticoke	Upstream
		Sharptown	08/21/2015	0152	08/21/2015	0410	Nanticoke	Downstream
		Seaford Drawbridge	08/22/2015	0825	08/22/2015	0850	Nanticoke	Upstream
		Sharptown	08/23/2015	0239	08/23/2015	0640	Nanticoke	Downstream
		Woodland Ferry	08/23/2015	0941	08/24/2015	0330	Nanticoke	Upstream
		Broad Creek	08/24/2015	0710	08/25/2015	0056	Broad Creek	Down/Upstream
		Woodland Ferry	08/25/2015	0921	08/25/2015	1606	Nanticoke	Down/Upstream
		Broad Creek	08/25/2015	2119	08/26/2015	0123	Broad Creek	Down/Upstream
		Seaford Drawbridge	08/26/2015	1150	08/26/2015	1658	Nanticoke	Down/Upstream
		Woodland Ferry	08/26/2015	1917	08/26/2015	2003	Nanticoke	Downstream
		Nanticoke Above Seaford	08/27/2015	0349	08/27/2015	1047	Nanticoke	Upstream
		Woodland Ferry	08/27/2015	2105	08/29/2015	2222	Nanticoke	Downstream
		Seaford Drawbridge	08/30/2015	0155	08/30/2015	1415	Nanticoke	Upstream
		Woodland Ferry	08/30/2015	2222	08/30/2015	2303	Nanticoke	Downstream
		Nanticoke Above Seaford	09/01/2015	1553	09/01/2015	1555	Nanticoke	Upstream
		Woodland Ferry	09/04/2015	1205	09/08/2015	2356	Nanticoke	Downstream
		Deep Creek	09/14/2015	0139	09/14/2015	0229	Deep Creek	Upstream
		Broad Creek	09/27/2015	1523	09/29/2015	0456	Broad Creek	Down/Upstream
		Ferry Point	09/30/2015	1411	09/30/2015	1739	Nanticoke	Downstream
		Palmer's Mill	10/01/2015	0644	10/01/2015	1421	Marshyhope	Upstream
		Roaring Point	10/10/2015	0220	10/12/2015	0519	Nanticoke	Downstream
		Chesapeake Bay Mouth	10/21/2015	0351	10/21/2015	2013	Chesapeake Bay	Downstream
27545	8/27/2014	Chesapeake Bay Mouth	04/20/2015	0235	04/20/2015	0235	Chesapeake Bay	Upstream
		Malkus Bridge	06/16/2015	0119	06/21/2015	1558	Choptank	Upstream
		Bow Knee Point	06/22/2015	1044	06/23/2015	0321	Choptank	Upstream
		Malkus Bridge	06/23/2015	1439	06/23/2015	1715	Choptank	Downstream
		Chapter Point	06/29/2015	1808	07/23/2015	0326	Nanticoke	Down/Upstream
		Fook's Pier	09/06/2015	0945	09/06/2015	1954	Marshyhope	Upstream
		Palmer's Mill	09/07/2015	0510	09/07/2015	0849	Marshyhope	Downstream
		Fook's Pier	09/07/2015	2027	09/07/2015	2030	Marshyhope	Upstream
		Palmer's Mill	09/08/2015	0303	09/10/2015	2246	Marshyhope	Downstream
		Fook's Pier	09/11/2015	0504	09/13/2015	0721	Marshyhope	Upstream
		Roaring Point	10/20/2015	0502	10/20/2015	0507	Nanticoke	Downstream
		Chesapeake Bay Mouth	10/24/2015	2127	11/05/2015	1318	Chesapeake Bay	Downstream

Table 6. Maryland DNR's acoustic receiver array. Maryland DNR maintains 30 acoustic receivers in four tributaries to the Chesapeake Bay on Maryland's Eastern Shore. The majority of these receivers are located in Marshyhope Creek in an attempt to locate Atlantic Sturgeon spawning areas.

River	Receiver Name	Latitude	Longitude	Type of attachment	Year Deployed
Choptank	Bow Knee Point	38.67393	-75.95104	USCG Channel Marker	2014
Choptank	Dover Bridge	38.73769	-75.99597	USCG Channel Marker	2014
Choptank	UMD Sturgeon Research	38.58476	-76.05799	Jim-Buoy	2013
Choptank	USCG Green 1	38.57627	-76.06491	USCG Channel Marker	2014
Marshyhope	Above Brookview	38.57738	-75.79529	Jim-Buoy	2016
Marshyhope	Above Walnut Landing	38.55611	-75.76728	Jim-Buoy	2016
Marshyhope	Below 392 Bridge	38.62329	-75.81859	Jim-Buoy	2016
Marshyhope	Below Brookview	38.56370	-75.77640	Jim-Buoy	2016
Marshyhope	Below Puckum's Branch	38.59077	-75.80344	Private pier	2016
Marshyhope	Below Yellow House	38.66141	-75.79587	Jim-Buoy	2016
Marshyhope	Brookview	38.57442	-75.78220	Jim-Buoy	2014
Marshyhope	Fook's Pier	38.66447	-75.78088	Private pier	2013
Marshyhope	Marshyhope Confluence	38.52742	-75.76008	Jim-Buoy	2016
Marshyhope	Palmer's Mill	38.64065	-75.81060	Jim-Buoy	2015
Marshyhope	Puckum's Branch	38.60235	-75.82292	Jim-Buoy	2016
Marshyhope	Red Banks	38.53705	-75.75634	Jim-Buoy	2016
Marshyhope	VFW Boat Ramp	38.67868	-75.77431	Jim-Buoy	2015
Marshyhope	Walnut Landing	38.54813	-75.77309	Jim-Buoy	2016
Marshyhope	Wright's Pier	38.65295	-75.80417	Private pier	2016
Marshyhope	Yellow House	38.66037	-75.79094	Jim-Buoy	2016
Nanticoke	Broad Creek	38.56894	-75.65476	Private pier	2015
Nanticoke	Chapter Point	38.37996	-75.86632	USCG Channel Marker	2014
Nanticoke	Ferry Point	38.47844	-75.82297	USCG Channel Marker	2014
Nanticoke	Lewis Wharf	38.42447	-75.83797	Jim-Buoy	2015
Nanticoke	MD/DE State Line	38.56086	-75.70159	State Line Marker	2016
Nanticoke	Riverton	38.51246	-75.75607	Private pier	2016
Nanticoke	Roaring Point	38.26578	-75.92290	Jim-Buoy	2015
Nanticoke	Sharptown	38.53877	-75.73178	USCG Channel Marker	2014
Pocomoke	Pocomoke City	38.07857	-75.57107	Public Pier	2013
Pocomoke	Rehobeth	38.03908	-75.66150	Private pier	2014
Pocomoke	Shelltown	37.98577	-75.63430	Private pier	2013

Table 7. Number of Atlantic Sturgeon detections by acoustic receiver from 2013-2016. The Chapter Point receiver on the Nanticoke River stands out with the most number of detections annually. 2016 data are currently incomplete, but Chapter point still indicates 1,000 more detections than the other receivers combined, to date.

Name	**2013**	**2014**	**2015**	**2016**
Bow Knee Point	-	0	123	0
Dover Bridge	-	0	0	-
UMD Sturgeon Research	0	43	81	0
USGC Green 1	-	101	113	0
Above Brookview	-	-	-	0
Above Walnut Landing	-	-	-	0
Below 392 Bridge	-	-	-	0
Below Brookview	-	-	-	0
Below Puckum's Branch	-	-	-	0
Below Yellow House	-	-	-	0
Brookview	0	490	2,002	0
Fook's Pier	0	314	175	0
Marshyhope Confluence	-	-	-	8
Palmer's Mill	-	-	1,728	0
Puckum's Branch	-	-	-	0
Red Banks	-	-	-	0
VFW Boat Ramp	-	-	0	0
Walnut Landing	-	-	-	0
Wright's Pier	-	-	-	0
Yellow House	-	-	-	0
Broad Creek	-	-	96	0
Chapter Point	-	12,936	20,021	9,182
Ferry Point	-	4,158	8,513	152
Lewis Wharf	-	-	5,968	968
MD/DE Line State	-	-	-	0
Riverton	-	-	-	160
Roaring Point	-	-	4,084	384
Sharptown	-	83	1,470	13
Pocomoke City	0	0	3,763	0
Rehobeth	-	0	374	0
Shelltown	0	582	190	0

Table 8. Current locations for MD DNR's tagged Atlantic Sturgeon as of June 30, 2016.

VEMCO ID	Date	Location
27543	06/22/2016	Chesapeake Bay Mouth
27545	04/08/2016	Chesapeake Bay Mouth
27546	06/08/2016	Sandy Hook Bay, New Jersey
27547	06/24/2016	Chesapeake Bay Mouth
26350	06/27/2016	Pamunkey River
26351	06/15/2016	Nanticoke River
26352	06/27/2016	Nanticoke River
26353	06/27/2016	Nanticoke River
26534	06/29/2016	Chesapeake Bay Mouth
23900	06/07/2016	Chesapeake Bay Mouth
23901	06/13/2016	Nanticoke River
23902	06/08/2016	Chesapeake Bay Mouth
23903	06/27/2016	Nanticoke River
23904	06/24/2016	Nanticoke River

Figures

Figure 1. Location information for Marshyhope Creek and Nanticoke River in Maryland and Delaware.

Figure 2. Onboard Atlantic Sturgeon holding tank. Once an Atlantic Sturgeon was captured in the net, it was held aboard the boat in a 340 L tank filled with fresh river water. The water was supplemented with compressed oxygen while the sturgeon was in the boat. Electronarcosis paddles were placed at either end of the tank to anesthetize the fish for surgical transmitter implantation.

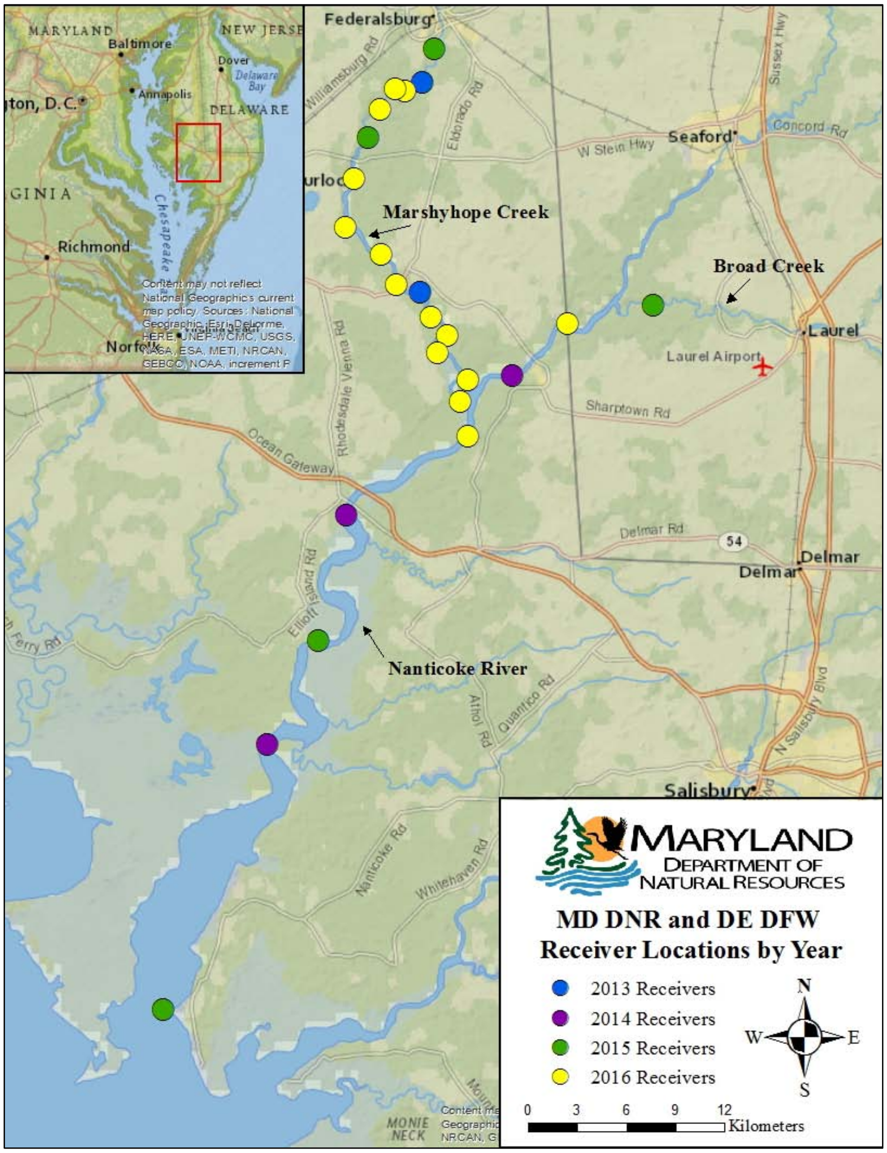

Figure 3. Maryland DNR acoustic receiver deployments in Marshyhope Creek and Nanticoke River by year. Two receivers were added in 2013; three in 2014; five in 2016 and 14 in 2016.

Figure 4. The primary acoustic receiver deployment method. Stainless steel cable was looped though 5.0 cm square tube steel and attached with zinc-plated copper crimps. The tube steel acted as an anchor. A loop in the cable, with a hydraulic tubing cover, was formed at the other end. The acoustic receiver was approximately 1 m above the steel tubing and attached to the steel cable with two hose clamps and two wire ties.

Figure 5. A Maryland DNR Jim-Buoy deployed with the acoustic receiver attached. The Jim-Buoy was anchored with two 22 kg cement anchors by a length of galvanized chain approximately 3 m longer than the depth at high tide. The receiver was attached to an eye bolt on the bottom of the Jim-Buoy with the primary acoustic receiver attachment method (Figure 1).

Figure 6. Atlantic Sturgeon ATS 27543 was recaptured one year after initial capture. The incision where the transmitter was inserted was fully healed with no infection present and the transmitter still functional.

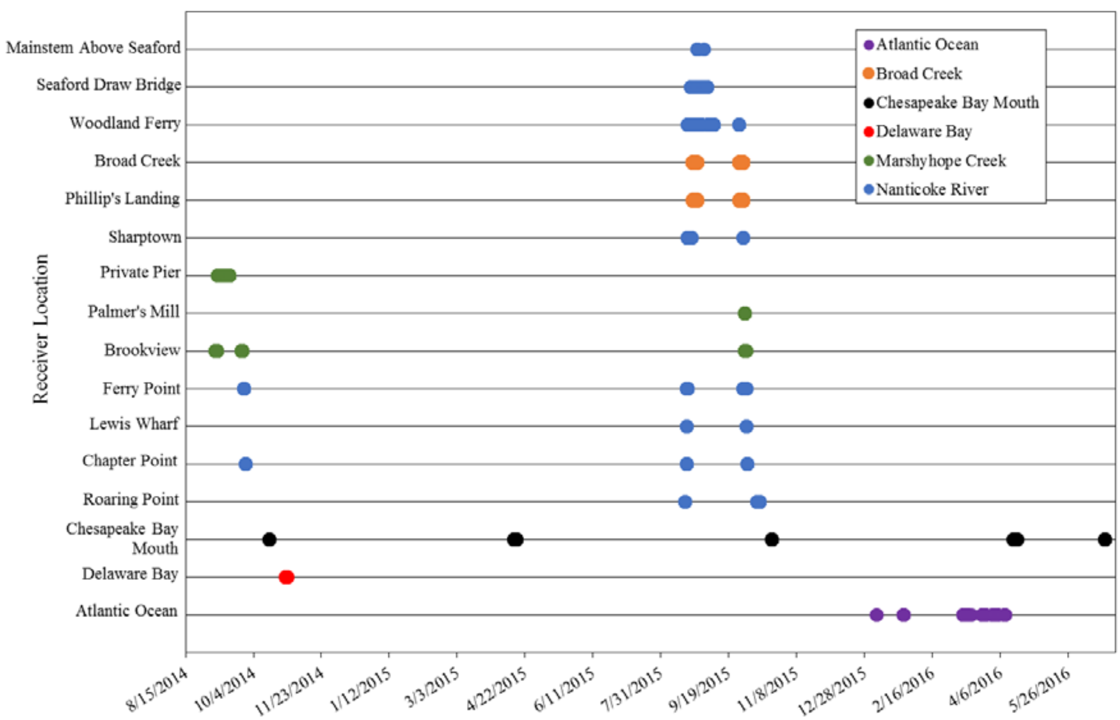

Figure 7. ATS 27543 movement since initial capture on September 5, 2014. Each color represents a different creek, river system, or overall area. Receivers deployed by MD DNR each have their own line to represent the detection data. Within a river system, the receivers are placed in geospatial order as you move upstream to indicate the directional movement of the Atlantic Sturgeon. Receivers owned by cooperators are represented by a single line (Chesapeake Bay Mouth, Delaware Bay, Atlantic Ocean) even though the fish may have been detected on multiple receivers.

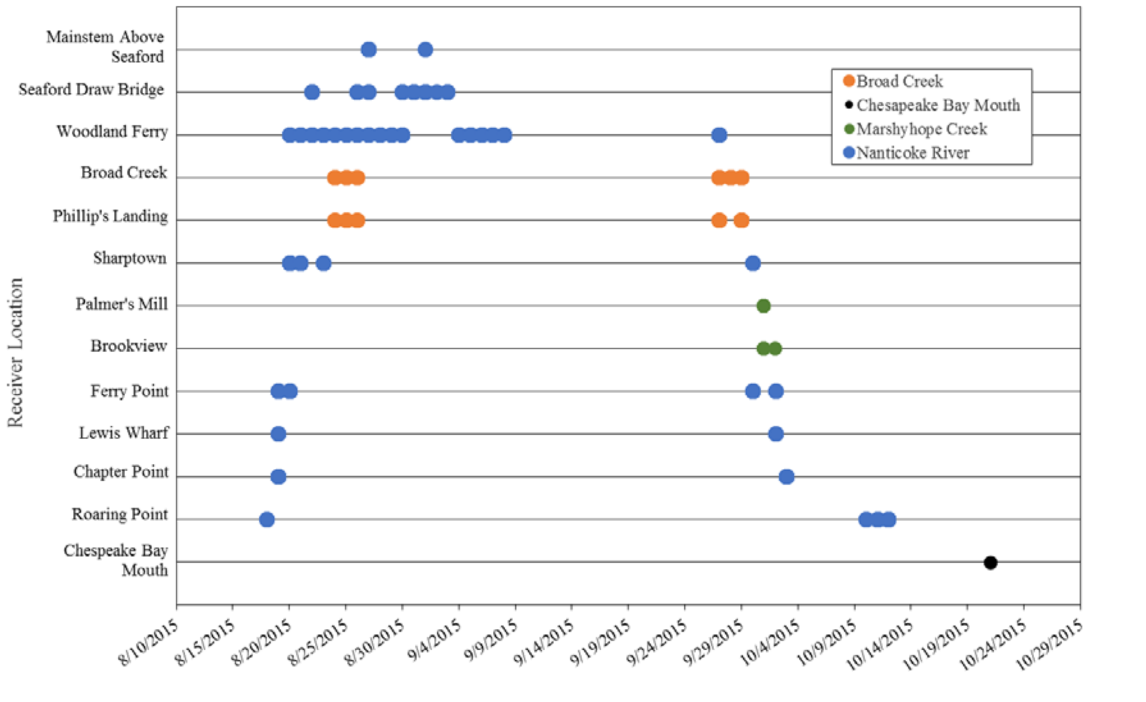

Figure 8. ATS 27543 movement in 2015 within the Nanticoke River system.

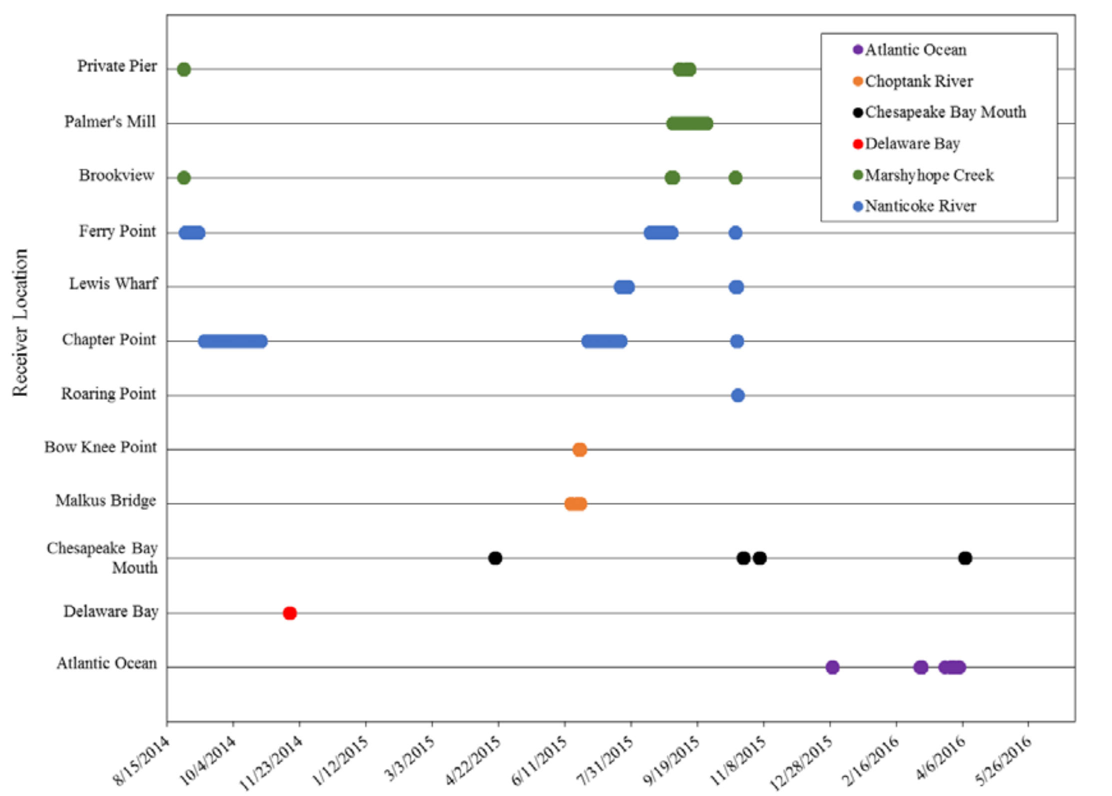

Figure 9. ATS 27545 movements since initial capture on August 27, 2014.

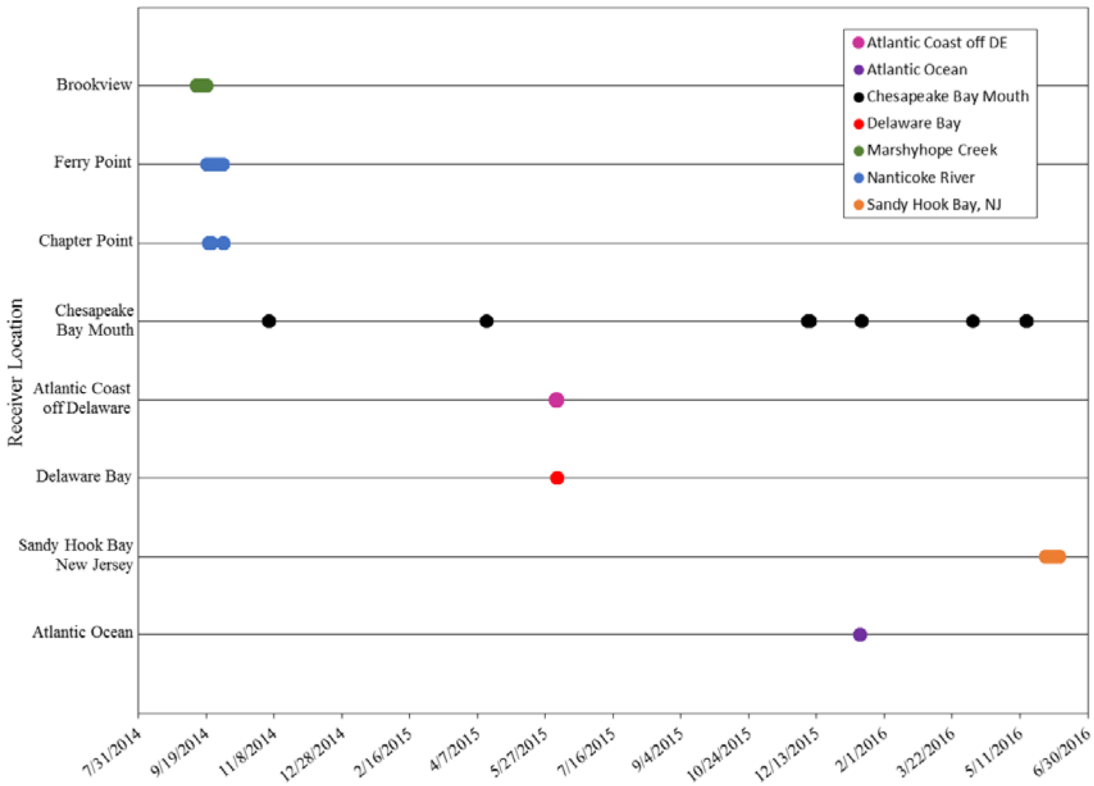

Figure 10. ATS 27546 movements since initial capture on September 11, 2014.

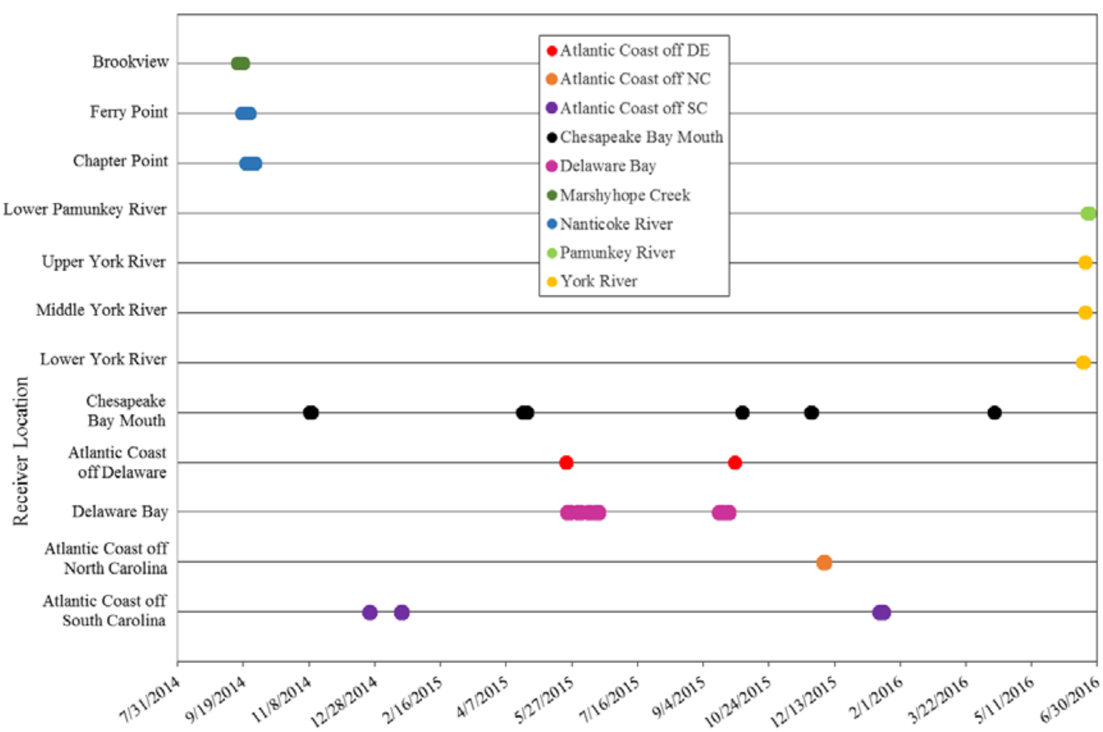

Figure 11. ATS 27547 movements since initial capture on September 11, 2014.

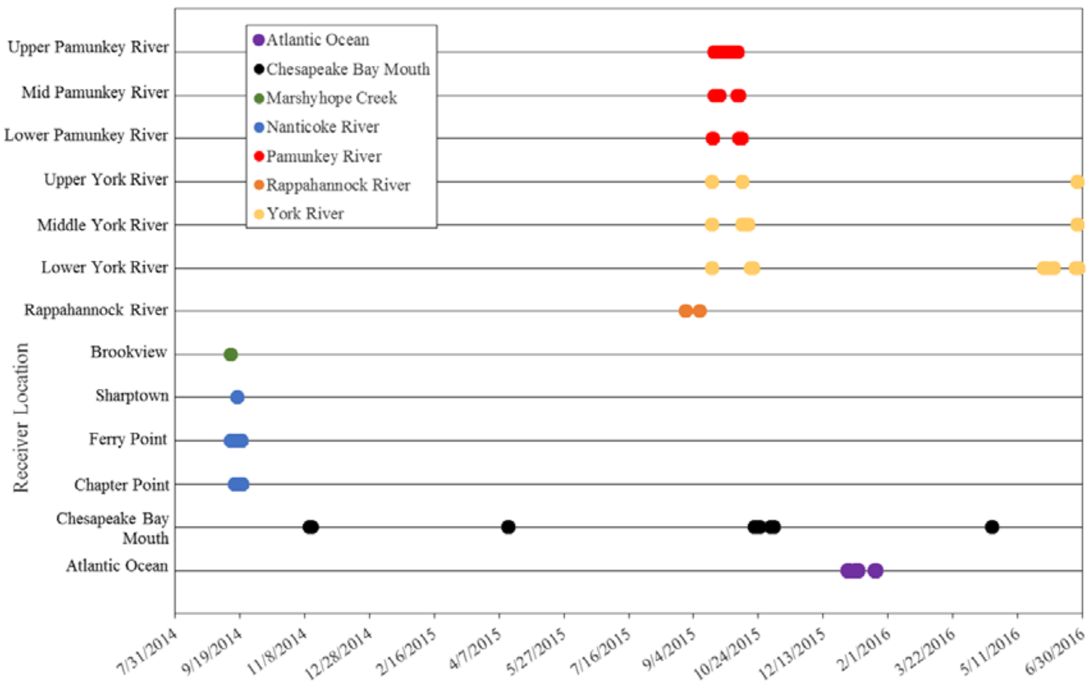

Figure 12. ATS 26350 movements since initial capture on September 11, 2014.

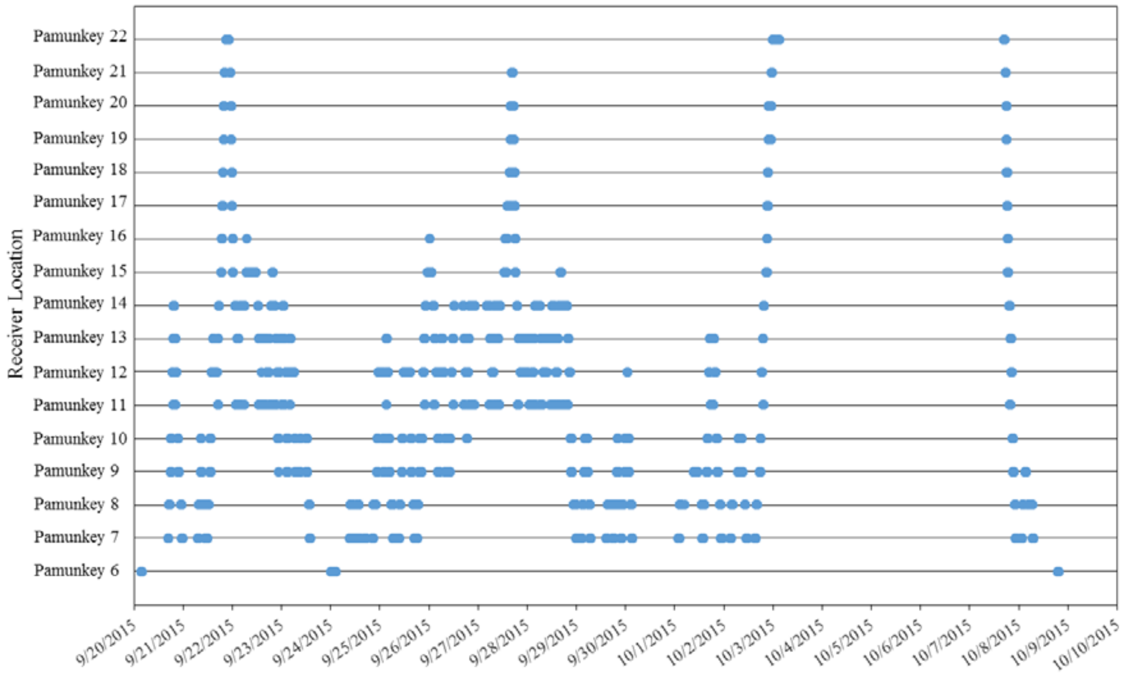

Figure 13. ATS 26350 movements in the upper Pamunkey River from September 20 to October 8, 2014. The distance between Pamunkey 6 and Pamunkey 22 is 30.2 river km with 13.7 km between Pamunkey 6 and Pamunkey 7. From October 3 to 7, this sturgeon moved above the furthest upstream receiver (Pamunkey 22) on the Pamunkey River, hence there were no detections during this time. This graph indicates the large amount of time and distance the fish spent moving within the river.

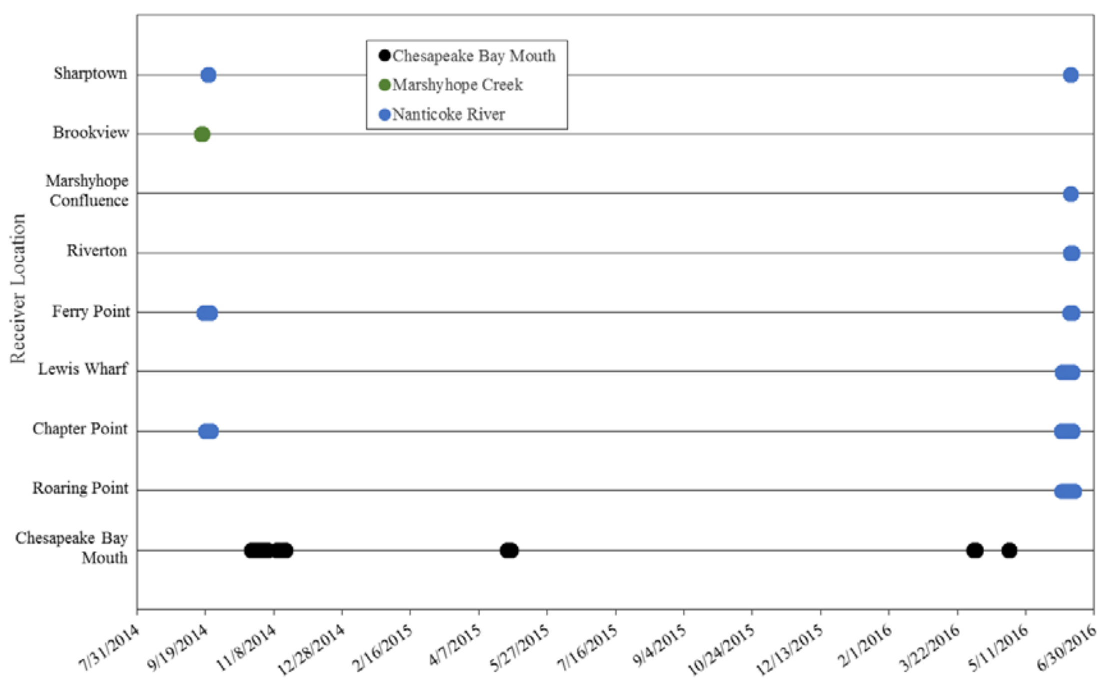

Figure 14. ATS 26351 movements since initial capture on September 16, 2014.

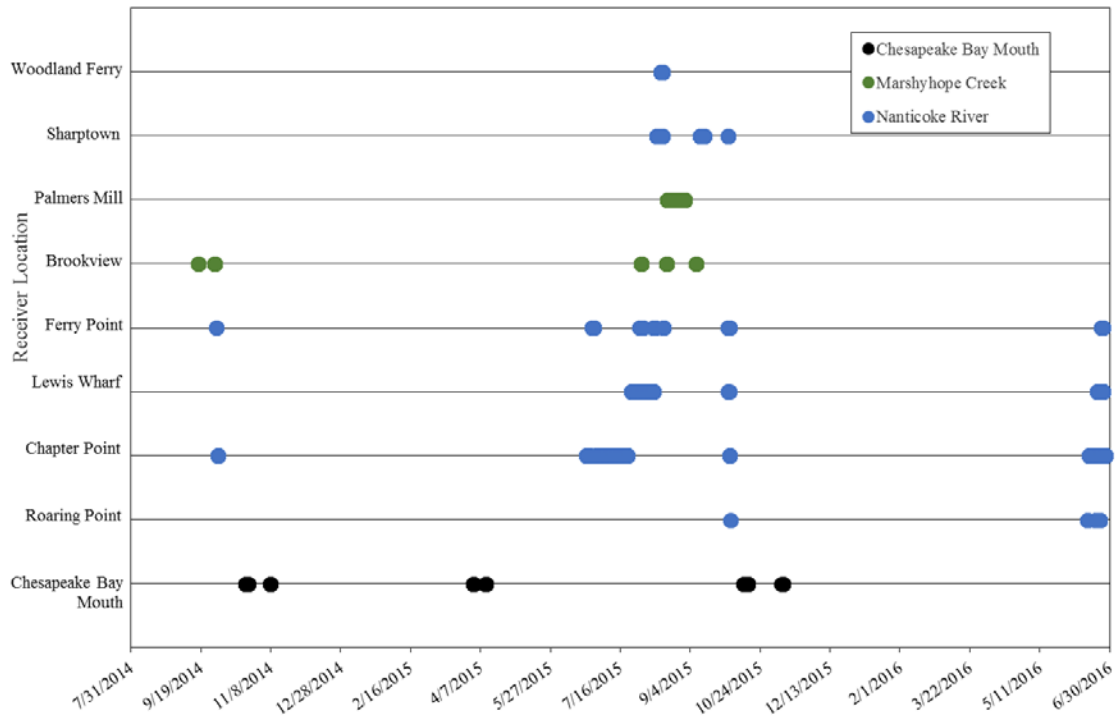

Figure 15. ATS 26352 movements since initial capture on September 16, 2014.

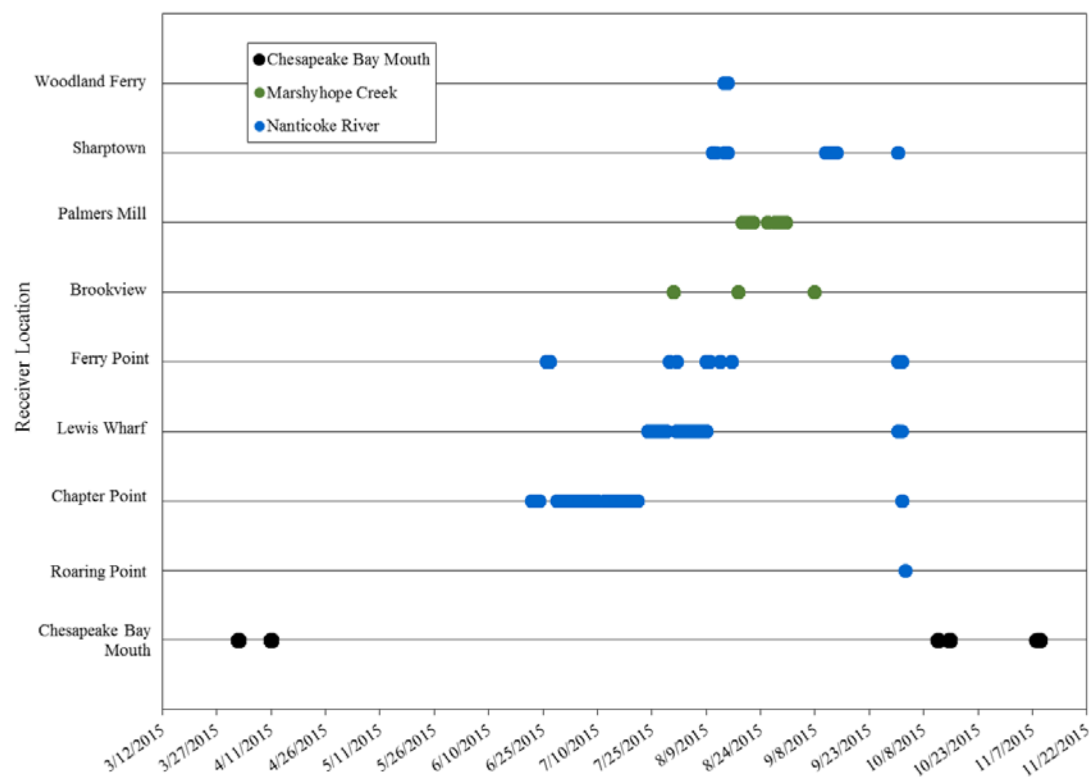

Figure 16. ATS 26352 movement in 2015 within the Nanticoke River system.

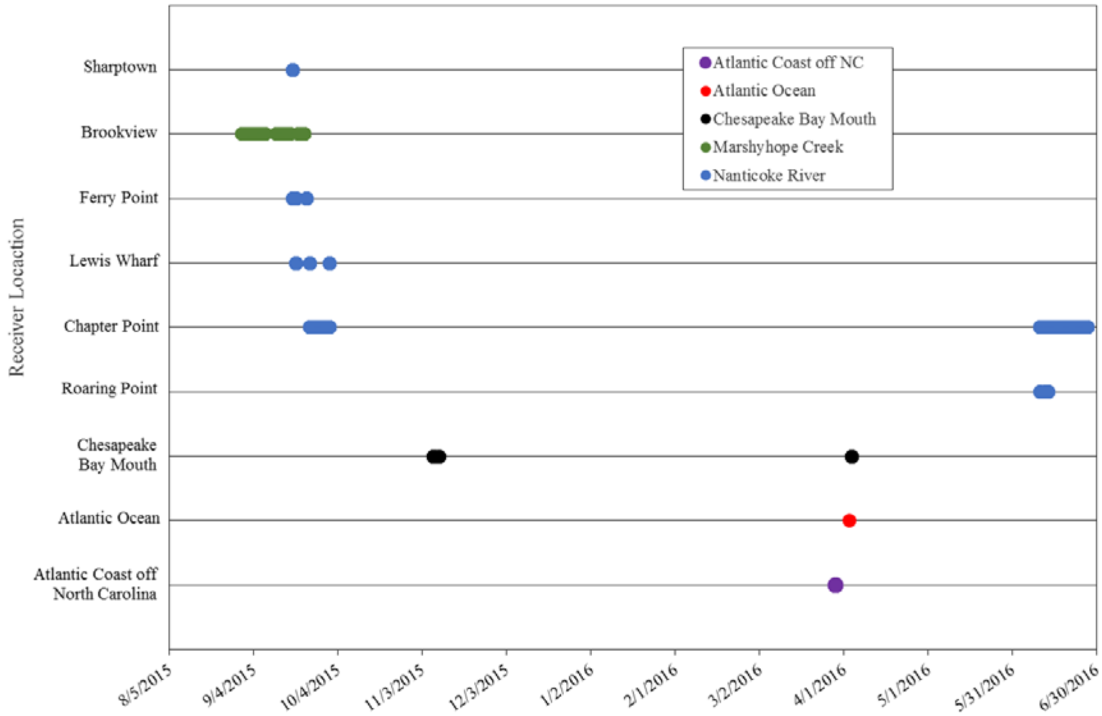

Figure 17. ATS 26353 movements since initial capture on August 31, 2015.

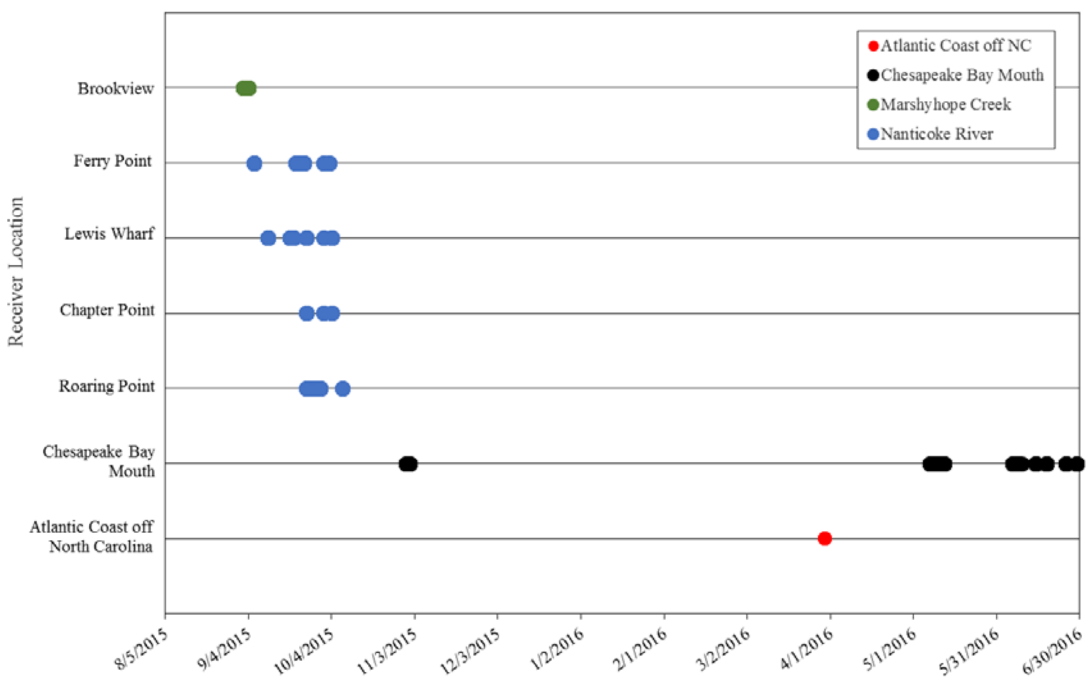

Figure 18. ATS 26354 movements since initial capture on August 31, 2015.

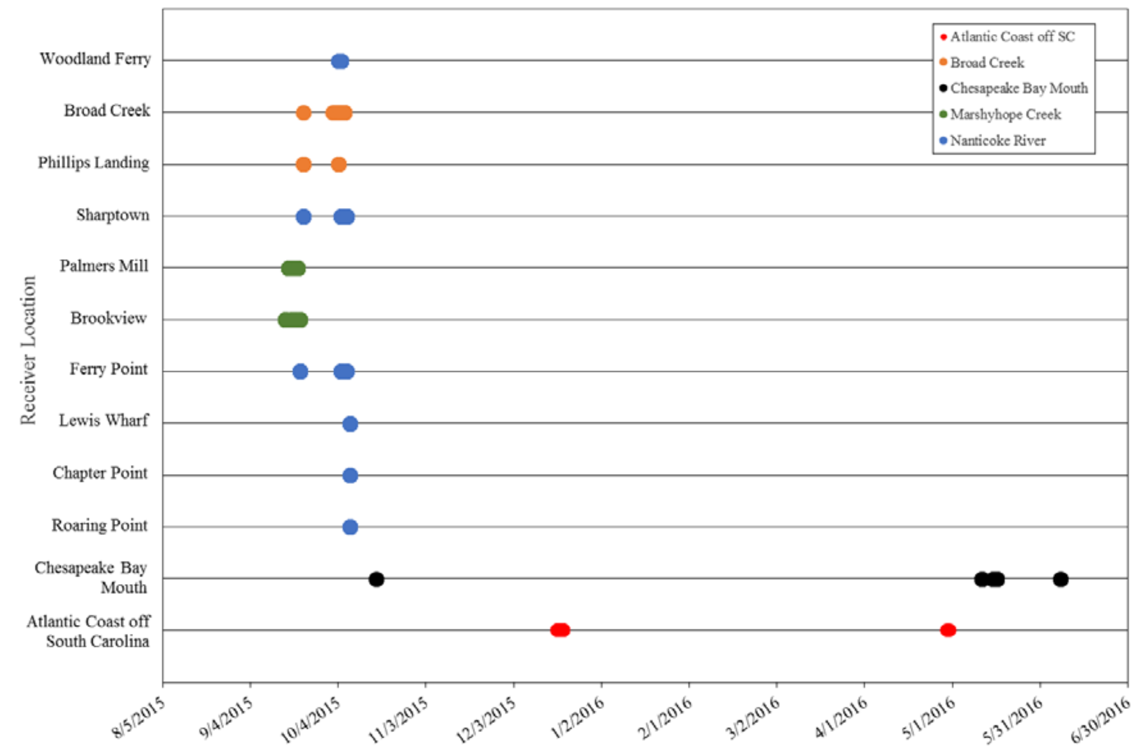

Figure 19. ATS 23900 movements since initial capture on September 15, 2015.

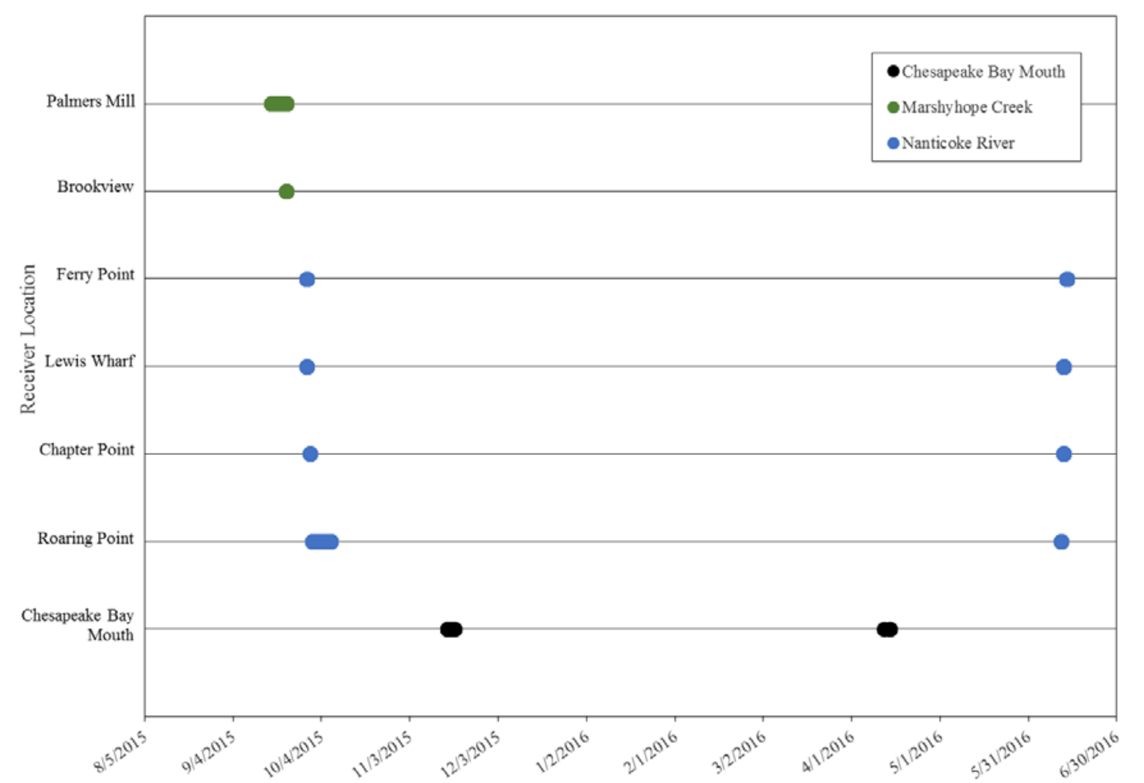

Figure 20. ATS 23901 movements since initial capture on September 15, 2015.

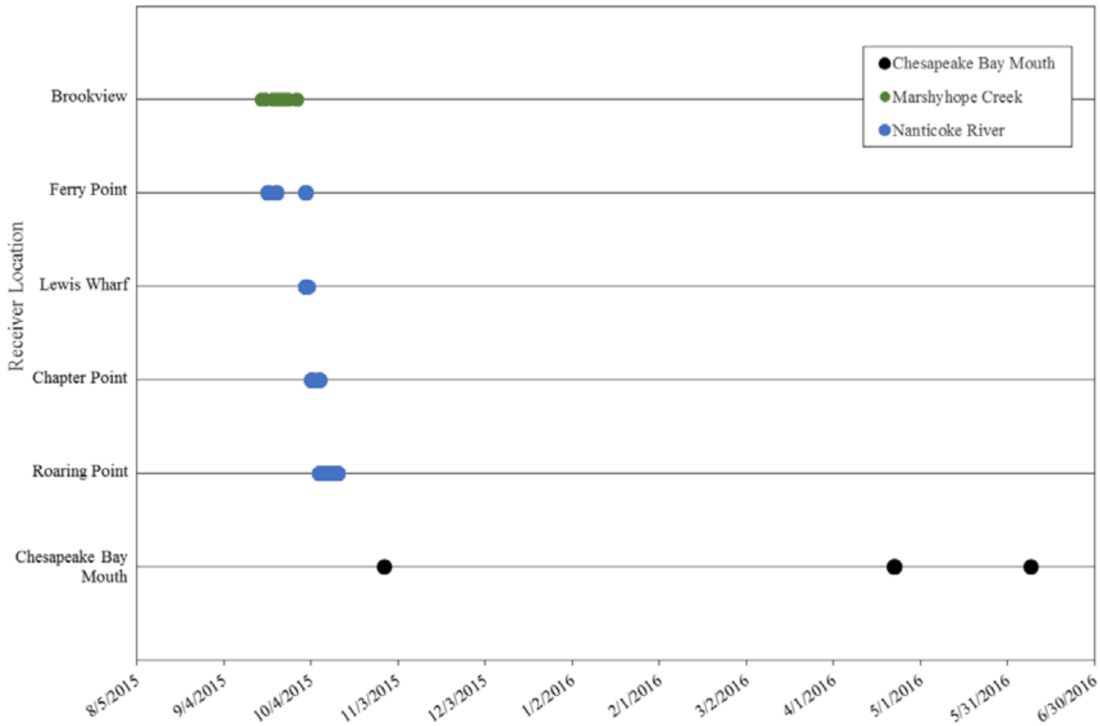

Figure 21. ATS 23902 movements since initial capture on September 17, 2015.

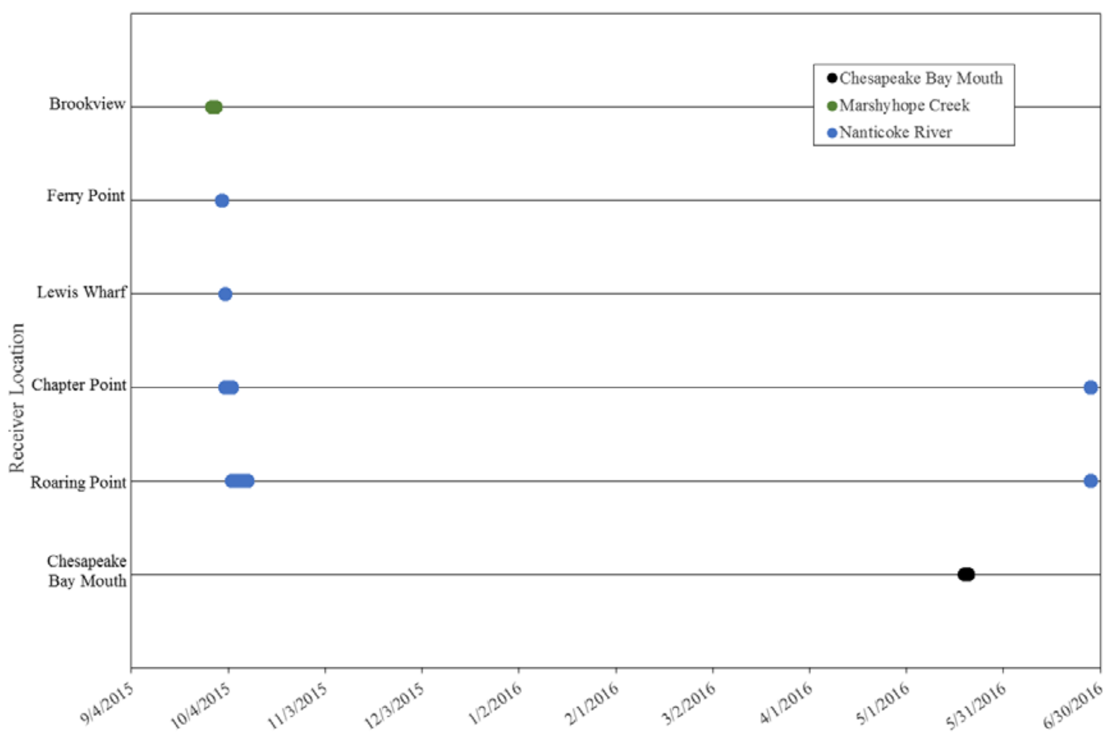

Figure 22. ATS 23903 movements since initial capture on September 29, 2015.

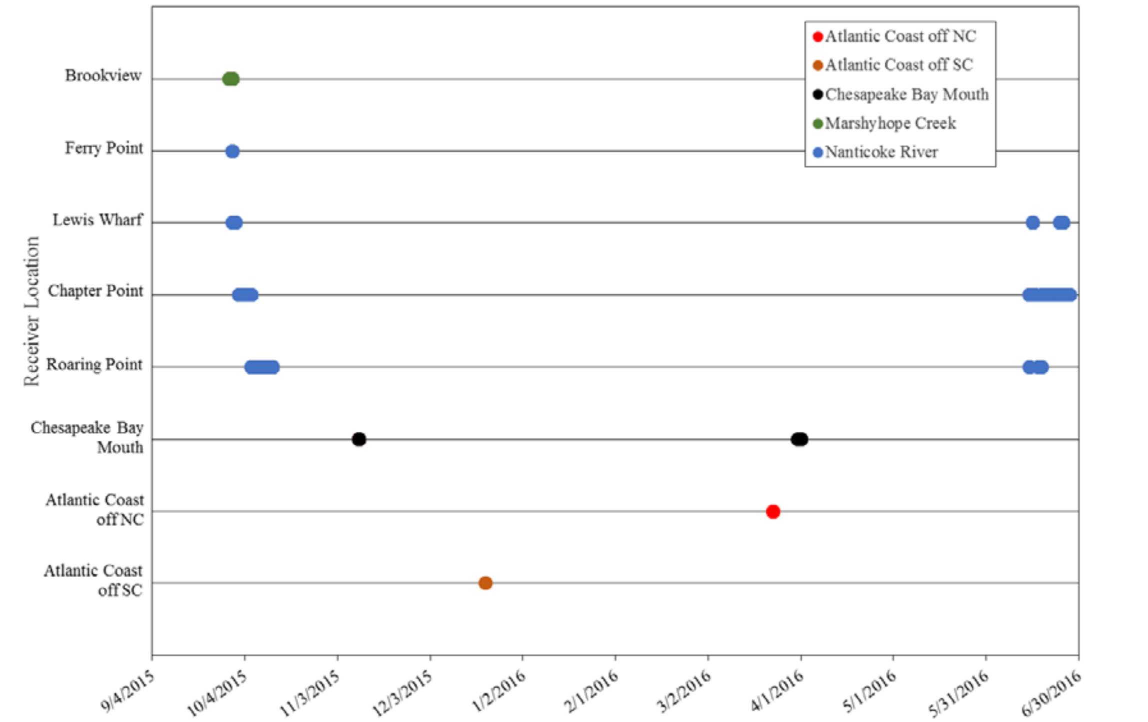

Figure 23. ATS 23904 movements since initial capture on September 29, 2015.

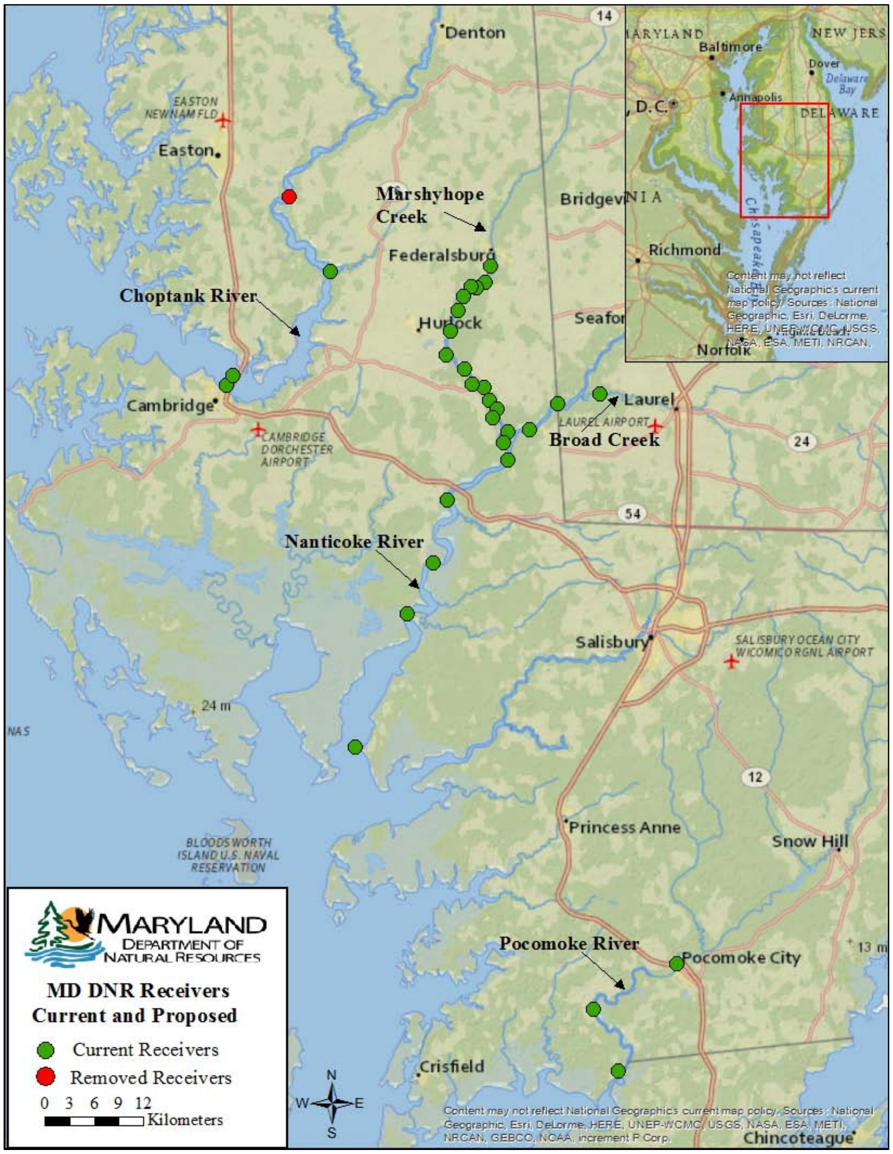

Figure 24. Maryland DNR's 2016 acoustic receiver array. There are 16 receivers located on Marshyhope Creek, seven on the Nanticoke River, and three each on the Choptank and Pocomoke rivers.

Figure 25. Maryland DNR current acoustic receiver locations and names on Marshyhope Creek.

Figure 26. Maryland DNR current acoustic receiver locations and names on the Nanticoke River.

Figure 27. Maryland DNR current acoustic receiver locations and names in the Choptank River. The “Dover Bridge” receiver was removed in 2016 due to the lack of Atlantic Sturgeon detections.

Figure 28. Maryland DNR current acoustic receiver locations in the Pocomoke River.

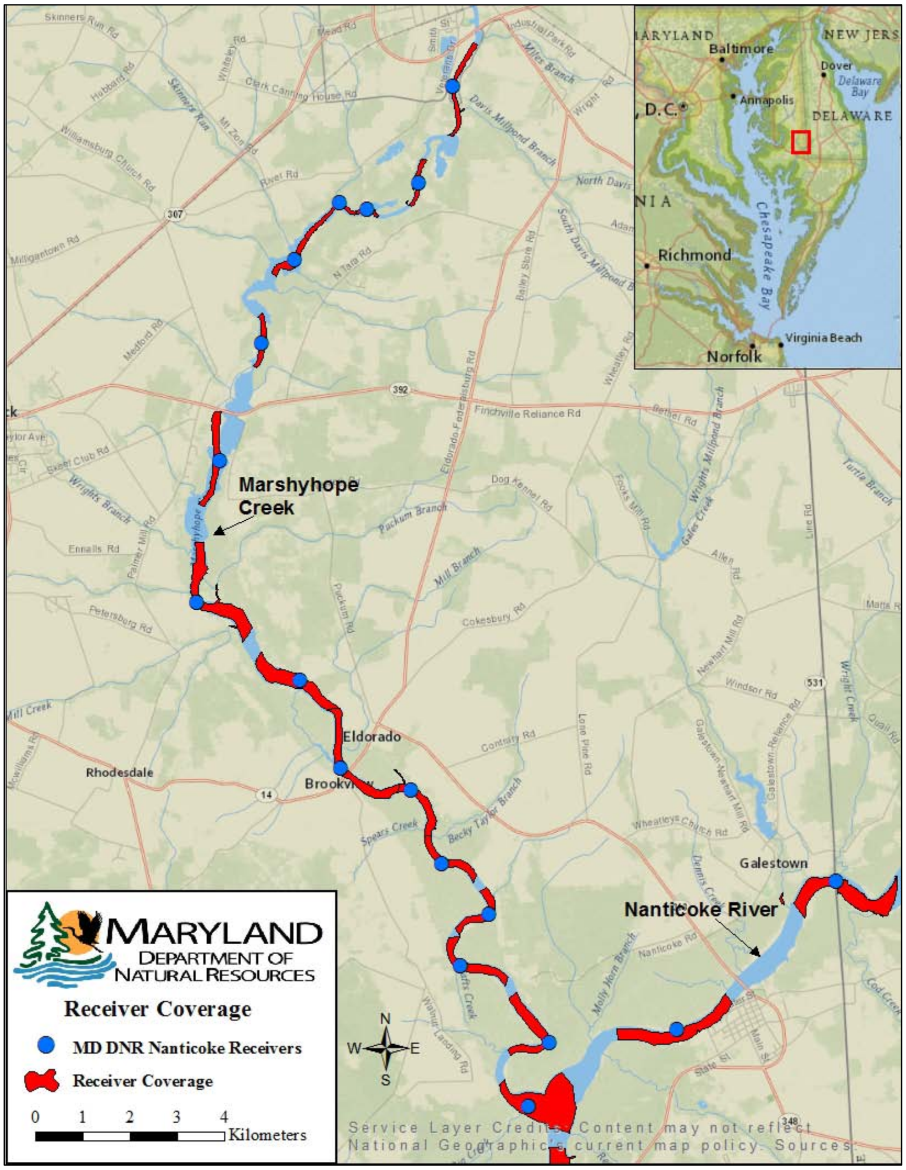

Figure 29. Maryland DNR acoustic receiver coverage area in Marshyhope Creek. Receiver coverage on the Marshyhope Creek is between 75-90%. The high receiver coverage rate will allow MD DNR biologists to determine spawning sites on Marshyhope Creek.

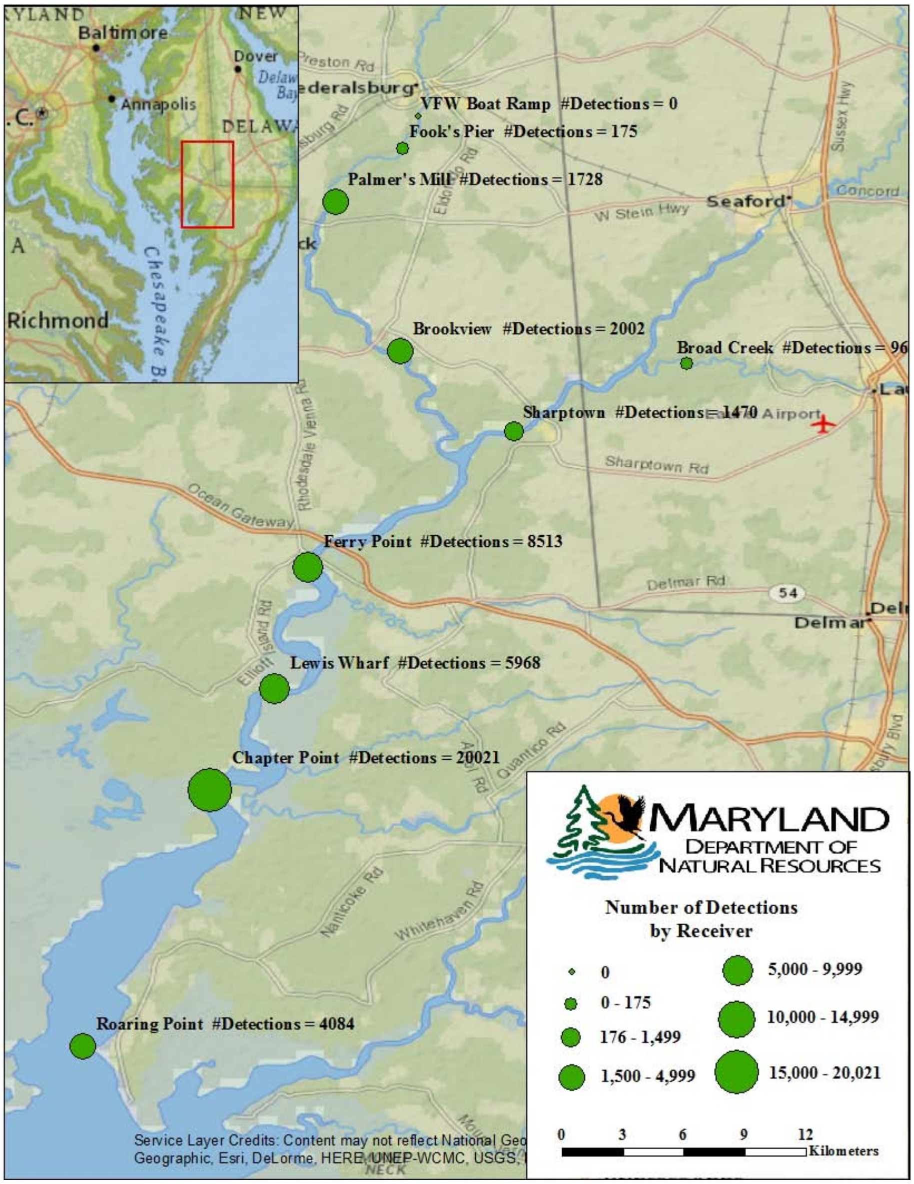

Figure 30. Number of detections per acoustic receiver in 2015. Some of the receivers indicated a large number of detections (20,021 detections at Chapter Point) while most other receivers indicated a smaller number of detections (1,278 detections at Palmer's Mill). Some of these receivers were placed in staging locations where Atlantic Sturgeon moved about in a limited area, which resulted in a high number of detections. Other receivers were placed in areas where the sturgeon quickly transitioned through from staging areas to putative spawning habitat, which resulted in fewer detections.

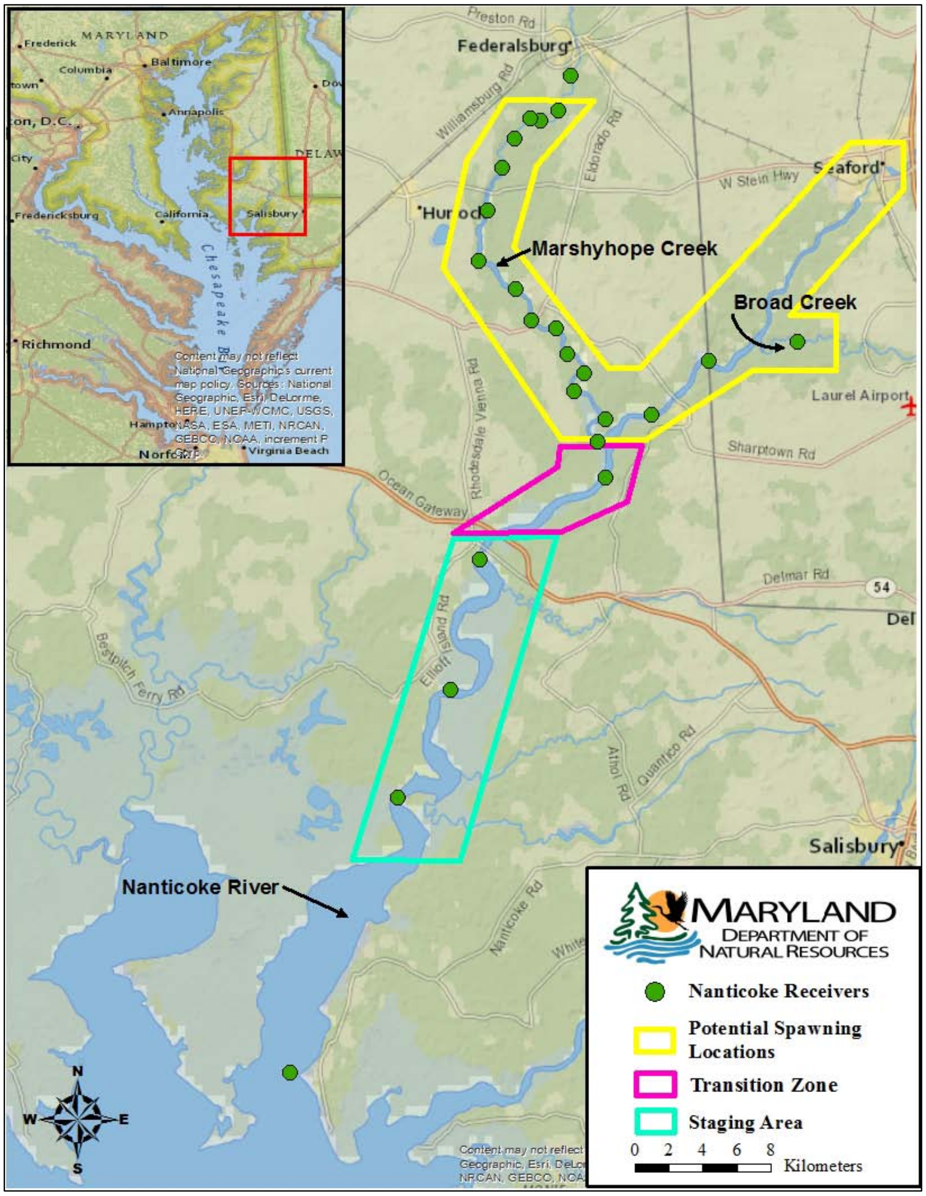

Figure 31. Maryland DNR acoustic receiver map with staging, transition and spawning locations indicated. The Nanticoke River from Chapter Point to Ferry Point appears to be a staging area for the Atlantic Sturgeon. They spent a larger amount of time in these areas, and were sometimes in residence for days at a time. The sturgeon always returned to these areas after their short upstream runs. In the Transition Zone, the sturgeon tended toward continual upstream or downstream movement, and were usually only detected on the receivers a limited number of times. The putative Spawning Location includes areas of Marshyhope Creek and the upper Nanticoke River, where MD DNR biologists believe spawning would occur.

Section II

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CBL receiver deployment and monitoring

CBL maintains receiver arrays in the C&D Canal, below the Bay Bridge off Kent Islands (deployed by CBL but maintained by DNR), mid-Bay off Cedar Point, at Solomons off CBL's research pier, and off Ocean City in a widely spaced array that extends 50 miles offshore (Figure 1). Additionally, CBL tends two arrays within the Potomac River off Piney Point and at Nice Bridge (Route 301), which are supported through funding by the Atlantic States Marine Fisheries Commission (ASMFC). Most arrays were visited only visited once during the reporting period due to frequent unsafe marine conditions in the spring and vessel unavailability in the early summer (Table 1).

The Maryland offshore array is scheduled to be tended during the weeks of July 24, 2016 and November 6, 2016. All other arrays will be tended during the weeks of July 31, 2016, September 25, 2016, and December 4, 2016.

Station	Dates Tended		
C&D Canal	1/8/2016		
Kent Island	1/13/2016	5/9/2016	
CBL Pier	1/7/2016	5/24/2016	
Cedar Point	1/6/2016		
Route 301	12/16/2015		
MD Offshore	2/27/2016	5/23/2016	*

Table 1. Dates within the reporting period when CBL arrays were tended. *Site V-2 in the MD Offshore array (second-closest to shore) was not recovered during the February cruise and was abandoned. Site V-3 (third closest to the shore) was not recovered during the May cruise and was abandoned.

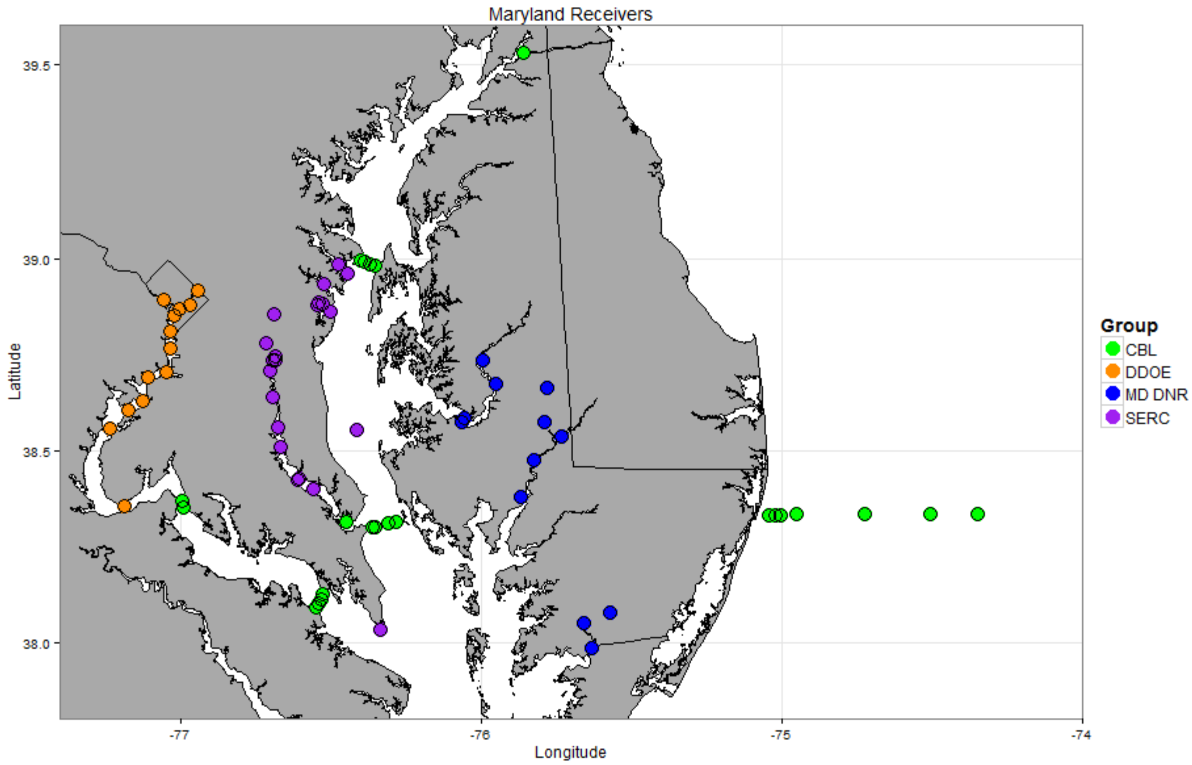

Figure 1. Known receivers deployed within Maryland waters. DDOE=DC Department of Environment, SERC=Smithsonian Environmental Research Center.

From November through May, receivers deployed by CBL and MD DNR detected 77 Atlantic sturgeon tagged by 9 investigators, with 3 of those being CSI collaborators (Table 2). Detections during this reporting period exhibited a similar trend to those in 2015, with fall detections occurring within the Chesapeake and its tributaries and winter/spring detections occurring in coastal waters. The bulk of detections occurred in the late-fall/early-winter time period, likely the result of post-spawn sturgeon leaving the Chesapeake Bay and entering the ocean. Relatively few detections occurred in the late-winter/early-spring, indicating that the sturgeon may not overwinter in Maryland waters.

A total of 226 individual fish were detected during the reporting period by CBL and MD DNR receivers, including Atlantic Sturgeon, blue catfish, great white sharks, sand tiger sharks, and striped bass. Relevant data has been transmitted to PIs associated with detected individuals.

Table 2. Detections of Atlantic sturgeon in Maryland acoustic receiver arrays (MD DNR and CBL) during the period of November 2016 – May 2016.

Week	System	Array	Detections	Note
11/1 - 11/7/2015	Atlantic	MD Coastal	524	CSI Collaborator
11/1 - 11/7/2015	Chesapeake	Upper Bay	11	CSI Collaborator
11/8 - 11/14/2015	Atlantic	MD Coastal	167	CSI Collaborator

11/8 - 11/14/2015	Chesapeake	Mid Bay	15	CSI Collaborator
11/15 - 11/21/2015	Atlantic	MD Coastal	186	CSI Collaborator
11/22 - 11/28/2015	Atlantic	MD Coastal	68	
11/29 - 12/5/2015	Atlantic	MD Coastal	26	
12/6 - 12/12/2015	Atlantic	MD Coastal	78	
12/13 - 12/19/2015	Atlantic	MD Coastal	67	CSI Collaborator
12/20 - 12/26/2015	Atlantic	MD Coastal	29	
12/27/2015 - 1/2/2016	Atlantic	MD Coastal	43	CSI Collaborator
1/3 - 1/9/2016	Atlantic	MD Coastal	171	
1/10 - 1/16/2016	Atlantic	MD Coastal	441	
1/17 - 1/23/2016	Atlantic	MD Coastal	57	CSI Collaborator
1/24/2016 - - 3/19/2016				No recorded detections
3/20 - 4/2/2016	Atlantic	MD Coastal	1	
4/3 - 4/9/2016	Atlantic	MD Coastal	5	
4/10 - 4/16/2016	Atlantic	MD Coastal	12	
4/17 - 4/23/2016	Atlantic	MD Coastal	7	
4/24 - 4/30/2016	Atlantic	MD Coastal	16	
5/1 - 5/7/2016	Atlantic	MD Coastal	4	CSI Collaborator
5/8 - 5/14/2016	Atlantic	MD Coastal	37	CSI Collaborator

York River Mobile Telemetry

In collaboration with Virginia Institute of Marine Science (VIMS) scientists (E. Hilton and M. Fisher), CBL conducted six and seven mobile telemetry-water quality surveys in the York and Pamunkey Rivers in June-October 2014 and 2015, respectively. Analysis of habitat selection by Atlantic sturgeon as related to concurrent water quality was conducted during the reporting period following the cruises.

Pamunkey River bottom water quality where sturgeon were detected in the 2015 surveys was similar to that which occurred in the same period of 2014 (Figure 3). High temperatures, low dissolved oxygen, and low habitat suitability (predicted from a bioenergetics model) characterized this period. More fish were detected in 2015 than in a similar period of 2014, most likely due to extensive tagging efforts by multiple research groups in the Pamunkey River. The water column was well-mixed throughout the river and had similar values in the early-summer and late fall across years (Figure 4). The month of August, however, was more suitable for sturgeon growth in 2014. Water quality was more suitable for growth in July than in the June period. In the summer months of both years, detections of Atlantic sturgeon predominantly occurred in water with dissolved oxygen values greater than 60% saturation and temperatures in the middle of those concurrently-available range (Figure 5). This contrasts with the late-fall, where remaining sturgeon were detected in warmer waters.

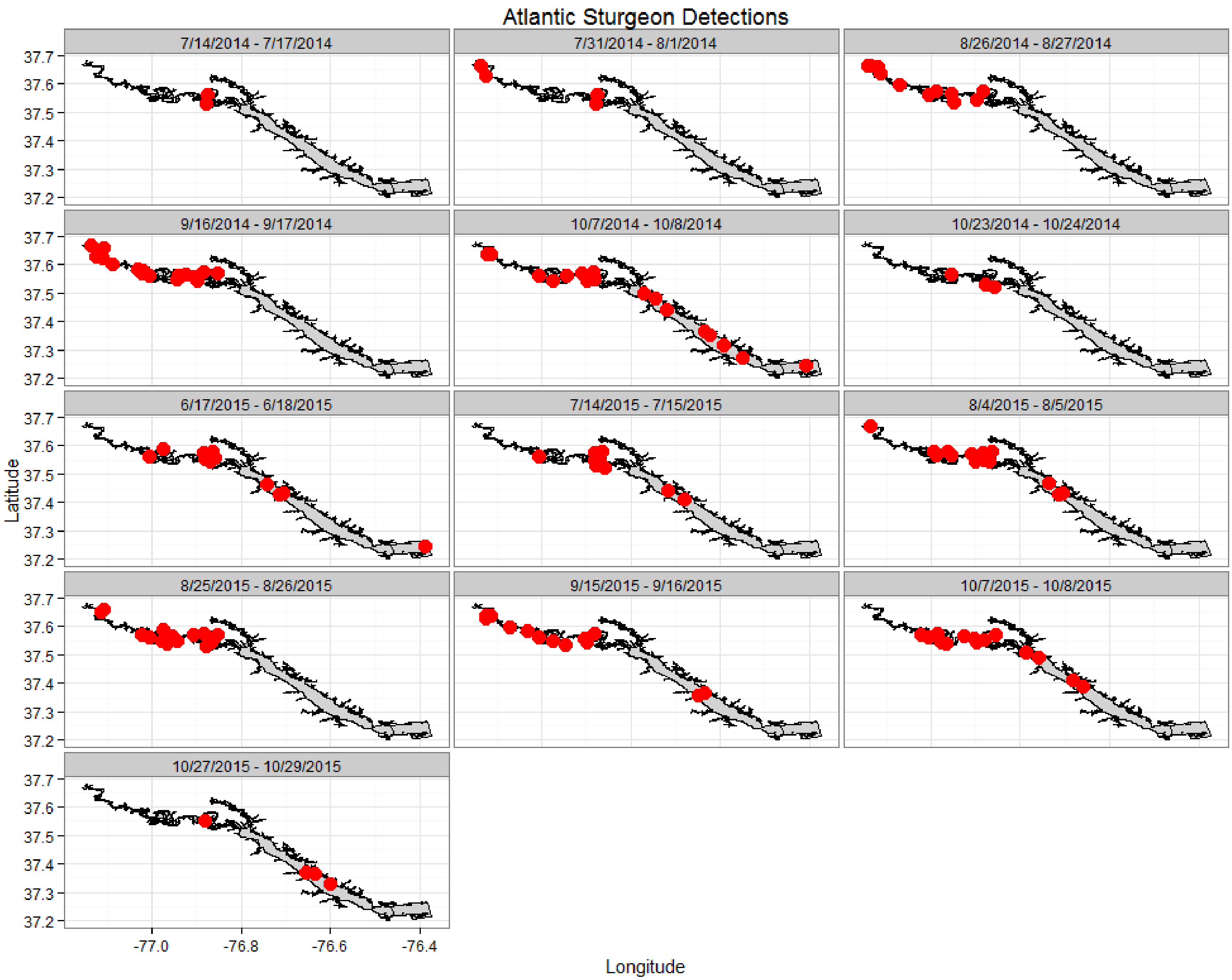

Figure 2. Distribution of Atlantic sturgeon detections in the York-Pamunkey River system, July-October 2014 (top two rows) and June-October 2015 (bottom three rows). Each river map represents single surveys with Atlantic sturgeon detections shown. Note that most detections occurred in the Pamunkey River.

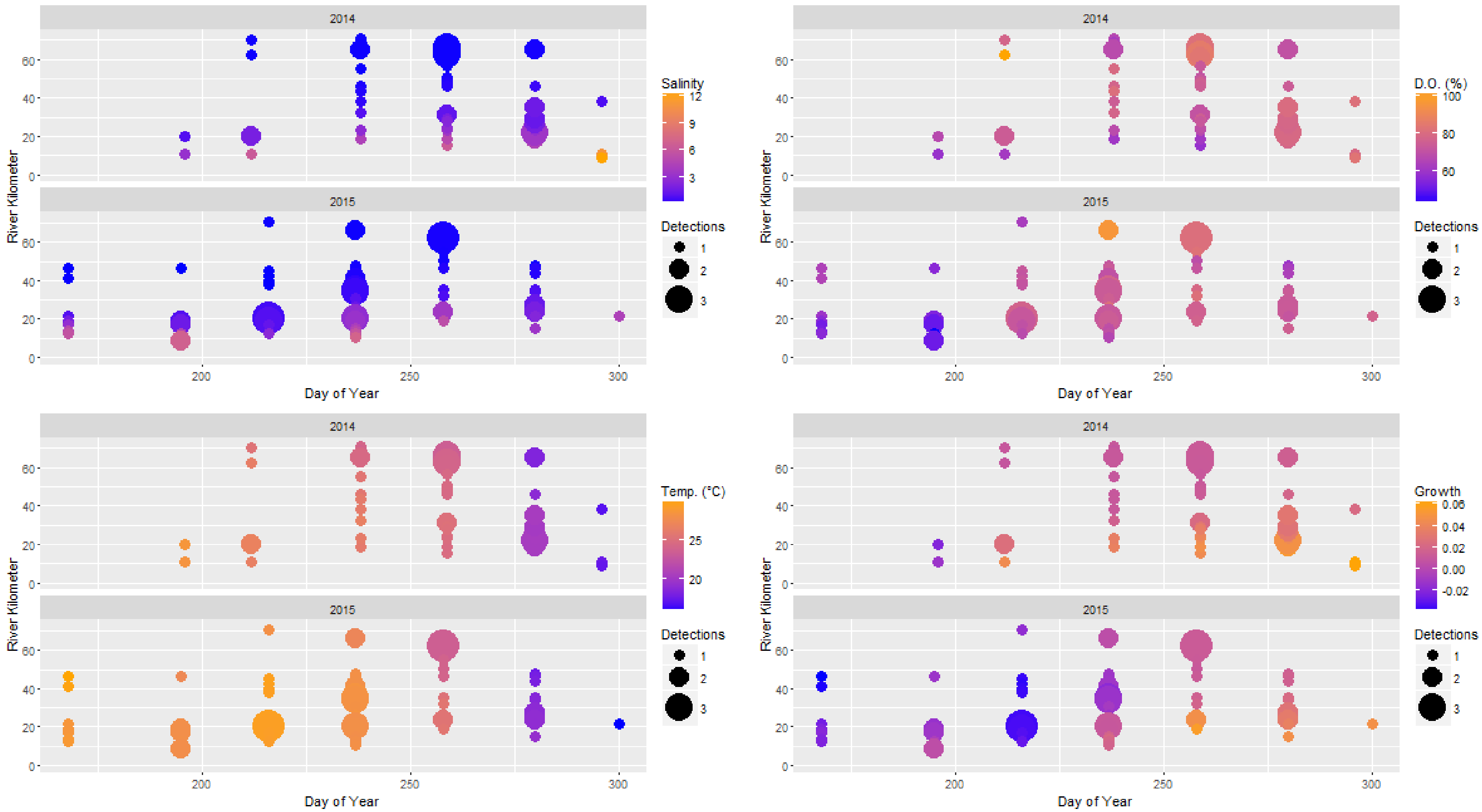

Figure 3. Bottom salinity, dissolved oxygen (% saturation), temperature (°C), and calculated growth rate at Pamunkey river kilometers with Atlantic sturgeon detections. 2014 (top) and 2015 (bottom) periods are shown. Warm colors reflect high vales with cool colors representing low. Habitat suitability is presented as predicted growth in the lower right panel, and is predicted from a bioenergetics model.

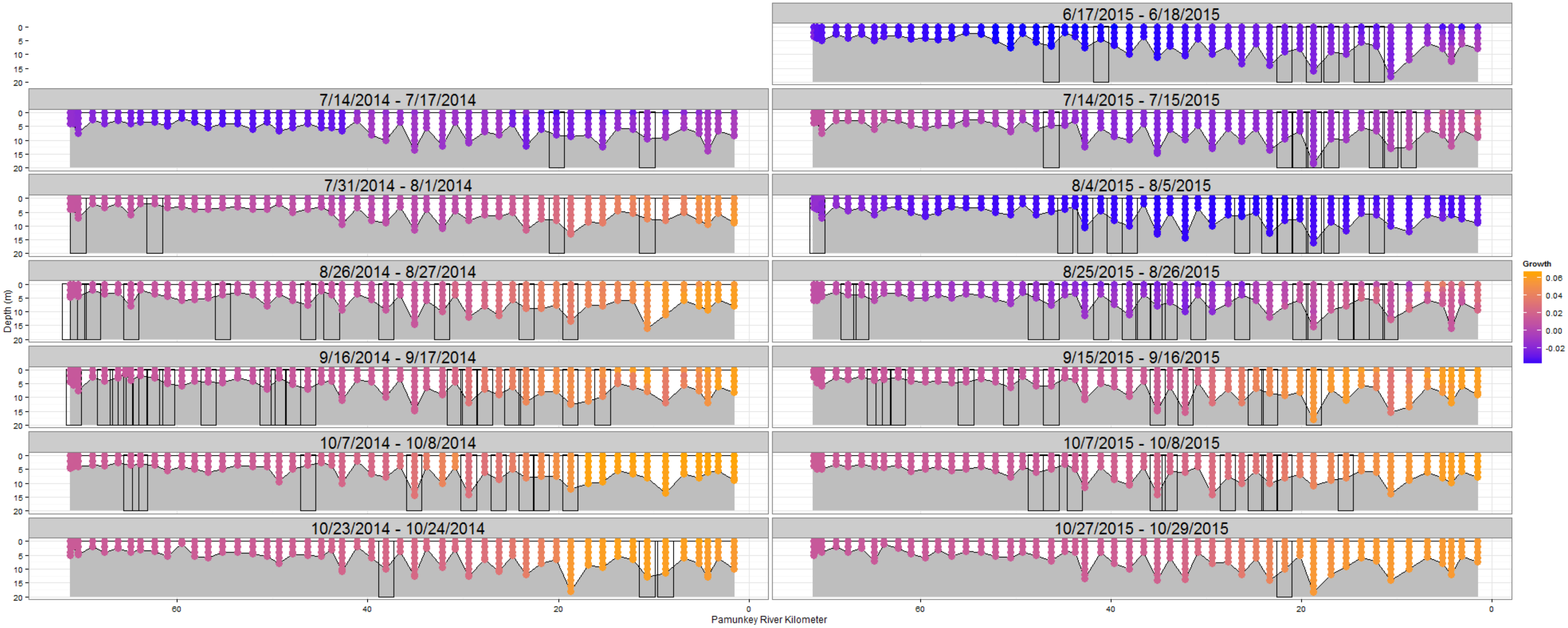

Figure 4. Habitat suitability for the Pamunkey River calculated instantaneous growth potential for all 2014 and 2015 periods. Each dot represents a depth-specific measurement from the mouth of the Pamunkey River (towards right of graph) to upestuary-Pamunkey region (towards left of the graph). Colors of dots indicate instantaneous growth rate calculated from survey-based dissolved oxygen, temperature, and salinity values. Purple represents near-zero growth rates, orange represents relatively high growth rates. Boxes represent where Atlantic sturgeon were detected.

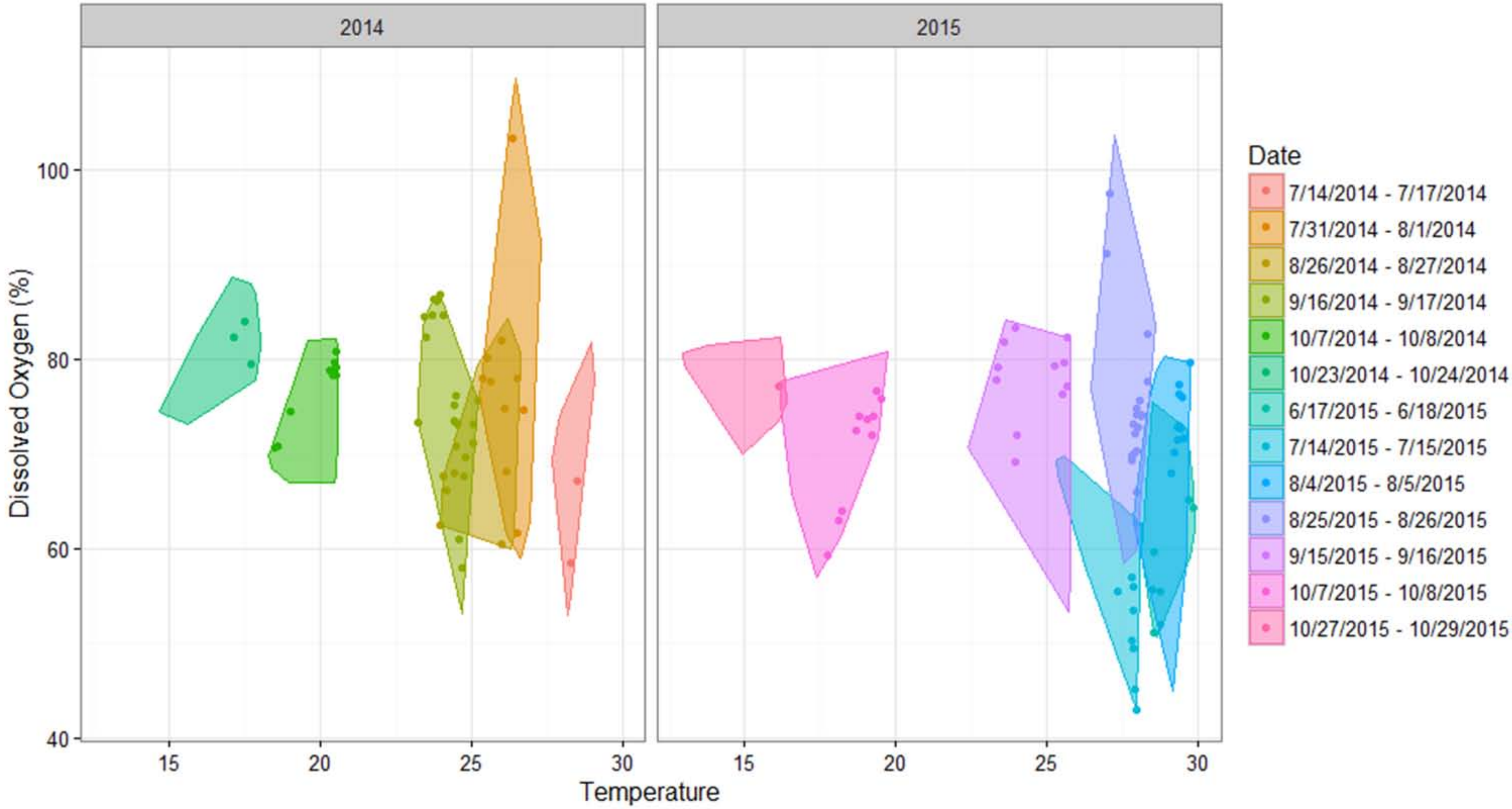

Figure 5. Convex hulls encompassing the range of temperature and dissolved oxygen values within the Pamunkey River for each cruise in 2014 and 2015. Points represent the values of bottom temperature and dissolved oxygen at the point of Atlantic sturgeon detection. With the exception of early-August 2015, sturgeon were predominantly detected in waters with dissolved oxygen values greater than 60% saturation.

Preference in predicted growth and temperature values was analyzed using single-parameter quotient analysis. Values of water quality parameters were first divided into approximately five bins. The proportion of sites within each water-quality bin and the proportion of detections occurring at sites containing values within each water-quality bin was then calculated. The quotient value was determined by dividing the proportion of detections by the proportion of sites; a quotient of 1 indicates no preference, a quotient greater than one indicates preference, and a quotient less than one indicates avoidance. The proportion of sites within each water quality bin was resampled via bootstrapping without replacement to determine 95% confidence intervals.

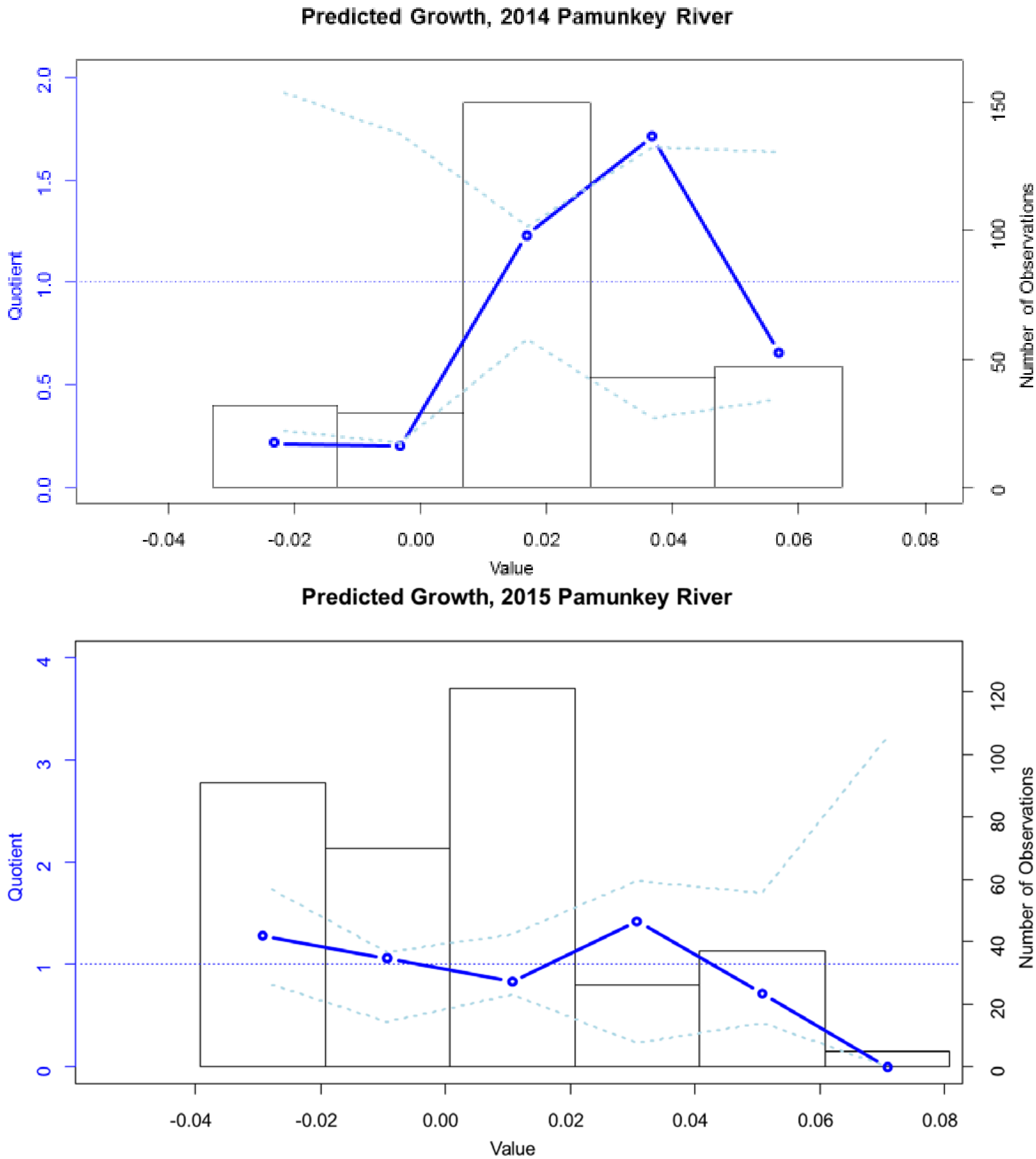

Figure 6. Quotient analyses of predicted growth (from bioenergetics model) within the Pamunkey River in 2014 and 2015. Bars represent the number of observations within a predicted growth bin, blue circles represent the calculated quotient, and dashed blue lines represent the 95% confidence interval of the quotient value.

In 2014, sturgeon displayed significant avoidance of habitats with negative growth potential and preference for habitats with moderate growth potential (figure 6). The analysis suggested no selection of the highest growth potential habitats. In 2015, Atlantic sturgeon detections displayed a distribution independent of their predicted growth.

Habitat Modeling

Ms. Erin Markin is a PhD candidate supported by the award to assist with application of the habitat suitability model. She has obtained code for the model and spatial interpolation algorithm, as well as Chesapeake Bay Program water quality data from 1990-2013, and conducted interpolations using the bioenergetics habitat suitability model. Effort during this reporting period concentrated on evaluating seasonal habitat suitability on a tributary basis (total of 15 tributaries) (Figure 7a.b.). The tributaries were ranked to determine the top- and bottom-five seasonal production rates on a yearly basis. The rankings were evaluated to determine trends in habitat suitability (Table 3a.b.). In 1999 and 2005, Virginia tributaries and the Lower Eastern Shore were routinely ranked in the top five for winter, spring, and summer. Fall rankings tended to have different tributaries in the top five, but, given the high fall production rates in the Chesapeake Bay, these results may not have ecological significance. In addition, capture data for Atlantic sturgeon was obtained from USFWS and MD DNR and was used to validate the model. Atlantic sturgeon were captured in areas of positive production despite typically not selecting for areas of higher habitat value (Figure 8). Use of capture data confounds this result, suggesting that alternate data sources, such as telemetry data, can assist in determining selection by Atlantic sturgeon.

Since temperature and dissolved oxygen drive the bioenergetics model, capture results within the framework of temperature and dissolved oxygen were analyzed to determine if the Chesapeake Bay criterion (dissolved oxygen: 5 mg/L (60% at 25°C)) is sufficiently protective of Atlantic sturgeon. We determined that Atlantic sturgeon were routinely captured at dissolved oxygen concentrations below 60%, especially during summer months (Figure 9). Atlantic sturgeon were less likely to be caught in areas with water temperatures exceeding 25°C (Figure 10).

In addition to comparing production values within tributaries and capture locations, future work will attempt to apply electivity analyses to determine probability of Atlantic sturgeon being captured in high-value habitat within specific segments.

Ms. Markin also ran juvenile cohort analyses through the first year of life using monthly production values dependent on spawning dates in spring and fall 1997-1998.

In this specific example, fall-spawned individuals were larger than spring-spawned individuals at the end of one year of growth despite spring-spawned sturgeon attaining twice the size going into winter months than fall-spawned sturgeon (Figure 11). We do not know if this will result in increased mortality for fall-spawned individuals during winter months. Additional years will be tested to see if this result continues. We will also run the analysis using production values generated on a bi-weekly basis.

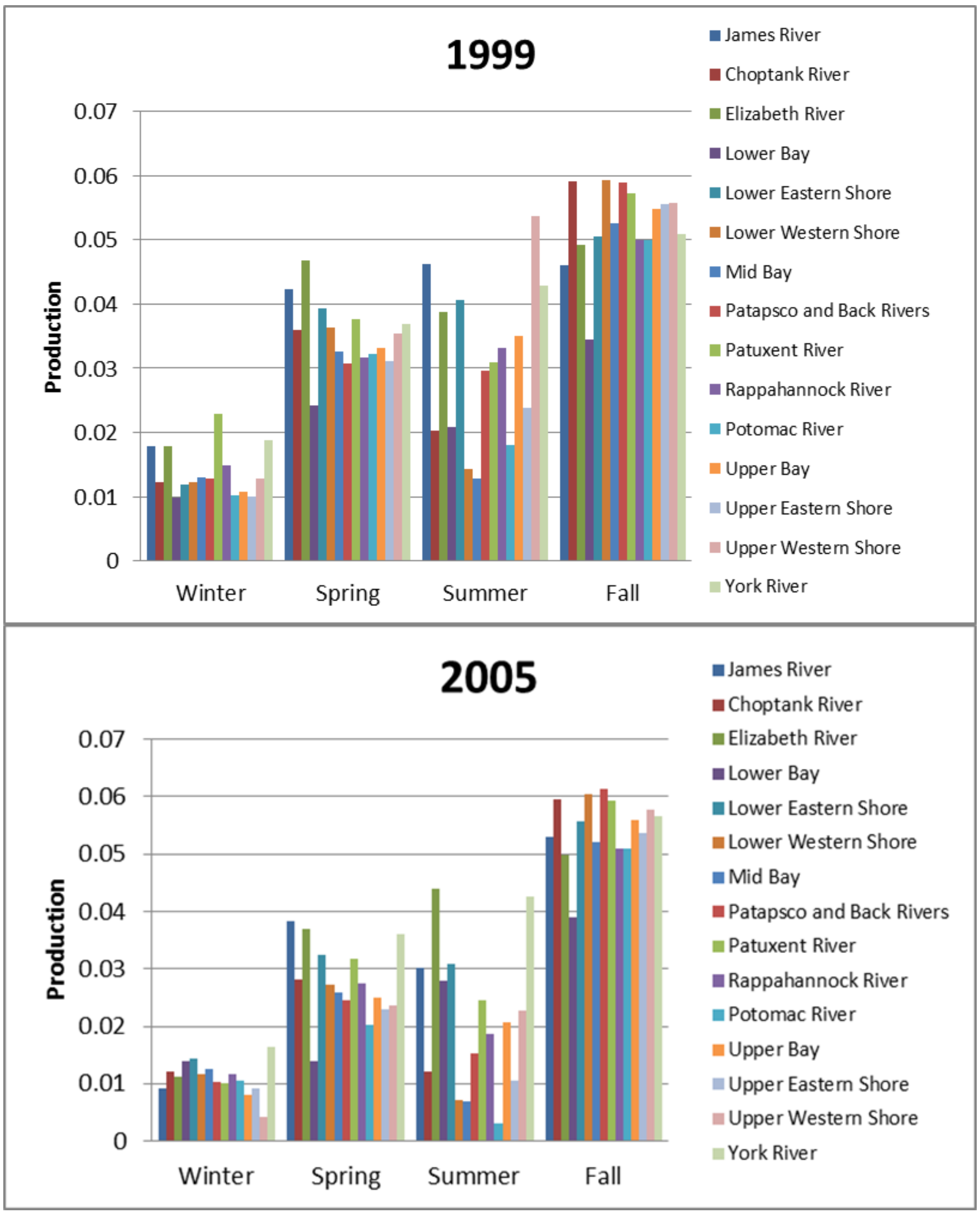

Figure 7. Seasonal production rates among fifteen segments within the Chesapeake Bay in 1999 (a) and 2005(b).

Table 3a. Top 5 of 15 segments ranked 1 through 5 by seasonal production rates				
Season	**Winter**	**Spring**	**Summer**	**Fall**
Year		**1999**		
	Patuxent River	Elizabeth River	Upper Western Shore	Lower Western Shore
	York River	James River	James River	Choptank River
	James River	Lower Eastern Shore	York River	Patapsco and Back Rivers
	Elizabeth River	Patuxent River	Lower Eastern Shore	Patuxent River
	Rappahannock River	York River	Elizabeth River	Upper Western Shore
Year		**2005**		
	York River	James River	Elizabeth River	Patapsco and Back Rivers
	Lower Eastern Shore	Elizabeth River	York River	Lower Western Shore
	Lower Bay	York River	Lower Eastern Shore	Choptank River
	Mid Bay	Lower Eastern Shore	James River	Patuxent River
	Choptank River	Patuxent River	Lower Bay	Upper Western Shore

Table 3b. Bottom 5 of 15 segments ranked 11 through 15 by seasonal production rates				
Season	**Winter**	**Spring**	**Summer**	**Fall**
Year		**1999**		
	Lower Eastern Shore	Potomac River	Lower Bay	Potomac River
	Upper Bay	Rappahannock River	Choptank River	Rappahannock River
	Potomac River	Upper Eastern Shore	Potomac River	Elizabeth River
	Upper Eastern Shore	Patapsco and Back Rivers	Lower Western Shore	James River
	Lower Bay	Lower Bay	Mid Bay	Lower Bay
Year		**2005**		
	Patuxent River	Patapsco and Back Rivers	Choptank River	Mid Bay
	Upper Eastern Shore	Upper Western Shore	Upper Eastern Shore	Potomac River
	James River	Upper Eastern Shore	Lower Western Shore	Rappahannock River
	Upper Bay	Potomac River	Mid Bay	Elizabeth River
	Upper Western Shore	Lower Bay	Potomac River	Lower Bay

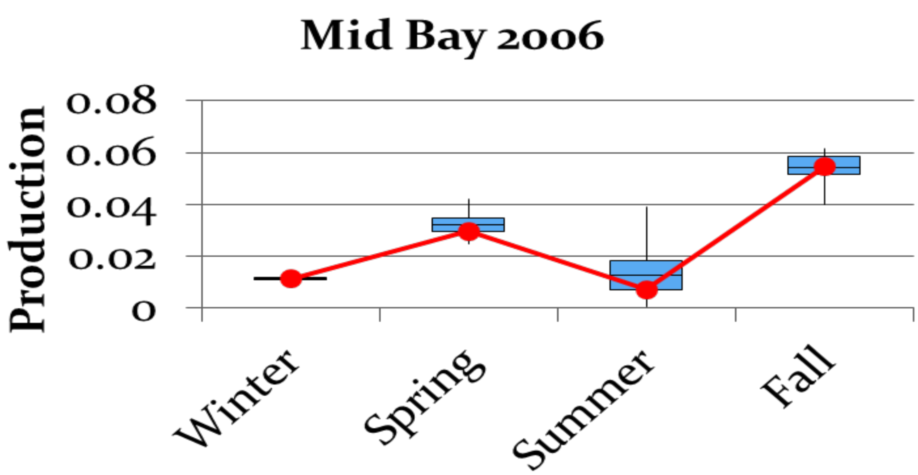

Figure 8. Mean production values at sturgeon capture sites (line-points) and segment habitat (boxes).

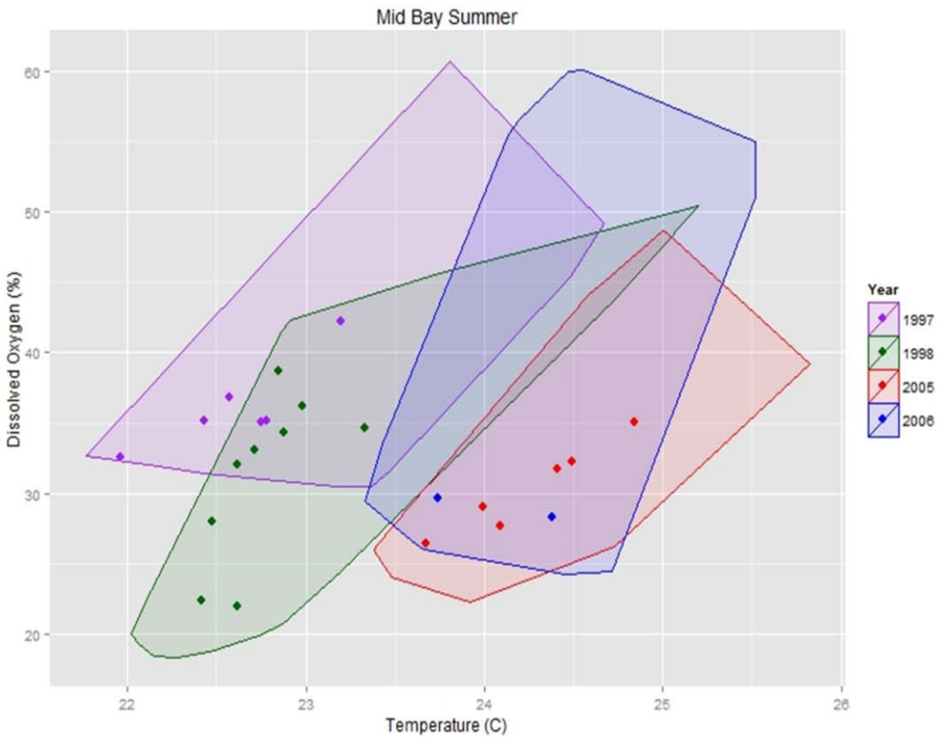

Figure 9. Convex hulls encompass the range of habitat available during the summer in the Mid Bay. Individual points represent locations of captured Atlantic sturgeon. Note all captures occurred in areas with <60% dissolved oxygen.

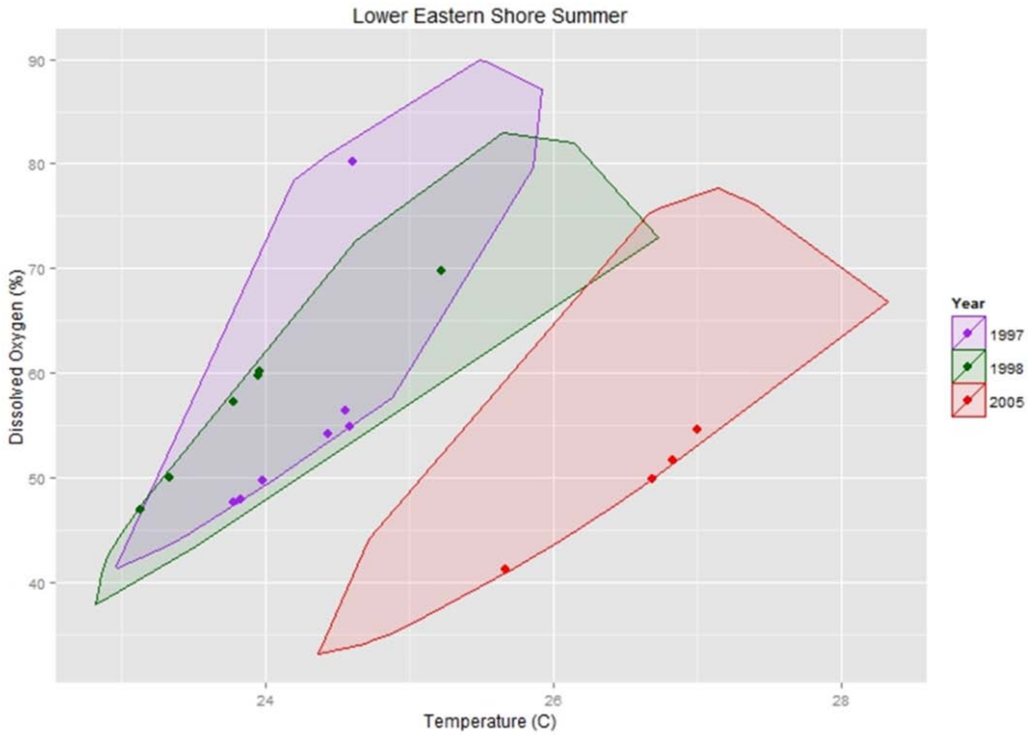

Figure 10. Convex hulls encompass the range of habitat available during the summer in the Lower Eastern Shore. Individual points represent locations of captured Atlantic sturgeon. Note captures occurred in areas where temperatures exceed 25°C.

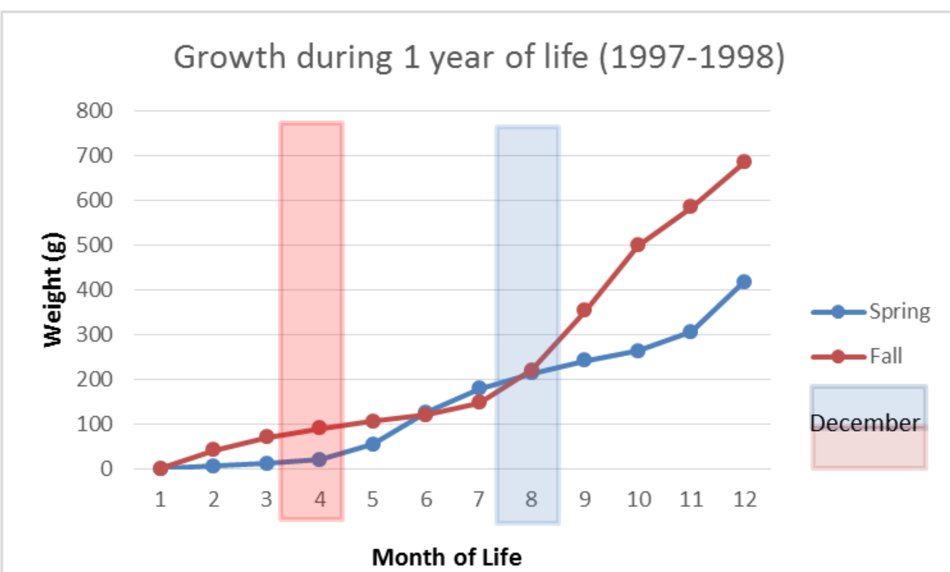

Figure 11. Atlantic sturgeon juvenile growth during first year of life using monthly model-generated production values. Spring-spawned sturgeon were modeled to have spawned May 1. Fall-spawned sturgeon were modeled to have spawned September 1.

Products during the Reporting Period

Chesapeake Bay Atlantic Sturgreon Workshop. Solomons, MD, 17 Dec, 2015.

A workshop on Chesapeake Bay Atlantic sturgeon was conducted on December 17, 2015 at the Chesapeake Biological Laboratory in Solomons, MD to present and discuss new findings on Atlantic sturgeon inhabiting Chesapeake Bay waters (see attached report). The workshop was attended by researchers (17 CSI, 3 other), managers (5), and members of the press (2). Major discovered presented included detections of adult sturgeon in new Chesapeake Bay tributaries, including a discrete spawning group in the Nanticoke River, support for differences in staging behavior between spring- and fall-spawning fish, and the lack of avoidance of low-oxygen waters. Workshop products included coordination of acoustic receiver deployments within the Chesapeake Bay and tributaries, a renewed call for broad-level receiver metadata and detection data to beta test the MATOS database, and a plan to coordinate research takes of Atlantic sturgeon within the Bay.

Presentations and Publications

Secor, D. Fisheries Stewardship in Dynamic Seascapes. Global Climate Change Biology, Gordon Research Conference, Waterville, NH, July 2016.

Markin, Erin. Bioenergetics model of habitat suitability for Atlantic sturgeon in the Chesapeake Bay. 2015 Annual Meeting of North American Sturgeon and Paddlefish Society, Oshkosh, WI, October 19-22, 2015.

Summary of 2015 Chesapeake Bay Atlantic Sturgeon Workshop

Venue: Univ. Maryland Center for Environmental Science Chesapeake Biological Laboratory, Solomons MD ; 17 December 2015, D. Secor (host)

Synopsis: A packed room of ~30 scientists representing state, federal, academic, and nonprofit groups presented and discussed new findings on Atlantic sturgeon inhabiting Chesapeake Bay waters. New discoveries presented at the workshop included,

- Apparent differences in staging behaviors by fall vs. spring spawning runs of Atlantic sturgeon in the James River.
- Latitudinal gradients in the propensity of populations to support a fall spawning run.
- Preliminary evidence for the feasibility of detecting the presence of Atlantic sturgeon through environmental DNA.
- Movement by adults between major tributaries; fish tagged in the Pamunkey were detected during fall in the Rappahannock, Nanticoke, and Pocomoke.
- Possible discrete spawning group in the Nanticoke based on preliminary genetic evidence.
- New detections of adult fish, tagged elsewhere, in the Rappahannock and Potomac during fall months.
- Apparent lack of selection against lower dissolved oxygen levels (<50% saturation) by adult and sub-adult Atlantic sturgeon.
- Gravel and cobble bottom habitats identified through sonar bathymetry in the Marshyhope Creek in regions where ripe adults have been collected.

Next Steps: The group reviewed receiver deployment plans in major tributaries, the mainstem, and in shelf waters near the Chesapeake Bay. Plans for electronic tag deployments were also briefly discussed. Data and participation needs were discussed for,

- MATOS (The Mid-Atlantic Telemetry Observing System): Participants requested for beta testing. MATOS represents a database principally for distribution of detection (receiver) data. The program has recently developed a new database architecture that is compliant with the Ocean Tracking Network.
- Chesapeake Bay Atlantic Sturgeon takes: Albert Spells (USFWS) will continue to coordinate take permits in the Chesapeake and would like to hold a workshop in March for those planning to sample and tag sturgeon.
- A bench mark stock assessment is planned for next year, which will include continued collection of new data. Several participants at the workshop will contribute and participate in this effort.
- A future workshop is planned for data analysis of telemetry data, hosted again at Chesapeake Biological Laboratory.

Annual Workshop: ***Chesapeake Sturgeon Initiative Science Workshop***

Date: December 17, 2015

Location: Room No. 1101, Bernie Fowler Building, Chesapeake Biological Laboratory, Solomons MD

<u>Agenda</u>

9:30-9:45: Introductions, lunch orders

9:45-11:30: Reproductive Behaviors and Habitats

- James River (M. Balazik, G. Garman, R. Greenlee, A. Bunch)
- York River (J. Kahn, C. Hager, C. Watterson)
- Nanticoke (C. Stence, I. Park, M. O'Brien)
- Rappahannock (M. Balazik)
- Marshyhope habitat survey (D. Bruce)

11:30-12:30 Critical Nursery Habitats

- Sub-adult tagging efforts (E. Hilton, M. Fisher)
- Mobile telemetry/bioenergetic modeling (M. O'Brien, M. Fisher)
- Baywide bioenergetic modeling (E. Markin, D. Secor)
- Hunt for larvae and young juveniles
    - James (M. Balazik)
    - York (J. Kahn)

12:30-1:00: Ordered lunch

1:00-2:00: Population Structure of Chesapeake Bay DPS

- Genetics (T. King)
- Incidence of adult sturgeon across Chesapeake tributaries (group inventory)

1:30-2:10: Chesapeake-mainstem distributions

- Seasonal incidence in lower Chesapeake Bay (C. Watterson)
- Seasonal incidence in the mid-Bay and MD Shelf waters (M. O'Brien)
- Seasonal patterns of incidence within the Chesapeake (group)

2:10-2:30 Break

2:30-3:30 Receiver arrays, MATOS, data sharing, and outreach

Plans for receiver deployments (group)

James River array

York, Rappahannock array

MD arrays

DE arrays

Ocean Arrays

MATOS (K. Schabow)

Allocation of takes (A. Spells)

ASMFC Stock Assessment (K. Drew and K. Arnstead)

3:30-4:00: Other research outcomes

Ship channel study (M. Balazik)

Attendees

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