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

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Executive Summary:

The states of Virginia and Maryland along with Virginia Commonwealth University (VCU), Virginia Institute of Marine Science (VIMS) and University of Maryland Center for Environmental Science (UMCES) partnered to assess critical habitat for recovering the Chesapeake Bay Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) distinct population segment. The primary objectives were to assess reproductive habitat in the James River, nursery habitat in the James and York Rivers and the degree of dependence of those populations to habitat in the Chesapeake Bay. A suite of standard techniques were used including, egg mats, gillnetting, trawl and newer techniques such as acoustic telemetry, side scan sonar, and VEMCO Positioning System array. Most key objectives were met. Among the various outcomes met, we: 1) described the physio-chemical habitat of a 94 km reach of the James River (>11,000 measurements) that is believed to support spawning and age 0-2 nursery habitat; 2) mapped 60 km of James River benthic hardness using side scan in the tidal freshwater reach and completing a GIS based analysis; 3) implanted almost 200 and exactly 120 acoustic long-lived transmitters in James River adults and subadults, respectively; 4) implanted 25 acoustic long lived transmitters in York

system subadults; 5) actively tracked tagged subadults in the James and Pamunkey while in their summer foraging habitat and mapped locations in GIS; 6) worked closely with project partners and cooperators including the Virginia Department of Game and Inland Fisheries (VDGIF), VIMS, VCU, the Department of the Navy, UMCES, and others to track movements of Atlantic Sturgeon using a GIS-based analysis of this extensive dataset to elucidate temporal and spatial patterns of movement and behavioral responses; 7) assisted UMCES in water quality and sturgeon tracking in the York system (reported by Maryland); 8) developed, tested and published improvements (e.g. electronarcosis) for conducting surgeries on sturgeon that have been adopted for use under ESA permits; 9) deployed three VEMCO Positioning System arrays and VR2C (real time) acoustic receivers in the James River to better understand fine scale movements of target fish in response to threats including vessels and dredging; 10) used data from long term population monitoring to confirm existence of separate Fall and Spring spawning cohorts (races) in the James which was confirmed by geneticist Dr. Timothy King (USGS); 11) used the same long term data to develop a preliminary mark-recapture population estimate for male, fall-run Atlantic sturgeon in the James that exceeds earlier estimates by at least an order of magnitude which, together with 'discoveries' of adult Atlantic sturgeon in the York and Rappahannock systems, support the hypothesis of an on-going but modest recovery in the Virginia component of the Chesapeake Bay DPS; 12) in Spring, 2016, the first Shortnose Sturgeon collected in the James River during modern times was documented by VCU and that identification was later confirmed by genomic analysis; 13) a total of 8 articles in peer-review journals, numerous technical presentations, several thesis, independent study projects, reports, and platform presentations expanded the impact of research conducted during the project period and provided public access to data generated; 14) deployed and maintained extensive receiver arrays in the James, York, Mattaponi, Pamunkey, Rappahannock, and Piankatank Rivers; and, 15) cooperated with other researchers through the ACT network. Objectives not met: we were unable to document successful spawning or the presence of early juvenile (age 0-2) Atlantic Sturgeon in the James River as well as early juvenile presence in the Pamunkey or Mattaponi Rivers. These combined outcomes will help to inform and guide future sturgeon conservation efforts in the Chesapeake Bay DPS.

Section 1: Supporting assessment of Atlantic sturgeon habitat in the James River

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Project objectives: To support the overarching goals of this project i.e., assessing habitat (reproductive, nursery, forage and connectivity) by: 1) providing project oversight and administration; and, 2) maintaining the James River telemetry receiver array and data distribution and archiving.

Methods:

Receiver and Data Maintenance

DGIF biologists and technicians conducted periodic maintenance of the James River receiver array throughout the grant period, conducting receiver maintenance and data download and maintenance for receiver stations distributed in the tidal river from Richmond downstream to Burwell Bay.

Education and Outreach

DGIF staff worked closely with other groups, Atlantic Coast Telemetry Network (ACT), Mid-Atlantic Acoustic Telemetry Observation System (MATOS), United States Navy, and other Section 6 PIs to encourage data distribution and sharing in support of Atlantic sturgeon conservation. DGIF has worked with several outreach partners to use viewing of breaching sturgeon during the fall spawning migration as an educational and outreach opportunity. School groups, teacher workshops, government leadership training groups, media outlets and members of the public have participated and benefited from these experiences.

Results and Discussion:

In 2013, receivers were deployed over several days in early March, with the first detection being recorded on March 16th. DGIF biologists and technicians maintained 30 receiver stations distributed in the tidal river from G169 near Richmond downstream to Newport News (Navigation Buoy G1), receivers were also deployed at one station each in the Appomattox River and Burwell Bay; and, the array remained deployed during the winter months until early January when the array was pulled due to predicted prolonged cold weather and the threat of icing over. In 2014, the lower array was redeployed on April 2nd and the upper array was deployed on May 5th. The lower array consisted of receivers from Burwell Bay (G1) to just upstream from the Chickahominy River (R68), while the upper array consists of receivers from Fort Pocahontas to G169 near Richmond. The array was maintained and deployed throughout the winter of 2014-2015, and the array remained deployed through the duration of the project. At the end of the project the array consisted of 27 receiver stations. The lower array consisting of receivers from Burwell Bay (G1) to just upstream from the Chickahominy River (R68), the upper array consisting of receivers from Fort Pocahontas to G169 near Richmond, with an additional receiver added to the array in the Appomattox River in mid-May. All deployed receivers were functional throughout the period since the January 2016 progress report, and continue to be maintained to-date (Figure 1). As was the case last winter, the intent is to leave the receivers deployed throughout the winter of 2016-2017.

Data generated from the James River array were critical to assessing spatiotemporal occurrence patterns and likely habitat requirements during this project, and will continue to be used in ongoing work to refine and develop spatial analysis tools for management agency use in assessing likely occurrence and potential protective time of year restriction recommendations (TOYR) in the environmental review process. All downloaded receiver data are being archived in a dedicated database, and data distribution to other Section 6 PIs and other interested groups continues to occur as requested.

While the current configuration of the James River array was sufficient to achieve project objectives, giving adequate spatiotemporal understanding of gross movement patterns in the mainstem river, we note that major tributaries lacked coverage (e.g., Powell Creek, Upper Chippokes Creek and others) and we did not track movements upstream of G169. Sturgeon were documented above the G169 receiver, however tracking movement in the upstream non-tidal reaches would require deploying different technology (i.e., radio telemetry) due to acoustic noise associated with the fall zone (an extended reach characterized by rapids and bedrock substrate). The fall zone, having clean exposed hard substrates, warrants further investigation as potential spawning habitat.

Section 2: Assessment of Critical Habitats and Threats for Recovery of the Chesapeake Bay Atlantic Sturgeon Distinct Population Segment in the James River

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VCU Project Objectives:

Objective 1: Assess putative critical Atlantic Sturgeon reproductive habitats, including physico-chemical (water quality) and structural (bathymetry, substrate composition) components of critical habitats in the Tidal James River, Virginia.

Objective 2: Assess status of Early Juvenile (ages 0-2) Atlantic Sturgeon in the Tidal James River.

Objective 3: Assess degree of dependence of James River Atlantic sturgeon on Chesapeake Bay Habitats and conduct population threat assessment focused on vessel and dredge interactions.

Objective 4: Contribute to education and outreach activities aimed a variety of stakeholders including: resource managers, scientists, non-government stakeholders, and the general public.

Methods:

Reproductive Habitat Assessment (VCU Objective 1)

We conducted a comprehensive, quantitative assessment of water quality (physico-chemical habitat assessment) for a 94-km reach of the tidal James River between Richmond, Virginia and the Rice Rivers Center in Charles City County. This reach is associated with Fall spawning by Atlantic Sturgeon and has been documented recently as nursery habitat for early juvenile (age 0-2) Atlantic Sturgeon. We believe it to be critical habitat for the recovery of the Fall cohort of ATS in the James River. Between February 12, 2013 and December 15, 2015, VCU conducted weekly sampling for water quality parameters, including temperature (°C), pH (units), specific conductance (S/m), and dissolved oxygen (mg/l; % saturation) at nine fixed locations in the channel. We used a vessel to sample both near-surface (0.5 m below) and near-bottom (0.5 m above) sections of the water column using a recently-calibrated YSI 6600 multi-probe sonde. All measurements on a given date were taken within the same 2-h period in order to minimize tidal influence among sites. A total of 1,112 water samples were collected during this period and the data from these samples (>11K measurements) are adequate to characterize longitudinal, seasonal and inter-annual variability for this important reach of the James River.

VCU biologists also used side scan sonar to complete high-resolution mapping of benthic substrate hardness and composition (i.e., structural habitat) throughout the tidal freshwater reach (documented reproductive and nursery habitat for Fall cohort ATS) of the James River. VCU completed a GIS-based analysis of this extensive dataset during the project period and as one component of this project objective. Data collection started just downstream of the City of Richmond, Virginia and continued approximately 60 rkm downstream to the mouth of the Appomattox River. Side scan sonar data generation, resulting in a total of 11 km^2 of river bottom imagery and 9.4 km^2 of substrate hardness data, took place from August 9, 2013 until August 10, 2014. Bathymetric mapping of surficial habitat was accomplished through the use of a boat-mounted geo-referencing side scan sonar transducer (Humminbird 998c SI, Humminbird, Inc., Eufaula, AL, USA) positioned directly below a GPS receiver mounted on the port side of the research vessel. The transducer was positioned approximately 0.5 m below the water surface and was adjusted to represent the actual water surface-to-bottom depth. Water surface-to-bottom depth measurements were validated using a weighted tape. A real time data feed to an onboard computer ensured a consistent sampling pattern for the data collection. Post processing of depth, hardness, and side scan sonar imagery data was accomplished using Dr. DepthPC and ArcMap Ver. 9.3 (ESRI 2011).

Ground truth substrate samples were collected by benthic dredge and used to establish signal strength thresholds for particle size categories for each substrate type. The substrate samples aided in the development and validation of a substrate classification scheme. In order to better understand how substrate composition throughout the reach has changed over the past 160 y, total hard bottom habitat was compared to historical sounding and substrate observations from 1853 and 1880. Analyzing the historic percent of hard bottom sounding observations and current percent hard bottom habitat area over a specific area enabled a comparison of historical substrate composition, and indicated which river sections may have historically supported sturgeon spawning success in 1853 and 1880.

Gill Net Sampling (VCU Objectives 2 & 3)

Fixed, small-mesh gill nets (7 - 8.3 cm stretch mesh) were deployed using standard and permit-compliant methods for early juvenile (ages 0-2) Atlantic Sturgeon during the most recent (and final) grant period. Fishing effort (91.4 m of net for 1-h sets) for the tidal James River totaled 334.5 h and captured 2,843 fish, which were processed and returned to the water. Nearly 90% of the fish captured during by gill netting during the project period represented a single, introduced, non-target species; no Atlantic Sturgeon were collected. In previous project years (2013-15), we mimicked the fishing protocols and locations of commercial fishers who successfully collected early juvenile Atlantic Sturgeon during 1997 and 1998, as part of a USFWS reward program. This approach was eventually determined to be unsuccessful due to high by-catch of introduced, non-target fish and was abandoned in 2016, when we focused effort on other James River locations, including Sturgeon Point and Weyanoke Point (rkm 90 and 97; Figure 2). These two locations are the deepest holes (≈ 27 m) in the James River and we know that subadult Atlantic Sturgeon utilize these habitats during periods of riverine residence. During Winter months, early juvenile Atlantic Sturgeon in the Delaware River move into areas occupied by subadult fish in other seasons (Matthew Fisher, pers. comm.). The two James River locations targeted by VCU in Winter, 2015 were not sampled much in previous years to the high probability of snagging and leaving 'ghost nets' in known sturgeon habitats. Instead of making sets of long duration and fishing the nets every few hours, we followed techniques used by Delaware researchers and did short sets (1-2 h) during the tide change (Matthew Fisher, pers. comm.). We varied our fishing methods by setting parallel to the current instead of cross-current and this modification, together with short sets, dramatically reduced the likelihood of snagged nets and allowed retrieval of all gill nets deployed by VCU. Although no early juvenile Atlantic Sturgeon were captured during the project period, we believe that these two locations have high potential as Winter habitat for early juvenile Atlantic Sturgeon in the James River. During this sampling period, VCU captured a Shortnose Sturgeon—the first of this species to be documented for the James River (captured at rkm 40) on March 13 (Figure 3). We performed no invasive techniques as we were not permitted to do so at this time. The fish was measured, scanned for PIT tags, a quick photo was taken and then the fish was released. The fish exhibited a strong swim away response. The unique occurrence was verified by genetic analysis (T. King, USGS, unpubl. data) and suggests that targeted efforts for Shortnose Sturgeon may yield additional individuals.

Otter Trawls (VCU Objectives 2 & 3)

A new 16' semi-balloon otter trawl specifically designed to catch early juvenile Atlantic Sturgeon was deployed for the first time in the James River during the project period (Figure 2). The new trawl was set-up by mid-January and fished starting in February, 2016. To improve sampling efficiency and coverage for target life history stages, trawling was usually conducted synoptically with gill net sampling. Trawling should be an effective gear for young sturgeon, as the most recent captures of YOY Atlantic Sturgeon in the Chesapeake Bay were from trawls. Most of our trawling was in water depths < 10 m (Figure 2) and the target trawling speed was 3 knots. We trawled for a total of 1,123 min and captured 7,711 fish (Table 1). A substantial proportion of our trawling effort, especially in early March, focused on the vicinity of James River rkm 100 because that was where the Chesapeake Bay Foundation caught a 15-cm (TL) Atlantic Sturgeon in March of 2004 (Figure 2). (To the best of our knowledge, no early juvenile Atlantic Sturgeon has been captured in the James since 2004, but see below). Trawl sampling failed to capture Atlantic Sturgeon of any size; trawl collections were numerically dominated by two species: introduced Blue Catfish (63%) and Hogchokers (25%). VCU stopped trawling in late March, 2016 and shifted sampling effort to Spring-run, adult fish (see below).

Spring Sampling for Reproductive Adults (VCU Objective 3)

We used the same sampling gears and methods in Spring, 2016 that were successful in prior years. We captured adult Atlantic Sturgeon eight of 11 sampling trips on the James between April 15 and May 19, 2016. All fish were running males and samples of sperm were removed via catheter or recovered from the urogenital vent. During this period we captured n=20 different individuals; of the 20 unique fish, 16 were first time captures for VCU. VEMCO acoustic telemetry tags were placed surgically in five of the new captures, following permit-compliant procedures. One of the Spring, 2016 recaptures was first captured in 2014, while the other three were first captured in 2015. The average fork length of Spring 2016 captures was 175 cm (range: 158-203 cm FL). The 158 cm fish captured on April 26 is the smallest fish we have ever captured during the Spring spawning season, and was likely a Spring spawning fish considering sperm was collected and we have never collected sperm from a Fall-run fish before August. Tissues from the 16 ‘novel’ Atlantic Sturgeon were collected and submitted for genetic analysis. Preliminary results of genetic analysis from Atlantic Sturgeon samples collected in 2015 suggest clear genetic differentiation between the Spring and Fall spawning cohorts in the James River (T. King, USGS, unpubl. data). Other efforts, described in previous reports, focused on identifying habitat associations for adult and early juvenile ATS, based on spatially explicit habitat layers (ArcGIS) and site-specific captures of targeted cohorts in several seasons across three consecutive years. All sturgeon-related activities by VCU personnel during this period were fully compliant with university (IACUC), state, and federal (ESA) guidelines and requirements.

Acoustic Telemetry (VCU Objectives 2 & 3)

We helped to generate and analyzed acoustic telemetry data from VEMCO receivers (VDGIF VR2W array, VCU VR2C array, VCU V100 active receivers), as well as NOAA’s VEMCO Positioning System (VPS) array, which VCU deployed in the James River on at least two occasions during the project period. We also cooperated with other sturgeon researchers through the ACT network to share location data for tagged fish.

Egg Mats (VCU Objective 2)

In-system movements of tagged, adult Atlantic Sturgeon, delineated by active acoustic surveys were used to help determine optimal placement of standard Dacron egg mats during the project period. Comparable to other years, fish spent a large proportion of time in a manmade river channel (Turkey Island cut-through) located near rkm 120; this narrow, artificial channel has ideal spawning habitat (Austin 2012) but also exposes sturgeon to interactions with large commercial vessels. Egg mats were set across the tide along the channel bottom and approximately 2 m apart; 15 egg mats were set on each line. A total of four lines were set. The egg mats were attached to a lead-core line to limit sweeping and to ensure the equipment stayed out of boat propellers. Egg mats were deployed for 4-h periods over 8 days during various flow and tide regimes between May 2 to May 11 (Figure 4). Reproductive male sturgeon were in the general vicinity during all sets (Figure 4). No eggs were collected but, collectively, these sets covered < 1% of the putative spawning area. No gill nets were set on hypothesized areas because we did not want to interfere with spawning sturgeon. A limited number of benthic D-nets were also set in the same area and during the same period but no larval sturgeon were collected.

High resolution acoustic array (VCU Objective 3)

Fall, 2014 data from the VEMCO Positioning System (VPS) that was deployed by VCU in the constructed, Turkey Island Channel shows adult fish spending long periods of time in the middle of the channel (Figure 5). Preliminary analysis suggests that sturgeon drop to deeper areas during periods of high vessel traffic (Figure 5). The left panel of Figure 5 is a subsample of low boat traffic and the right panel is high traffic. We just received the data from the 2015 VPS-based hydraulic dredge study in the James River, conducted with the cooperation of the Corps of Engineers (Norfolk District). Spatially explicit positions were estimated for 127 different sturgeon, including 84 adults and 43 subadults while the dredge was operational. There were 5,964 positions estimated during the project period: 44% were from adults and 56% were from subadults. Adult sturgeon generally passed through the area of operation quickly, which explains why there were so few detections for adult fish. We just received rough location and working time data for the dredge from COE and are in the early stages of integrating the dredge location and telemetry data.

Results:

Key VCU Findings

- Since 2013, and using permit-compliant procedures, VCU biologists implanted nearly 200 VEMCO acoustic transmitters into Atlantic Sturgeon (ATS), focusing on fish captured in the James River, Virginia. Roughly 160 of those tags still have power and many have up to 10 y of battery live remaining. We have worked closely with project partners and cooperators, including the Virginia Department of Game and Inland Fisheries (James River passive array), VIMS, the Department of the Navy, University of Maryland, and others to track and evaluate in-system and coastal movements of Atlantic Sturgeon, especially in the tidal James River and Chesapeake Bay. A GIS-based analysis of this extensive dataset elucidated temporal and spatial patterns of movement and behavioral responses to environmental variables.
- VCU also deployed three VEMCO Positioning System (VPS) arrays and VR2C (real-time) acoustic receivers in the James River to better understand fine-scale movements of target fish in response to potential threats, including vessels and dredging. Data from those deployments are partially analyzed and published.
- We developed, tested, and published improvements (e.g. electronarcosis) for conducting surgeries on adult and sub-adult sturgeon under field conditions. Some of these improvements have been adopted for use under ESA permits.
- Acoustic telemetry data on sturgeon riverine movements, as well as the application of other technologies like side-scan sonar and *in-situ* water quality sondes were used to describe and map putative sturgeon staging, spawning, and nursery habitats in the tidal James River, Virginia. Comparison to historical (i.e., baseline) conditions documented a significant loss (up to 60% in some locations) of critical spawning habitat for Atlantic Sturgeon in the James River.
- Data from long-term population monitoring of adult Atlantic Sturgeon by VCU biologists confirmed the existence—hypothesized since 2010—of separate Fall and Spring spawning cohorts in the James. The genetic distinctiveness of these two races has since been confirmed by Dr. Timothy King (USGS). The likely existence of an ATS metapopulation has significant implications for the species' recovery and management in the James River. These data were also used to develop a preliminary mark-recapture population estimate for male, Fall-run Atlantic Sturgeon in the James that exceeds earlier (pre-listing) estimates by at least an order of magnitude. These results, together with recent 'discoveries' of Atlantic Sturgeon in the Rappahannock (VCU) and York systems (VIMS), support the hypothesis of an on-going but

modest recovery of the species for the Virginia component of the Chesapeake Bay DPS, based on the relative abundance of adult fish.

- In spite of exhaustive sampling efforts using several types of appropriate gears deployed in likely habitats, VCU biologists failed to document successful spawning or the presence of early juvenile (age 0-2) Atlantic Sturgeon in the James River since 2013. These results suggest a worrying recruitment failure, in spite of (relatively) large numbers of reproductively active male and female fish, particularly during the Fall run in the James. We hypothesize that limited availability of suitable, hard-bottom habitat, as well as other threats to early life history stages, are likely causal factors.
- VCU biologists focused significant effort during the grant on population threats from vessel interactions and published findings that suggest large commercial vessels, and not smaller recreational boats, are the most important source of ship-strike injuries and death for adult Atlantic Sturgeon. Since 2007 we have documented well over 150 mortalities, mostly as a consequence of vessel interactions, in the James River alone.
- We conducted a comprehensive, quantitative assessment of water quality (physico-chemical habitat assessment) for a 94-km reach of the tidal James River between Richmond, Virginia and the Rice Rivers Center in Charles City County. This reach is associated with Fall spawning by ATS and has been documented as nursery habitat for ATS. We believe it to be critical habitat for the recovery of the Fall cohort of ATS in the James River. Between February 12, 2013 and December 15, 2015, VCU conducted weekly sampling for water quality parameters, including temperature, pH, specific conductance, turbidity, and dissolved oxygen at nine fixed locations in the channel. We sampled both surface and benthic sections of the water column and generated >11,000 measurements to characterize water quality in this section of the James.
- During this grant, VCU biologists used side scan sonar to complete high-resolution mapping of benthic substrate hardness and composition throughout the tidal freshwater reach (reproductive habitat for Fall cohort ATS) of the James River. VCU also completed a GIS-based analysis of this extensive dataset during the project period and as one component of this project objective.
- In Spring, 2016, the first Shortnose Sturgeon collected in the James River during modern times was documented by VCU and that identification was later confirmed by genomic analysis.
- A total of 8 articles in peer-review journals (see Appendix B) and numerous technical presentations provided public access to data generated under the VCU contract. In addition, several thesis, independent study projects, reports, and platform presentations expanded the impact of research conducted during the project period. We also cooperated with other researchers through the ACT network and participated in VCU's Outreach Education Program to provide K-12 teacher training and student enrichment activities related to Atlantic Sturgeon.

Reproductive Habitat Description and Assessment (Objective 1)

Over 11,000 measurements of key water quality parameters, including temperature, specific conductance (salinity), and dissolved oxygen (summarized in Table 5a and 5b; complete dataset provided in Appendix A) for the tidal reach of the James River successfully characterized the longitudinal, seasonal, and inter-annual physico-chemical habitat in reaches known to support spawning and early juvenile (age 0-2) residence by Atlantic Sturgeon. Across years, seasons, and locations dissolved oxygen levels never dropped below 5.0 mg/l (hypoxia), averaged between 8.9 and 9.7 mg/l, and occasionally reflected supersaturated conditions, probably due to high algal productivity. Salinity (measured as specific conductance) occasionally exceeded 0.5 ppt near the river bottom at downstream sampling locations (e.g. rkm 74 below Hopewell, Virginia) and this location typically defined the lower limit of the tidal freshwater reach, although salinities varied widely among seasons and years. Water temperatures occasionally exceeded 33 °C at the surface. Generally, water quality in the tidal James River, Virginia was good. Unlike some locations within Chesapeake Bay, water quality (physico-chemical habitat)—specifically dissolved oxygen—does not appear to be a limiting factor to recovery of ATS in the tidal James River. These data are summarized in Table 5; raw water quality data are provided in Appendix A of this report.

The availability of suitable substrate composition plays a critical role in determining the reproductive success of Atlantic sturgeon. A geospatial analysis of benthic habitat in the tidal freshwater portion of the James River, Virginia, was performed to quantify remaining sturgeon spawning habitat within the James River system. Structural habitat, substrate distribution, and river bathymetry was assessed through remote sensing from Richmond, Virginia to the Appomattox River confluence. A classification assessment was developed to describe the dominant substrate type (mud/silt, sand, gravel, bedrock) using side scan sonar data and benthic substrate samples collected from study transects. River depth, bottom imagery, substrate density (hardness), and ground truth substrate samples were interpolated into a GIS assessment to spatially describe and quantify essential sturgeon spawning habitat. We performed a GIS-based change analysis of historical substrate composition throughout the study area. Gravel, cobble, and bedrock, swept clean of silt or mud, was deemed a hard bottom substrate suitable for spawning success (Figure 6).

Mud and silt dominated the vast majority of James River substrates in putative reproductive habitats. Sixteen percent of the reach was hard bottom habitat consisting of a substrate dominated by gravel, cobble, or bedrock. The majority of hard bottom habitat was located in major bends of the river where scouring occurs. The historical comparison of available hard bottom habitat identified a 24 % loss of hard bottom since circa 1853. The greatest losses in hard bottom occurred in the upper portions of the study area (55 % loss in hard bottom habitat.) Comparison of three historically altered oxbows identified heavy siltation and reduced depths likely due to anthropogenic alterations in the meander bends linked to shipping channel creation. The increased availability of hard bottom habitat within the confines of the shipping channel has indicated that the alteration of the river bottom, through flow modification and dredging practices, may have replaced a portion of lost historical spawning habitat. Fisheries managers could use the data from the substrate analysis to better understand and protect essential areas necessary for Atlantic sturgeon spawning success. This may be critical for the James River, which carries one of the highest sediment loads of any Chesapeake Bay tributary. Findings support the hypothesis that, although structural habitat (i.e., clean, hard substrate) may be a limiting factor for future Atlantic sturgeon restoration in the James River, remaining refugia of historically abundant hard substrate may help explain the nascent recovery of Atlantic sturgeon over the past decade, and prior to ESA listing, in this system.

Assessment for early juvenile (age 0-2) Atlantic Sturgeon (Objective 2)

During the project period, VCU deployed 120 egg mats in potential ATS Fall spawning locations throughout the upper tidal James River. In addition to placement on two constructed ATS spawning reefs being monitored by VCU, we deployed between 70 and 100 egg mats from rkm 138 to rkm 155 thrice weekly from September 7 to October 16, 2016. Mats were fished overnight and examined the next morning. No ATS eggs were recovered during this project period, in spite of relatively intensive sampling in high quality habitat with accepted methods. Synoptic acoustic telemetry data showed multiple adult female ATS between rkm 140 to 150 during the 2016 Fall spawning season.

Reconnaissance of the lower tidal Appomattox River (near Hopewell, Virginia; Figure 4) during Fall, 2016, suggested the occurrence of significant hard-bottom habitat for ATS spawning, as well as provided anecdotal evidence of regular occupancy by adult ATS up to Petersburg, Virginia (fall zone). Very limited sampling for early juvenile ATS during Fall, 2016 with D-nets by VCU did not produce any fish but targeted sampling should be expanded in 2016, if resources are available. In addition, the relatively un-explored Appomattox River will be the focus for a future ATS habitat assessment using side-scan sonar (David Bruce, NCBO, personal communication). Exploratory gill-net sampling of the upper tidal Rappahannock River in Fall, 2015 by VCU produced a single adult male ATS. Although based on very limited effort, this result suggests that future sampling for adults and characterization of spawning habitat and timing in this system should be a high priority for 2016 and beyond.

From October 1 to December 30, 2016, VCU set two 600' reaches of net, one 2.75" stretch mesh and one 3.25" stretch mesh in the tidal James River and one major tributary for early juvenile (Ages 0-2) ATS. The 2.75" nets were fished for 247 hours (combined) while the 3.25" nets were fished 236 hours (combined). Half of each net was tied down; tie downs are known to be more effective for catching sturgeon in river systems. This is the size mesh other sturgeon researchers have success with outside of Chesapeake Bay and what commercial fishers used to catch juvenile ATS during the 1990s USFWS reward program.

The other new location sampled in Fall 2015 was just below Skiffes Creek on the lower tidal James. In the past we fished just upstream of the creek; this year we focused just downstream of the creek. Commercial fishers caught dozens of juvenile ATS here during the USFWS reward program in the late 1990s and some of these individuals provided advice to VCU biologists in 2015, allowing VCU to mimic historically successful methods, gears, set locations, and time of year. Sampling in 2015 by VCU in these locations produced large numbers of fish, but no Atlantic Sturgeon. Two subadult ATS were collected by VCU in Cobham Bay (lower James River) on November 17, 2015 but both exceeded our size threshold for 'early juvenile' ATS.

Experienced sturgeon biologists with VCU expended considerable sampling effort (> 3,500 gill net hours and > 6,500 trawl minutes) in 2013, 2014, and through December, 2015 to target early juvenile ATS in the tidal James River with two primary gears (Table 2, Figure 7). For this effort the tidal James River was partitioned into 30-km sampling segments and sampling effort units were standardized as 92 net sets for 1 h. Activities described in previous VCU progress reports and manuscripts (Austin, et al., in prep.) used side-scan sonar to characterize and geo-reference benthic habitats (as potential critical habitats for spawning adult and early juvenile ATS) and other habitat attributes (e.g., water chemistry) throughout the upper tidal James River mainstem.

More recent efforts, described in this report, focused on identifying habitat associations for adult and early juvenile ATS, based on spatially explicit habitat layers (ArcGIS) and site-specific captures of targeted cohorts in several seasons across three consecutive years. All sturgeon-related activities by VCU personnel during this period were fully compliant with university (IACUC), state, and federal (ESA) guidelines and requirements.

Fixed, small-mesh gill nets (2-5" stretch) were fished in all seasons of 2013, 2014, and 2015 for early juvenile ATS. A total of 82,724 individual fish were caught and processed; only five (5) early juvenile Atlantic Sturgeon (presumed ages 0-2) were captured in 2014 and 2015, in spite of substantial, targeted effort (3,027 h) throughout the tidal James River (Table 2, 3 and Figure 2). The attributes (e.g. locations, timing, net type and deployment) of this significant sampling effort deliberately mimicked a successful reward program funded and operated by USFWS (Albert Spells) that captured 116 early juvenile (age 0-2) James River ATS in the late 1990s (Figure 8). Historically successful gears and techniques, as described by Mr. Spells and commercial fishers who participated in the USFWS program, were adopted with modification by VCU to meet this project objective. As a consequence, the majority (82%) of VCU sampling effort under this grant objective focused on the fresh-saline interface (reach 30-60 rkm; Figure 9); all five early juvenile ATS captured by VCU were resident in this reach of the James during early Spring. These fish were tagged internally with VEMCO acoustic tags and released near capture locations. No young-of-the-year (YOY) ATS have been captured in the James River by VCU in 2013, 2014, or 2015, in spite of a substantial targeted effort.

The early juvenile ATS tagged and tracked by VCU in 2014 left the Chesapeake Bay a few weeks after being tagged, behaviorally suggesting it is a subadult. In comparison, four juvenile fish tagged in 2015 stayed in the river; two moving upstream of rkm 30-60 and two moving downstream, based on approximately two months (as of this writing) of data from the James River passive acoustic array maintained by VDGIF. VCU also attempted to fish drifting gill nets but those attempts were not successful (Table 3). All five of the previously-tagged, age 2+ Atlantic Sturgeon juveniles left the study area during the Winter. One fish (#12952, 58 cm FL, tagged April 30, 2015) returned to the James River in 2016 and was located primarily in the deep hole at rkm 90, which is where it remained during most of 2015. Unfortunately, transmitter 12952 reached the end of its useful battery life in early June, 2016. The other four VCU tags in age 2+ fish probably stopped transmitting prior to their expected return to the James River in 2016. All five of these fish spent Winter months in the Chesapeake Bay.

A 16' semi-balloon otter trawl was also deployed (fished at 2-4 knots; effort in tow minutes) by VCU biologists in multiple locations and seasons, and targeted important habitat types for early juvenile ATS. Combined VCU fishing effort (2013, 2014, 2015) for this gear was 6,467 minutes. We focused on trawling during Winter based on successful techniques used in the Delaware River and South Carolina rivers, as well as the capture of four YOY fish in the York system by VIMS in 2012 (Table 3). To date, VCU has deployed fixed gill nets and bottom trawls—of the correct types and orientations—in all seasons, habitats, locations, and conditions deemed appropriate for capturing early juvenile ATS, based on historical success in the James River and elsewhere (e.g. Delaware River). In spite of this extensive, targeted effort by experienced sturgeon biologists over three consecutive years, and in locations that historically (circa late 1990s) produced fish, VCU has collected only 5 early juvenile ATS, and no YOY fish, from the James River. This result suggests that, in spite of relatively high numbers (see below) of adult, reproductive adult ATS annually in the James River, successful spawning and recruitment by this population is being compromised by one or more factors.

Because no sampling gear can exclusively target early juvenile ATS, the extensive sampling effort described above generated an equally extensive by-catch: 28 estuarine and anadromous species and 172,117 individual fish (Table 2). This dataset is valuable in its own right because it represents the fish community with which migrating and resident James River ATS potentially interact. Very little is known about biotic interactions (e.g. competition, predation) among early juvenile (i.e., resident) ATS and other resident fishes in coastal rivers, including the James. Until we have a better understanding of biotic interactions among ATS and other resident fishes, novel biotic interactions involving nonindigenous fishes should be included with potential reasons for the current scarcity of evidence for successful ATS spawning and recruitment of early juveniles in the James system. Other factors, including limited availability of ATS critical spawning and nursery habitat (Austin, et al., in prep.) compared to historical conditions, should also be considered.

Population Assessment of Adult Atlantic Sturgeon (Objective 3)

For the first year since 2010, VCU did not do a lot of adult sampling in the James River in 2015 due to other research priorities and an unfortunate limit to the number of research 'takes' made available to VCU under the "Virginia" ESA permit. We tried to avoid catching males by setting gillnets 14" stretch mesh and larger. We hoped fishing the larger mesh would still allow us to catch females and keep male catch down. From June 3 to October 21, 2015 we fished Deep Water Shoals on 12 dates using 1-hour sets. We caught 37 male and 12 female ATS during this period. Four females caught between July 16 and 28, 2015 were pre-spawn; eight females caught between October 12 and 21, 2015 were post-spawn. All the females captured had spawned or released eggs. This is strong evidence that ATS attempted to spawn in the James River during Fall, 2015, even though extensive sampling by VCU for eggs with egg mats (see above) in likely spawning habitats was not successful this year. Together with the lack of capture success for early juveniles (Ages 0-2) after extensive effort, our findings are consistent with a hypothesis of recruitment failure for James River ATS during the past several years.

Based on data recovered from the VEMCO passive array managed by VDGIF, all 13 telemetered, Spring-captured Atlantic Sturgeon still at large returned to the James River in 2016; all were males. Eleven of the 13 Spring males entered the James River between March 24 and April 7 and moved to the primary staging area (vicinity of rkm 90) within two days of entering the river (Figure 10). The two remaining fish entered the river on April 27 and May 5 and moved up to rkm 90 within two days of entering the river. Most Spring fish returned to riverine habitats earlier in 2016, compared to prior years. In 2013-2015, most Spring fish were detected on staging areas between April 15-20. Repeating the same general pattern from previous years, the Spring fish stayed in deep holes (<27 m deep) at rkm 90 and rkm 97 throughout April and moved upstream to at least rkm 120 at the beginning of May. In previous years fish rarely moved above rkm 123 (Figure 11) but in 2016 Atlantic Sturgeon fish were detected as far upstream as rkm 133 (Figure 10, 12).

Evaluation of Dredging Activities on Adult and Sub-adult Atlantic Sturgeon (Objective 3)

Because of recently-documented (e.g. Fall 2014) ATS mortalities from hydraulic dredging in the Delaware River, there is renewed interest in describing ATS-dredge interactions in Chesapeake Bay tributaries, including the James River, Virginia. The Norfolk ACOE office uses dredging to maintain a shipping channel upstream to Richmond. An earlier study of potential dredge effects in the James may have been compromised by some aspects of the study design, including the relocation and immediate release of experimental (tagged for active acoustic tracking) ATS in the vicinity of an operating dredge. Several factors, including access to VEMCO receivers (most on loan from NOAA and ACOE) for a VPS array, the large number of VCU-tagged and at-large adult ATS expected to be in-system during Fall 2015, and the cooperation of the Norfolk ACOE office, created a unique opportunity to conduct a new study of dredge effects during Fall 2015. An ad-hoc group including VIMS, USFWS, NOAA, VDGIF, VCU, and ACOE proposed to assess potential dredge effects on the riverine behavior of previously tagged ATS (> 140 adults) in the James River as they moved through a VPS passive array deployed during Fall, 2015 in the vicinity of a dredge operated by the ACOE contractor (Figure 13,14).

In 2011, VCU started tagging adult male Atlantic Sturgeon during the fall spawning season with VEMCO internal acoustic transmitters. By the end of the 2013 fall spawning season, 143 adult males had internal tags, 108 of which returned in 2014. Telemetry data show that about 70% of males return every year to spawn; we expected at least 100 telemetered males to return to James River staging areas in 2015. Starting in 2013 the Virginia Institute of Marine Science (VIMS) tagged subadult ATS in the lower James River. As of March 23rd 2015, 46 subadults were tagged by VIMS; these fish represent a unique pool of experimental animals that were likely in-system at the time of proposed dredge study.

The project benefitted from pre-study input from VEMCO for VPS array design, placement, and retrieval along with data analysis by VEMCO. In Summer 2015, VCU and other participants conducted a tag range test beside an active dredge in the area where dredging would occur during September of 2015. The range test was analyzed using software provided by VEMCO. The range test showed a relatively high detection percentage during the study period. As expected, the high power tags, similar in power to VPS 'sync' tags, had a higher detection percentage as distance increased compared to the low power tag. Dredge locations were provided by the ACOE and the distance of the active dredge from the range test were determined using GIS software (ESRI). Although the exact times the dredge was cutting were not specified, dredge time per day was provided. When the dredge was at its closest distance to the range test array (~240 m) the high power tag was detected over 80% of the time 300 m away and over half of the time detection percentage was 95% or higher. The results of the range test were shared with VEMCO which suggested 300 m spacing between receivers for the VPS study design. The study was completed and the VPS array was recovered by VCU during December, 2015. Data are currently being analyzed by VEMCO. We had 174 fish detected in the VPS array, including tagged adults (VCU) and subadults (VIMS).

Population-level Threat Assessment (ship-strikes):

In earlier reports and publications (Balazik et al. 2012), VCU documented a significant number of ship-strike mortalities involving adult ATS in the James River and determined that commercial vessel interactions represented a threat to the effective recovery of ATS in this system. In Fall, 2013--with additional support from NOAA and advice from VEMCO--VCU deployed a VEMCO Positioning System (VPS) array in the vicinity of the VCU Rice Rivers Center (RRC) and a section of the James River shipping channel maintained by ACOE-Norfolk (Figure 15). We also deployed a low-light, high-resolution video webcam 24/7 on the RRC boathouse to document shipping traffic in the VPS study reach during the period SEPT 5-OCT 25, 2013. A total of 17 georeferenced, VEMCO VR2W receivers were deployed based on VEMCO's pre-study inputs (Figure 15); VEMCO post-study analyses showed that the VPS array generated over 100 tag detections representing at least 20 individual ATS during the study period. Review of several hundred hours of video produced the following summary of vessel traffic within the VPS array: 1,674 recreational vessels (793 moving downstream, 881 moving upstream)(Figure 16); 17 large commercial ships (9 down, 8 up); 130 commercial tugs and/or barges (66 down, 64 up); 3 sailboats (1 down, 2 up).

We evaluated fish behavior by comparing calculated velocity and directional changes of an individual fish while in the vicinity of a vessel (synoptic) and then when no vessel was present within the VPS 'box.' Transient behavioral events (< 120 s duration) were not captured by our methods. We used Tracking Analyst software in an attempt to quantify fish behaviors (e.g. searching, cruising, holding) that were either synoptic or non-synoptic with vessel occurrence. Although further analysis of these data is necessary, preliminary results suggest slight differences in ATS behavior when fish are near large commercial vessels, but no effect from the presence of recreational vessels or tugs. Data from a second VPS deployment in 2014 in the Presque Isle channel are currently being analyzed by VEMCO.

Outreach and Education (Objective 4)

VCU participated in a significant number of technical and community presentations related to this NOAA grant and published 8 peer-reviewed papers (Appendix B) related to work conducted with NOAA support under this grant award. VCU biologists also participated in 10 outreach education events, focused on K-12 teacher training and student enrichment activities at the VCU Rice Rivers Center (www.ricerivers.vcu.edu). We provided content to a James River Sturgeon facebook page hosted by Ms. Anne Wright and contributed to sturgeon awareness activities by the James River Association.

Section 3: Assessment of sub-adult and early juvenile Critical Habitats for Recovering the Chesapeake Bay Atlantic Sturgeon Distinct Population Segment in the York and James Rivers

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Project objectives:

Objective 1: Assess critical sub-adult and juvenile Atlantic Sturgeon nursery and foraging habitats in the York and James Rivers, Virginia

Objective 2: Assess degree of dependence of York and James River subadult Atlantic sturgeon on Chesapeake Bay Habitats

Objective 3: Assess seasonal patterns and egress of sub-adult Atlantic sturgeon from the York, James River and Chesapeake Bay

Introduction

A primary research goal for VIMS was to acoustically tag subadult and adult Atlantic sturgeon encountered in the York and James River systems. A second goal was to conduct intensive summertime water-quality and active tracking surveys in the York River system (in collaboration with researchers at Chesapeake Bay Laboratory, Solomons, MD which is reported on the Maryland portion of the final report). A third goal was to actively acoustically track subadult Atlantic sturgeon in the James and Pamunkey rivers. The final goal was to monitor and maintain an acoustic receiver array in the York and Rappahannock River systems. Activities related to exploratory work on juvenile (0 - 2 yr) Atlantic sturgeon that were conducted as a subcontract to Mr. Jason Kahn are also reported herein. The aforementioned goals relate directly to the 3 project objectives above.

Methods:

An Endangered Species Permit (permit # 050312) from Virginia Department of Game and Inland Fisheries was received; all personnel included. Work was conducted under NMFS Permit # 16547 issued to Mr. Albert Spells, USFWS.

Receiver array deployment, maintenance and data downloading

Vemco ®VR2W receivers were deployed strategically according to areas of need to achieve overarching project goals in the York, Pamunkey, Mattaponi and Rappahannock. Locations were refined by coordinating with other array managers (U.S. Navy, Chesapeake Scientific, VCU, VDGIF) to optimize coverage within our project area. In the Pamunkey, Mattaponi and upper Rappahannock, when the waterway was narrow enough to detect tagged fish across the waterway receivers were hung from landowners docks and at VDGIF boat ramps that provided access by land. Ideally, sites on the outside of river bends that provided a larger sonic window area and increased probability of fish detection were selected. This land based access strategy optimized our efficiency by being able to download receivers by truck with one staff member and no vessel time. Landowners were called by phone prior to accessing their property. Each receiver was maintained and downloaded approximately every month (Table 6). Some receiver locations were no longer utilized and listed as inactive due to finding a safer location nearby or to more efficiently coordinate receiver placement with other groups such as the US Navy and Chesapeake Scientific.

Gillnetting

Several methods were used to capture Atlantic sturgeon and were based on commercial fishing methods that had been successful in the past. During all James River efforts targeting subadult Atlantic sturgeon a commercial fisherman was contracted to deploy and retrieve nets with VIMS personnel on board. Nets 274 m X 3.7 m with 15.2 cm stretch mesh were anchored and set parallel to the flow. Soak time was guided by the conditions set forth in the NMFS Chesapeke Bay Atlantic sturgeon research permit (administered by A. Spells). In the York River, nets 183 m and 3.7 m high with 15.2 cm stretch mesh were anchored and set parallel to the flow to target subadult sturgeon. This method was not as effective in the York River as it was in the James River therefore new methodology to target subadults was employed in the York system in spring of 2015. In 2015, York system fishing effort was refocused to the Pamunkey and Mattaponi subadult foraging areas where sturgeon are potentially more concentrated and have a smaller home range. Effort in the Pamunkey and Mattaponi consisted of setting anchored nets 600’ in length with 300’ panels of 10.2 and 15.2 cm stretch mesh tied together. Sets were made perpendicular to the flow during slack tide for 1 hour. Manual tracking of previously tagged animals and a Humminbird® 800 kHz side scan were used to determine best net set locations. This methodology proved effective at capturing subadult Atlantic sturgeon foraging in the York system. Prior to adoption of this methodology and due to the lack of success in the Pamunkey and Mattaponi opportunistic sampling of the adult spawning run occurred in the fall of 2013 and 2014. Due to the size range of individuals captured in the James River spawning run it was hypothesized that subadults may co-occur with the spawning adults so sampling the spawning run could be used to accomplish subadult objectives. This hypothesis was proved incorrect. Adult Atlantic sturgeon were targeted in the Pamunkey and Mattaponi using 61 and 91 m nets anchored and set perpendicular to the flow with 27.0, 30.5, and 35.5 cm stretch mesh.

Active tracking

Active tracking and corresponding water quality data of subadult Atlantic sturgeon locations occurred in the James and Pamunkey Rivers in July and August of 2015 using an omni directional and directional hydrophone with a VR100®. Active tracking was opportunistic in that if water temperatures exceeded 28 ºC gillnetting could not occur therefore field time was used for tracking. The omni-directional hydrophone was dipped every 800 to 1000m for the duration of the delay of available tags (180 seconds) working in the same direction as the tidal flow. When a tag was detected, we switched to the directional hydrophone and using 2 separate detection directions to triangulate the sturgeons' location, the boat was moved to that location which was recorded using GPS. Water quality was noted for each tag detection location.

Manual tracking in the James River occurred from the upper most extent of subadult summering locations to the confluence with the Chickahominy River. Manually tracking the lower James River below the Chickahominy confluence was time and cost prohibitive due to the widening of the river to approximately 4km. However, based on passive detections a portion of subadults were summering below the confluence with the Chickahominy River in the James River.

Manual tracking in the Pamunkey River occurred in the entire subadult summering area (based on passive receiver data of tagged animals). Exact locations were determined with a directional hydrophone which is in contrast to the CBL tracking and water quality efforts (see MDNR companion project report) which monitored at pre-determined water quality stations using an omni-directional hydrophone.

Results and Discussion:

Receiver Array

Twenty five VR2W receivers were deployed and maintained in the York (2), Pamunkey (6), Mattaponi (9), and Rappahannock (8) Rivers (Table 6). Receiver data was imported into VUE® and filters were created using ACT network researcher information. Downloaded data was sent to researchers utilizing the ACT network on a monthly basis. The receiver array provided valuable information regarding immigration and emigration and habitat use.

Passive tracking James. Of the 145 transmitter tags surgically implanted in sturgeon during this project 42 were in James River subadults in the late winter and spring of 2014 and another 58 were in James River subadult during the spring of 2015. The James River subadult Atlantic sturgeon were captured at Jamestown Island, Cobham Bay and Burwells Bay. The telemetry locations of subadult sturgeon tagged in the James were analyzed to examine the fate of their summertime foraging regions in 2014 and 2015 (Figure 4). Telemetry locations were provided by the Atlantic Coastal Telemetry Network (ACT). In both years (2014 and 2015) the James River had the greatest portion of summer residents at 33% and 44%, respectively. This was followed by the Delaware River and Bay at 24% in both years and the Hudson River at 10% and 7% in 2014 and 2015, respectively. In 2014, 10% were detected in the Atlantic Ocean north of the Hudson River, however, none were detected in the Atlantic Ocean north of the Hudson in 2015. In 2014 and 2015, 21% and 25% of individuals were not detected during the summer months. Known arrays in the New York Bight and Chesapeake Bight that did not detect any of the James subadults in the summertime which include the Rappahannock, Pamunkey, Mattaponi, Nanticoke, Rhodes, and Elk Rivers. Passive receiver data analysis from the James of all subadults is not included in this report but is ongoing as it is received from cooperators.

Passive tracking York, Mattaponi and Pamunkey. In 2014, 8 adult male Atlantic sturgeon were tagged with transmitters near the spawning grounds in the Pamunkey river. The following fall of 2015, 7 of the 8 returned to the York system (Figure 5) with the 8^{th} sturgeon residing in the Nanticoke River (Chuck Stence MDDNR, pers. com.) The sturgeon spawning grounds have been estimated to be from rkm 120-140 (J. Kahn, pers. com). On September 30th, 2015 a high flow event from the remnants of hurricane Jaoquin caused most tagged sturgeon to drop down below the spawning grounds, with most adults returning to the spawning grounds 6 days later.

In 2014, 1 adult female sturgeon was tagged with a transmitter near potential spawning grounds in the Pamunkey River on August 21st. This individual was subsequently recaptured by J. Kahn on Sept 17th, 2014 and reported to the USFWS recapture database and recaptured again on Sept 22nd, 2014 (P. McGrath, pers. comm.). On September 23rd this individual moved off the spawning grounds and descended and exited the York River system. The following fall (2015) this individual returned to the York system but ascended the Mattaponi River to Aylett (rkm 112) and Walkerton (rkm 97) where it remained for the fall spawning season (Figure 6). It is interesting to note successive spawning year behavior in a female Atlantic sturgeon. Especially noteworthy is the spawning behavior occurring in 2 different rivers. This behavior may be an indication of a Pamunkey and Mattaponi metapopulation. This is also the first adult Atlantic sturgeon detected in the Mattaponi River except for anecdotal reports.

Pamunkey subadults were tagged in 2015 and 2016. Movement analysis is still occurring as passive receiver data is being received from cooperators.

Passive tracking Rappahannock. No Rappahannock subadults were tagged in this project. However, one individual was detected by the receiver array in the Rappahannock during the spring of 2015 and ascended as far as Hicks Landing.

Further analyses of these detection data will be completed and submitted for publication to describe temporal and spatial movements of sub-adult Atlantic sturgeon in the Chesapeake Bay Distinct Population Segment. We will also incorporate detections provided by colleagues from outside the Chesapeake Bay region.

Based on the telemetry data related to Atlantic sturgeon sub-adults that were collected as part of this project, over the course of the next three years, we will expand our critical-habitat assessments (reproductive, nursery and forage habitats, and habitat connectivity) to include additional river reaches that may support Atlantic sturgeon populations. Newly discovered patterns from other portions of their range link spatial habitat use by early juvenile and subadult Atlantic sturgeon. In the next three years we will use our subadult sampling and habitat-use and migration data, including targeted new tagging efforts in under-sampled systems (Mattaponi and Rappahannock) to attempt to document the habitat use and behavior of early juvenile Atlantic sturgeon in the Chesapeake Bay. Finally, we will synthesize available Atlantic sturgeon habitat and occurrence information in Chesapeake rivers and make it accessible to state and federal agencies, thereby affording agencies the ability to base their protection and management efforts for various life history stages on the results of robust data synthesis and GIS analysis.

Gillnetting

During the entire project 145 transmitters (9 V9, 122 V16 and 14 V16P) were deployed in Atlantic sturgeon (Table 7) during 815 net sets in the James, Mattaponi, Pamunkey and York Rivers (Table 8). James sampling for subadults was extremely successful throughout the project with 120 of the 145 VIMS transmitter tagged fish occurring in the James. In year 1 and a portion of year 2 of the project attempts to capture subadults in the York, Mattaponi and Pamunkey had limited success. During this time period, only 2 individual subadults were captured in the York using methods that resembled commercial fishing efforts that captured subadult sturgeon as bycatch in various spring fisheries. In addition, it was hypothesized (based on the size distribution of James fall spawn captures) that subadults would co-occur with adults on the spawning grounds in the Pamunkey and Mattaponi. This hypothesis proved to be incorrect as only adult sized sturgeon (n=10) were captured on the spawning grounds so that effort was abandoned but the results are found in this report. In the late spring of the second year of the project new gillnetting methodology was adopted as described in the methods and produced 13 tagged subadult sturgeon. Twelve subadults were tagged with transmitters in the Pamunkey and one in the

Mattaponi. These sturgeon were captured on or near their foraging grounds so they produced valuable habitat and movement data.

Juvenile sampling. As a subcontract to J. Kahn, gillnetting using small mesh 70 - 112 mm stretch and trawling using 8- and 16-foot trawls was conducted. Effort occurred in the lower stretches of the Pamunkey and Mattaponi Rivers as well as York River to Croaker Landing. The targeted areas follow the methodology identified in Schueller and Peterson (2010) and Sweka et al. (2007). They both describe deep areas with soft, sandy bottoms as preferred habitat. Kahn would initiate sampling in those locations, then sample the edges of holes in shallower water to see what else could be caught. Attempts were made to acquire exact sampling locations for reporting purposes but Kahn did not provide that information. When trawling, Kahn would also sample runs in those rivers. Salinity varied between 0 and 12 ppt. Any Atlantic sturgeon encountered during this sampling was expected to be larval to age-2 fish. During the three years, four Atlantic sturgeon ranging from 525 to 571 mm (total or fork length is unknown) were captured, but no Atlantic sturgeon that qualified as juveniles were encountered (under 500 mm FL). It is unknown if the four Atlantic sturgeon ranging from 525 to 571 mm were tagged with PIT and T-bar tags or what river system they were captured in as specific sampling information was not provided by Kahn. If these 4 sturgeon would have been tagged with transmitters they could have been used to aid the VIMS objective of tagging subadults in the York system but Kahn did not put transmitters in those fish.

Bycatch primarily consisted of blue catfish. Other less common catches included hogchoker, juvenile spot, juvenile croaker, blue crabs, American shad, gizzard shad, alewives, inland silversides, bay anchovies, juvenile stripers, white perch, brown bullheads, white catfish, and channel catfish. Sampling began using a 16-foot trawl during all seasons. After a season without catching Atlantic sturgeon, Kahn consulted with fishermen from the York River as well as researchers sampling juvenile Atlantic sturgeon on the East Coast and Mississippi River basin to increase his odds of locating juveniles. Based on the consultations the direction of trawling was changed and Kahn began using 8-foot and 16-foot trawls as well as seasonally incorporating gillnetting. Trawling was performed all year but gillnetting was added when Atlantic sturgeon were more active during summer. It is unclear why Kahn hypothesized juveniles would be more active during the summer months. Downstream sampling occurred in higher saline water after learning that young-of-year Atlantic sturgeon could be captured in abundance in waters up to 20 ppt (D. Peterson, pers. comm. to Kahn).

Kahn was unable to capture juvenile Atlantic sturgeon in his efforts. A likely contributing factor that led to poor results was the assumption that larval to juvenile Atlantic sturgeon that have been shown to prefer <=1.0 salinity could also be found in abundance in higher salinities. That assumption was based on the range of salinity captures of Altamaha River juveniles which is a population that can generally be described as abundant and possibly near historical levels. Altamaha juveniles have likely saturated their preferred habitat and now additionally occupy fringe habitat in salinities >1.0 ppt at lower levels. Based on the low number of historical captures of juvenile sturgeon in the Pamunkey and Mattaponi, it should have been recognized that the Pamunkey and Mattaponi populations are dissimilar to the Altamaha in that the juvenile populations are nowhere near the point of preferred habitat saturation and thus spending considerable effort sampling less preferred habitat during this project was misguided. Efforts were made by the more experienced juvenile sturgeon researchers on this project to educate Kahn on these points to make his sampling more effective for juvenile sturgeon but had no effect.

Active tracking

Active tracking and corresponding water quality data of subadult Atlantic sturgeon locations was completed in the James and Pamunkey Rivers in July and August of 2015 during 7 and 13 days, respectively (Figures 2 and 3). Active tracking was included because subadult habitat is poorly understood. Due to the patchy nature of subadult distribution determining subadult habitat locations through active tracking supported our goal of capturing and tagging sturgeon using gillnetting by making our effort more efficient. The active tracking in addition to passive tracking of animals proved to make our gillnetting more efficient over the course of the 3 year project.

In the James, the tracking area was confined to the upper most extent of subadult summering locations (as indicated by passive array detections) to the confluence with the Chickahominy River (Figure 2). Tributaries were not included as part of the tracking area. Fourteen individuals were tracked, three of which were tagged by other groups (Connecticut River, Offshore of New Jersey, Great Pee Dee River(SC)) and verified to be subadults so they are included in the subadult tracking analysis. Salinity at subadult sturgeon tracking locations averaged 0.9 ppt salinity with a range of 0.1 to 2.2 ppt. The average dissolved oxygen saturation 3 meters below the surface (the maximum extent of the instrument's cable) was 77.3% with a range of 60.9% to 123.8%. Water temperature averaged 28.8°C with a range of 27.8 to 30.1°C. One tracked individual had a pressure sensor tag that indicated the fish was at 10.1m depth. Depth of water column was not recorded due to the difficulty of a sonar depth finder conflicting with ultrasonic frequency tracking. However, depth to bottom can be estimated by examining the overlay of locations on a bathymetry chart. Depth to bottom ranges from 7.9 to 28.6 meters and averages 17.2 m.

In the Pamunkey, the tracking area occurred throughout the subadult summering area (based on passive receiver data) (Figure 3). Tributaries and cut-throughs with potentially sufficient depth for sturgeon are present in 2 locations but were not tracked due to time and manpower limitations. Seven individual subadults were tracked. Salinity at subadult tracking locations averaged 1.2 ppt salinity with a range of 0.1 to 2.6 ppt. The average dissolved oxygen saturation 3 meters below the surface (the maximum extent of the instrument's cable) was 62.8% with a range of 55.8% to 70.2%. Water temperature averaged 28.0°C with a range of 27.4 to 29.6°C. Two tracked individuals had pressure sensor tags that produced 11 depths of sturgeon for an average depth of 8.1m and a range of 1.7m to 13.0m. Depth of water column was not recorded due to the difficulty of a sonar depth finder conflicting with ultrasonic frequency tracking. However, depth to bottom can be estimated by examining the overlay of detections on a bathymetry chart. Depth to bottom ranges from 5.5 to 16.5 meters and averages 10.6 m

Dissemination of results.

A meeting was held at VIMS on September 4, 2014 that served as the first annual meeting for project PIs and personnel, as well as other regional biologists with interests in sturgeon (27 attendees). Presentations on or discussion of activities and plans were made by researchers from VIMS, VCU, VDGIF, CBL, MDDNR, USFWS, WVU, USGS, and the US Navy. Other participants presented information relevant to Atlantic sturgeon in the Chesapeake Bay. These presentations included USACoE (studies of sturgeon interactions with dredging) and D. Wilson (an update and discussion on the status of the Mid-Atlantic Acoustic Telemetry Observation System, MATOS). A follow up meeting of VIMS, US Navy, and USFWS researchers conducting work in the York River system to coordinate efforts was held on September 18, 2014. Following this meeting, a contract to Chesapeake Scientific, LLC (CS) to assist with tagging subadults in the York River system in 2014-2015 was drafted in October and modified upon request by CS in April 2015. Another follow up meeting of VIMS, US Navy on May 7, 2015 produced a signed contract and work by CS, however work was not completed. Compensation was cited as the primary factor. VIMS staff attended a webinar on November 23, 2015 to provide feedback on the development of the acoustic telemetry database, MATOS. A workshop on Atlantic sturgeon science in the Chesapeake Bay was held on December 17, 2015 at Solomons, MD, and this served as the annual meeting for project PIs as well as other regional biologists with interests in sturgeon. Presentations were made by researchers from VIMS, VCU, CBL, MDDNR, WVU and the US Navy. Tim King presented the latest Atlantic sturgeon genetic research. VIMS personnel were unable to attend the NOAA Atlantic/Shortnose Sturgeon workshop May 16-18, 2016 in WV due to prior obligations.

Genetic samples were sent in 2 batches. The first was sent to the repository in Charleston, South Carolina in April of 2014. The second batch of genetic samples were sent to Dr. Tim King in April 2016 after the National

Ocean Service Atlantic sturgeon genetic repository in Charleston, SC had been transferred to his lab (USGS Leetown Science Center, Kearneysville, WV).

All tag release data were sent to the USFWS tag recapture database managed by Mike Mangold. Transmitter tag release information was sent to the Atlantic Coast Telemetry Network (ACT).

Receiver data from the VIMS array was sent to all researchers that submitted their telemetry tag codes to ACT

Water quality monitoring and sturgeon tracking.
Monitoring water quality in combination with mobile telemetry was performed by CBL (D. Secor and M. O'Brien) and VIMS scientists (E. Hilton, M. Fisher and P. McGrath) in the York River from June to October in 2014 and 2015. These data will be described more fully by CBL scientists, which served as the lead on this portion of the project, in the companion project report from MDNR.

Outreach. The VIMS webpage concerning sturgeon research has been updated during the project period. (http://www.vims.edu/research/topics/sturgeon/index.php). Information regarding the VIMS sturgeon project was provided to VDGIF for a sturgeon article in *Virginia Wildlife* by Aaron Bunch. Thank you letters with a summary of the goals and accomplishments of the VIMS sturgeon project were sent annually to landowners that provided access to their docks where receivers were deployed in the Pamunkey, Mattaponi and Rappahannock Rivers. Information was sent regarding sturgeon detections and life history to the Friends of the Rappahannock for an article in their newsletter.

Plans and needs for additional work

VIMS, VCU and VDGIF partnered with MD DNR on a proposal for 3 years of section 6 funding and won the award. For VIMS part, we will focus on the systems where we don't have much information regarding habitat and movements of subadult and juvenile sturgeon (eg. Pamunkey, Mattaponi, Rappahannock). We will be maintaining the existing array in the Pamunkey, Mattaponi, York, Piankatank, Rappahannock and expanding coverage in the Rappahannock. We will initially focus on subadults and use that data to target juveniles as there has been habitat use overlap found in other systems (Delaware).

Acknowledgements

The VIMS sturgeon project would like to acknowledge the help of Peter Konstantanidis and VIMS graduate students too many to name for their help in the field, George Trice for his gillnetting expertise, and Theresa Robitaille for data entry and editing skills.

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Table 1. Bycatch from early juvenile Atlantic Sturgeon sampling (various gears described above) in the tidal James River, Virginia during this award period.

Species	Common Name	Gill Net	Trawl	Total
Acipenser brevirostrum	Shortnose Sturgeon	1	0	1
Alosa aestivalis	Blueback Herring	0	1	1
Alosa mediocris	Hickory Shad	23	1	24
Alosa pseudoharengus	Alewife	0	0	0
Ameiurus catus	White Catfish	50	3	53
Brevootia tyrannus	Atlantic Menhaden	56	1	57
Cyprinus carpio	Common Carp	4	1	5
Dorosoma cepedianum	Gizzard Shad	46	78	124
Etheostoma olmstedi	Tessellated Darter	0	18	18
Ictalurus furcatus	Blue Catfish	2523	4892	7415
Ictalurus punctatus	Channel Catfish	2	168	170
Leiostomus xanthurus	Spot	2	0	2
Lepisosteus osseus	Longnose Gar	19	2	21
Morone americana	White Perch	95	542	637
Morone saxatilis	Striped Bass	22	20	42
Notropis hudsonius	Spottail Shiner	0	130	130

Trinectes maculatus	Hogchoker	0	1938	1938

Table 2. Summary of VCU sampling effort targeting early juvenile Atlantic Sturgeon in the James River during this projectin 2013, 2014, and 2015. Gillnet effort is in hours and trawl effort is in minutes.

Gillnet					
	Winter	Spring	Summer	Fall	Total
30-60	305	986	448	752	2491
60-90	0	86	0	73	159
90-120	0	0	0	185	185
120-150	168	0	0	24	192
Total	473	1072	448	1034	3027
Trawl					
	Winter	Spring	Summer	Fall	Total
30-60	672	455	385	231	1743
60-90	539	286	182	770	1777
90-120	1162	483	427	399	2471
120-150	385	91	0	0	476
Total	2758	1315	994	1400	6467

Table 3. Summary of juvenile (presumed age <=2 based on length) Atlantic Sturgeon captures in the tidal James River, Virginia during 2014 and 2015. The VIMS gillnetting effort that produced these captures is reported in Section 3.

Capture Date	Lat	Long	Fork Length (cm	Mass (kg)	Tag Space	Vemco ID	Tag Life
4/18/2014	37.04833	-76.6285	62	1.9	V-9	12948	427
4/15/2015	37.04716	-76.6154	57	1.8	V-9	12949	427
4/30/2015	37.18477	-76.7277	58	1.9	V-9	12952	427
4/30/2015	37.18607	-76.7165	55	1.7	V-9	12953	427
5/9/2015	37.21277	-76.8009	57	1.7	V-9	27281	427

Table 4. Summary of VCU sampling activities targeting adult Atlantic Sturgeon in the tidal James River, Virginia, during the period 2013-2015.

Year	2012		2013		2014		2015
Spawning Cohort	Spring	Fall	Spring	Fall	Spring	Fall	Spring
Number Caught	1	73	0	163	2	110	23
Telemetry Tags Placed	1	72	0	54	2	10	12
Recaptures	0	6	0	10	0	12	1
Collection Dates	Apr 20	Aug 18/ Oct 13	0	Aug 16/ Oct 4	Apr 19, May 12	July 17/ Nov 4	Apr 15/ May 11
River kilometer caught	93	118-133	0	118-121	33-95	38-121	33-95
Telemetry Tag returns	0	13	1	59	1	108	2
Residence of Returns	NA/ May 12	May 5/ Nov 2	Apr 10/ May 20	May 10/ Nov 5	Apr 4/ May 17	May 10/ Nov 5	Apr 8/ May 20

River kilometer reached	102	142+	127	155	120	155	102

Table 5a. Summary of physico-chemical habitat assessment for the tidal freshwater reach of the James River, Virginia in 2013, 2014, and 2015. Values in table represent **near-surface** conditions averaged across nine fixed locations and twelve months. Values in parentheses represent the total number of water samples analyzed.

Year	Temperature (°C)	Specific Conductance (S/m)	Dissolved Oxygen (mg/l)
2013 (n=343)			
_mean	18.5	197.5	8.9
_min	4.4	47.2	5.0
_max	33.3	1211.0	13.5
2014 (n=405)			
_mean	18.3	243.0	9.7
_min	0.5	82.0	5.5
_max	32.1	2356.0	14.8
2015 (n=364)			
_mean	19.2	213.2	9.1
_min	1.1	88.0	5.3
_max	34.2	2032.0	14.0

Table 5b. Summary of physico-chemical habitat assessment for the tidal freshwater reach of the James River, Virginia in 2013, 2014, and 2015. Values in table represent **near-bottom** conditions averaged across nine fixed locations and twelve months. Values in parentheses represent the total number of water samples analyzed.

Year	Temperature (°C)	Specific Conductance (S/m)	Dissolved Oxygen (mg/l)
2013 (n=343)			
_mean	18.1	204.2	8.9
_min	5.1	51.7	5.0
_max	31.2	1346.1	13.2
2014 (n=405)			
_mean	18.2	249.1	9.4
_min	1.7	81.3	6.2
_max	31.3	2384.0	14.3
2015 (n=364)			
_mean	19.6	219.3	8.9
_min	0.9	92.0	5.4
_max	32.4	2081.0	13.7

Table 6. Location of VIMS receiver placements as of the end of the award period. Please note inactive receivers are placements that were utilized during the award period but have been moved to safer locations or to coordinate receiver deployments with other groups.

Receiver	Location –Station name	Latitude	Longitude
VR2W-129300	Mattaponi - Gwathmey	37.840964	-77.130835
VR2W-122013	Mattaponi - Aylett	37.783208	-77.09946
VR2W-129301	Mattaponi - Jensen	37.755601	-77.089586
VR2W-122019	Mattaponi - Walkerton	37.723591	-77.025501
VR2W-122014	Mattaponi - McDevitt	37.695817	-76.91722
VR2W-125854	Mattaponi - Melrose	37.637178	-76.855045
VR2W-125856	Mattaponi - Yolanda	37.617452	-76.838883
VR2W-122018	Mattaponi - Enos	37.57112	-76.79981
VR2W-125575	Mattaponi - Williams	37.54821	-76.77613
VR2W-125576	Pamunkey - Greenlee	37.68644	-77.2272
VR2W-122016	Pamunkey - Parker	37.65893333	-77.17621667
VR2W-122022	Pamunkey - Wallace	37.636794	-77.128849
VR2W-122017	Pamunkey - Powers	37.57816	-77.025353
VR2W-123520	Pamunkey - Sweet Hall	37.57273	-76.88094
VR2W-123519	Pamunkey - Jenkins	37.552614	-76.819048
VR2W-125855	York - Guinea Marsh	37.25914	-76.37829
VR2W-129302	York - VIMS Pier	37.245874	-76.505638
VR2W-125574	Rappahannock - Four Winds	38.240893	-77.275944
VR2W-127538	Rappahannock - Hopyard Landing	38.244773	-77.223054
VR2W-125573	Rappahannock - Hicks	38.185234	-77.240019
VR2W-125572	Rappahannock - Pratt	38.16378	-77.161831
VR2W-127537	Rappahannock - Dewey	38.092885	-77.013896
VR2W-127539	Rappahannock - Carter's Wharf	38.072461	-76.926851
VR2W-123517	Rappahannock - Entrance 7R	37.585794	-76.328972
VR2W-123518	Rappahannock - Entrance 8R	37.601678	-76.355162
Inactive	Pamunkey Upriver	37.667056	-77.191655
Inactive	Pamunkey Upriver 2	37.676101	-77.184752
Inactive	Pamunkey Upriver 3	37.679543	-77.201701
Inactive	Pamunkey - Mills	37.76721667	-77.32378333
Inactive	York North	37.51005	-76.78603333
Inactive	York South	37.50863333	-76.79066667
Inactive	Rappahannock - Towles pt. north	37.633724	-76.509371
Inactive	Rappahannock - Towles pt. south	37.620171	-76.509049
Inactive	Rappahannock - North Shore	37.67353333	-76.54733333
Inactive	Rappahannock - South Shore	37.6731	-76.56936667

Table 7. Acoustic tags deployed in Atlantic sturgeon during this award; June 1, 2013 to June 30, 2016. Sex; M = male, F = female, U = undetermined. If the sturgeon was an appropriate size, sex was determined to be male or female if there was expression of milt or eggs upon palpating the gonadal area. Sex was undetermined if the sturgeon was captured outside of the spawning time period or was not an appropriate size.

Release Date	Tag type	VEMCO ID #	River	Latitude	Longitude	Total Length (cm)	Fork Length (cm)	Sex	Genetics
2/25/2014	V16	A69-9001-26397	James	37.0525555	-76.62233333	80	68.8	U	Y
2/25/2014	V16	A69-9001-26401	James	37.0525555	-76.62233333	79.1	67.5	U	Y
3/4/2014	V16	A69-9001-26400	James	37.049	-76.6248	82.1	71	U	Y
3/5/2014	V16	A69-9001-26404	James	37.05208	-76.62019444	84.3	72.5	U	Y
3/11/2014	V16	A69-9001-26403	James	37.05258333	-76.62436111	103	87	U	Y
3/12/2014	V9	A69-1601-12678	James	37.05236111	-76.62102778	79.5	68.5	U	Y
3/12/2014	V16	A69-9001-26396	James	37.04788889	-76.62819444	87.4	76	U	Y
3/12/2014	V16	A69-9001-26399	James	37.04516667	-76.62819444	94.5	83	U	Y
3/12/2014	V16	A69-9001-26410	James	37.05236111	-76.62102778	99.5	86.8	U	Y
3/19/2014	V9	A69-1601-12677	James	37.04566667	-76.61655555	75.5	64	U	Y
3/19/2014	V9	A69-1601-12679	James	37.04566667	-76.61655555	76	66	U	Y
3/19/2014	V16P	A69-9002-13200	James	37.04566667	-76.61655555	135	117.5	U	Y
3/20/2014	V16	A69-9001-26402	James	37.05344444	-76.62513889	78	67	U	Y
3/20/2014	V16	A69-9001-26406	James	37.04583333	-76.61430556	84.5	74.5	U	Y
3/20/2014	V16	A69-9001-26407	James	37.04605556	-76.61791667	151	134	U	Y
3/25/2014	V16	A69-9001-26395	James	37.04736111	-76.62277778	94	79.5	U	Y
3/28/2014	V16	A69-9001-26391	James	37.05213889	-76.618	79	68	U	Y
3/28/2014	V16	A69-9001-26392	James	37.05213889	-76.618	85	73	U	Y
3/28/2014	V16	A69-9001-26405	James	37.04794444	-76.61480556	85	73	U	Y
3/28/2014	V16	A69-9001-26408	James	37.05230556	-76.62330556	79.3	70	U	Y
3/28/2014	V16	A69-9001-26409	James	37.04727778	-76.62122222	81.5	70.5	U	Y
3/31/2014	V16	A69-9001-26394	James	37.04536111	-76.61772222	110	95	U	Y
3/31/2014	V16P	A69-9002-13198	James	37.04625	-76.62638889	116.5	100	U	Y
4/1/2014	V16	A69-9001-26393	James	37.04872222	-76.61922222	72	62	U	Y
4/1/2014	V16	A69-9001-26411	James	37.04711111	-76.63269444	72	63	U	Y
4/18/2014	V16	A69-9001-26382	James	37.05216667	-76.622	76	70	U	Y
4/18/2014	V16	A69-9001-26383	James	37.04827778	-76.61947222	80	71	U	Y
4/18/2014	V16	A69-9001-26385	James	37.04819444	-76.63016667	124	111	U	Y

Table 7 (continued). Acoustic tags deployed in Atlantic sturgeon during this award; June 1, 2013 to June 30, 2016. Sex; M=male, F=female, U=undetermined. If the sturgeon was an appropriate size sex was determined to be male or female if there was expression of milt or eggs upon palpating the gonadal area. Sex was undetermined if the sturgeon was captured outside of the spawning time period or was not an appropriate size.

Release Date	Tag type	VEMCO ID #	River	Latitude	Longitude	Total Length (cm)	Fork Length (cm)	Sex	Genetics
4/18/2014	V16	A69-9001-26388	James	37.04830556	-76.62838889	80	70	U	Y
4/21/2014	V16P	A69-9002-13197	James	37.04777778	-76.62119444	103	93	U	Y
4/22/2014	V16	A69-9001-26384	James	37.05169444	-76.6155	75.5	66	U	Y
4/23/2014	V16	A69-9001-26375	James	37.0515	-76.62002778	84	73	U	Y
4/23/2014	V16	A69-9001-26389	James	37.0515	-76.62002778	95	84	U	Y
4/28/2014	V16	A69-9001-26376	James	37.04791667	-76.62613889	91	80	U	Y
4/28/2014	V16	A69-9001-26378	James	37.04713889	-76.62308333	82.5	70	U	Y
5/5/2014	V16	A69-9001-26379	James	37.0455	-76.62069444	92	82	U	Y
5/6/2014	V16	A69-9001-26373	James	37.04677778	-76.63019444	86	75	U	Y
5/6/2014	V16	A69-9001-26377	James	37.04363889	-76.61441667	83.5	70.5	U	Y
5/7/2014	V16	A69-9001-26374	James	37.04752778	-76.6255	80	69	U	Y
5/7/2014	V16	A69-9001-26386	James	37.04466667	-76.61833333	85	75	U	Y
5/7/2014	V16	A69-9001-26387	James	37.04752778	-76.6255	124	109	U	Y
5/7/2014	V16	A69-9001-26390	James	37.04466667	-76.61833333	79	68	U	Y
12/1/2014	V16	A69-9001-24482	James	36.9975	-76.48732	90	78	U	Y
12/1/2014	V16	A69-9001-24490	James	37.00312	-76.49133	90	77	U	Y
12/1/2014	V16	A69-9001-24491	James	36.9975	-76.48732	91.2	78.8	U	Y
2/28/2015	V16	A69-9001-24480	James	37.18084	-76.758577	90	78.5	U	Y
3/20/2015	V9	A69-1601-23355	James	37.194882	-76.697718	85.5	75	U	Y
3/21/2015	V16	A69-9001-24494	James	37.1767	-76.74101667	98	84	U	Y
3/30/2015	V16	A69-9001-23941	James	37.05264	-76.62225	73	64	U	Y
3/31/2015	V16	A69-9001-23942	James	37.05412	-76.62296	78	68	U	Y
3/31/2015	V16	A69-9001-23943	James	37.05412	-76.62289	94	81	U	Y
4/3/2015	V16	A69-9001-23944	James	37.05278	-76.6383	81	72	U	Y
4/4/2015	V9	A69-1601-23352	James	37.05166	-76.61694	72	63	U	Y
4/4/2015	V16	A69-9001-23953	James	37.05135	-76.63688	76.5	66	U	Y
4/4/2015	V16P	A69-9002-12518	James	37.05137	-76.6262	95	84	U	Y
4/9/2015	V9	A69-1601-23353	James	37.05208	-76.62778	77	66	U	Y
4/9/2015	V16	A69-9001-23950	James	37.052	-76.6247	93.5	83	U	N
4/9/2015	V16P	A69-9002-12519	James	37.05208	-76.62778	145	127	U	Y

Table 7 (continued). Acoustic tags deployed in Atlantic sturgeon during this award; June 1, 2013 to June 30, 2016. Sex; M=male, F=female, U=undetermined. If the sturgeon was an appropriate size sex was determined to be male or female if there was expression of milt or eggs upon palpating the gonadal area. Sex was undetermined if the sturgeon was captured outside of the spawning time period or was not an appropriate size.

Release Date	Tag type	VEMCO ID #	River	Latitude	Longitude	Total Length (cm)	Fork Length (cm)	Sex	Genetics
4/10/2015	V16	A69-9001-23945	James	37.05153	-76.62348	98.5	85.5	U	Y
4/10/2015	V16	A69-9001-23951	James	37.05209	-76.62721	100.5	87.5	U	Y
4/11/2015	V9	A69-1601-23354	James	37.05191	-76.62264	79	66	U	Y
4/13/2015	V16	A69-9001-23946	James	37.05378	-76.62725	89	79	U	Y
4/13/2015	V16	A69-9001-23947	James	37.05342	-76.62479	89	77	U	Y
4/15/2015	V16	A69-9001-23948	James	37.05164	-76.63988	99	82	U	Y
4/15/2015	V16	A69-9001-23949	James	37.04716	-76.61544	75	66	U	Y
4/16/2015	V16P	A69-9002-12698	James	37.05159	-76.63988	124.5	109	U	Y
4/17/2015	V16	A69-9001-23933	James	37.05244	-76.62044	83	72	U	Y
4/18/2015	V16	A69-9001-23906	James	37.05317	-76.62468	82	71	U	Y
4/18/2015	V16	A69-9001-23907	James	37.05279	-76.62207	102	88	U	Y
4/18/2015	V16	A69-9001-23910	James	37.04699	-76.61436	93	81	U	Y
4/18/2015	V16	A69-9001-23925	James	37.05279	-76.62207	93.5	82.5	U	Y
4/18/2015	V16	A69-9001-23926	James	37.0535	-76.64626	77	66	U	Y
4/18/2015	V16	A69-9001-23938	James	37.05317	-76.62468	88	76	U	Y
4/21/2015	V16	A69-9001-23935	James	37.177539	-76.741172	81	68.5	U	Y
4/21/2015	V16	A69-9001-23936	James	37.176812	-76.737215	101.5	86.5	U	Y
4/21/2015	V16	A69-9001-23937	James	37.177541	-76.734658	91.5	78.75	U	Y
4/23/2015	V16	A69-9001-23927	James	37.23314	-76.82176	113	101	U	Y
4/23/2015	V16	A69-9001-26056	James	37.23228	-76.81716	86	73	U	Y
4/24/2015	V16	A69-9001-23924	James	37.21598	-76.82732	106	93	U	Y
4/28/2015	V9	A69-1601-23368	James	37.18201	-76.73635	71	60	U	Y
4/28/2015	V9	A69-1601-23369	James	37.1775	-76.7417	84	63.5	U	Y
4/28/2015	V16	A69-9001-23939	James	37.18209	-76.7364	104	89	U	Y
4/29/2015	V16	A69-9001-23930	James	37.18318	-76.73439	91.5	81	U	Y
4/29/2015	V16	A69-9001-23934	James	37.18319	-76.73439	78.75	68.5	U	Y
4/29/2015	V16	A69-9001-23940	James	37.18339	-76.73421	94	78.75	U	Y
4/30/2015	V16	A69-9001-23928	James	37.1792333	-76.71331667	99	86	U	Y
4/30/2015	V16P	A69-9002-12699	James	37.18606667	-76.71646667	98	86.5	U	Y
5/1/2015	V16	A69-9001-23909	James	37.21541667	-76.8024833	87.5	75	U	Y

Table 7 (continued). Acoustic tags deployed in Atlantic sturgeon during this award; June 1, 2013 to June 30, 2016. Sex; M=male, F=female, U=undetermined. If the sturgeon was an appropriate size sex was determined to be male or female if there was expression of milt or eggs upon palpating the gonadal area. Sex was undetermined if the sturgeon was captured outside of the spawning time period or was not an appropriate size.

Release Date	Tag type	VEMCO ID #	River	Latitude	Longitude	Total Length (cm)	Fork Length (cm)	Sex	Genetics
5/1/2015	V16	A69-9001-23931	James	37.21244	-76.80481	76	65.5	U	Y
5/2/2015	V16	A69-9001-23908	James	37.18317	-76.73071	72.4	63.5	U	Y
5/2/2015	V16	A69-9001-23912	James	37.17997	-76.73316	78.75	67.3	U	Y
5/3/2015	V16	A69-9001-23911	James	37.21718	-76.8185	75	63.5	U	Y
5/3/2015	V16	A69-9001-23913	James	37.21608	-76.80166	94	81.3	U	Y
5/4/2015	V16	A69-9001-23418	James	37.21359	-76.79817	75	67.3	U	Y
5/4/2015	V16	A69-9001-23914	James	37.21265	-76.80039	96.5	86.3	U	Y
5/4/2015	V16	A69-9001-23915	James	37.21265	-76.80115	94	83.8	U	Y
5/4/2015	V16	A69-9001-23916	James	37.79774	-76.79774	85	75	U	Y
5/4/2015	V16	A69-9001-23917	James	37.21359	-76.79817	83.8	73.6	U	Y
5/4/2015	V16	A69-9001-23919	James	37.21265	-76.80039	89	81.3	U	Y
5/6/2015	V16	A69-9001-24520	James	37.21419	-76.80173	101.6	83.8	U	Y
5/7/2015	V16	A69-9001-23921	James	37.21397	-76.8016	72.4	63.5	U	Y
5/9/2015	V16	A69-9001-23922	James	37.21163	-76.79975	91.5	83.8	U	Y
5/9/2015	V16	A69-9001-24507	James	37.21163	-76.79975	111.8	99	U	Y
4/15/2016	V16	A69-9001-24508	James	37.4625	-76.9145	79	69	U	Y
4/16/2016	V16	A69-9001-24509	James	37.463	-76.93278	133	119	U	Y
4/23/2016	V16	A69-9001-24512	James	37.33194	-76.7872	90	81	U	Y
4/24/2016	V16	A69-9001-24511	James	37.302	-76.745	93	79	U	Y
4/29/2016	V16	A69-9001-24510	James	37.39361	-76.80527	91	81	U	Y
4/29/2016	V16	A69-9001-24514	James	37.39361	-76.80527	92	83	U	Y
4/30/2016	V16	A69-9001-24513	James	37.175	-76.6697	108	97	U	Y
5/2/2016	V16	A69-9001-24484	James	37.379	-76.782	130	113	U	Y
5/3/2016	V16	A69-9001-24493	James	37.3661	-76.7916	96	83	U	Y
5/4/2016	V16	A69-9001-24517	James	37.348	-76.78694	93	82	U	Y
5/4/2016	V16	A69-9001-24518	James	37.3525	-76.81472	94	82	U	Y
5/5/2016	V16	A69-9001-24515	James	37.34361	-76.8445	70	61	U	Y
5/5/2016	V16	A69-9001-24516	James	37.309	-76.8383	96	81	U	Y
5/6/2016	V16	A69-9001-24487	James	37.35416	-76.74945	83	72	U	Y
5/6/2016	V16	A69-9001-24488	James	37.375	-76.77278	99	87	U	Y

Table 7 (continued). Acoustic tags deployed in Atlantic sturgeon during this award; June 1, 2013 to June 30, 2016. Sex; M=male, F=female, U=undetermined. If the sturgeon was an appropriate size sex was determined to be male or female if there was expression of milt or eggs upon palpating the gonadal area. Sex was undetermined if the sturgeon was captured outside of the spawning time period or was not an appropriate size.

Release Date	Tag type	VEMCO ID #	River	Latitude	Longitude	Total Length (cm)	Fork Length (cm)	Sex	Genetics
5/9/2016	V16	A69-9001-24485	James	37.3625	-76.7972	99	86	U	Y
5/10/2016	V16	A69-9001-24506	James	37.40472	-76.96972	101	88	U	Y
4/23/2015	V16P	A69-9002-12701	Mattaponi	37.55314	-76.77881	88	77	U	Y
10/8/2013	V16P	A69-9002-13199	Pamunkey	37.65905	-77.177	198	174	U	Y
8/7/2014	V16	A69-9001-26381	Pamunkey	37.6587	-77.17846667	180	156	M	Y
8/14/2014	V16	A69-9001-26380	Pamunkey	37.65868333	-77.17845	189	167	M	Y
8/14/2014	V16P	A69-9002-12704	Pamunkey	37.65896667	-77.17718333	185	167	M	Y
8/15/2014	V16	A69-9001-24473	Pamunkey	37.65928333	-77.17185	168	133	M	Y
8/21/2014	V16	A69-9001-24476	Pamunkey	37.65903333	-77.17603333	177	158	M	Y
8/21/2014	V16P	A69-9002-12707	Pamunkey	37.65861667	-77.1786	240	215	F	Y
8/28/2014	V16	A69-9001-24477	Pamunkey	37.65971667	-77.1705	171	156	M	Y
8/28/2014	V16	A69-9001-24479	Pamunkey	37.65971667	-77.1705	165	147	M	Y
8/28/2014	V16	A69-9001-24481	Pamunkey	37.65905	-77.17496667	183.5	160	M	Y
7/9/2015	V16	A69-9001-24475	Pamunkey	37.5563	-76.87371	98	86	U	Y
7/9/2015	V16P	A69-9002-12705	Pamunkey	37.5563	-76.87371	98	88	U	Y
7/9/2015	V16P	A69-9002-12706	Pamunkey	37.5563	-76.87371	94	87	U	Y
7/10/2015	V16	A69-9001-23920	Pamunkey	37.56075	-76.87308	92	82	U	Y
7/17/2015	V16	A69-9001-23905	Pamunkey	37.57083	-76.88148	104	88	U	Y
7/17/2015	V16	A69-9001-24519	Pamunkey	37.57347	-76.88107	102	90	U	Y
8/12/2015	V16	A69-9001-24483	Pamunkey	37.57228	-76.8831	80	68.5	U	Y
8/12/2015	V16	A69-9001-24486	Pamunkey	37.57228	-76.8831	82	70	U	Y
10/14/2015	V16	A69-9001-23954	Pamunkey	37.564567	-76.933071	73	65	U	Y
6/16/2016	V16	A69-9001-24489	Pamunkey	37.57042	-76.8791	66	76	U	Y
6/30/2016	V16P	A69-9002-12703	Pamunkey	37.55669	-76.87322	119	103	U	Y
7/7/2016	V16	A69-1601-44009	Pamunkey	37.5816	-76.86975	63	55	U	Y
4/8/2014	V16	A69-9001-26398	York	37.3425	-76.62223333	82.5	70.5	U	Y
4/9/2014	V16	A69-9001-26412	York	37.41905	-76.70801667	74	63	U	Y

Table 8. Frequency of gillnet sets by the VIMS sturgeon project targeting Atlantic sturgeon by river.					
	James	Mattaponi	Pamunkey	York	Total
2013	0	14	38	10	62
2014	143	22	73	55	293
2015	149	29	66	24	268
2016	116	32	44	0	192
Total	408	97	221	89	815

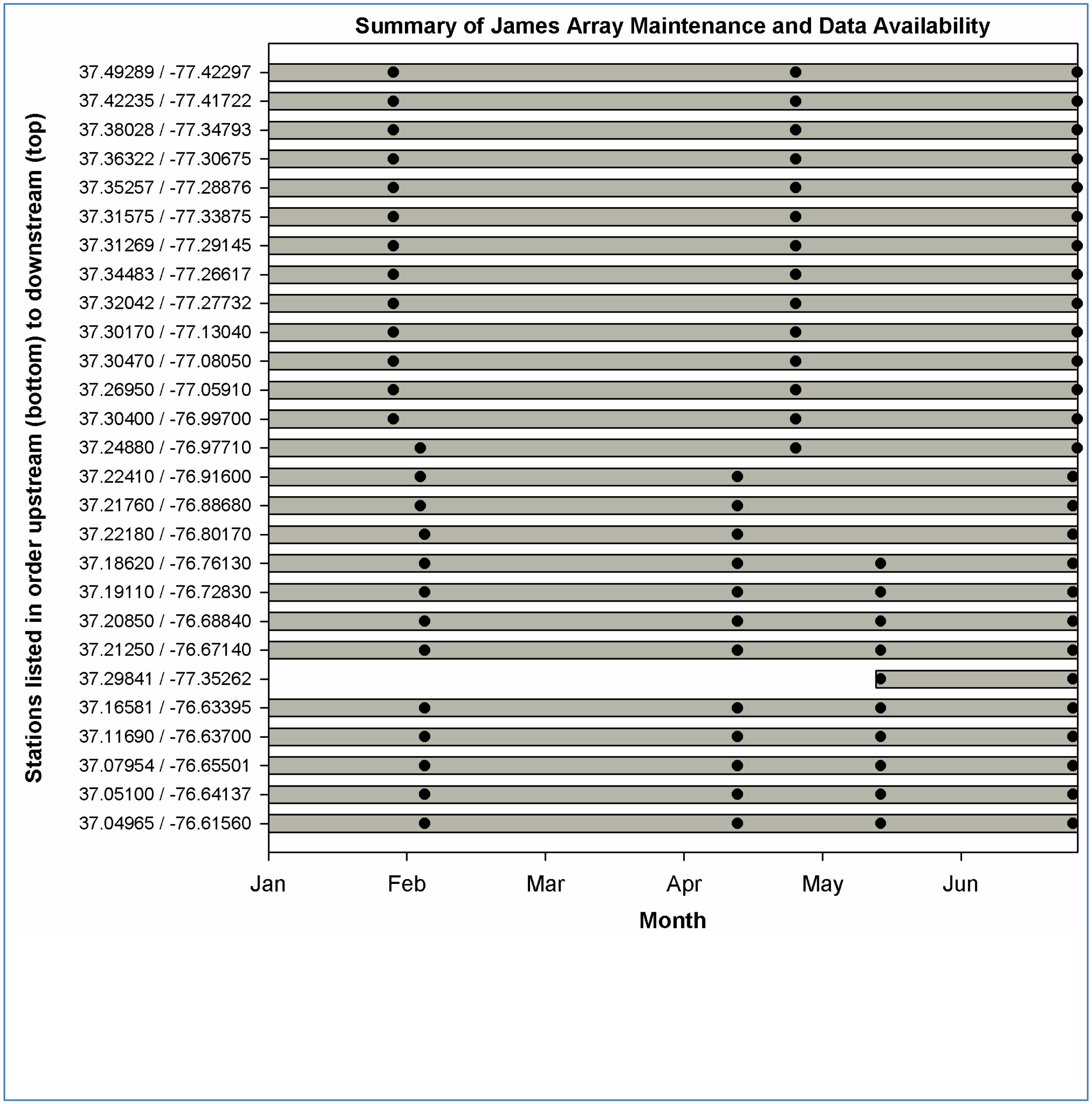


Figure 1. Gray bars indicate data availability, timing of deployment, for each receiver station. Black dots indicate receiver maintenance and data download dates in 2016 through the end of the grant period.

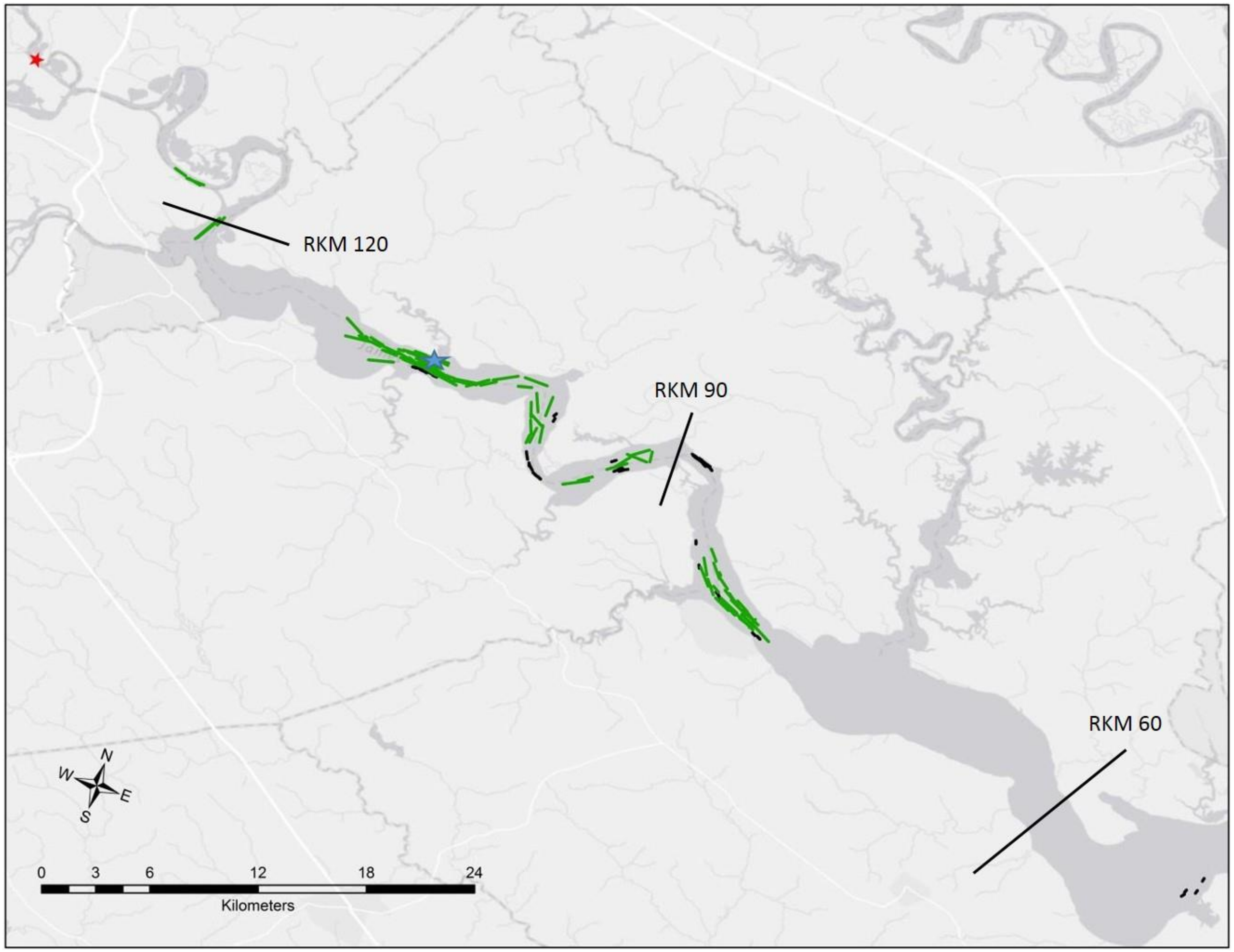


Figure 2. Summary of James River early juvenile Atlantic Sturgeon sampling effort conducted during January 1 to June 30, 2016. Green lines are trawl sampling paths and black lines are gillnet sets (Table 1). The red star in the upper left corner (~rkm 140) signifies where two post-larvae were captured by Dominion contractors. The two larvae were captured in early October 2015. The blue star around rkm 100 shows the location of the only confirmed young-of-year capture in the James River since 2004.

Figure 3. Shortnose Sturgeon 133 mm TL captured on March 13, 2016 in the tidal James River, Virginia by VCU biologists.

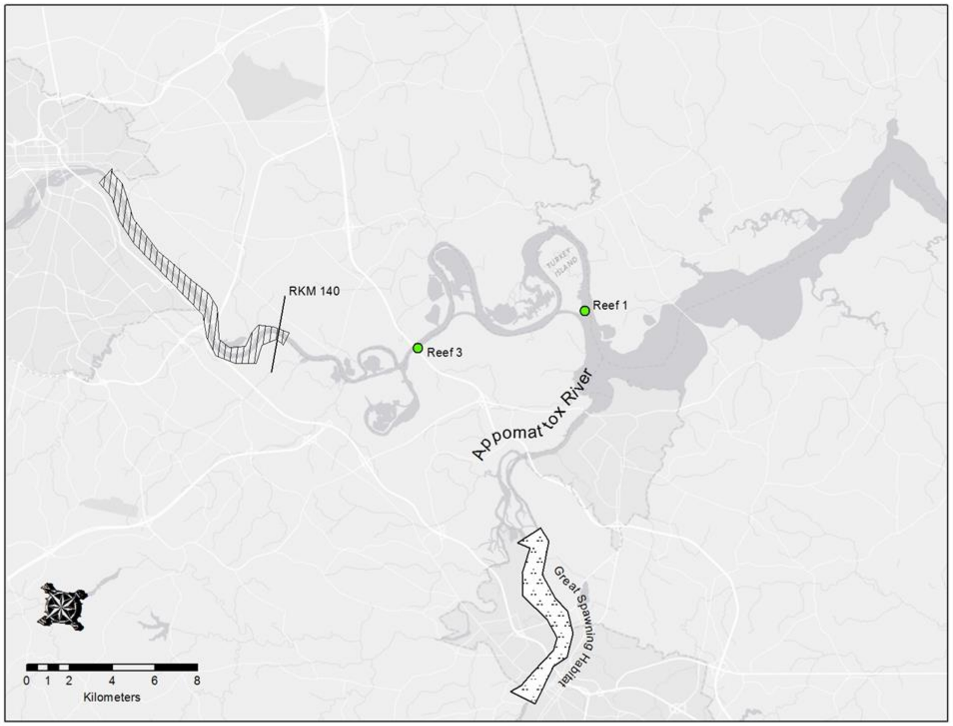


Figure 4. Upper tidal James River in the vicinity of Hopewell, Virginia. Hashed area is where ATS egg mats were deployed in 2015; stippled reach of the Appomattox River represents potential ATS spawning habitat that we plan to evaluate in 2016.

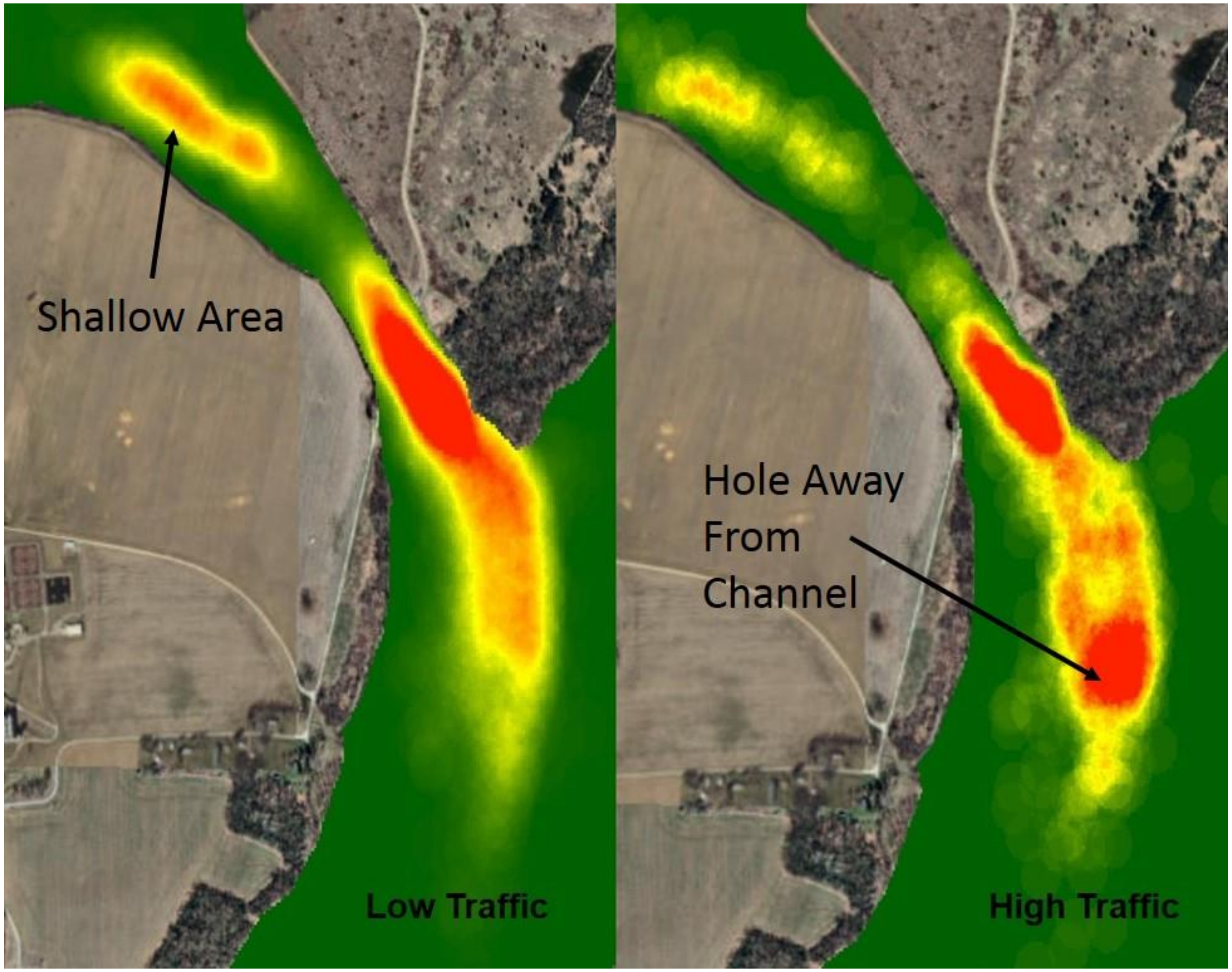


Figure 5. Occurrence-density plots showing Atlantic Sturgeon positions during a 1- week period during the Fall, 2015 spawning run. Data were generated by VEMCO Positioning System (VPS) array and post-processed by VEMCO. Reddish hues are associated with high-residency locations. The left plot represents periods of low vessel traffic and the right plot documents sturgeon positions during periods of high boat traffic. Preliminary results suggest Atlantic Sturgeon move into deep water (≈27 m) during periods of high vessel traffic.

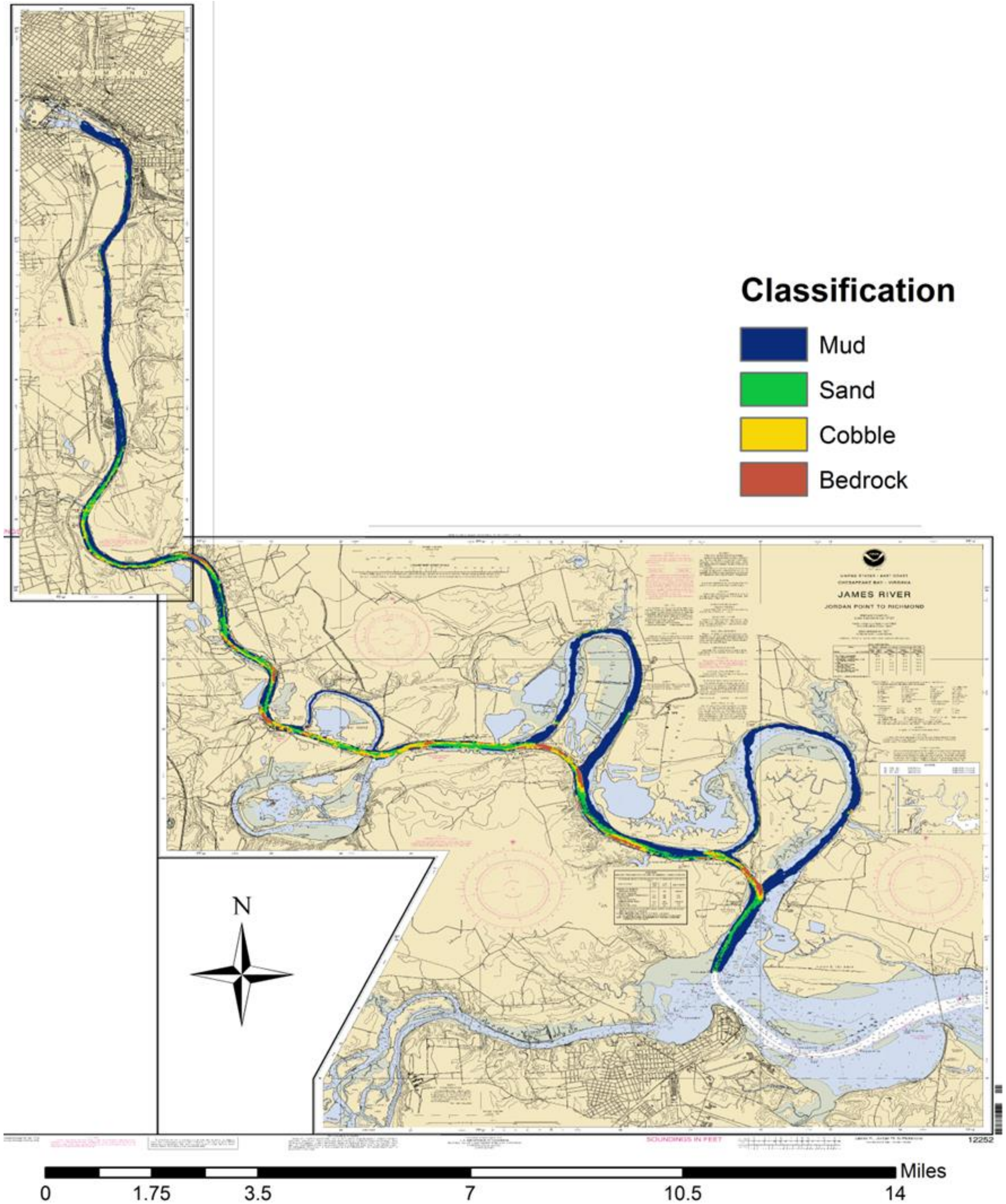

Classification
Mud
Sand
Cobble
Bedrock
JAMES RIVER
JORDAN POINT TO RICHMOND
N
SOUNDINGS IN FEET
12252
Miles
0
1.75
3.5
7
10.5
14

Figure 6. Map of the tidal freshwater James River, Virginia, describing the dominant substrate within the reach based on the four classification types. Classification groups were determined from the statistical analysis of ground truth samples and side scan sonar hardness values. Cobble and bedrock classifications are considered potential spawning habitat for Atlantic Sturgeon. Hard bottom habitat was dominant within the shipping channel, especially around major bends hydromodified areas (cut-throughs) where scouring may occur. Data are available as an ArcGIS shape file from the principle investigator.

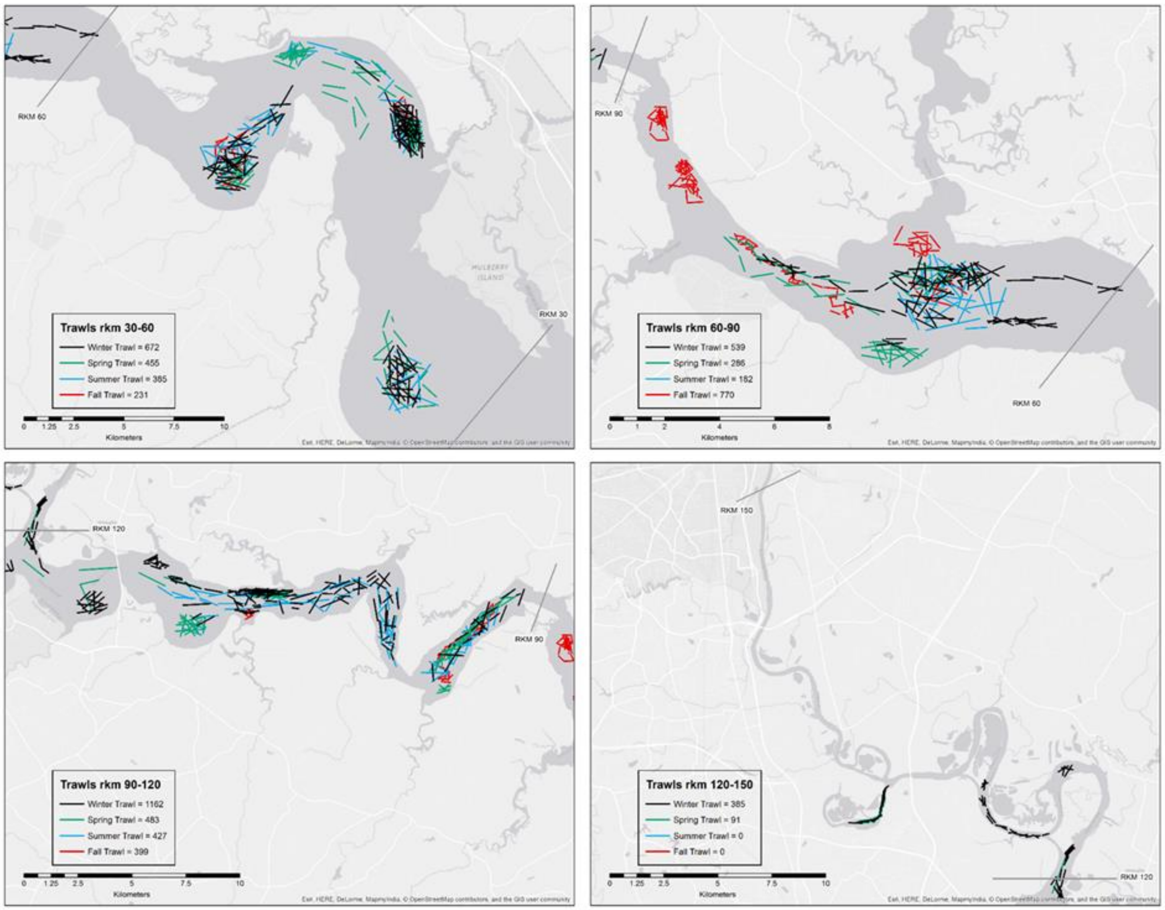


Figure 7. Map of tidal James River, Virginia showing locations of trawls for early juvenile ATS by VCU biologists in 2013, 2014, and 2015.

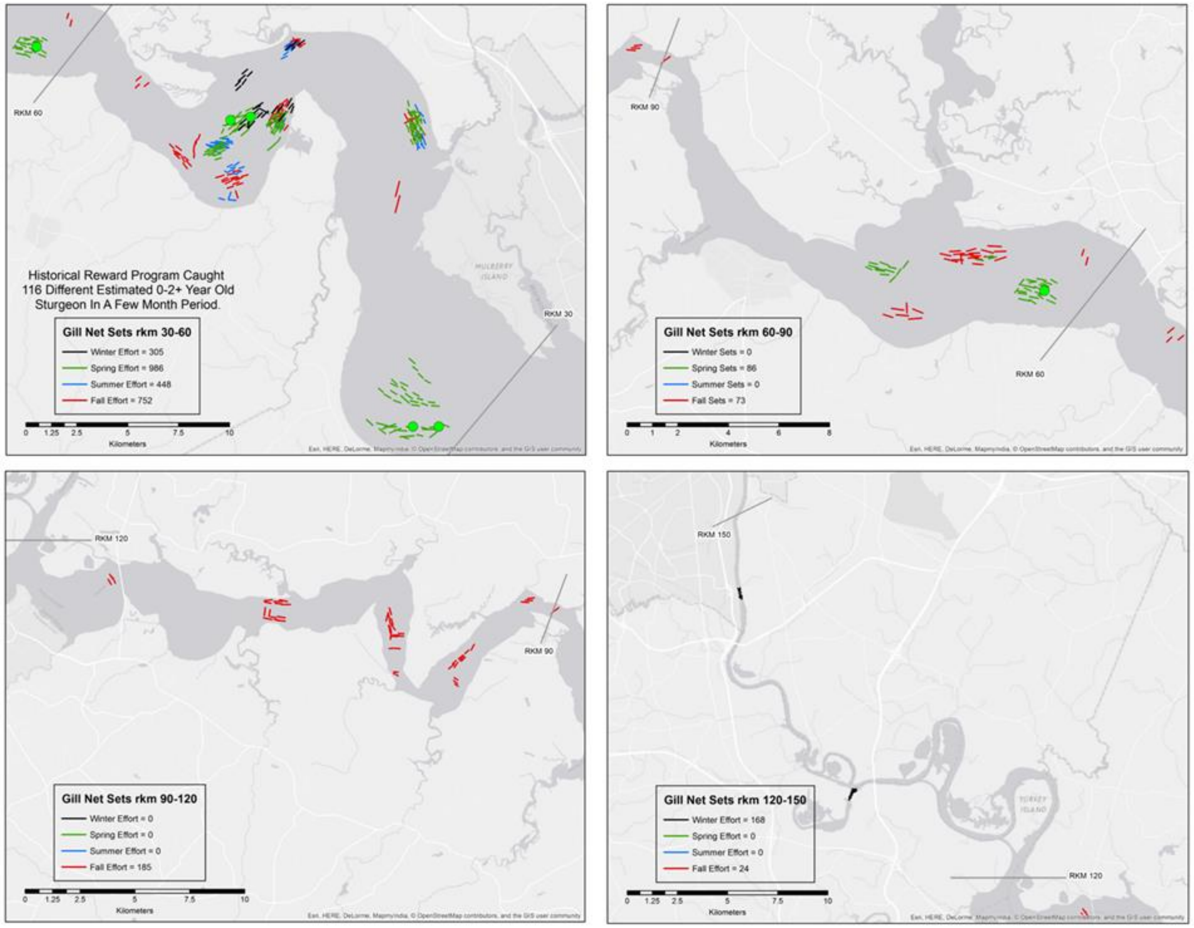


Figure 8. Maps of the James River, Virginia summarizing recent (VCU; 2014 and 2015) and historical (USFWS Reward Program; late 1990s) gill net sampling activity for early juvenile ATS.

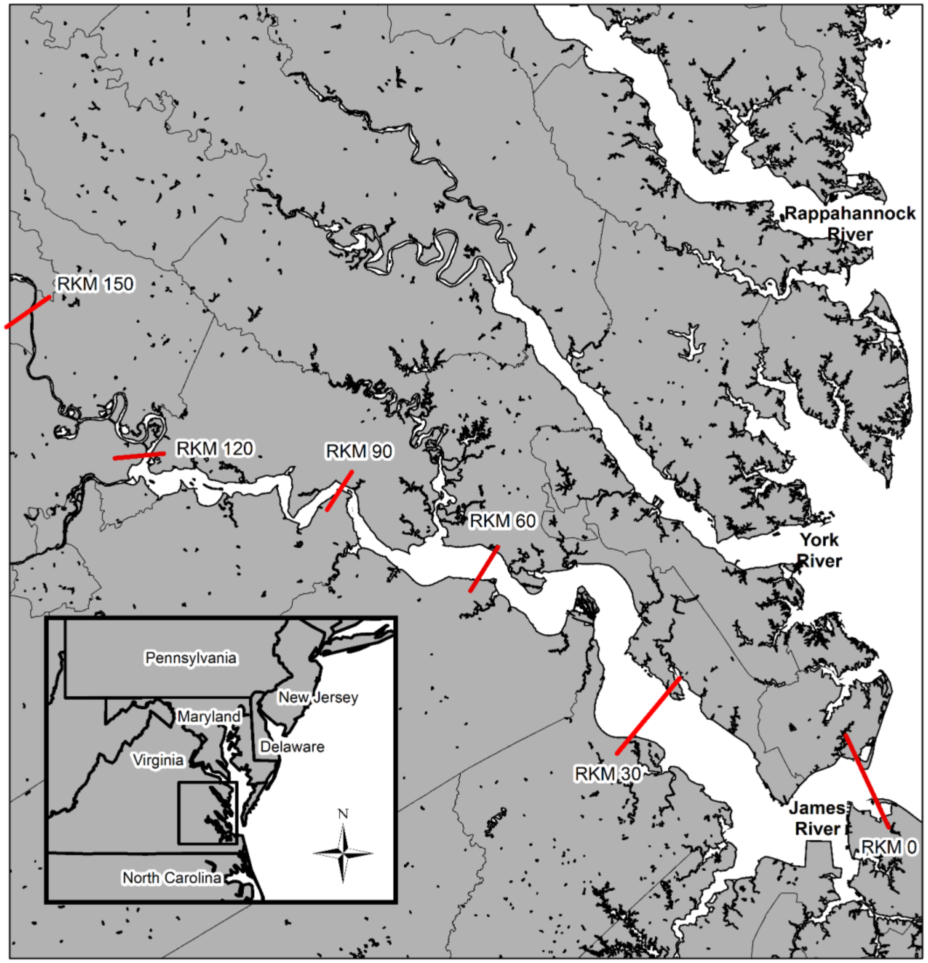


Figure 9. Map of James River, Virginia showing river kilometers (rkm) and VCU study reaches referenced in the text and Table 2.

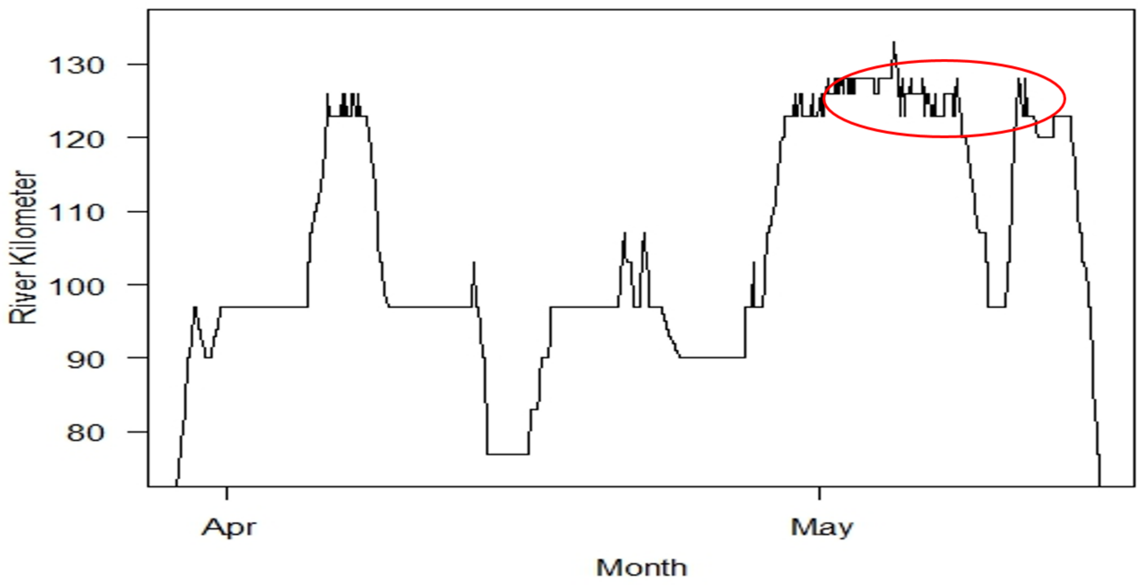


Figure 10. Plot showing typical in-system movements by adult male Atlantic sturgeon during the 2016 Spring run. The red oval shows when and where egg mats were set. Refer to previous maps for river kilometer (rkm) locations.

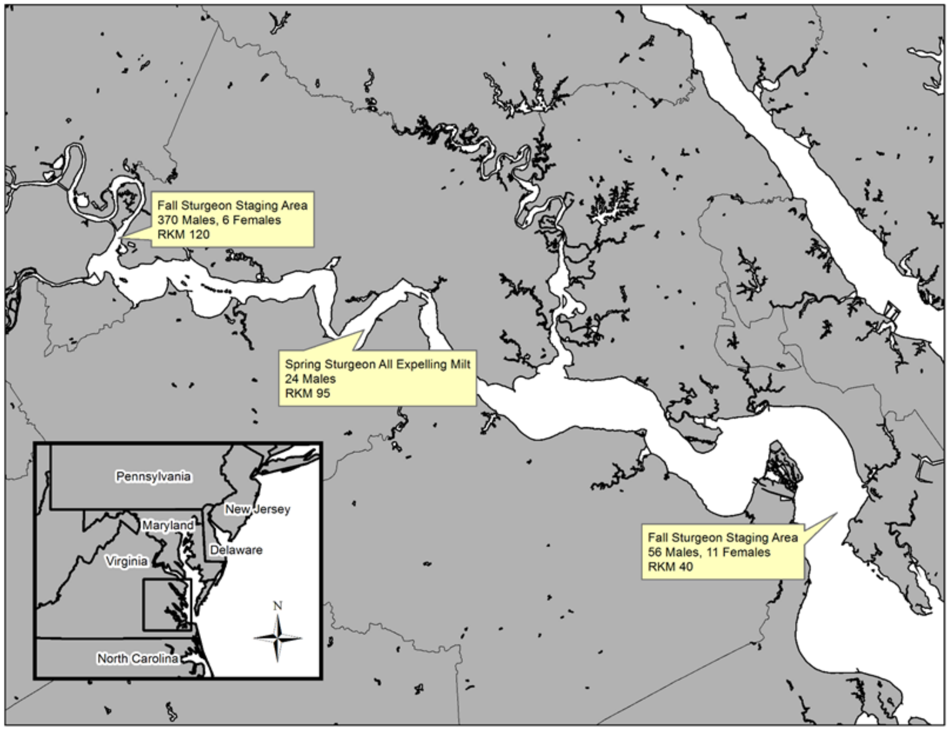
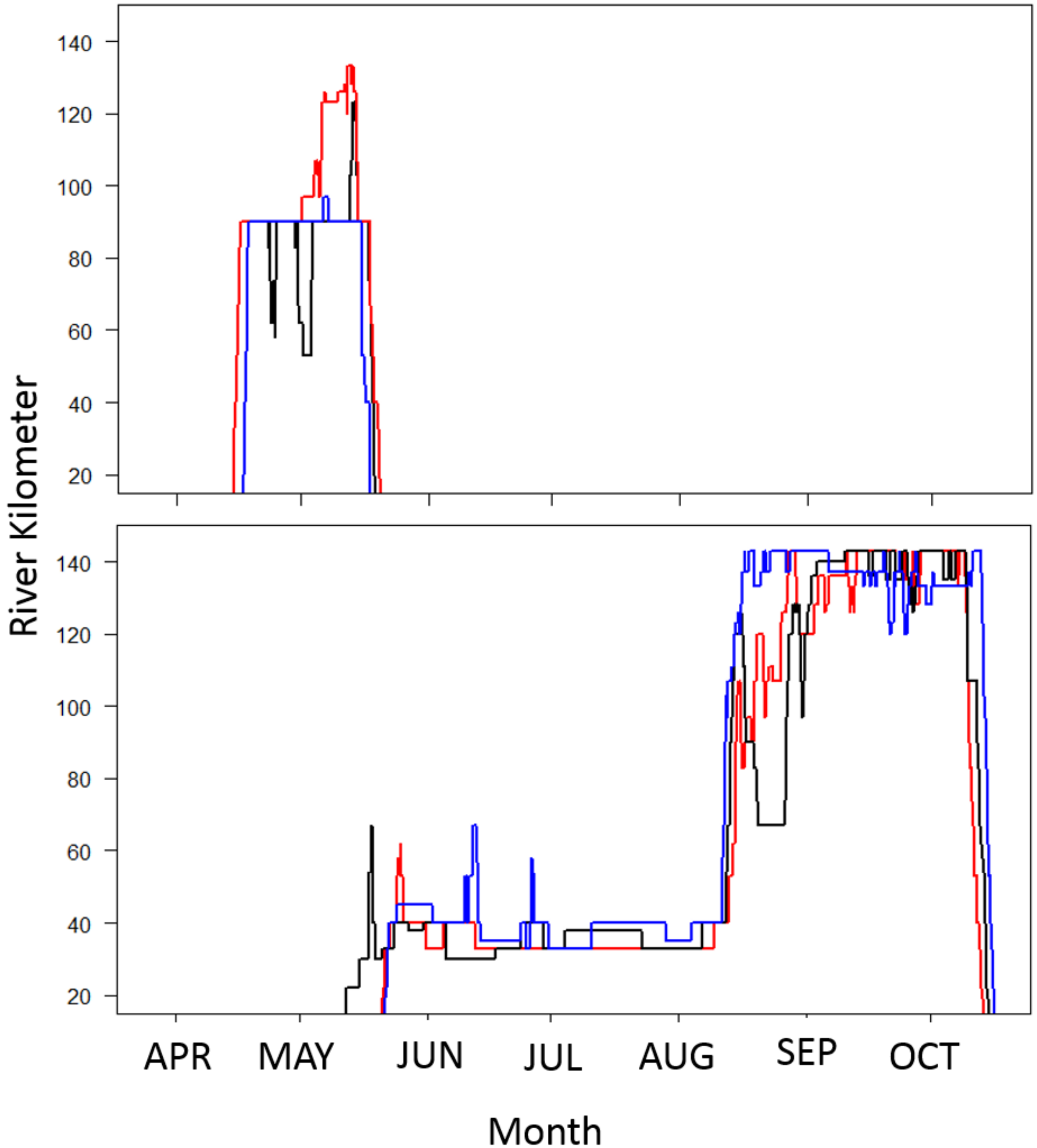


Figure 11. Map of the James River, Virginia showing locations of adult (reproductive) Atlantic Sturgeon collections by VCU in 2014 and 2015.



140
120
100
80
60
40
20
River Kilometer
APR
MAY
JUN
JUL
AUG
SEP
OCT
Month

Figure 12. Acoustic telemetry movements (2012=black, 2013=red, and 2014=blue) of mature male Atlantic Sturgeon returning repeatedly to the James River, Virginia. The top panel (A) is a representative Spring-caught adult Atlantic Sturgeon (tagged in 2012) and the bottom panel (B) represents the typical migration behavior of Fall-run Atlantic sturgeon in the James River; this Fall-run male was tagged in September of 2011 at rkm 120.

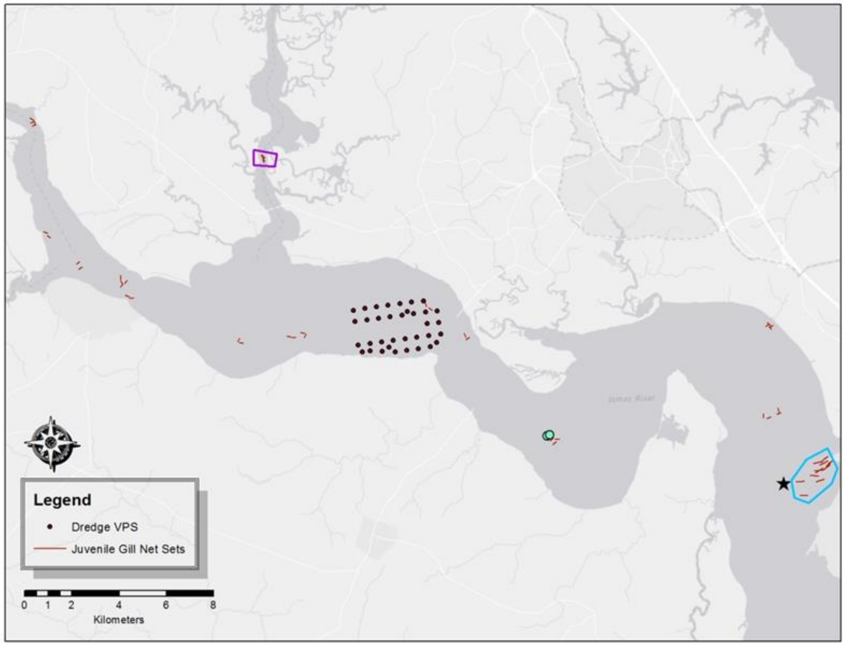


Figure 13. Map summarizing VCU's lower James River activities during Fall, 2015 and related to Section 6 objectives. The star is where we caught pre and post spawn adult ATS. VPS receivers show the location for the dredge effects VPS location. Blue polygon is Skiffes Creek flatwater where dozens of 0-2+ year ATS were caught during the USFWS reward program in the late 1990s. Attempts by VCU to mimic these successful methods during the project period produced no ATS.

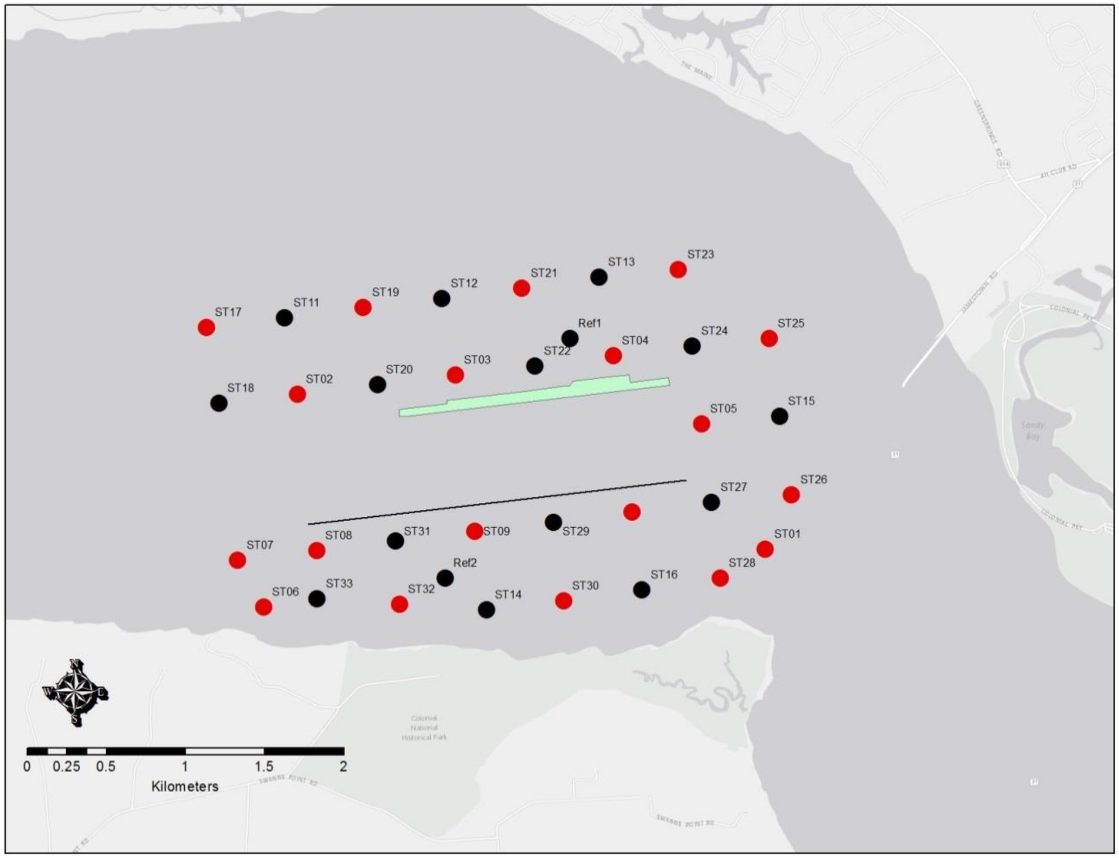


Figure 14. Deployment of VEMCO VPS array in the lower tidal James River, Virginia during Fall, 2015 by VCU biologists in cooperation with ACOE personnel. Red symbols are synched acoustic tags and black symbols are VR2W receivers. Green polygon is the actual ACOE dredge area for operations completed Fall, 2015. The long black line delineates the area we had to avoid due to dredging operations.

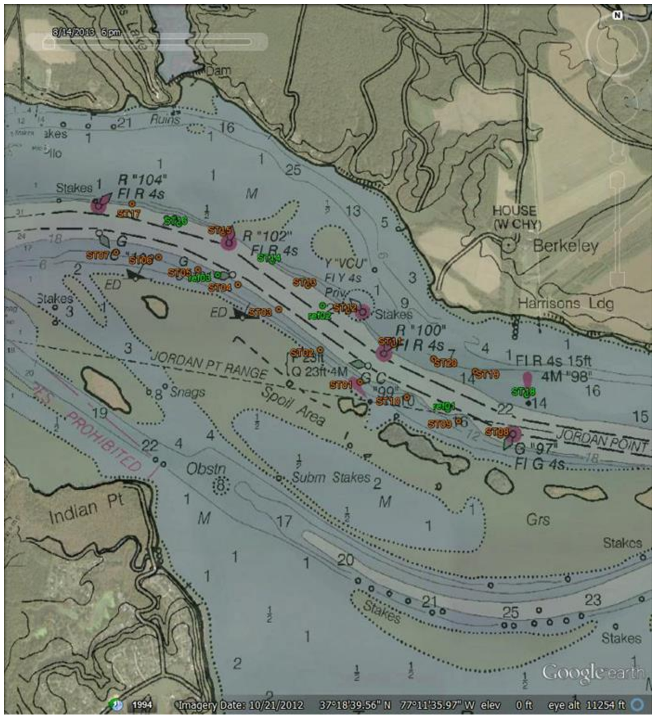


Figure 15. 2013 deployment of a VEMCO Positioning System (VPS) array, comprised of 17 VR2W acoustic receivers, in the James River, Virginia near Jordan Point. The ACOE-maintained shipping channel is marked.

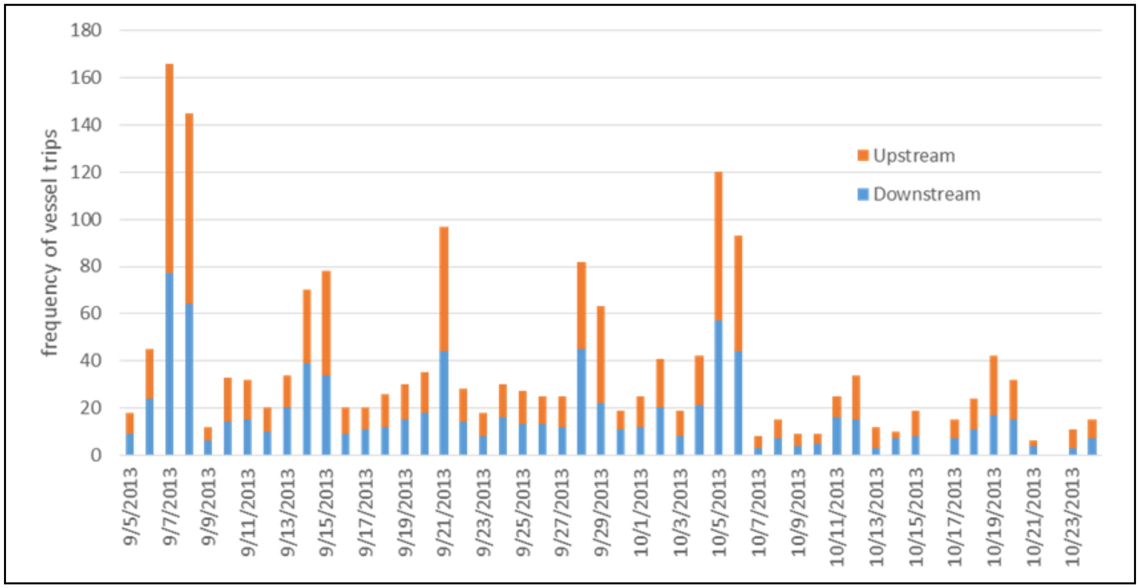


Figure 16. Frequency of vessel trips within the VPS array for the period SEP 5 – OCT 24, 2013, based on a review of video from a webcam mounted at VCU's Rice Rivers Center. The array was deployed in the vicinity of the maintained James River shipping channel downstream of Hopewell, Virginia.

Figure 17. Location of receivers deployed by VIMS, US Navy and VDGIF.

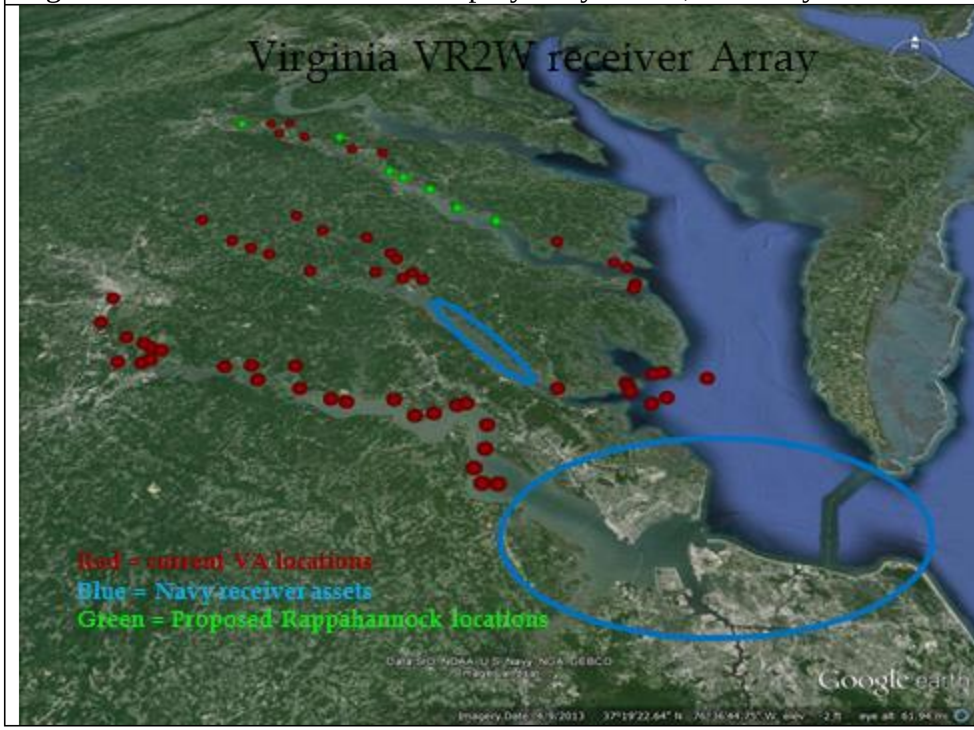


Figure 18. James River directional hydrophone manual tracking locations of subadult Atlantic sturgeon in July and August 2015. The tracking area was confined to the general area of the map below. Passive detections confirmed that no subadult sturgeon were in locations upstream (west) of this tracking area. However, a portion of subadults were downstream (east) of this area. The area downstream was not tracked due to manpower limitations.

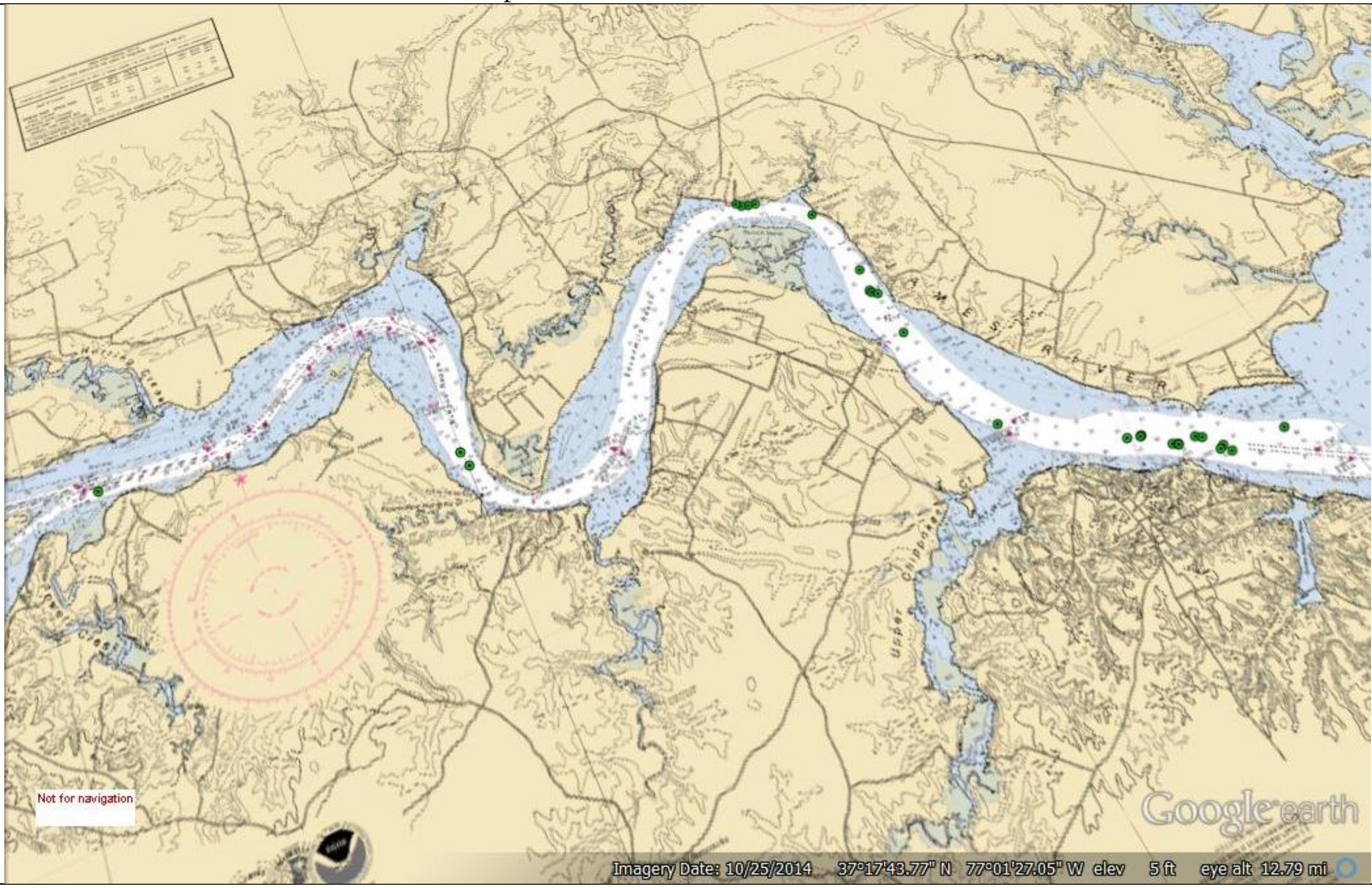


Figure 19. Pamunkey River directional hydrophone manual tracking locations of subadult Atlantic sturgeon in July and August 2015. Passive detections confirmed that no tagged subadult sturgeon were present outside of the general area of this map during the tracking time period.

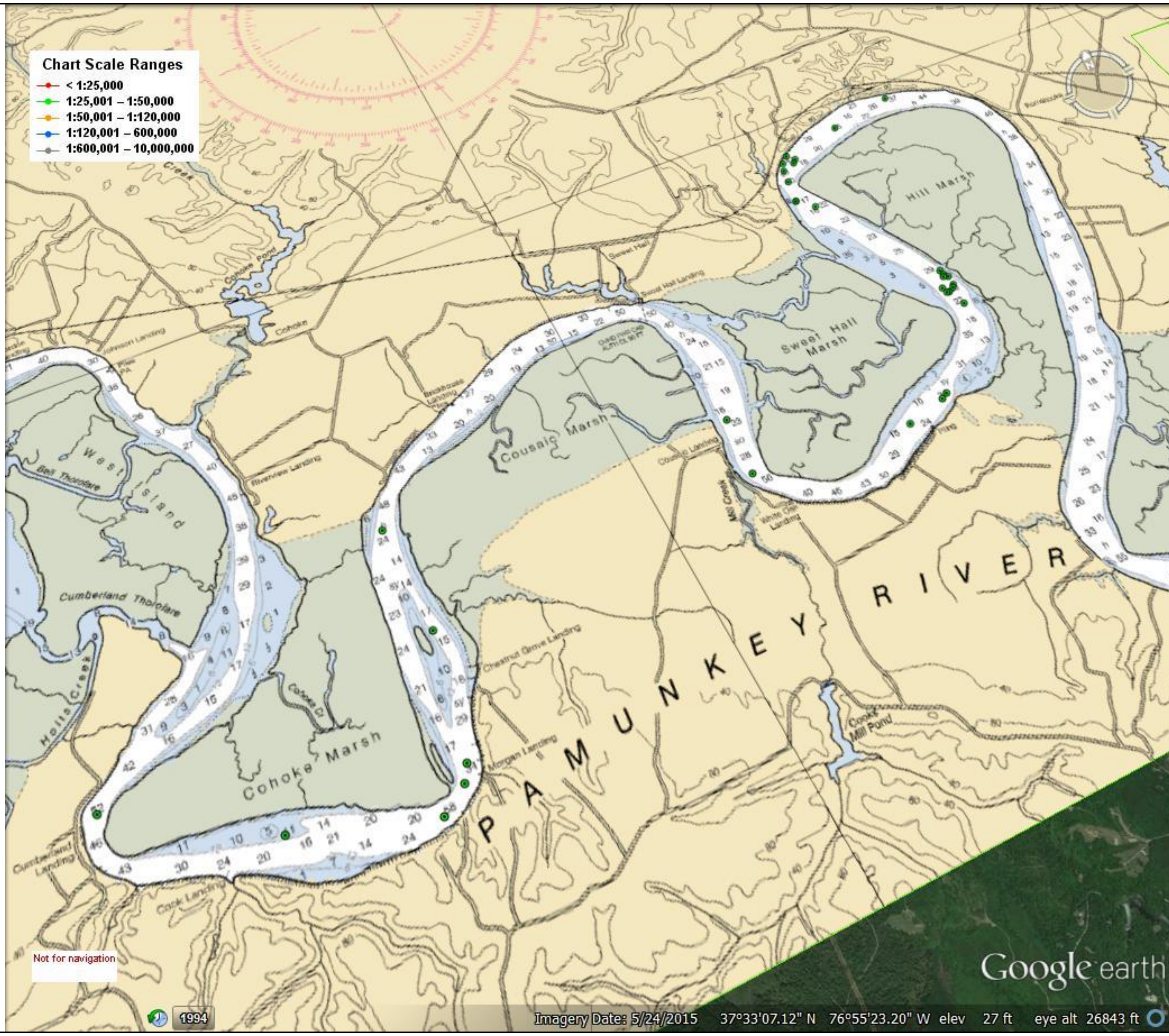
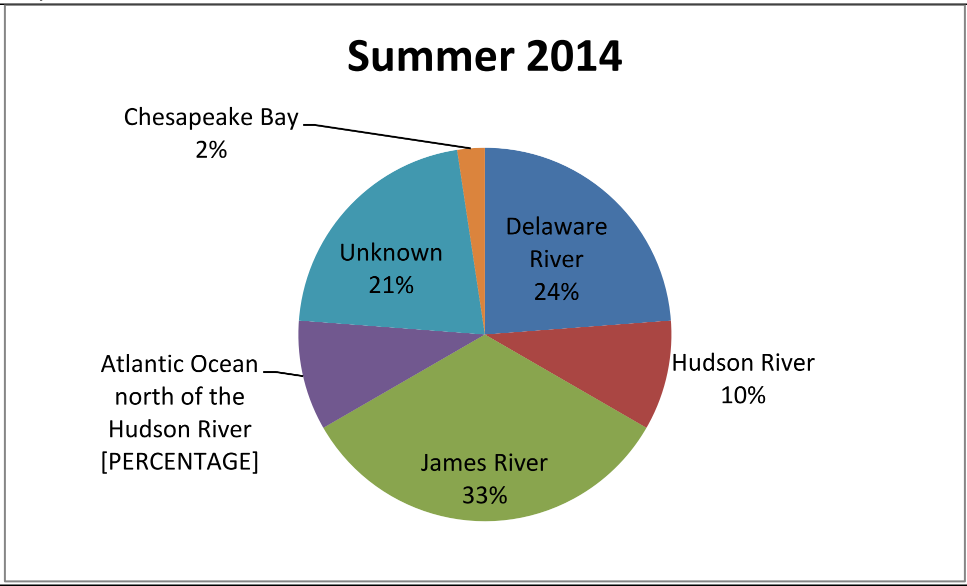


Figure 20. Summertime (June, July, August) fate of subadults tagged in the spring of 2014 and 2015 in the James River at Jamestown island, Cobham Bay and Burwells Bay based on receiver reports from researchers through the Atlantic Coastal Telemetry Network (ACT). In 2014, n=42 individuals were at-large and in 2015 n=100 individuals at-large. Known arrays in the NY bight and Chesapeake bight that did not detect any of the James subadults in the summertime include; Rappahannock, Pamunkey, Mattaponi, Nanticoke, Rhodes, Elk and Connecticut Rivers.



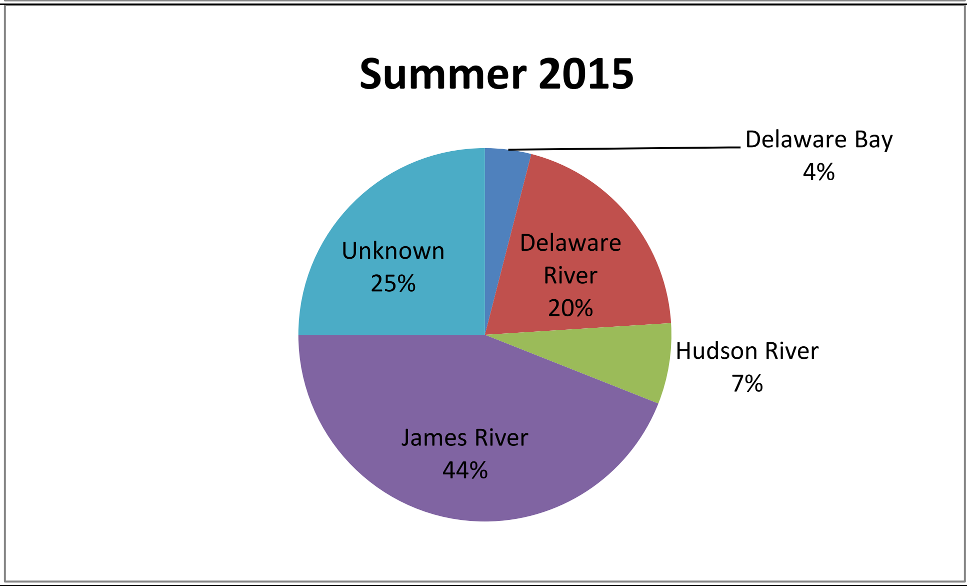


Figure 21. Pamunkey and York River telemetry array detections of adults Atlantic sturgeon tagged in 2014 that returned in 2015. The sturgeon spawning grounds have been estimated to be from rkm 120-140 (pers. com J. Kahn). On September 30th, 2015 a high flow event from the remnants of hurricane Jaoquin caused most tagged sturgeon to drop down below the spawning grounds with most adults returning 6 days later.

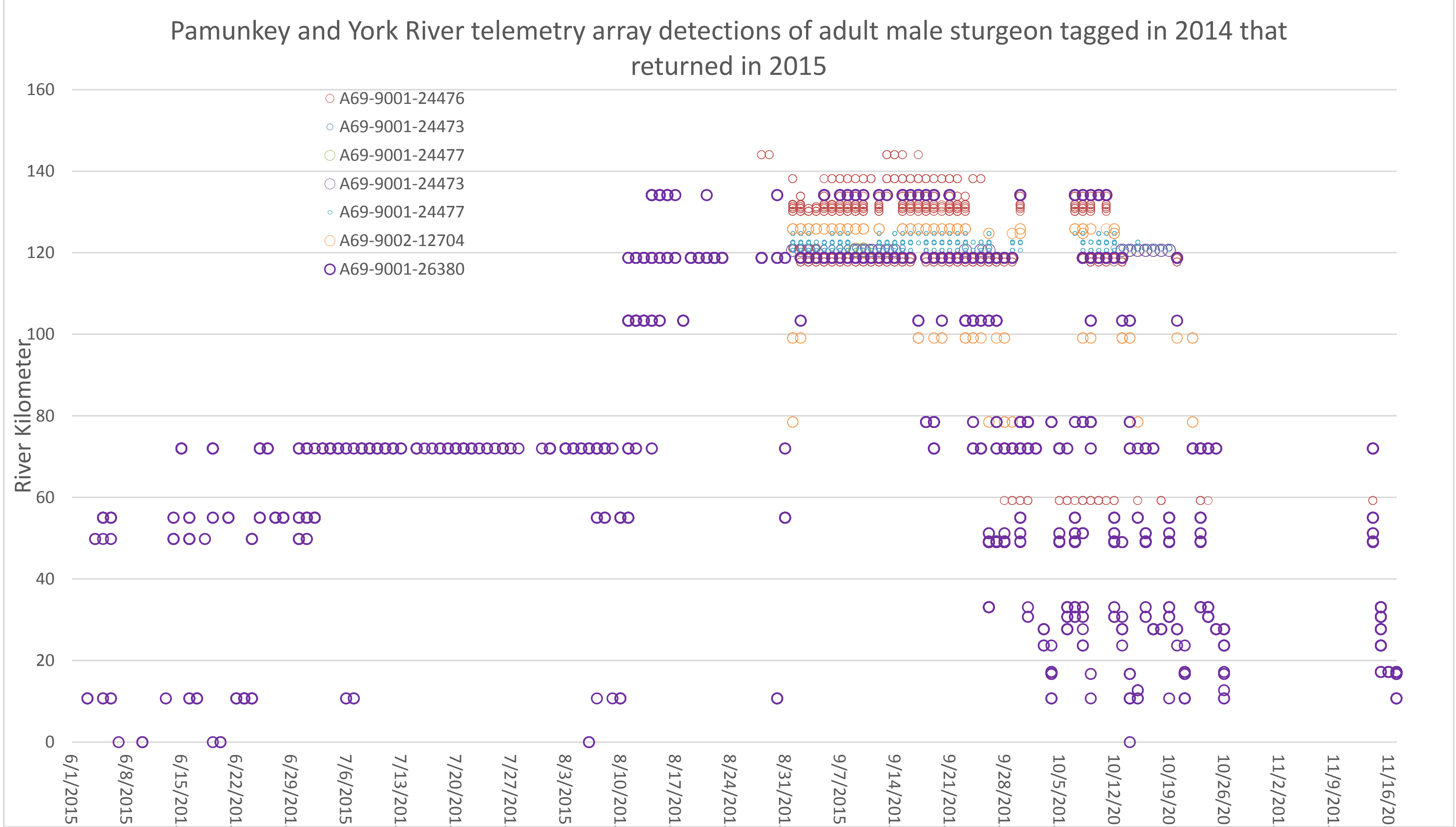
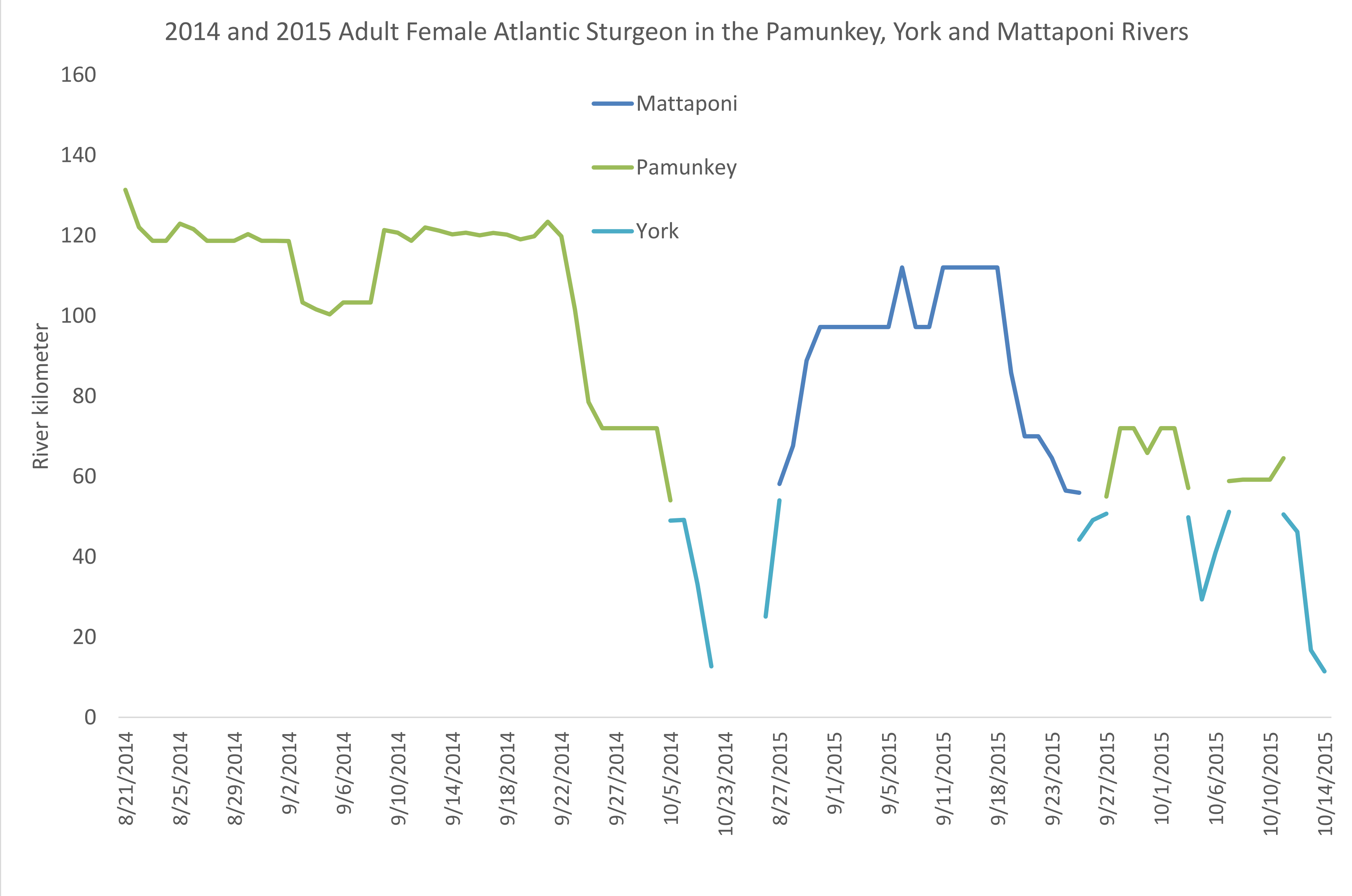


Figure 22. Movement of 2014 and 2015 Adult female Atlantic sturgeon in the Pamunkey, York and Mattaponi Rivers by river kilometer over time. Transmitter was applied by VIMS on 8-21-2014 and this individual was subsequently recaptured by J. Kahn on 9-17-2014 and 9-23-2014.



Appendix A. Summary of weekly water quality measurements (i.e., physico-chemical habitat) for the tidal freshwater James River, Virginia for the period February, 2013 – December, 2015. Water samples were collected along a 94-km reach at nine fixed locations (river channel) and at near-surface and near-bottom depths between the City of Richmond ("Huguenot"), Virginia and the Rice Rivers Center (B74). "App 1.5" is the mouth of the Appomattox River at Hopewell, Virginia. Location numbers are river kilometers. Empty cells mean no data were available. These data are summarized in VCU's Table 5, above.

		Surface				Bottom			
Date	**Site**	**Temp (°C)**	**pH**	**SpCond**	**DO (mg/L)**	**Temp (°C)**	**pH**	**SpCond**	**DO (mg/L)**
2/12/2013	Huguenot	4.44	6.60	156..6	12.43				
	B168	6.71	8.07	154.9	12.29	6.83	7.94	154.3	12.24
	B166	7.81	7.45	158.2	12.07	7.18	8.60	158.0	12.05
	B157	6.70	7.00	169.6	12.22	6.51	8.17	170.0	12.35
	B150	8.37	7.59	176.9	11.71	7.66	8.10	172.7	11.95
	B138	8.15	6.99	174.4	11.52	8.10	7.31	173.8	11.57
	B107	7.88	6.71	148.4	11.36	7.86	6.79	146.9	11.43
	B91	7.96	7.14	139.1	11.39	7.90	7.04	137.2	11.28
	B74	7.65	5.81	130.5	11.08	7.59	5.88	130.5	10.91
2/19/2013	Huguenot	5.85	7.22	187.3	12.72				
	B168	5.59	6.95	184.2	12.55	5.56	7.08	185.3	12.54
	B166	6.59	6.85	187.6	12.35	6.60	7.24	189.3	12.35
	B157	6.33	6.71	210.1	12.08	6.24	6.76	209.7	12.15
	B150	8.45	6.68	215.9	11.17	8.94	6.68	224.9	11.70
	B138	7.77	6.54	208.4	11.18	8.00	6.56	210.6	11.19
	B107	6.71	6.66	177.5	11.47	6.90	6.58	178.5	11.33
	B91	6.36	5.38	164.8	11.40	6.41	6.14	165.3	11.54
	B74	6.74	6.37	138.4	11.03	6.89	6.11	138.6	10.91
2/26/2013	Huguenot	6.92	7.12	200.1	9.89				
	B168	6.59	6.51	204.9	11.87	6.50	6.75	183.7	12.02
	B166	6.73	7.18	204.0	12.49	6.70	7.39	205.9	12.46
	B157	6.97	6.77	233.5	11.86	6.83	7.03	233.4	12.00
	B150	10.10	6.77	247.9	10.59	9.95	6.99	238.2	11.36
	B138	8.15	6.73	239.9	11.00	7.85	6.86	239.9	11.43
	B107	7.53	6.61	208.4	10.87	7.47	6.70	201.8	11.01
	B91	6.95	6.61	196.6	10.88	6.69	6.66	197.1	11.20
	B74	6.79	6.32	158.1	10.73	5.85	6.28	161.0	11.49
3/12/2013	Huguenot	12.47	6.67	143.3	11.04				
	B168	10.06	6.40	148.3	10.94	10.06	6.42	151.6	10.86
	B166	9.75	6.38	133.1	11.18	9.63	6.38	136.9	11.18
	B157	10.16	6.27	142.9	11.09	10.05	6.33	143.9	11.11
	B150	10.78	6.18	146.6	10.81	10.37	6.24	146.8	11.01
	B138	9.86	6.13	149.1	11.01	9.77	6.16	150.0	11.03
	B107	9.65	6.16	142.7	11.11	9.65	6.13	147.4	11.14
	B91	10.02	6.27	160.0	10.91	9.49	6.22	157.3	11.15
	B74	9.74	6.20	191.4	10.97	9.36	6.25	190.7	11.00
3/19/2013	Huguenot	10.79	6.46	118.2	11.65				
	B168	8.19	7.00	125.7	11.78	8.05	7.03	123.8	11.79
	B166	8.22	6.69	123.0	11.63	8.30	6.65	123.1	11.64
	B157	8.51	6.66	137.9	11.41	8.26	6.66	138.3	11.44
	B150	8.83	6.71	133.4	11.34	8.71	6.57	132.7	11.29
	B138	9.56	6.53	138.7	10.83	9.57	6.57	137.5	10.93
	B107	9.46	6.60	142.9	10.56	9.26	6.71	142.3	10.69

	B91	9.14	6.63	152.7	10.38	9.41	6.59	153.0	10.27
	B74	9.32	6.29	153.4	9.98	9.44	6.36	153.4	10.01
3/26/2013	Huguenot	8.91	6.75	144.6	11.61				
	B168	7.22	5.87	149.2	12.11	7.12	6.33	150.8	11.94
	B166	7.32	5.98	154.0	11.91	6.94	6.28	152.7	11.80
	B157	7.53	6.35	176.0	11.20	7.69	6.31	179.8	11.48
	B150	9.65	6.60	188.5	10.62	8.50	6.66	183.0	11.18
	B138	8.02	6.61	180.7	11.28	8.18	6.58	183.8	11.10
	B107	8.32	6.51	153.4	10.83	8.21	6.64	154.5	10.78
	B91	7.68	6.72	144.2	11.05	7.71	6.70	145.9	11.01
	B74	7.92	6.42	138.8	10.58	8.05	6.47	139.2	10.76
4/2/2013	Huguenot	13.31	7.04	163.6	10.92				
	B168	10.50	5.93	163.8	10.93	9.87	6.64	161.3	10.97
	B166	11.01	6.74	165.6	10.72	11.18	7.75	165.9	10.60
	B157	10.81	5.16	185.6	10.69	10.61	6.74	185.1	10.71
	B150	11.89	6.31	178.4	10.58	11.31	6.55	179.7	10.56
	B138	11.10	6.35	166.3	10.69	10.72	6.57	168.6	10.54
	B107	11.21	6.36	168.4	10.94	11.09	6.52	169.1	10.65
	B91	10.20	6.22	166.1	10.97	10.62	6.56	166.9	10.81
	B74	9.35	5.70	148.8	10.72	9.58	6.22	147.9	10.56
4/16/2013	Huguenot	19.23	7.13	184.0	9.50				
	B168	18.75	7.27	190.7	9.28	18.71	7.34	190.8	9.25
	B166	18.84	7.38	187.5	9.17	18.76	7.16	186.7	9.23
	B157	18.99	7.41	185.2	9.01	18.81	7.18	185.4	9.08
	B150	19.01	7.15	183.2	8.86	18.89	7.13	184.0	8.89
	B138	19.33	6.89	179.4	8.77	19.07	6.81	180.4	8.71
	B107	19.58	7.11	171.7	9.01	19.79	6.82	170.6	8.87
	B91	19.20	6.88	186.3	9.32	19.25	7.04	188.0	9.23
	B74	18.28	6.64	180.0	8.97	18.33	6.62	179.4	8.85
4/23/2013	Huguenot	15.26	7.29	132.5	10.44				
	B168	15.58	7.31	127.4	9.89	15.57	7.38	127.1	9.97
	B166	15.55	7.28	126.0	9.86	15.55	7.36	126.6	9.85
	B157	15.52	7.27	128.8	9.78	15.57	7.30	129.2	9.74
	B150	16.27	7.23	133.2	9.51	16.44	7.29	131.4	9.48
	B138	16.01	7.25	137.9	9.34	16.42	7.28	135.1	9.37
	B107	16.68	7.23	153.4	8.97	16.81	7.22	154.1	8.87
	B91	16.75	7.39	155.8	9.16	16.90	7.33	156.5	9.10
	B74	17.74	7.18	177.5	8.46	18.47	7.16	177.4	8.12
4/30/2013	Huguenot	17.55	7.54	140.4	9.64				
	B168	17.28	7.35	143.1	10.27				
	B166	17.68	7.26	145.7	10.18				
	B157	17.52	7.18	156.0	9.73	17.46	7.17	155.8	9.77
	B150	18.55	7.12	155.1	9.78	18.56	7.15	155.1	9.48
	B138	18.08	7.13	151.9	9.38	18.23	7.12	151.4	9.44
	B107	17.80	7.10	146.2		17.98	7.16	146.9	
	B91	18.01	7.01	144.4		17.89	7.15	144.6	
	B74	17.87	6.98	159.9	8.67	17.16	7.11	160.2	8.08
5/14/2013	Huguenot	16.53	7.21	129.9	10.24				
	B168	16.50	7.27	125.1	9.68	16.44	7.25	126.0	9.83
	B166	16.57	7.28	123.6	9.70	16.48	7.51	123.7	9.74
	B157	16.75	7.18	123.9	9.59	16.81	7.25	124.4	9.52
	B150	17.17	7.06	122.8	9.22	16.94	7.07	122.9	9.37

	B138	17.43	6.95	124.7	9.13	17.38	7.05	124.2	9.15
	App1.5	17.39	6.94	115.3	8.65	17.50	6.92	115.1	8.78
	B107	17.27	6.83	118.8	8.60	17.42	6.88	117.1	8.66
	B91	17.36	6.81	112.7	8.65	17.55	6.84	114.0	8.28
	B74	17.01	6.73	114.9	8.03	17.47	6.70	115.2	8.16
5/21/2013	Huguenot	23.48	7.95	150.1	8.94				
	B168	21.47	7.69	146.7	8.77	21.33	7.57	149.1	8.86
	B166	21.71	7.59	149.3	8.57	21.44	7.47	148.5	8.63
	B157	22.36	7.41	159.3	8.66	21.98	7.58	159.8	8.62
	B150	23.18	7.39	156.7	8.09	22.43	6.74	155.7	8.46
	B138	22.49	7.25	156.5	8.19	22.44	7.28	155.7	8.29
	App1.5	22.44	7.20	145.9	7.98	22.32	7.16	149.6	8.13
	B107	22.54	7.13	154.5	7.86	22.26	7.12	146.9	7.70
	B91	22.49	7.14	147.2	8.27	22.38	7.14	148.2	8.36
	B74	21.55	6.73	123.0	8.25	21.50	6.89	122.6	7.93
5/28/2013	Huguenot	24.50	7.61	171.3	8.31				
	B168	21.08	7.75	169.7	8.06	20.92	7.51	170.0	8.05
	B166	21.74	7.56	173.7	7.87	21.36	7.66	173.8	7.82
	B157	22.52	7.76	177.3	7.84	21.73	7.69	176.5	7.84
	B150	22.95	7.45	187.3	7.72	22.60	7.57	186.6	7.67
	B138	22.94	7.33	188.8	7.64	22.83	7.22	189.4	7.61
	App1.5	23.09	7.50	161.3	7.29	22.46	7.29	159.7	7.55
	B107	22.59	7.38	169.5	7.25	22.19	7.40	168.6	7.77
	B91	21.87	7.26	150.7	7.64	21.91	7.02	151.2	7.53
	B74	21.87	7.25	141.4	6.65	21.91	7.18	141.8	6.82
6/4/2013	Huguenot	27.16	7.98	115.1	7.72				
	B168	26.07	7.78	117.3	6.77	26.25	7.68	117.3	6.79
	B166	26.78	7.96	115.3	7.07	26.75	7.97	115.4	6.99
	B157	27.26	7.75	134.8	6.38	26.99	7.79	135.0	6.58
	B150	30.37	7.57	152.8	5.97	28.98	7.61	150.0	6.04
	B138	27.46	7.51	146.6	6.03	27.38	7.63	146.2	5.94
	App1.5	26.05	7.78	75.4	7.19	26.27	7.07	76.2	7.31
	B107	26.17	7.68	126.1	6.47	26.12	7.53	127.5	6.55
	B91	25.76	7.79	124.7	7.55	25.96	7.76	123.3	7.32
	B74	24.70	7.49	105.0	7.05	24.85	7.40	104.8	6.87
6/18/2013	Huguenot	24.82	7.56	97.3	7.61				
	B168	24.05	7.66	93.6	7.55	24.04	7.35	93.1	7.48
	B166	24.00	7.36	91.9	7.54	23.91	7.54	92.0	7.51
	B157	24.86	7.59	95.4	7.22	24.79	7.49	95.5	7.13
	B150	25.76	7.19	96.7	6.98	25.16	7.31	95.6	7.07
	B138	24.81	7.51	92.5	7.11	24.83	7.27	92.7	6.94
	App1.5	24.91	7.44	88.9	6.84	24.90	7.38	91.1	6.83
	B107	25.04	7.31	88.5	7.00	25.08	7.25	87.9	6.76
	B91	24.96	7.57	95.1	7.21	25.03	7.43	95.1	7.01
	B74	25.16	7.40	87.4	6.27	25.29	7.27	87.5	6.42
6/25/2013	Huguenot	29.02	7.66	101.2	7.26				
	B168	26.89	7.59	99.4	7.30	26.49	7.40	100.1	7.32
	B166	27.62	7.52	104.4	7.09	26.67	7.56	102.1	7.14
	B157	28.10	7.55	119.4	6.97	27.63	7.40	117.4	6.96
	B150	29.57	7.23	124.0	6.84	27.85	7.39	122.0	6.95
	B138	27.52	6.99	120.2	6.90	27.77	7.45	121.0	6.96
	App1.5	27.84	7.39	72.5	6.72	27.46	7.00	73.3	6.70
	B107	27.20	7.43	107.7	6.99	27.02	7.38	107.8	7.02

	B91	26.94	7.31	97.4	7.37	26.94	7.38	96.4	7.17
	B74	26.46	7.64	96.0	6.55	26.37	7.29	95.6	6.59
7/9/2013	Huguenot	27.98	7.85	95.2	7.42				
	B168	25.94	7.63	91.4	7.28	25.94	7.63	91.1	7.20
	B166	25.81	7.52	90.6	7.12	25.75	7.54	90.2	7.18
	B157	26.42	7.55	97.7	6.94	26.27	7.50	97.6	7.02
	B150	29.35	7.44	104.6	6.23	26.82	7.35	94.9	6.86
	B138	27.27	7.33	104.8	6.61	26.76	7.13	100.6	6.69
	App1.5	28.24	7.53	58.5	6.45	28.29	7.24	57.8	6.31
	B107	27.57	7.47	115.4	6.52	27.47	7.40	116.5	6.41
	B91	28.18	7.64	118.5	6.76	28.60	7.55	118.9	6.54
	B74	28.47	7.60	102.2	6.33	28.68	7.13	101.7	6.22
7/16/2013	Huguenot	28.01	7.61	99.5	7.35				
	B168	26.63	7.55	103.8	7.18	26.48	7.51	103.2	7.22
	B166	26.84	7.55	102.4	7.13	26.11	7.46	101.4	7.19
	B157	27.13	7.40	106.7	6.99	26.47	7.29	106.2	7.16
	B150	29.23	7.21	107.3	6.77	26.82	7.31	109.7	6.95
	B138	28.44	7.14	93.2	6.93	26.87	7.24	92.7	7.79
	App1.5	28.21	7.07	47.2	6.61	27.19	7.17	79.7	6.66
	B107	28.55	7.21	80.1	6.80	27.48	7.21	72.6	6.56
	B91	28.02	7.38	78.2	7.00	27.74	6.95	79.0	6.69
	B74	28.17	7.68	104.0	6.59	28.15	7.17	103.6	6.73
7/23/2013	Huguenot	29.43	7.93	120.5	7.01				
	B168	29.13	7.72	121.1	6.66	28.69	7.78	121.7	6.69
	B166	29.86	7.63	122.4	6.54	29.24	7.76	122.6	6.43
	B157	30.24	7.72	150.7	6.61	29.61	7.69	143.4	6.49
	B150	33.32	7.53	136.1	5.54	30.48	7.49	134.8	5.52
	B138	30.85	7.26	87.9	5.78	31.24	7.32	130.2	5.71
	App1.5	29.67	7.65	52.8	5.64	28.80	7.07	51.7	5.65
	B107	29.75	7.60	113.6	5.75	29.82	7.51	113.6	5.69
	B91	29.40	7.54	95.6	5.76	29.25	7.35	96.8	5.77
	B74	29.42	7.30	83.1	4.97	29.38	7.20	83.1	5.16
7/30/2013	Huguenot	27.94	8.06	139.2	7.47				
	B168	27.92	8.02	135.5	6.89	26.93	7.95	135.8	6.75
	B166	28.85	8.26	139.5	7.09	28.71	8.29	140.8	6.78
	B157	27.76	7.89	149.6	6.08	27.68	7.70	150.2	5.82
	B150	29.34	7.81	167.8	6.15	29.29	7.77	168.7	6.12
	B138	29.04	7.83	153.7	6.56	28.96	7.75	155.4	6.30
	App1.5	28.88	7.81	139.4	7.24	28.88	7.74	138.7	6.88
	B107	28.86	7.58	132.5	7.02	28.86	7.66	133.2	6.79
	B91	28.29	7.41	118.4	6.60	28.71	7.38	118.4	6.28
	B74	28.50	7.32	95.2	5.20	28.64	6.98	94.4	5.01
8/13/2013	Huguenot	28.60	7.95	131.1	7.04				
	B168	27.79	7.56	123.2	6.67				
	B166	29.09	7.73	136.0	6.21				
	B157	28.37	7.56	139.0	5.99				
	B150	29.86	7.65	135.6	5.93				
	B138	29.67	7.50	140.1	5.84				
	App1.5	29.51	8.13	148.0	6.45				
	B107	29.18	8.01	150.0	7.37				
	B91	28.58	7.62	143.3	6.89				
	B74	28.30	7.76	128.2	5.93				
8/20/2013	Huguenot	24.79	7.83	107.1	7.68				

	B168	23.33	7.79	153.4	7.59	23.31	7.87	154.4	7.58
	B166	24.86	7.82	154.3	7.51	23.48	7.65	153.4	7.48
	B157	24.99	7.72	159.4	7.05	24.34	7.60	158.5	7.08
	B150	28.51	7.57	160.2	5.84	26.41	7.62	154.7	6.34
	B138	26.02	7.52	152.2	6.29	25.90	7.48	151.8	6.21
	App1.5	24.82	7.48	97.7	6.16	24.65	7.24	96.5	6.18
	B107	25.62	7.60	153.4	5.89	25.78	7.53	153.9	5.74
	B91	24.97	7.62	155.4	6.42	25.03	7.61	155.9	6.58
	B74	25.09	8.11	147.0	6.31	25.29	7.58	147.8	6.19
8/27/2013	Huguenot	26.41	7.92	115.9	7.58				
	B168	25.94	7.98	120.9	7.10	25.28	7.78	122.2	7.01
	B166	26.89	7.95	121.9	7.07	26.63	8.01	122.5	7.08
	B157	26.29	7.73	128.5	6.54	25.89	7.62	130.5	6.53
	B150	27.00	7.75	136.3	6.76	27.16	7.56	137.2	6.59
	B138	26.71	7.51	139.9	6.96	26.74	7.61	140.4	6.55
	App1.5	26.39	7.89	136.5	6.91	26.23	7.65	134.5	6.68
	B107	26.05	7.86	148.9	7.45	26.01	7.65	152.6	7.17
	B91	25.90	7.58	155.7	6.92	26.01	7.64	156.3	6.92
	B74	25.78	8.02	149.6	5.42	26.15	7.69	149.7	5.30
9/10/2013	Huguenot	27.80	8.13	153.7	7.32				
	B168	27.09	8.03	151.8	6.90	26.84	8.02	151.6	6.88
	B166	27.24	7.93	151.9	6.67	26.99	7.92	150.0	6.58
	B157	27.51	7.73	176.4	6.36	26.86	7.70	180.2	6.45
	B150	28.63	7.55	164.2	6.65	28.31	7.58	162.5	6.28
	B138	27.99	7.41	151.9	6.11	28.10	7.52	152.5	6.02
	App1.5	27.48	8.00	148.8	6.21	27.40	7.64	147.8	6.43
	B107	27.22	7.60	157.8	6.91	27.48	7.51	157.3	6.69
	B91	26.96	7.45	153.1	6.57	27.05	7.60	153.1	6.31
	B74	26.57	7.52	164.0	5.37	26.68	7.38	164.1	5.68
9/17/2013	Huguenot	22.93	8.07	228.6	8.92				
	B168	24.35	8.01	250.4	8.31	23.69	8.15	248.8	8.26
	B166	24.40	7.91	247.2	7.86	24.27	7.98	245.7	7.89
	B157	25.06	7.88	281.0	7.46	24.94	7.94	280.7	7.40
	B150	27.60	7.79	302.5	7.48	27.28	7.81	303.6	7.22
	B138	25.73	7.78	281.2	7.75	25.67	7.67	280.6	7.34
	App1.5	23.94	7.79	211.1	8.13	23.71	7.67	224.6	7.90
	B107	24.16	7.68	245.7	7.75	24.00	7.52	246.0	7.67
	B91	23.62	7.51	241.6	7.76	24.07	7.54	241.3	7.78
	B74	23.52	7.29	252.5	6.42	24.95	7.24	255.3	6.62
9/24/2013	Huguenot	21.85	8.44	236.7	9.01				
	B168	22.05	7.92	252.8	8.44	21.82	8.02	252.1	8.56
	B166	22.53	8.02	258.8	8.08	22.28	7.87	258.0	8.13
	B157	22.93	7.94	276.7	8.04	22.48	7.75	275.3	7.99
	B150	24.64	8.03	300.3	8.35	24.61	7.64	301.6	7.95
	B138	23.83	7.99	293.4	7.56	24.07	7.58	294.9	7.94
	App1.5	22.32	7.74	263.4	8.07	22.48	7.77	261.0	8.02
	B107	21.82	7.78	257.4	8.59	21.98	7.86	261.7	8.29
	B91	21.36	7.77	249.7	8.19	22.29	7.64	245.1	7.97
	B74	22.20	7.55	573.4	7.01	22.80	7.67	572.9	6.98
10/8/2013	Huguenot	22.21	8.13	279.7	8.84				
	B168	22.91	7.94	279.4	8.00	22.85	7.73	282.9	7.92
	B166	23.70	7.81	304.2	7.79	23.14	7.90	302.9	8.00
	B157	23.28	7.65	372.9	7.48	22.82	7.74	373.9	7.67

	B150	25.06	7.62	350.4	7.52	24.59	7.83	350.1	7.31
	B138	24.30	7.55	318.1	7.14	24.06	7.62	316.9	7.13
	App1.5	22.61	7.76	274.5	7.41	22.40	7.65	276.1	7.40
	B107	22.98	7.63	300.2	7.49	22.89	7.69	298.2	7.55
	B91	22.82	7.64	306.1	7.52	23.02	7.59	291.2	7.59
	B74	22.19	7.27	1211.0	7.24	22.64	7.40	1210.0	7.07
10/15/2013	Huguenot	19.66	8.22	220.9	9.65				
	B168	19.34	7.90	243.7	9.28	19.11	7.88	244.1	9.14
	B166	18.54	7.69	345.3	9.13	18.38	7.72	276.0	9.08
	B157	18.75	7.72	295.6	8.87	18.52	7.67	291.1	8.86
	B150	19.94	7.47	308.6	7.63	20.59	7.50	308.5	7.94
	B138	19.69	7.50	306.9	7.71	19.56	7.47	310.2	7.89
	App1.5	19.84	7.70	289.7	7.73				
	B107	19.76	7.74	306.1	7.73	19.04	7.67	310.1	8.09
	B91	19.12	7.75	306.2	7.97	19.12	7.60	299.9	7.74
	B74	19.47	7.36	1100.0	6.99	19.18	7.49	1159.0	7.20
10/22/2013	Huguenot	17.77	8.23	253.9	10.11				
	B168	17.93	8.54	259.9	9.31	18.07	8.53	258.3	9.26
	B166	17.90	8.29	254.6	9.05	18.06	8.21	253.7	8.98
	B157	18.49	8.46	277.1	8.67	18.31	8.36	275.1	8.59
	B150	21.52	7.72	301.0	8.20	21.78	7.54	295.0	8.15
	B138	19.85	7.69	297.1	8.10	20.02	7.61	294.6	8.02
	App1.5	18.49	8.62	224.8	8.45	18.63	8.49	224.1	8.36
	B107	18.91	8.10	300.3	8.57	19.03	8.01	300.1	8.19
	B91	18.20	8.06	312.0	8.97	18.58	7.94	304.7	8.75
	B74	18.77	7.63	721.3	7.19	19.01	7.72	706.0	7.67
10/29/2013	Huguenot	13.82	7.38	230.2	10.59				
	B168	13.77	7.57	255.1	10.48	13.52	7.61	259.2	10.42
	B166	13.85	7.52	266.9	10.18	13.63	7.54	271.5	10.14
	B157	14.69	7.32	332.9	9.57	14.31	7.39	335.9	9.66
	B150	17.30	7.10	335.8	9.01	17.35	7.20	332.2	8.94
	B138	16.65	7.83	312.0	9.30	16.83	7.81	309.6	9.22
	App1.5	16.04	7.69	290.7	9.81	16.23	7.66	290.0	9.77
	B107	15.46	7.77	308.0	10.26	15.60	7.74	307.1	10.08
	B91	15.15	7.50	318.3	10.14	15.35	7.58	312.3	10.15
	B74	16.21	7.21	676.9	8.32	16.42	7.49	711.0	8.31
11/12/2013	Huguenot	10.33	7.53	267.2	11.00				
	B168	11.49	7.74	256.3	10.79	11.27	7.75	262.3	10.81
	B166	12.04	7.66	278.9	10.40	11.84	7.76	283.0	10.41
	B157	13.04	7.56	317.1	9.51	12.88	7.67	315.1	9.53
	B150	14.91	7.87	345.9	9.54	14.87	7.69	339.9	9.59
	B138	14.07	7.87	335.5	10.00	14.01	7.71	333.1	10.03
	B107	13.24	8.04	327.0	10.76	13.31	8.14	326.0	10.74
	B91	13.23	7.82	346.1	10.61	13.15	7.99	337.7	10.58
	B74	13.75	7.09	1029.0	9.14	13.75	8.17	1205.0	9.01
11/19/2013	Huguenot	11.26	7.38	274.0	11.28				
	B168	11.57	7.56	290.1	10.64	ND	ND	ND	ND
	B166	11.18	7.47	291.3	10.89	10.96	7.40	286.7	10.94
	B157	10.96	7.73	324.4	10.78	10.52	7.43	324.6	10.90
	B150	16.22	7.45	334.4	9.77	14.07	7.84	327.3	10.14
	B138	13.97	7.52	330.9	10.27	13.29	7.51	328.1	10.24
	B107	12.30	7.94	328.8	11.02	12.17	7.94	326.3	11.02
	B91	11.95	8.18	351.4	11.05	11.77	8.19	339.4	11.02

	B74	12.38	7.43	950.1	9.84	12.16	8.83	1001.0	10.03
11/26/2013	Huguenot	7.48	7.51	273.4	12.04				
	B168	7.43	7.62	282.0	12.14	7.40	7.87	282.1	12.15
	B166	7.90	6.93	285.9	11.63	7.79	8.06	285.6	11.83
	B157	10.06	7.81	315.0	10.72	10.01	6.93	314.1	10.74
	B150	12.22	6.84	359.8	10.53	11.44	8.17	338.1	10.69
	B138	10.66	7.81	334.5	11.04	10.63	7.89	334.1	11.03
	B107	9.02	7.01	335.5	11.33	9.05	7.52	334.9	11.31
	B91	9.61	7.69	365.4	11.02	9.29	7.74	348.1	11.32
	B74	10.20	8.15	1042.0	10.36	10.12	6.75	1346.0	10.51
12/3/2013	Huguenot	6.83	7.35	244.2	12.85				
	B168	4.94	7.41	258.1	13.03	5.07	7.47	260.7	13.05
	B166	6.09	6.97	258.4	12.59	5.43	7.49	260.9	12.86
	B157	4.99	7.12	285.3	12.92	5.21	7.17	285.2	13.22
	B150	8.81	7.08	268.8	11.45	6.69	7.13	280.2	12.33
	B138	7.15	6.88	244.2	12.05	7.19	7.04	244.9	12.11
	B107	6.92	6.95	191.9	11.87	6.99	6.97	191.6	12.20
	B91	7.03	7.23	234.1	11.05	7.12	7.04	230.4	11.17
	B74	7.77	6.94	327.3	10.80	7.88	7.03	330.9	10.59
12/10/2013	Huguenot	6.43	6.98	121.9	12.57				
	B168	6.09	7.05	109.1	12.70	6.03	7.05	108.2	12.63
	B166	6.15	7.07	111.6	12.60	6.21	7.06	122.9	12.60
	B157	6.62	7.07	124.7	12.41	6.53	7.07	124.8	12.44
	B150	7.27	7.14	135.4	12.07	7.18	7.11	134.6	12.12
	B138	7.72	7.16	188.1	11.57	7.77	7.11	184.5	11.66
	B107	7.77	7.00	254.3	11.03	7.64	7.04	254.9	11.02
	B91	7.99	7.13	233.9	10.75	7.94	7.09	233.1	10.89
	B74	8.13	6.89	310.9	10.46	8.04	6.97	314.8	10.49
12/17/2013	Huguenot	6.26	6.63	113.4	13.47				
	B168	5.00	7.18	113.2	13.14	5.11	7.25	113.9	13.13
	B166	4.94	7.09	115.9	13.15	5.06	7.34	116.1	13.15
	B157	5.97	7.12	127.7	12.89	5.67	7.13	126.8	13.01
	B150	8.92	7.02	152.0	11.67	9.39	7.08	152.5	11.56
	B138	6.28	7.16	147.3	12.29	6.51	7.23	146.2	12.40
	B107	6.10	7.61	146.0	12.07	6.13	7.09	148.3	12.16
	B91	5.90	6.96	160.2	12.01	6.02	6.97	157.2	12.08
	B74	5.94	6.89	157.8	11.87	5.78	6.95	157.5	11.73
MEAN		**18.54**		**197.5**	**8.92**	**18.16**		**204.1**	**8.90**
MIN		**4.44**		**47.2**	**4.97**	**5.06**		**51.7**	**5.01**
MAX		**33.32**		**1211.0**	**13.47**	**31.24**		**1346.0**	**13.22**

Appendix A (cont). Summary of weekly water quality measurements for the tidal freshwater James River, Virginia for the period February, 2013 – December, 2015. Water samples were collected along a 94-km reach at nine fixed locations (river channel) and at near-surface and near-bottom depths between the City of Richmond ("Huguenot"), Virginia and the Rice Rivers Center (B74). "App 1.5" is the mouth of the Appomattox River at Hopewell, Virginia. Location numbers are river kilometers. Empty cells mean no data were available. These data are summarized in VCU's Table 5, above.

1/9/2014	Huguenot	2.56	6.91	125.3	14.58				
	B168	1.68	6.96	120.8	14.26	1.92	6.07	122.7	14.33
	B166	1.70	6.44	119.8	14.18	1.82	6.94	123.9	14.17
	B157	2.54	7.29	128.9	13.86	2.45	6.00	128.7	13.90
	B150	3.78	4.63	144.9	13.27	3.79	7.33	144.3	13.29
	B138	3.29	6.90	142.7	13.21	3.42	7.07	142.5	13.27
	B107	3.64	6.94	131.5	12.47	3.66	7.13	132.3	12.52
	B91	3.51	8.20	121.7	12.54	3.44	7.34	121.8	12.59
	B74	4.00	6.03	123.7	12.24	3.94	7.17	123.6	12.11
1/16/2014	Huguenot	6.93	7.20	125.1	13.01				
	B168	5.86	6.81	133.7	12.90	5.87	6.81	129.0	12.94
	B166	5.75	7.47	129.8	12.81	5.82	7.26	128.9	12.87
	B157	5.83	7.33	137.0	12.68	5.81	7.34	136.9	12.76
	B150	6.82	7.26	139.7	12.33	6.37	7.36	138.1	12.93
	B138	6.20	6.66	134.6	12.45	6.32	7.23	135.3	12.45
	B107	5.74	6.61	108.1	12.59	5.57	7.05	98.3	12.55
	B91	5.50	6.69	101.5	12.49	5.56	6.00	101.6	12.49
	B74	5.70	6.79	105.5	12.51	5.51	6.17	102.1	12.44
1/21/2014	Huguenot	4.82	7.63	128.0	13.72				
	B168	4.25	7.66	128.4	13.26	4.36	7.38	132.1	13.23
	B166	4.39	7.57	131.3	13.18	4.25	7.85	131.3	13.23
	B157	5.19	7.73	138.0	12.93	5.18	7.70	138.5	12.89
	B150	5.36	7.93	140.5	12.84	5.14	7.55	140.5	12.89
	B138	5.99	7.16	139.0	12.56	5.91	7.33	139.6	12.49
	B107	5.90	7.56	147.9	12.20	5.68	7.26	142.0	12.32
	B91	5.65	6.91	118.9	12.14	5.62	7.17	119.4	12.16
	B74	5.80	7.90	108.2	12.09	5.54	7.59	108.3	12.14
1/28/2014	Huguenot	0.50	7.14	136.6	14.80				
	B168								
	B166	1.12	6.99	163.8	14.22				
	B157	0.68	8.80	159.7	14.30				
	B150	2.17	7.72	163.2	13.72				
	B138	2.31	6.63	160.9	13.61				
	B107	1.39	7.68	149.3	13.44				
	B91	1.25	7.43	133.2	13.45				
	B74	2.14	6.28	119.2	12.92	1.70	7.68	118.8	13.32
2/11/2014	Huguenot	3.90	7.09	121.0	14.03				
	B168	3.43	8.05	119.6	13.62	3.36	8.04	120.9	13.72
	B166	3.62	7.60	121.1	13.59	3.40	8.07	121.0	13.54
	B157	4.10	7.48	131.9	13.23	3.87	8.36	131.6	13.35
	B150	5.50	8.47	134.5	12.72	5.71	7.92	135.5	12.75
	B138	4.54	8.23	131.5	12.97	4.36	7.40	131.8	13.09
	B107	4.59	7.93	118.8	12.75	4.37	7.91	118.7	12.86

	B91	4.36	6.95	124.4	12.62	4.31	6.69	123.9	12.78
	B74	4.25	7.60	155.3	12.54	4.23	7.69	153.6	12.66
2/18/2014	Huguenot	5.15	7.43	135.1	13.70				
	B168	4.36	8.19	140.6	13.12	4.55	8.44	140.5	13.00
	B166	4.88	8.26	141.3	12.73	5.30	8.33	140.3	12.64
	B157	3.86	7.77	156.1	13.30	4.27	8.12	154.6	13.16
	B150	6.73	7.78	168.5	12.27	5.20	7.72	163.9	12.90
	B138	4.43	7.78	168.9	13.01	4.78	7.71	165.0	13.06
	B107	3.98	7.34	159.9	12.91	4.07	7.39	155.4	12.90
	B91	4.05	7.69	177.9	12.84	4.06	7.43	180.3	12.79
	B74	4.17	6.10	144.4	12.59	3.95	6.03	143.1	12.55
2/25/2014	Huguenot	7.54	7.15	103.5	12.04				
	B168	6.83	7.61	112.7	12.27	6.67	8.02	112.4	12.16
	B166	6.78	7.71	116.9	12.19	6.80	7.83	117.1	12.16
	B157	7.02	7.80	126.9	12.07	7.01	8.02	128.3	12.08
	B150	7.63	7.53	136.3	11.88	7.35	7.54	134.1	11.89
	B138	7.57	8.35	139.3	11.70	7.73	7.93	138.9	11.69
	B107	7.38	8.07	142.4	11.78	7.38	7.56	142.8	11.79
	B91	7.75	8.55	151.9	11.68	7.67	8.69	152.5	11.61
	B74	8.34	8.17	148.1	11.47	8.12	7.83	146.3	11.47
3/11/2014	Huguenot	10.94	7.50	141.9	12.56				
	B168	8.23	7.29	143.0	11.99	8.08	7.61	144.3	12.15
	B166	8.10	7.61	143.5	12.12	7.69	7.41	144.4	12.50
	B157	8.05	8.57	154.3	12.19	7.66	8.68	153.3	12.25
	B150	9.26	7.53	165.1	11.89	8.65	7.14	160.9	11.93
	B138	8.08	8.65	159.9	12.34	7.67	7.83	160.4	12.26
	B107	8.60	8.82	164.1	12.20	8.23	7.57	160.9	12.26
	B91	7.40	8.27	171.7	12.46	7.44	7.66	172.3	12.43
	B74	7.14	6.90	152.4	12.57	6.57	7.22	151.2	12.46
3/18/2014	Huguenot	6.86	7.88	156.7	12.98				
	B168	6.33	7.35	159.1	12.54	6.31	7.68	170.0	12.51
	B166	6.54	7.65	165.2	12.42	6.39	7.71	171.2	12.34
	B157	7.36	7.62	192.3	12.03	7.28	7.29	186.8	12.12
	B150	8.15	7.61	182.6	11.53	7.79	7.63	181.7	11.60
	B138	7.87	7.49	175.1	11.62	8.11	7.61	176.0	11.50
	B107	7.91	7.55	163.7	11.46	6.95	7.54	163.4	11.86
	B91	7.59	7.17	161.5	11.55	7.66	7.53	161.2	11.50
	B74	7.70	7.31	167.7	11.61	7.23	7.69	166.5	11.76
3/25/2014	Huguenot	9.42	7.68	165.1	12.43				
	B168	8.63	8.18	159.2	11.89	8.69	7.87	161.1	11.85
	B166	8.73	9.07	161.5	11.80	8.51	8.37	162.1	11.94
	B157	10.01	8.70	175.9	11.56	9.92	7.09	176.9	11.58
	B150	9.40	8.72	179.0	11.42	9.19	7.89	174.4	11.37
	B138	9.79	8.74	172.3	11.20	9.66	8.73	172.1	11.25
	B107	9.23	9.54	170.0	11.63	8.99	8.31	169.7	11.55
	B91	9.33	9.49	175.8	11.57	9.14	8.34	176.7	11.60
	B74	8.93	8.61	165.8	11.54	8.82	8.24	166.2	11.46
4/8/2014	Huguenot	13.79	7.34	128.4	10.91				
	B168	13.94	7.54	134.5	10.28	13.91	7.60	134.1	10.29
	B166	13.92	7.75	136.4	10.26	13.81	7.43	135.1	10.27
	B157	14.22	7.63	150.1	10.04	14.04	8.07	148.8	10.08
	B150	15.19	7.61	142.8	9.74	14.49	8.11	149.9	9.82
	B138	15.06	7.54	143.4	9.91	14.54	8.16	143.3	9.81

	B107	15.08	7.71	148.4	10.04	15.07	7.54	158.2	9.94
	B91	14.95	7.51	161.1	10.27	14.90	7.48	169.3	10.11
	B74	14.74	7.51	161.8	10.39	14.66	7.26	162.5	10.31
4/16/2014	Huguenot	15.90	7.41	128.5	9.80				
	B168	16.34	7.77	130.8	10.01	16.06	7.15	131.3	10.07
	B166	15.77	7.88	133.1	9.94	15.61	7.70	133.2	9.96
	B157	16.45	8.90	150.4	9.40	16.03	7.61	151.0	9.48
	B150	17.51	7.62	153.4	8.99	17.24	7.51	155.4	9.05
	B138	16.67	7.86	158.6	9.05	16.92	6.99	158.3	9.01
	B107	16.02	8.56	150.9	9.39	16.08	7.73	147.7	9.26
	B91	16.67	7.61	148.1	9.52	15.77	7.51	148.0	9.65
	B74	16.82	7.37	135.1	9.52	16.74	7.21	134.4	9.51
4/22/2014	Huguenot	17.71	7.71	126.5	10.61				
	B168	15.77	7.44	123.8	10.07	15.53	7.68	125.7	10.09
	B166	15.65	7.71	125.2	10.05	15.03	7.77	124.7	10.00
	B157	16.63	7.91	135.7	9.91	16.11	7.54	134.9	9.84
	B150	16.13	7.58	141.2	10.06	15.35	7.47	141.0	10.07
	B138	16.46	7.85	146.7	10.01	15.59	7.67	146.7	9.95
	B107	16.64	8.56	133.8	10.47	15.77	7.69	135.4	10.14
	B91	15.94	7.66	129.7	10.98	15.54	7.19	128.8	10.01
	B74	16.25	7.66	148.4	9.22	16.31	7.40	147.7	9.29
4/29/2014	Huguenot	16.18	7.63	141.2	10.25				
	B168	16.02	7.53	138.7	9.78	15.85	7.54	140.0	9.83
	B166	16.48	7.48	140.3	9.55	16.29	7.39	140.1	9.64
	B157	17.04	7.44	162.5	9.27	17.00	7.44	162.1	9.24
	B150	17.35	7.42	166.7	8.91	16.90	7.44	167.0	9.02
	B138	17.37	7.39	166.3	8.70	17.57	7.40	168.1	8.88
	B107	16.96	7.48	145.4	8.86	16.93	7.49	144.8	8.99
	B91	17.29	7.44	144.2	9.25	17.14	7.45	145.2	9.33
5/6/2014	Huguenot	18.29	7.48	110.4	10.03				
	B168	17.34	7.35	108.1	9.70	17.30	7.17	109.1	9.70
	B166	17.41	7.46	108.6	9.56	17.14	7.18	107.8	9.56
	B157	17.28	7.26	114.4	9.42	17.16	7.34	115.3	9.43
	B150	17.87	7.20	114.3	9.31	17.56	7.10	114.4	9.31
	B138	17.74	7.50	112.4	9.00	17.86	7.01	113.0	9.13
	B107	18.03	7.21	94.2	8.83	17.71	6.90	93.3	8.86
	B91	17.62	6.99	101.0	8.66	17.62	6.83	102.0	8.54
	B74	17.35	7.31	100.4	8.16	17.32	6.85	99.8	8.16
5/15/2014	Huguenot	24.68	7.87	146.8	8.80				
	B168	23.58	7.60	145.5	8.58	23.55	7.67	145.5	8.61
	B166	24.08	7.62	147.1	8.24	23.80	7.64	146.4	8.24
	B157	24.47	7.54	171.9	8.20	24.31	7.56	173.0	8.05
	B150	24.96	7.50	167.4	7.87	24.45	7.50	167.1	7.70
	B138	25.11	7.48	168.1	7.67	24.78	7.48	166.8	7.61
	B107	24.95	7.44	154.3	8.02	24.64	7.35	154.7	7.90
	B91	24.49	7.40	148.6	8.52	24.34	7.42	142.0	8.40
	B74	23.46	7.56	113.2	7.56	22.83	7.39	213.2	7.98
5/20/2014	Huguenot	18.78	7.48	90.4	9.52				
	B168	17.86	7.55	89.0	9.74	17.77	7.21	89.4	9.74
	B166	17.83	7.33	90.0	9.71	17.71	7.27	89.2	9.79
	B157	18.07	7.17	95.0	9.53	17.64	7.38	95.2	9.90
	B150	18.18	7.65	98.6	9.35	17.93	7.23	98.2	9.35
	B138	18.35	7.40	102.7	9.19	18.34	7.33	102.9	9.22

	B107	19.41	7.47	116.5	8.50	19.28	7.19	116.9	8.56
	B91	20.37	6.79	112.2	7.95	19.89	7.38	110.4	8.05
	B74	20.14	6.90	81.8	7.27	20.02	7.37	81.3	7.48
5/27/2014	Huguenot	25.93	7.84	135.0	8.63				
	B168	23.53	7.64	131.5	8.46	23.24	7.66	134.4	8.50
	B166	24.19	7.36	134.0	8.19	24.39	7.67	133.2	8.27
	B157	25.31	7.59	152.7	8.39	24.00	7.34	154.8	8.37
	B150	26.62	7.46	154.7	7.77	23.59	7.63	150.0	8.25
	B138	24.38	7.12	149.8	8.07	24.27	7.12	151.6	8.07
	B107	24.06	7.14	134.6	8.33	23.59	7.29	133.3	8.17
	B91	24.09	7.13	115.2	8.46	23.67	6.74	115.1	8.43
	B74	23.35	7.27	100.6	7.61	23.27	7.18	100.2	7.51
6/3/2014	Huguenot	25.70	8.15	156.2	8.98				
	B168	23.78	7.88	148.2	8.50	23.06	8.00	150.3	8.56
	B166	24.87	7.99	149.5	8.64	24.42	8.20	150.1	8.14
	B157	23.54	7.68	174.2	9.41	23.09	8.04	170.5	8.97
	B150	25.81	7.77	170.1	9.86	24.73	7.91	171.4	9.02
	B138	24.60	7.67	167.0	8.63	24.59	7.51	166.5	8.49
	B107	24.67	7.55	155.6	9.40	24.23	7.81	159.0	8.88
	B91	24.24	7.34	139.9	8.92	24.04	7.51	140.2	8.52
	B74	23.50	7.96	108.5	7.54	23.54	7.84	107.8	7.09
6/10/2014	Huguenot	27.44	8.24	187.1	8.62				
	B168	26.88	8.22	193.2	7.68	26.72	8.04	194.0	7.74
	B166	27.60	8.18	190.7	7.74	27.44	8.40	191.9	7.59
	B157	27.27	7.88	207.8	7.73	26.57	7.89	204.4	7.61
	B150	31.57	7.83	214.0	7.19	28.25	7.90	202.8	7.45
	B138	28.52	7.83	210.2	7.39	28.37	7.83	209.3	6.99
	B107	27.63	8.13	190.7	7.82	27.26	7.92	192.7	7.75
	B91	27.30	8.02	175.4	9.28	27.19	8.09	175.7	9.02
	B74	26.04	7.86	149.2	8.55	25.94	7.84	146.9	8.40
6/17/2014	Huguenot	29.26	7.68	162.1	8.48				
	B168	28.28	7.43	175.0	7.45	27.75	7.41	174.0	7.48
	B166	30.40	7.44	167.3	7.50	28.68	7.58	170.6	7.48
	B157	28.84	7.28	195.9	7.46	28.05	7.34	197.0	7.14
	B150	30.45	7.23	192.2	7.28	29.88	7.22	192.1	7.25
	B138	29.39	7.47	191.8	7.10	29.38	7.31	191.7	6.98
	B107	29.62	7.92	192.5	9.41	28.87	7.83	195.6	8.58
	B91	28.78	7.79	187.2	10.37	28.07	8.08	189.8	9.19
	B74	27.60	7.52	163.7	8.18	27.60	7.47	162.9	8.07
6/24/2014	Huguenot	28.08	7.73	189.9	8.47				
	B168	26.62	7.53	194.9	7.98	26.17	7.51	196.2	8.00
	B166	28.27	7.50	191.3	7.64	27.51	7.59	191.8	7.52
	B157	28.43	7.36	217.2	7.41	27.76	7.37	223.6	7.35
	B150	32.14	7.39	230.6	7.11	29.34	7.40	222.9	6.87
	B138	30.24	7.63	221.9	7.41	29.74	7.49	221.9	6.95
	B107	28.78	8.27	196.8	8.50	28.75	7.89	195.7	8.20
	B91	28.33	7.68	197.4	9.43	27.83	7.85	198.9	8.03
	B74	27.75	7.67	185.2	7.34	28.15	7.48	182.1	6.86
7/1/2014	Huguenot	29.05	7.72	171.5	8.27				
	B168	28.99	7.62	191.6	7.14	28.70	7.62	192.2	7.22
	B166	29.21	7.64	189.6	7.82	28.44	7.69	187.2	7.77
	B157	29.20	7.45	211.1	7.26	29.17	7.48	210.0	7.16
	B150	30.82	7.40	234.6	7.10	30.61	7.42	235.7	7.10

	B138	30.10	7.48	236.5	7.13	30.09	7.43	236.7	7.11
	App1.5	29.37	7.73	223.7	7.79	29.18	7.64	223.6	7.66
	B107	28.97	7.66	223.8	8.10	28.98	7.79	224.5	7.96
	B91	28.67	7.40	204.0	7.46	28.39	7.51	206.7	7.18
	B74	28.22	7.84	191.3	6.89	28.26	7.55	191.4	6.98
7/8/2014	Huguenot	28.98	8.01	204.3	8.18				
	B168	29.13	7.78	196.8	7.33	28.72	7.78	195.6	7.21
	B166	28.75	7.61	272.6	7.81	27.87	7.69	210.1	7.68
	B157	29.51	7.62	233.8	7.55	28.45	7.69	235.6	7.28
	B150	30.94	7.67	247.6	6.94	30.17	7.63	248.0	6.80
	B138	29.87	7.86	247.9	7.49	29.84	7.77	248.7	7.05
	App1.5	29.90	8.02	239.6	8.85	28.81	7.96	252.3	7.78
	B107	28.54	7.74	253.1	7.69	27.89	7.82	253.4	7.36
	B91	28.08	7.50	222.7	7.38	27.51	7.52	221.9	7.12
	B74	28.29	7.59	203.1	7.72	28.08	8.12	201.7	7.67
7/15/2014	Huguenot	30.22	7.85	208.6	7.94				
	B168	30.46	7.78	244.9	7.06	30.45	7.86	247.8	7.08
	B166	29.85	7.59	242.2	6.98	29.48	7.69	241.1	6.81
	B157	29.84	7.49	290.4	7.35	29.39	7.59	289.0	7.02
	B150	31.81	7.49	287.4	7.21	31.29	7.53	285.4	6.88
	B138	30.54	7.47	270.5	7.08	30.52	7.51	270.5	6.94
	App1.5	29.88	7.57	256.2	6.92	29.94	7.56	255.7	6.95
	B107	29.12	7.69	255.9	7.38	29.04	7.66	256.0	7.09
	B91	28.89	7.48	236.4	7.45	28.66	7.63	236.9	7.51
	B74	28.08	7.40	274.9	6.83	28.40	7.34	270.9	6.92
7/22/2014	Huguenot	28.44	7.92	243.5	8.65				
	B168	28.06	7.70	246.4	7.75	27.35	7.67	242.4	7.67
	B166	28.41	7.44	413.1	7.69	27.70	7.66	262.1	7.36
	B157	30.16	7.51	295.9	7.66	28.43	7.59	288.8	6.95
	B150	30.55	7.51	305.6	7.37	29.86	7.56	304.1	6.84
	B138	29.18	7.85	289.6	7.67	29.05	7.64	290.1	7.12
	App1.5	28.87	7.91	275.6	8.92	28.69	7.97	278.3	8.89
	B107	27.96	7.58	276.4	7.89	27.81	7.65	277.1	7.39
	B91	28.29	7.44	250.6	7.78	27.50	7.57	252.4	6.94
	B74	27.84	7.59	341.7	7.22	27.73	7.45	359.4	6.32
7/29/2014	Huguenot	27.47	7.50	307.2	7.16				
	B168	27.48	7.66	237.0	7.26	26.99	7.64	232.8	7.36
	B166	27.93	7.57	247.0	7.32	27.53	7.48	247.9	7.28
	B157	28.54	7.46	291.2	7.00	27.17	7.52	285.5	6.82
	B150	30.68	7.44	304.1	6.92	29.13	7.47	298.9	6.76
	B138	29.02	7.40	303.1	7.37	28.33	7.53	304.3	7.02
	App1.5	27.42	7.89	202.4	8.15	27.15	7.69	195.1	7.99
	B107	27.32	7.95	285.7	8.05	27.11	7.93	285.2	7.95
	B91	26.99	7.69	273.5	7.81	26.73	7.94	274.0	7.83
	B74	27.31	7.94	282.6	7.23	27.13	7.67	283.6	6.97
8/5/2014	Huguenot	27.70	8.25	269.0	8.58				
	B168	28.69	7.93	255.9	7.81	27.20	8.00	257.7	7.59
	B166	27.59	7.75	254.7	7.78	26.57	7.77	256.1	7.33
	B157	29.72	8.06	319.0	8.60	26.74	7.88	326.8	7.09
	B150	29.15	8.11	310.5	8.62	28.81	8.05	313.2	7.37
	B138	28.01	8.27	292.7	9.81	28.12	8.14	293.6	8.16
	App1.5	28.15	8.35	270.3	10.59	26.46	8.31	276.8	8.71
	B107	28.48	8.57	285.2	10.50	27.05	8.42	283.9	8.68

	B91	26.29	7.68	264.9	8.51				
	B74	26.31	7.19	340.1	7.55				
8/12/2014	Huguenot	26.73	7.95	277.2	8.15				
	B168	27.10	7.71	301.7	7.88	27.02	7.80	302.2	7.85
	B166	27.68	7.56	300.2	7.66	27.22	7.72	299.1	7.59
	B157	27.89	7.46	388.1	7.29	27.74	7.50	388.1	7.35
	B150	30.94	7.43	366.5	7.09	29.74	7.48	368.7	7.03
	B138	28.84	7.37	332.7	7.44	28.88	7.41	333.5	7.44
	App1.5	27.42	7.56	261.7	7.35	27.36	7.18	261.4	7.42
	B107	27.61	7.54	306.1	7.66	27.50	7.55	305.2	7.52
	B91	27.26	6.92	299.2	7.42	27.16	6.99	290.6	7.35
	B74	27.11	6.84	531.1	6.40	27.16	6.68	527.7	6.50
8/19/2014	Huguenot	27.63	7.94	255.8	8.38				
	B168	27.25	7.67	259.7	7.84	26.46	7.77	253.5	7.81
	B166	27.39	7.62	269.3	7.52	26.85	7.63	307.1	7.47
	B157	27.63	7.50	311.4	7.20	27.18	7.53	310.1	7.09
	B150	29.02	7.31	348.8	6.96	28.86	7.52	356.8	6.84
	B138	28.36	7.49	349.2	7.03	28.26	7.51	350.2	6.79
	App1.5	27.82	7.52	330.4	7.43	27.67	7.54	331.7	6.95
	B107	27.58	7.39	328.7	7.08	27.29	7.54	326.8	6.69
	B91	27.08	7.51	316.0	6.42	26.96	7.45	308.9	7.00
	B74	26.84	7.23	762.9	6.62	26.91	7.29	774.6	6.44
8/26/2014	Huguenot	26.98	8.15	216.9	8.97				
	B157	27.48	7.77	306.6					
	B150	31.13	7.93	321.9	8.01	27.92	7.77	303.1	7.41
	B138	29.20	8.06	328.4	8.32	28.36	7.98	334.2	7.54
	App1.5	27.41	7.98	328.4		28.01	8.37	279.1	
	B107	27.09	8.14	332.9		26.95	8.13	335.1	
	B91	26.97	8.41	339.9					
	B74	25.91	7.65	545.3	7.47	26.40	7.41	682.3	7.13
9/2/2014	Huguenot	30.15	8.14	260.9	8.26				
	B168	29.82	7.66	275.2	7.74	29.65	7.94	278.1	7.61
	B166	29.78	7.40	281.9	7.74	28.96	7.79	274.6	7.14
	B157	29.39	7.55	316.4	7.70	28.22	7.68	316.9	6.89
	B150	31.34	7.40	318.6	8.03	30.40	7.53	320.3	6.82
	B138	30.23	7.58	320.5	7.37	29.74	7.69	322.9	7.16
	App1.5	29.18	7.71	315.2	8.19	28.84	7.79	317.7	7.36
	B107	29.56	7.80	343.9	9.42	28.49	8.02	346.8	6.78
	B91	28.45	7.75	355.0	8.51	27.89	7.84	346.0	6.81
	B74	28.13	7.54	799.1	7.21	27.68	7.59	821.5	6.23
9/9/2014	Huguenot	26.33	8.05	254.7	8.27				
	B91	26.01	7.86	389.7	6.50				
	B74	26.33	7.23	1285.0	5.50				
9/16/2014	Huguenot	24.68	8.30	247.0	9.60				
	B168	24.78	8.12	252.0	8.58	24.66	8.25	255.0	8.61
	B166	25.25	7.85	276.0	8.12	24.00	7.96	249.0	8.66
	B157	26.06	7.80	291.0	7.64	25.25	7.85	290.0	7.66
	B150	28.16	8.01	323.0	8.65	26.64	7.93	327.0	7.76
	B138	27.01	8.16	323.0	9.36	25.94	7.99	324.0	7.84
	App1.5	25.43	8.18	322.0	9.73	24.75	7.99	321.0	8.19
	B107	25.34	8.16	342.0	8.93	24.50	7.97	350.0	8.97
	B91	26.10	7.89	424.0	8.36	24.82	7.83	401.0	7.50
	B74	25.38	7.38	1785.0	5.96	25.26	7.45	1859.0	6.69

9/23/2014	Huguenot	22.82	8.29	275.0	8.57				
	B168	23.33	8.04	285.0	8.22	23.04	8.13	286.0	8.50
	B166	23.41	7.97	282.0	7.87	22.86	8.03	283.0	8.32
	B157	23.64	7.92	302.0	7.66	23.30	7.88	301.0	7.97
	B150	26.70	8.16	312.0	8.36	25.74	8.09	312.0	8.07
	B138	24.87	7.95	319.0	8.41	24.54	8.01	320.0	8.29
	App1.5	23.27	7.95	285.0	8.63	22.65	7.94	295.0	8.66
	B107	23.27	8.01	333.0	8.52	22.89	7.98	334.0	8.25
	B91	23.46	7.98	405.0	8.52	23.05	8.00	386.0	8.56
	B74	23.75	7.50	1442.0	6.25	23.59	7.53	1531.0	6.83
9/30/2014	Huguenot	23.07	8.43	278.0	9.25				
	B157	22.97	7.78	352.0	7.86	22.12	7.80	352.0	7.77
	B150	24.33	7.82	342.0	8.01	24.02	7.76	343.0	7.79
	B138	23.79	7.75	328.0	7.82	23.79	7.78	329.0	7.77
	App1.5	22.45	7.73	292.0	8.19	22.11	7.74	289.0	8.29
	B107	22.57	7.77	360.0	8.35	22.52	7.80	358.0	8.04
	B91	22.22	7.75	520.0	8.26	22.09	7.77	480.0	8.03
	B74	22.45	6.87	1801.0	6.33	22.49	7.11	1807.0	6.21
10/14/2014	Huguenot	20.40	8.16	290.0	9.57				
	B168	20.72	8.13	274.0	8.89	20.66	8.23	274.0	8.90
	B166	19.92	8.00	284.0	8.82	19.76	8.06	280.0	8.90
	B157	20.41	7.91	328.0	8.16	20.20	7.88	325.0	8.41
	B150	23.71	7.80	369.0	7.66	23.69	7.87	369.0	7.92
	B138	22.25	7.88	380.0	7.75	22.30	7.80	380.0	7.66
	B107	21.04	8.05	411.0	9.11	20.97	8.11	390.0	9.09
	B91	20.70	8.03	648.0	9.00	20.58	8.00	594.0	8.45
	B74	20.77	7.69	2356.0	7.39	20.78	7.61	2384.0	7.12
10/21/2014	Huguenot	17.74	8.08	274	9.87				
	B168	17.41	8.08	288	9.51	17.32	8.03	288	9.48
	B166	18.26	7.97	282	9.42	17.85	8.10	283	9.35
	B157	18.33	7.87	304	9.16	17.22	7.93	303	9.24
	B150	21.80	7.83	285	8.46	19.54	7.89	288	8.63
	B138	19.47	7.83	264	8.67	19.51	7.80	265	8.51
	B107	18.46	8.13	294	9.11	18.33	8.01	287	9.06
	B91	18.81	8.11	297	9.53	18.47	8.22	367	9.43
	B74	19.38	7.85	696	8.48	19.34	7.87	725	8.03
10/28/2014	Huguenot	17.16	8.16	160	10.15				
	B168	17.05	7.79	185	9.60	16.62	7.91	184.0	9.52
	B166	16.52	7.85	189	9.44	16.00	7.90	181.0	9.56
	B157	17.09	7.78	279	9.32	16.79	7.78	279.0	9.35
	B150	18.05	7.80	310	9.02	17.78	7.78	308.0	9.03
	B138	18.30	7.92	316	9.11	18.55	7.89	317.0	9.03
	B107	17.19	8.12	290	10.10	17.50	8.12	289.0	9.79
	B91	17.35	8.03	336	10.03	17.01	8.14	320.0	9.96
	B74	17.95	7.35	737	8.07	17.78	7.56	742.0	8.00
11/11/2014	Huguenot	12.84	8.09	233.0	11.09				
	B168	13.62	8.02	229.0	10.90	13.05	8.10	229.0	10.39
	B166	12.76	7.89	225.0	10.31	12.57	8.02	223.0	10.29
	B157	13.26	7.83	272.0	9.75	12.84	7.81	271.0	9.81
	B150	17.19	7.84	287.0	9.23	15.87	7.87	283.0	9.44
	B138	14.66	7.91	286.0	9.83	14.73	7.90	285.0	9.74
	B107	13.14	7.96	308.0	10.34	13.21	8.01	305.0	10.35
	B91	12.86	7.88	395.0	9.88	12.70	7.90	345.0	10.07

	B74	13.84	7.73	1217.0	8.70	13.52	7.67	1356.0	9.26
11/18/2014	Huguenot	7.94	8.05	231	11.95				
	B168	9.67	7.86	227	10.98	9.38	7.79	223	10.61
	B166	9.84	7.84	251	10.70	9.35	7.84	318	11.06
	B157	10.59	7.84	313	10.06	10.18	7.80	314	10.29
	B150	13.34	7.85	302	9.79	13.69	7.85	302	9.88
	B138	12.19	7.99	294	10.26	12.11	7.96	295	10.13
	B107	10.36	8.01	318	11.27				
	B91	10.42	8.06	358	10.60				
11/25/2014	Huguenot	8.66	8.04	258	11.92				
	B168	9.69	7.88	266	11.12	9.87	8.65	266.0	11.02
	B166	8.98	7.76	268	11.52	8.99	7.92	266.0	11.44
	B157	7.96	7.91	172	11.50	7.48	7.88	312.0	11.68
	B150	13.42	7.82	317	10.24	11.78	7.88	281.0	10.62
	B138	12.08	7.89	168	10.53	12.13	7.88	318.0	10.43
	B107	11.30	7.97	298	10.91	11.34	7.94	298.0	10.84
	B91	10.51	8.15	333	11.40	10.37	8.12	322.0	11.38
	B74	11.89	7.80	1027	9.73	10.85	7.82	1075.0	10.00
12/2/2014	Huguenot	7.45	7.87	211.0	12.11				
	B168	7.32	7.75	214.0	11.84	7.28	7.74	216.0	11.90
	B166	7.82	7.58	214.0	11.68	7.69	7.69	217.0	11.70
	B157	7.45	7.55	213.0	11.70	7.10	7.59	215.0	11.81
	B150	8.94	7.52	205.0	11.25	8.67	7.55	198.0	11.31
	B138	8.94	7.68	208.0	10.96	8.21	7.69	203.0	11.41
	B107	9.65	7.65	252.0	10.85	9.54	7.62	250.0	10.88
	B91	9.23	7.90	324.0	11.13	8.96	7.85	282.0	11.24
	B74	10.12	7.88	846.0	10.43	9.35	7.77	1006.0	10.46
12/9/2014	Huguenot	6.49	7.82	143	12.32				
	B168	6.27	7.75	163	12.09	6.19	7.75	163	12.08
	B166	6.49	7.72	171	11.98	6.34	7.74	171	12.00
	B157	6.98	7.68	179	11.87	9.60	7.73	179	11.92
	B150	11.17	7.48	189	10.46	8.02	7.69	185	10.99
	B138	7.79	7.46	187	11.19	7.28	7.55	185	11.35
	B107	7.92	7.41	204	11.00	7.83	7.44	201	11.06
	B91	8.07	7.45	236	10.62	7.69	7.44	234	10.88
	B74	9.31	7.72	309	10.20	8.40	7.59	311	10.38
12/16/2014	Huguenot	6.44	7.75	136	12.31				
	B168	5.78	7.69	139	11.97	5.66	7.62	139.0	12.09
	B166	6.56	7.58	137	11.94	6.51	7.68	138.0	11.94
	B157	6.64	7.55	147	11.71	6.37	7.58	146.0	11.76
	B150	8.11	7.44	161	11.15	7.94	7.44	151.0	11.19
	B138	7.53	7.44	156	10.63	7.57	7.41	154.0	11.06
	B107	7.43	7.44	191	10.53	7.45	7.43	191.0	10.63
	B91	7.24	7.56	216	10.61	7.18	7.56	212.0	10.76
	B74	8.51	7.89	278	10.14	7.70	7.80	275.0	10.24
MEAN		**18.34**		**243**	**9.66**	**18.24**		**249.1**	**9.41**
MIN		**0.50**		**82**	**5.50**	**1.70**		**81.3**	**6.21**
MAX		**32.14**		**2356**	**14.80**	**31.29**		**2384.0**	**14.33**

Appendix A (cont.). Summary of weekly water quality measurements for the tidal freshwater James River, Virginia for the period February, 2013 – December, 2015. Water samples were collected along a 94-km reach at nine fixed locations (river channel) and at near-surface and near-bottom depths between the City of Richmond ("Huguenot"), Virginia and the Rice Rivers Center (B74). "App 1.5" is the mouth of the Appomattox River at Hopewell, Virginia. Location numbers are river kilometers. Empty cells mean no data were available. These data are summarized in VCU's Table 5, above.

1/6/2015	Huguenot	6.17	8.10	147	12.91				
	B166	6.25	7.78	160	12.19	6.17	7.74	159.0	12.15
	B157	7.18	7.70	181	11.71	6.70	7.73	180.0	11.82
	B150	10.80	7.48	204	10.80	8.30	7.70	199.0	11.36
	B138	7.93	7.32	190	11.28	7.93	7.42	195.0	11.55
	B107	7.74	7.32	167	11.10	7.70	7.33	167.0	11.16
	B91	8.24	7.45	157	10.80	7.79	7.48	158.0	10.97
	B74	8.84	8.95	170	10.72	7.91	8.17	169.0	10.93
1/13/2015	Huguenot	2.70	8.09	180	14.04				
	B168	2.35	7.90	182	13.47	2.32	7.82	183.0	13.45
	B166	2.12	7.83	180	13.67	2.25	7.85	178.0	13.61
	B157	2.71	7.78	198	13.41	2.33	7.86	199.0	13.73
	B150	4.98	7.62	192	12.47	4.99	7.68	192.0	12.60
	B138	4.70	7.32	177	12.13	4.84	7.49	178.0	12.22
	B107	4.12	7.21	187	11.83	4.08	7.35	188.0	11.77
	B91	3.91	7.21	169	12.14	3.85	7.24	177.0	12.09
	B74	6.22	7.80	174	11.15	5.43	7.37	171.0	11.36
1/20/2015	Huguenot	5.38	7.92	150	13.43				
	B168	4.95	7.59	144	12.53	4.27	7.57	147.0	12.60
	B166	4.73	7.40	149	12.68	4.76	7.63	149.0	12.44
	B157	4.99	7.41	165	12.30	4.04	7.42	165.0	12.45
	B150	7.48	7.36	176	11.61	6.02	7.46	175.0	11.86
	B138	5.81	7.21	172	11.89	5.86	7.33	173.0	11.98
	B107	5.07	7.28	169	11.73	5.10	7.29	164.0	11.98
	B91	5.25	7.37	193	11.65	5.27	7.35	202.0	11.66
	B74	5.86	8.11	184	11.18	4.65	7.76	182.0	12.68
1/29/2015	Huguenot	4.80	7.80	166	13.58				
	B168	3.17	7.60	155	13.06				
	B166	3.40	7.60	153	13.01				
	B157	3.40	7.54	155	12.66				
	B150	5.13	7.50	155	12.07				
	B138	4.90	7.39	157	11.92				
	B107	4.73	7.31	166	11.71				
	B91	4.78	7.39	175	11.42				
	B74	5.23	8.32	190	11.30	4.50	7.67	187.0	11.81
2/11/2015	Huguenot	6.93	8.01	155	12.93				
	B168	4.81	7.85	161	12.46	4.59	7.54	165.0	12.52
	B166	5.18	7.87	165	12.32	4.87	7.88	165.0	12.55
	B157	5.76	7.75	171	12.16	5.56	7.90	171.0	12.26
	B150	6.89	7.60	174	12.03	6.24	7.76	174.0	12.05
	B138	5.85	7.48	170	11.94	5.75	7.63	171.0	12.06
	B107	5.14	7.35	184	11.80	4.89	7.42	185.0	11.98
	B91	5.11	7.37	174	11.76	4.54	7.39	173.0	11.97

	B74	6.07	7.77	199	11.16	4.67	7.37	196.0	11.80
2/25/2015	Huguenot	3.22	7.87	143	13.81				
	B157	1.10	7.71	177	13.49	0.90	7.55	174.0	13.68
	B150	3.29	7.55	207	12.86	3.43	7.50	207.0	12.83
	B138	3.29	7.46	215	12.58	3.28	7.50	218.0	12.61
	B107	3.10	7.59	178	12.79	3.00	7.68	179.0	12.66
	B91	1.44	7.50	182	12.64	1.53	7.63	183.0	13.09
	B74	1.29	8.43	188	12.51	1.17	8.14	186.0	12.77
3/10/2015	Huguenot	6.18	7.63	93	12.80				
	B168	5.76	7.56	93	12.53	5.75	7.57	93.0	12.53
	B166	5.80	7.47	93	12.44	5.78	7.52	92.0	12.50
	B157	5.71	7.51	97	12.55	5.79	7.51	97.0	12.38
	B150	5.76	7.49	99	12.33	5.86	7.47	99.0	12.36
	B138	6.02	7.42	104	12.29	5.89	7.46	102.0	12.31
	B107	6.08	7.56	109	12.49	6.05	7.43	106.0	12.22
	B91	6.12	7.35	137	12.05	5.93	7.32	134.0	12.14
	B74	6.47	7.76	167	11.43	5.53	7.51	164.0	11.90
3/17/2015	Huguenot	11.07	7.98	134	11.42				
	B168	8.89							
	B166	8.89							
	B157	8.89							
	B150	10.00							
	B138	9.44							
	B107	9.44							
	B91	9.44							
	B74	9.44							
3/24/2015	Huguenot	11.35	7.69	125	11.78				
	B168	11.41	7.55	124	11.23	10.88	7.76	125.0	11.33
	B166	11.06	7.55	125	11.10	10.41	7.62	126.0	11.14
	B157	11.37	7.42	132	10.88	11.42	7.52	132.0	10.96
	B150	11.45	7.43	133	10.81	10.89	7.42	132.0	11.03
	B138	11.45	7.28	136	10.55	11.43	7.36	137.0	10.65
	B107	11.03	7.22	132	10.48	11.04	7.28	133.0	10.66
	B91	10.80	6.94	134	10.26	10.88	7.14	136.0	10.58
	B74	11.09	8.13	122	10.56	10.43	7.42	122.0	10.43
3/31/2015	Huguenot	12.20	7.77	128	11.52				
	B168	10.38	7.51	125	11.30	10.84	7.60	125.0	11.26
	B166	10.88	7.49	126	11.12	10.39	7.56	127.0	11.17
	B157	11.42	7.47	132	10.93	11.22	7.53	132.0	10.83
	B150	12.41	7.36	135	10.58	11.50	7.49	131.0	10.77
	B138	12.03	7.35	130	10.70	11.20	7.43	129.0	10.77
	B107	11.70	7.42	130	10.69	11.21	7.41	128.0	10.74
	B91	11.43	7.36	151	10.80	11.19	7.41	154.0	10.79
	B74	11.58	8.13	137	10.61	11.14	7.68	137.0	10.55
4/14/2015	Huguenot	17.92	7.76	149	10.08				
	B168	17.23	7.67	142	9.59	17.28	7.69	142.0	9.51
	B166	17.24	7.70	140	9.53	16.81	7.73	140.0	9.49
	B157	17.83	7.53	146	9.24	17.68	7.64	148.0	9.28
	B150	17.15	7.48	146	9.37	17.24	7.52	147.0	9.44
	B138	17.34	7.46	148	9.22	17.22	7.52	147.0	9.32
	B107	17.78	7.56	149	9.27	17.68	7.53	148.0	9.28
	B91	17.77	7.32	172	9.38	17.72	7.41	172.0	9.47
	B74	17.72	7.52	157	8.93	17.22	7.37	155.0	8.96

4/21/2015	Huguenot	16.86	7.15	88	8.89				
	B168	16.70	7.26	104	9.63	16.58	7.26	104.0	9.68
	B166	17.24	7.30	113	9.44	16.66	7.27	113.0	9.55
	B157	17.41	7.28	130	9.18	17.10	7.28	131.0	9.23
	B150	17.82	7.27	129	8.97	17.47	7.29	130.0	9.03
	B138	17.82	7.27	131	8.74	17.77	7.29	131.0	8.88
	B107	17.97	7.37	131	8.53	17.88	7.24	130.0	8.74
	B91	18.71	7.23	153	8.68	18.52	7.30	154.0	8.79
	B74	19.26	7.52	166	8.30	18.85	7.01	164.0	8.50
4/28/2015	Huguenot	14.30	7.62	123	11.04				
	B168	13.35	7.28	123	10.43	13.13	7.35	123.0	10.50
	B166	13.61	7.36	122	10.30	13.15	7.36	122.0	10.35
	B157	13.90	7.25	135	9.80	13.36	7.29	134.0	10.15
	B150	15.47	7.01	144	9.69	14.55	7.23	140.0	9.80
	B138	14.08	6.94	136	9.61	13.98	7.01	136.0	9.78
	B107	14.75	6.93	128	9.17	14.42	6.91	128.0	9.35
	B91	15.38	6.91	126	9.01	15.04	6.93	127.0	9.22
	B74	15.96	7.35	130	7.85	15.42	6.98	124.0	8.72
5/5/2015	Huguenot	20.24	8.05	149	9.83				
	B168	18.94	7.43	143	9.53	18.72	7.53	145.0	9.52
	B166	18.37	7.58	144	9.36	17.17	7.52	141.0	9.36
	B157	19.24	7.39	153	9.24	19.16	7.48	153.0	9.10
	B150	18.82	7.31	153	9.18	18.52	7.37	153.0	9.30
	B138	18.80	7.31	155	9.20	18.35	7.34	156.0	9.24
	B107	18.44	7.52	153	9.37	18.14	7.40	153.0	9.27
	B91	19.08	7.26	154	9.75	18.66	7.36	155.0	9.76
	B74	18.25	7.69	139	9.35	18.06	7.33	137.0	9.50
5/12/2015	Huguenot	25.57	8.02	154	9.05				
	B168	24.02	7.73	152	8.25	23.69	7.66	152.0	8.22
	B166	25.37	7.54	152	7.86	24.51	7.72	151.0	7.80
	B157	24.80	7.47	168	7.63	23.68	7.50	170.0	7.64
	B150	25.23	7.39	166	7.56	24.57	7.54	167.0	7.55
	B138	24.72	7.61	168	7.80	24.51	7.52	168.0	7.65
	B107	24.20	7.45	172	7.87	23.92	7.47	171.0	7.99
	B91	23.88	7.41	162	7.76	23.77	7.51	162.0	7.93
	B74	22.33	7.92	155	7.72	22.41	7.58	154.0	7.88
5/19/2015	Huguenot	27.34	8.37	181	9.11				
	B168	26.09	7.87	185	7.24	25.68	7.82	183.0	7.59
	B166	27.63	7.79	182	6.41	26.81	7.89	184.0	6.27
	B157	26.24	7.72	207	6.90	25.73	7.74	207.0	6.77
	B150	29.13	7.54	205	6.62	27.08	7.71	204.0	7.00
	B138	27.21	7.60	196	6.90	26.91	7.55	197.0	6.69
	B107	26.69	7.81	180	7.77	26.53	7.73	182.0	7.41
	B91	25.45	7.86	172	8.59	25.24	7.90	172.0	8.39
	B74	24.45	7.98	164	8.46	24.42	7.85	161.0	8.45
5/26/2015	Huguenot	25.80	8.51	193	9.29				
	B168	24.74	7.82	201	7.75	24.36	7.91	201.0	8.46
	B166	24.65	7.69	200	8.52	24.11	7.75	200.0	8.09
	B157	25.21	7.66	233	7.36	24.14	7.65	233.0	7.14
	B150	25.83	7.73	242	7.66	25.71	7.71	241.0	7.74
	B138	25.37	8.25	234	7.93	24.21	7.93	233.0	7.59
	B107	24.56	8.36	213	9.21	24.33	8.31	212.0	9.02
	B91	24.56	8.26	196	10.08	24.02	8.43	197.0	9.53

	B74	24.10	7.80	179	8.42	24.18	7.87	178.0	8.43
6/2/2015	Huguenot	28.31	8.04	201	8.48				
	B168	27.44	7.88	196	6.80	27.18	7.76	196.0	6.58
	B166	28.47	7.78	209	7.35	28.24	7.91	211.0	7.44
	B157	28.20	7.70	245	6.90	27.79	7.76	245.0	6.88
	B150	31.01	7.49	258	6.06	29.26	7.71	253.0	6.22
	B138	29.12	7.52	259	6.26	28.58	7.57	261.0	6.17
	B107	27.66	7.67	242	6.91	27.55	7.72	244.0	6.59
	B91	27.14	7.60	227	6.99	27.15	7.76	228.0	6.94
	B74	26.07	7.96	194	6.59	26.21	7.73	192.0	6.82
6/9/2015	Huguenot	26.82	8.30	181	8.83				
	B168	25.29	8.09	191	8.04	24.75	7.95	192.0	7.96
	B166	26.97	8.00	194	8.00	26.10	8.27	197.0	7.99
	B157	25.95	7.96	230	8.40	24.80	8.01	147.0	7.84
	B150	26.77	7.90	234	8.49	26.39	7.94	235.0	8.49
	B138	26.13	8.02	239	8.43	25.86	7.93	239.0	8.35
	B107	25.52	8.29	242	8.61	25.70	8.19	245.0	8.69
	B91	25.73	8.77	239	9.85	25.30	8.96	239.0	9.38
	B74	25.27	8.24	210	8.14	25.56	8.24	207.0	8.61
6/16/2015	Huguenot	30.94	8.07	228	7.54				
	B168	31.21	7.88	237	6.92	30.99	7.98	248.0	6.60
	B166	30.59	7.78	226	6.98	30.24	7.89	226.0	6.86
	B157	30.35	7.78	270	6.02	29.95	7.69	269.0	5.36
	B150	32.90	7.80	269	6.52	31.58	7.86	266.0	6.99
	B138	31.34	8.15	255	7.96	31.08	7.99	253.0	7.47
	B107	29.50	7.51	243	8.84	29.64	8.60	242.0	8.57
	B91	29.06	8.21	240	8.32	28.99	8.41	240.0	8.13
	B74	27.55	8.14	225	7.38	27.88	7.95	226.0	7.63
6/23/2015	Huguenot	31.77	8.09	204	8.08				
	B168	30.69	7.83	203	6.73	30.46	7.74	204.0	6.97
	B166	31.41	7.83	215	6.97	31.02	7.92	215.0	7.00
	B157	31.69	7.97	261	6.62	30.53	7.94	260.0	6.28
	B150	32.71	8.14	311	7.48	32.39	8.09	310.0	6.49
	B138	32.73	8.34	306	7.53	32.33	8.25	308.0	7.40
	B107	31.04	8.53	265	8.66	31.73	8.73	266.0	7.31
	B91	30.49	8.25	246	7.86	30.15	8.41	250.0	7.22
	B74	29.46	8.36	279	7.51	29.61	8.11	278.0	7.07
6/30/2015	Huguenot	27.15	8.27	174	8.19				
	B168	25.56	7.88	136	8.10	25.59	7.90	137.0	8.06
	B166	25.54	7.61	139	8.07	25.23	7.93	137.0	8.02
	B157	26.96	7.46	150	7.45	26.84	7.44	152.0	7.44
	B150	27.44	7.54	173	7.10	26.34	7.77	163.0	7.20
	B138	27.52	7.48	187	7.08	26.61	7.49	172.0	7.49
	B107	27.91	7.83	197	7.37	27.64	7.73	202.0	6.95
	B91	27.99	7.93	235	8.35	27.81	7.97	237.0	8.02
	B74	27.75	7.83	264	7.02	27.83	7.91	264.0	6.96
7/7/2015	Huguenot	28.03	8.33	150	8.53				
	B168	27.60	7.99	154	7.98	27.05	8.00	162.0	7.71
	B166	28.53	8.02	165	7.42	27.86	8.10	163.0	7.29
	B157	28.01	7.95	215	7.81	27.33	7.93	210.0	7.38
	B150	28.83	7.92	266	7.32	28.73	7.88	265.0	7.45
	B138	28.82	8.01	264	8.20	28.68	7.94	267.0	7.37
	B107	28.55	8.23	221	8.24	27.44	8.26	224.0	8.07

	B91	28.40	8.25	200	8.16	28.20	8.16	199.0	7.78
	B74	27.59	8.27	238	7.40	28.14	8.38	233.0	7.46
7/14/2015	Huguenot	27.56	7.95	206	8.36				
	B168	27.10	7.60	212	7.71	26.54	7.72	213.0	7.83
	B166	27.54	7.64	218	7.56	27.31	7.70	217.0	7.51
	B157	27.23	7.70	229	7.43	27.00	7.62	240.0	7.48
	B150	31.77	7.46	228	6.70	28.34	7.84	212.0	7.37
	B138	28.76	7.45	215	7.01	28.65	7.54	216.0	7.08
	B107	28.53	7.96	211	7.36	28.53	7.74	211.0	7.23
	B91	26.51	7.87	234	8.48	27.91	8.51	235.0	8.12
	B74	27.94	8.16	219	8.09	28.17	8.33	210.0	7.60
7/21/2015	Huguenot	31.77	8.70	218	8.95				
	B168	30.82	8.26	213	6.84	30.89	8.40	213.0	6.99
	B166	31.24	8.57	213	7.69	30.02	8.26	212.0	7.51
	B157	30.61	8.17	229	7.37	29.92	8.16	229.0	7.37
	B150	32.02	7.87	227	7.44	31.55	7.97	227.0	7.38
	B138	31.00	8.08	223	7.50	31.16	7.87	223.0	7.40
	B107	30.39	8.45	236	8.85	30.11	8.35	235.0	8.32
	B91	29.81	8.33	229	9.18	29.42	8.39	229.0	7.63
	B74	28.81	7.76	230	7.22	29.20	7.78	225.0	7.25
7/28/2015	Huguenot	30.11	8.30	184	7.88				
	B166	30.66	7.66		6.51	30.10	7.88	281.0	6.66
	B157	30.74	7.56	279	6.44	29.84	7.41	283.0	6.04
	B150	34.24	7.77	292	6.58	31.62	7.60	295.0	6.22
	B138	31.90	7.88	276	7.53	31.02	7.79	272.0	7.29
	B107	30.12	8.42	238	8.13	29.55	8.14	238.0	7.11
	B91	29.59	8.50	237	8.17	29.28	8.51	239.0	7.17
	B74	28.44	7.90	243	6.32	28.68	7.87	236.0	6.32
8/4/2015	Huguenot	29.45	7.97	200	8.25				
	B168	30.40	8.05	197	7.08	29.86	8.31	199.0	6.97
	B166	29.74	7.79	208	6.92	29.37	7.91	207.0	7.13
	B157	30.31	8.05	229	6.35	29.88	7.94	228.0	6.33
	B150	31.81	8.01	255	9.84	31.52	8.09	260.0	6.52
	B138	31.02	8.00	267	7.01	30.91	8.14	269.0	6.88
	B107	29.76	8.39	265	7.36	29.77	8.32	267.0	6.91
	B91	29.70	7.80	248	7.16	29.20	8.09	251.0	6.72
	B74	29.05	8.18	283	6.40	29.25	7.98	279.0	6.29
8/11/2015	Huguenot	28.07	8.22	263	8.64				
	B168	26.74	7.65	280	7.41	27.55	7.67	286.0	7.39
	B166	27.70	7.60	261	7.16	27.31	7.62	272.0	6.90
	B157	28.36	7.76	293	6.40	27.77	7.53	301.0	5.84
	B150	31.26	7.50	290	6.75	31.09	7.77	291.0	7.16
	B138	28.94	7.43	274	7.08	28.97	7.60	273.0	6.67
	B107	27.31	7.46	254	7.28	27.31	7.46	254.0	7.28
	B91	27.17	7.44	258	6.98	27.21	7.57	256.0	6.68
	B74	27.32	7.29	403	5.28	27.60	7.38	398.0	5.83
8/20/2015	Huguenot	28.75	7.97	247	8.09				
	B168	28.66	7.52	256	7.16	28.63	7.77	256.0	7.42
	B166	28.70	7.56	240	6.39	28.33	7.54	239.0	6.16
	B157	29.05	7.68	326	6.31	28.80	7.63	324.0	6.11
	B150	30.76	7.60	330	6.39	30.48	7.66	326.0	6.75
	B138	29.58	7.40	310	6.36	29.67	7.62	311.0	7.15
	B107	28.59	7.43	271	5.84	28.52	7.49	270.0	5.91

	B91	28.18	7.43	274	6.46	28.16	7.54	265.0	6.39
	B74	27.67	7.17	665	5.50	27.67	7.25	666.0	5.52
8/25/2015	Huguenot	27.79	7.97	264	8.31				
	B168	26.81	7.76	299	7.50	27.89	7.21	298.0	7.52
	B166	28.35	7.62	309	7.11	27.60	7.77	302.0	6.98
	B157	28.12	7.67	336	6.71	28.50	7.69	336.0	6.35
	B150	28.98	7.50	346	6.69	30.79	7.71	348.0	6.56
	B138	31.14	7.26	328	6.66	29.44	7.52	335.0	6.59
	B107	29.49	7.35	294	6.17	27.52	7.33	295.0	5.87
	B91	27.41	7.31	286	6.18	27.66	7.41	272.0	5.95
	B74	27.66	7.24	623	6.48	27.49	7.44	685.0	6.32
9/1/2015	Huguenot	27.62	7.93	315	8.02				
	B168	27.50	7.61	347	7.08	27.51	7.82	347.0	7.04
	B166	28.29	7.53	345	6.75	27.59	7.62	336.0	6.63
	B157	29.40	7.54	389	6.66	28.16	7.65	399.0	6.34
	B150	30.29	7.37	372	6.12	30.41	7.46	370.0	5.77
	B138	28.33	7.16	338	6.05	28.36	7.34	341.0	6.03
	B107	27.47	7.28	309	6.63	26.99	7.34	309.0	6.43
	B91	26.89	7.26	349	6.44	26.99	7.29	339.0	6.32
	B74	26.44	6.80	1304	6.05	26.88	7.16	1345.0	5.64
9/8/2015	Huguenot	28.04	8.01	276	8.49				
	B168								
	B166								
	B157								
	B150								
	B138								
	B107								
	B91								
	B74								
9/15/2015	Huguenot	23.30	7.93	201	8.69				
	B168	24.80	7.94	243	7.88	24.18	8.05	243.0	8.21
	B166	24.80	7.68	253	7.13	24.44	7.85	239.0	7.38
	B157	25.68	7.61	313	6.47	25.62	7.68	309.0	6.54
	B150	27.24	7.77	337	6.81	27.13	7.70	338.0	6.72
	B138	26.42	7.53	335	6.53	26.97	7.69	339.0	6.65
	B107	25.10	7.74	314	7.68	25.04	7.81	309.0	7.78
	B91	24.87	7.57	406	7.55	24.92	7.74	369.0	7.59
	B74	22.94	7.58	1617	6.34	25.27	7.54	1634.0	6.17
9/29/2015	Huguenot	22.84	8.04	220	9.02				
	B168	22.82	7.84	260	8.26	22.73	7.93	261	8.31
	B166	22.30	7.61	262	8.01	22.75	7.74	262	8.01
	B157	22.72	7.52	327	7.15	22.17	7.61	325	7.35
	B150	26.85	7.48	334	6.43	26.94	7.49	335	6.27
	B138	24.39	7.42	334	7.02	24.43	7.48	336	6.58
	B107	22.75	7.48	342	7.86	22.74	7.59	339	7.86
	B91	22.56	7.53	520	7.88	22.40	7.62	481	8.04
	B74	23.00	6.57	2032	6.59	23.02	7.15	2081	6.55
10/13/2015	Huguenot	19.08	7.75	129	9.47				
	B168	18.10	7.65	132	9.22	18.35	7.66	133	9.25
	B166	19.10	7.51	134	9.03	18.83	7.70	136	8.96
	B157	18.59	7.46	149	8.74	18.49	7.49	149	8.82
	B150	21.83	7.36	157	8.18	19.59	7.45	154	8.51
	B138	19.69	7.18	150	8.21	19.87	7.33	152	8.24

	B107	18.25	7.12	136	8.09	18.48	7.27	134	8.44
	B91	18.65	7.17	131	7.98	18.61	7.26	130	8.21
	B74	18.75	8.01	163	7.34	18.59	7.61	155	7.38
10/20/2015	Huguenot	13.59	7.87	150	10.84				
	B168	14.82	7.75	149	10.13	14.50	7.92	149	10.16
	B166	14.31	7.67	147	9.80	13.83	7.72	148	10.14
	B157	16.07	7.44	166	9.16	16.32	7.69	167	9.42
	B150	18.10	7.46	165	8.78	18.00	7.51	163	8.85
	B138	17.22	7.29	157	8.92	17.46	7.48	157	8.76
	B107	15.31	7.27	147	9.30	15.38	7.51	151	9.88
	B91	16.14	7.03	139	8.42	15.29	7.26	139	8.77
	B74	16.63	6.78	151	6.54	16.82	7.04	152	6.93
10/27/2015	Huguenot	14.67	8.04	168	10.61				
	B168	14.55	7.89	174	10.17	14.42	8.05	172	10.23
	B166	15.15	7.83	175	9.68	14.99	7.87	174	9.82
	B157	15.40	7.64	219	9.56	15.65	7.72	218	9.53
	B150	18.85	7.54	212	8.90	17.76	7.83	212	9.19
	B138	17.03	7.42	202	9.40	16.77	7.43	199	9.46
	B107	15.73	7.45	171	9.67	15.84	7.51	173	9.78
	B91	15.63	7.03	160	9.73	15.51	7.33	156	9.91
	B74	16.14	6.17	157	8.46	15.85	6.82	160	8.63
11/3/2015	Huguenot	15.82	7.68	180	9.97				
	B168	14.54	7.46	167	10.34	14.20	7.47	170	10.45
	B166	14.88	7.53	163	10.25	14.21	7.61	161	10.32
	B157	15.33	7.34	194	9.94	14.38	7.56	197	10.16
	B107	16.51	7.52	177	8.95	16.45	7.47	172	8.90
	B91	16.66	7.39	191	9.46	16.59	7.60	192	9.94
	B74	16.37	7.80	174		16.18	7.63	173	
11/10/2015	Huguenot	14.24	7.16	149	9.94				
	B168	14.81	6.66	150	9.45	14.78	6.72	154	9.56
	B166	14.87	6.75	151	9.15	14.83	6.89	148	9.29
	B157	15.44	6.99	151	9.09	15.56	6.98	157	9.11
11/17/2015	Huguenot	11.43	7.78	189	11.40				
	B168	11.12	8.16	190	11.07	10.96	8.03	191	10.96
	B166	11.51	8.16	191	10.70	11.28	8.29	191	10.84
	B157	11.18	7.44	207	10.43	11.01	7.86	208	10.68
	B107	12.85	8.02	140	9.26	12.91	8.12	140	9.58
	B91	13.34	8.07	155	8.95	13.06	8.22	154	9.36
	B74	14.39	8.36	312	8.86	14.17	7.96	214	9.40
12/1/2015	Huguenot	9.66	7.81	148	11.68				
	B168	9.03	7.83	152	11.38	9.08	7.87	151	11.38
	B166	9.10	7.85	151	11.30	9.15	7.83	151	11.30
	B157	9.31	7.78	170	10.95	9.28	7.91	171	11.09
	B107	10.35	7.86	166	10.25	10.39	7.78	165	10.29
	B91	10.33	7.95	184	9.65	10.34	7.86	183	10.75
	B74	11.00	8.97	196	9.14	10.81	8.23	186	9.52
12/8/2015	Huguenot	7.81	7.16	127	12.26				
	B168	7.19	8.01	129	12.04	7.19	8.15	131	11.91
	B166	8.10	8.12	133	11.96	7.32	8.16	133	11.89
	B157	8.45	8.00	164	11.58	7.66	8.01	149	11.69
12/15/2015	Huguenot	12.84	7.79	159	11.16				
	B168	11.13	7.33	156	10.84	11.00	7.37	154	10.79
	B166	11.69	7.32	158	10.72	11.75	7.43	157	10.66

	B157	10.80	7.28	176	10.79	10.64	7.34	175	10.90
	B107	12.18	7.33	163	10.36	12.27	7.51	163	10.48
	B91	11.95	7.47	165	10.10	11.85	7.45	166	10.22
	B74	11.31	8.05	172	9.73	11.15	7.78	166	9.83
MEAN		**19.24**		**213.2**	**9.09**	**19.62**		**219.3**	**8.87**
MIN		**1.10**		**88.0**	**5.28**	**0.90**		**92.0**	**5.36**
MAX		**34.24**		**2032.0**	**14.04**	**32.39**		**2081.0**	**13.73**

Appendix B:

Peer-reviewed papers on Atlantic Sturgeon published by VCU during this award. This body of work is directly or indirectly related to the goals and objectives of the NOAA Section 6 grant award to VCU and represents a significant dissemination of data developed under that grant. Full-text versions of all publications are available on-line and provide acknowledgement of NOAA support, where appropriate.

Balazik, M., G. Garman, J. Van Eenennaam, J. Mohler and L. C.Woods. 2012. Empirical evidence of fall spawning by Atlantic Sturgeon in the James River, Virginia, USA. Transactions of the American Fisheries Society 141:1465-1471. doi: 10.1080/00028487.2012.703157

Balazik, M. 2015. Capture and brief invasive procedures using electronarcosis does not appear to affect post-release habits in Atlantic Sturgeon during the spawning season. North American Journal of Fisheries Management 35:398-402. doi:10.1080/02755947.2015.1011358

Balazik, M., J Musick. 2015. Dual annual spawning races in Atlantic Sturgeon. PLoS ONE.doi:10.371/journal.pone.0128234

Balazik, M., K. Reine, A. Spells, C. Fredrickson, M. Fine, G. Garman, and S. McIninch. 2012. The potential for vessel interactions with adult Atlantic Sturgeon in the James River, Virginia, USA. N. Amer. J. Fish. Management.

Balazik, M., S. P. McIninch, GC. Garman and R J. Latour. 2012. Age and growth of Atlantic Sturgeon in the James River, Virginia, 1997-2011. Transactions of the American Fisheries Society 141:1074-1080. doi: 10.1080/00028487.2012.676590

Balazik, M.T., G.C. Garman, M.L. Fine, C.H. Hager and S.P. McIninch. 2010. Changes in age composition and growth characteristics of Atlantic Sturgeon (Acipenser oxyrinchus oxyrinchus) over 400 years. Biology Letters 2010 6, 708-710.

North American Journal of Fisheries Management
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/ujfm20

Capture and Brief Invasive Procedures Using Electronarcosis Does Not Appear to Affect Postrelease Habits in Male Atlantic Sturgeon During the Spawning Season

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Published online: 15 Apr 2015.

Transactions of the American Fisheries Society
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/utaf20

Comparison of MS-222 and Electronarcosis as Anesthetics on Cortisol Levels in Juvenile Atlantic Sturgeon

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RESEARCH ARTICLE

Dual Annual Spawning Races in Atlantic Sturgeon

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Abstract

Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*, Acipenseridae) populations in the United States were listed as either endangered or threatened under the Endangered Species Act in 2012. Because of the endangered/threatened status, a better understanding of Atlantic sturgeon life-history behavior and habitat use is important for effective management. It has been widely documented that Atlantic sturgeon reproduction occurs from late winter to early summer, varying clinally with latitude. However, recent data show Atlantic sturgeon also spawn later in the year. The group that spawns later in the year seems to be completely separate from the spring spawning run. Recognition of the later spawning season has drastically modified estimates of the population status of Atlantic sturgeon in Virginia. With the combination of new telemetry data and historical documentation we describe a dual spawning strategy that likely occurs in various degrees along most, if not all, of the Atlantic sturgeon's range. Using new data combined with historical sources, a new spawning strategy emerges which managers and researchers should note when determining the status of Atlantic sturgeon populations and implementing conservation measures.

OPEN ACCESS

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Introduction

Sturgeon species (family Acipenseridae) are generally threatened along their entire range around the northern hemisphere [1, 2]. The Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*, Acipenseridae) occupies the Atlantic slope of North America and five distinct population segments were listed as either endangered or threatened under the U.S. Endangered Species Act in 2012 [3, 4]. Because of the endangered/threatened status, a better understanding of life-history traits and habitat use are necessary for more effective management. Over the past decades several reviews about the status and life history of Atlantic sturgeon (AS) have been published [5, 6, 7, 8]. The general consensus has been that AS spawning varies clinally along its range with spawning occurring in the spring around March in the Savannah River, GA, while progressing temporally to July in the St. Lawrence River in Quebec. Temporal spawning estimates have been derived mostly from historical fisheries data [9, 10, 11]. Historical fisheries targeted flesh and roe, the latter being more valuable [11, 12]. Since the collapse of

V: Federal, non-federal match, and total funds associated with the award

Total Funds: $1,482,484 Federal: $1,306,478 Non-Federal: $176,006