Final Report:
09/15/2010 to 9/15/2011

For contract EA133F10CN0317

Atlantic Sturgeon Review:
Gather data on reproducing subpopulation on Atlantic Sturgeon in the James River.

Project Purpose:

The overall objective of this contract was to gather data on the reproducing subpopulation of Atlantic sturgeon in the James River, and to begin to assimilate data on habitat use and potential spawning sites of this subpopulation. This is the first year final report. GIS maps produced cover the 2010 tracking year in its entirety. Other years of data will be added to these products once the methodology is approved and comments are received from NMFS. No comments have thus far been received (Dec. 27, 2011) so we are assuming that our approach is satisfactory and we will proceed.

Project Tasks:

Project tasks were as follows:

1. Continue to deploy the sonic array consisting of 40-45 receivers in the James River. This array will stretch from the lower James River, near river mile 28 to river mile 75, and it will provide 24 hour remote tracking year round. Additionally, the array may be augmented as resources allow, to include new areas that are identified as important by the partnership. As data are downloaded from the receivers, they will be made available to the partnership and to the Atlantic Coast Tagging Network when appropriate, to ensure the most efficient use of the array.

2. Subsequent tracks from the over sixty fish carrying transmitters will be examined by life stage (adults>1550mmTL, sub adults<1150 and YOY<550mm) for habitat use patterns to identify temporal and spatial migration trends and patterns in habitat occupation. This information will be displayed in GIS maps.

3. Adult tracks in the spring will be cross-referenced with benthic habitat maps to determine potential spawning habitats and this information will be shared with other partners who are leading spawning habitat restoration efforts.

4. Habitat use patterns will be examined by life stage (adult/sub-adult) and river mile to determine guidelines for time/area regulations and improved area based abundance models. This information will be displayed in GIS maps.

5. Migration patterns will be examined for temporal and spatial trends, as well as relationships with physical parameters such as temperature, moon cycle and potentially tide levels. This information will be displayed in GIS maps.

Task one has been completed. Project tasks 2-5 required analysis of data attained in task one and will be presented in an informal manuscript format.

Species Background:

The Atlantic sturgeon was once abundant in Chesapeake Bay and was an important resource for Native Americans and colonists alike. The species was heavily fished for roe (caviar) and flesh at the end of the 19th century. Coastal harvests peaked in 1890 at 7,382,000 pounds. By 1901, harvests had declined to 650,000 pounds, and to less than 100,000 pounds by the 1920s (Hildebrand & Schroeder, 1928). Collapse within the bay led Virginia to impose a total moratorium on sturgeon possession in 1974 and the Atlantic States Marine Fisheries Commission (ASMFC) imposed a coastal moratorium on Atlantic sturgeon possession throughout its jurisdiction in 1998. However, potentially significant sources of mortality persist today due to bycatch, a black market for flesh, and vessel strikes.

The anadromous Atlantic sturgeon has also suffered from habitat degradation and alteration, particularly in the tidal fresh water portions of native rivers that are critical to spawning and the provision of nursery habitats. Atlantic sturgeon spawn in tidal freshwater below the fall line, most often over hard substrates. Such habitats in most major rivers have been altered severely along the Atlantic coast by dredging for shipping, as well as dam construction for power generation and reservoirs. Many east coast rivers, like the James River in Virginia, have received sediment for hundreds of years from surrounding large scale agriculture. Hard benthos was buried by softer sediments containing elevated nutrient loads, which resulted in uncalculated benthic community shifts. In addition, during the late 19th and mid-20th centuries, tidal rivers became heavily polluted with pollutants from various industrial operations. Declines in water quality brought about the advent of the Clean Water Act in 1972. This act improved water quality in many habitats that sturgeon utilize, but it did not address historic alterations in aquatic habitat composition. Despite improvements in water quality and reductions in fishery- related mortalities, stocks have not recovered. Presently this species has been recommended for listing as *Threatened* under the Endangered Species Act by NOAA Fisheries Service (NMFS), due to its historically low abundance and lack of recovery.

Within the Chesapeake, spawning stocks of Atlantic sturgeon appear to be extirpated from Maryland tributaries and the Rappahannock River, Virginia (NMFS & USFWS 1998). Occasional occurrences of young-of-the-year (YOY) and reports of adult sturgeon in York River tributaries in Virginia suggest that remnant spawning is still occurring there (Musick et al., 1994). Historically, the James River contained the largest population of sturgeon in the Chesapeake (Hilldebrand and Shroeder ,1928) and today it contains the only confirmed viable spawning population (King, personal communication). An annual gillnet survey conducted since 2005 in the James River in Burwell Bay suggests that the spring population of sub-adult and adult sturgeon is increasing recently (Hager, unpublished). The James River stock is not only historically important but it is the only stock contributing to the Chesapeake distinct population

segment (DPS), which means that it is distinct with regard to all other reproducing populations coastally (ASSRT 2007; Wirgin et al., 2007; T. King, unpublished). In addition to supporting a native stock, the Chesapeake Bay provides preferred habitats to fish from other DPS (Barton et al., 2007). Tracking results suggest that the James River is also providing essential habitats to adults and sub-adults from other severely depleted DPS, but this aspect of the river's habitat value deserves greater investigation.

Introduction

In order to address tasks two through five, we expand upon information acquired and summarized under P.L 89-304 grant # NA03NMF4050200 (Bushnoe et al., 2005) and grant #NA06NMF4050068 (Hager & Musick, 2007). Bushnoe et al., (2005) delineated potential nursery and spawning habitats in Virginia by first reviewing historical data on physical parameters associated with such habitats and then overlapping these parameters with features found in Virginia's major rivers. Although precise data were available for many environmental parameters, such as water temperature, salinity, turbidity, pH, and oxygen, very little information was available on substrate composition and no direct observation of habitat selection by sturgeon had been documented. Hager and Musick (2007) focused on filling these data gaps, efforts which are ongoing through collaborations with ERDC and USFWS and this contract.

Benthic composition is a critical parameter for the determination of potential spawning habitats because hard bottom is required for successful egg attachment and incubation (Vladykov and Greeley, 1963; Huff ,1975; Smith, 1985a; Gilbert ,1989; Smith and Clugston, 1997; Secor et al., 2002). In most systems, gravel substrate has been preferred (Bain, 1997; Smith & Clugston, 1997). By studying water current data, reviewing geological maps and the distribution of gravel mines adjacent to the spawning rivers, Bushnoe, et al., (2005) identified river reaches that had the highest probability of containing gravel substrate. To confirm spawning habitats, Hager and Musick (2007) began implanting and tracking adult sturgeon in an effort to locate the spawning grounds in 2006. Subsequently, areas where benthic attributes and spring adult occupations overlapped were surveyed using side-scan sonar with help from the USFWS. Resulting images were categorized by image type, using a computer modeling program and benthic grab samples used to verify hypothesized bottom composition. Areas containing potential spawning habitat based on benthic characterization were thus identified and mapped through a contract with CCRM at VIMS. Maps of benthic composition were also expanded using data attained through collaborative efforts with NOAA Chesapeake Bay and the Commonwealth of Virginia's Department of Mines, Mineral and Energy (Dr. Berquist, College of William and Mary).

Methods

Since 2006, the Virginia Sturgeon Restoration Partnership has placed Vemco® passive tracking transmitters in 33 sub-adult (<1500 mm TL) and 32 adult fish (TL > 1500TL ~ FL 1300) in order to document behavior in the James by life stage. The majority of adult sturgeon, for which sex could be determined, were male, based on their active production of milt. Adult males are between 12 to 20 years old, and measure 1500 to 2100 mm in total length (Bain 1997). In order to better describe river habitation, the tributary was divided into river mile sections with a zero line designated as connecting Old Point Comfort light to Willoughby Spit (Hampton Roads).

Receiver stations are designated by site name as well as river mile (RM). The vast majority of implanted fish were collected and released within RM 18 (between the 18th mile and 19 th mile line) in the Burwell's Bay area in the spring (March–May) after being attained through the Burwell Bay survey. Several sub-adults were collected near RM 30 in February and a few adults were implanted after being captured in the upper river near RM 65 in the late summer. Although fish were not genetically examined to determine their origin, it may be assumed due to time of capture and subsequent upriver movements after release that the majority of fish being tracked are of native origin. Since the objective is to delineate preferred habitats of Atlantic sturgeon within the array (James), the origin of the fish matters little, as they must be protected while in residence regardless.

Array placement has remained relatively stable over the years. A gate has existed between RM 28 and 31 where the river narrows between Hog and Jamestown Islands since array inception. The array was recently (spring 2010) modified through the addition of a second gate, located farther down river in the Hampton Roads area (RM 0). This addition was deemed necessary because experimental down river receivers placed below the Jamestown gate, indicated that fish were remaining in the lower river far longer than previously suspected thus the original gate did not adequately reflect true river residence time.

All fish were surgically implanted with either a Vemco® V16 or 13 passive transmitters, depending on the fish's body weight. The majority were captured and released within an hour in the RM 18-19 section. Exceptions to this were the four sub-adults (807-855 mm FL) taken in February that were moved up river (~7 RM) and released at the mouth of the Chickahominy (RM 37) within an expanded array to examine the effects of dredge activity on fish behavior and movement. Additionally, there were three milt producing males (1560-1566 mm FL) that were captured in and released in the upper river (RM 65) in late summer of 2008. These fish were released into the Turkey Island cut area during vessel passage periods to examine the effects of vessel traffic on behavior.

The size structure of sturgeon chosen for tracking was not random. In 2006 and 2007, only the largest fish obtained were implanted. This approach was selected because the primary objective of Hager and Musick (2007) was to provide observations of adult fish during the spring to be combined with the Bushnoe, et al., (2005) spawning habitat identification model in order to locate the spawning grounds. After the USFWS and Army Corps of Engineers (ERDC) became collaborative investigators, the size range of sturgeon implanted was expanded to address our new joint goal: to attain as much information as possible on the behavior of available age classes. The results of our collections and the resulting size range of fish being tracked are presented in Figure 1.

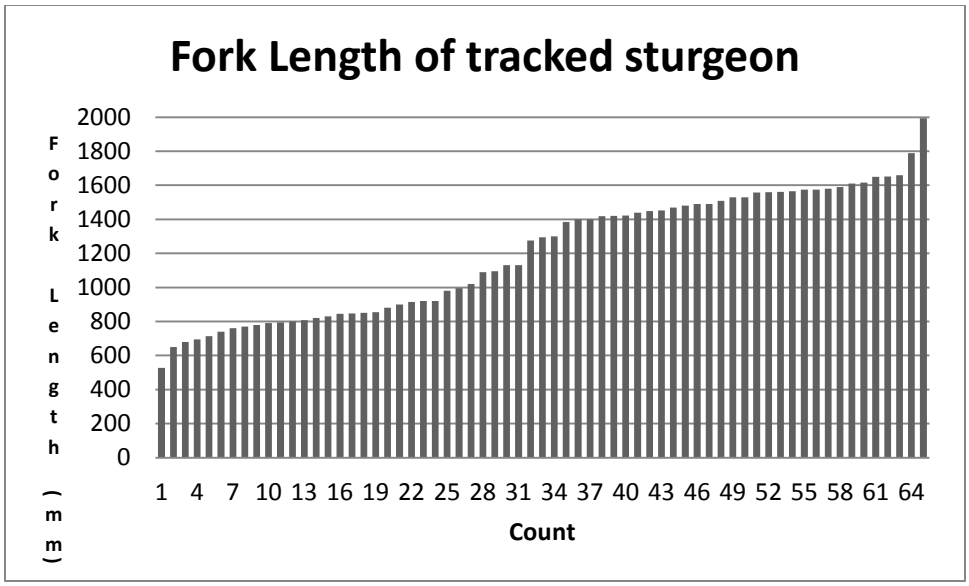

Figure 1. Figure one contains the size range of fish include in this report. Tags in some of the larger fish have now expired due to battery life.

An average receptive distance for receivers was calculated based on results of field tests designed to determine reception distance that were conducted within the study area. A V16 transmitter was placed within an array of receivers placed at defined distances. Receptions were recorded under varied environmental conditions and at varied depth and distance intervals between receiver and transmitter. The maximum reception distance, under calm sea conditions, with transmitter and receiver both in deep water was 1.3 km. Under very rough conditions with the transmitter or receiver placed in shallow water (1-2 m deep) receptive distance was reduced to .2 km. A reception distance of .7 km was selected to model the average receptive distance. This distance was chosen due to the shallowness of the majority of river habitats and the frequently rough conditions that occur especially in the lower river. Receivers were intentionally placed on channel buoys and day markers at a depth of around 8 feet on the edge of deep channels, so this estimated reception distance may be a little conservative.

Once the average reception distance was determined, benthic composition within each station's range was quantified by overlaying each station's site with numerous sources of benthic data composition (task 3). One of the greatest restrictions to this approach is the relative poverty of available benthic data where sturgeon congregate. No usable data exists below RM 48, and this area is heavily used, especially by sub-adults.

Limitations and Assumptions of Tracking Data

The Chesapeake DPS of Atlantic sturgeon depends upon a plethora of habitats and migration paths outside of the James River. This draft concentrates on habitats and migration corridors within the James River array in 2010 (RM 28-77). More data will be added (2008-11) in the future to illuminate greater detail of habitat occupation, selectivity and data gaps over time. This should be considered an evolving draft, one that will change and improve as data allows. Some receptions outside of the array will be mentioned, but including tracking data from other areas is

not specified in this contract, and thus it is not an immediate priority in the first year. This being said, this report and those that follow will go far beyond what is contractually required, in order to provide the best biological insight possible given data restraints.

Using tracking data based on a randomly attained sub-set of fish to model habitat use by the species, requires that some assumptions be made. The samples are assumed to represent the population at large, that is the data is assumed to be the result of normal/average fish behavior for a given life stage. If this assumption holds true, the resulting temporally and spatially specific habitat occupancy patterns can be used to model typical habitat use within the array by the species during the monitored period. Since fish appear to seek out habitats with desirable characteristics in order to maximize their bioenergetic budget (Hager, 2004; Niklitschek and Secor, 2005; Secor and Niklitschek, 2010) physical parameters that affect habitat selection must be incorporated into the occupation model appropriately if the model is to predict future habitat selection/occupation.

Task Maps

Preferred sites on task two maps are indicated by larger points by month and year (slides 1-30 in the power point appendix). Sub-adult data is presented first (slides 1-19), followed by adult data (slides 20-30). Pie charts present data on station use by number of receptions and percentage of receptions for a given period, and months are summarized first, followed by annual totals. The last pie charts for each life stage contain the number of fish within the array by month. Once numerous years are included, we hope to be able to alter the temporal component of the model through ARCGIS in order to actively model migrations and habitat use patterns through an animated time series (not in contract).

Task four maps (slides 31-49 power point appendix) are presented after task two maps in an effort to help the reader use maps during the discussion. Task three slides consist of the requested occupation maps (slides 50 and 51) and two examples of the .7 radius buffer ,as it was applied to two of the most popular receiver sites (slides 52 and 53). Receiver sites, for which benthic data is available, were broken down by percentage of assessed area (slides 53 and 54). No benthic maps are available for unlisted sites and none exists downriver of RM 48. Task five maps are presented on slides 56 - 62. Moon phase data and tidal velocity data are dependent variables integrally related through the moon's gravitational pull. Physical factors have not yet been incorporated into task five analyses through formal mathematical models. In order to examine and identify trends in migration patterns (tasks 2 and 5) numerous years of data must be included because identification of trends is not possible based on one year of data.

When numerous years of tracking are incorporated and physical data attained from VCU, who controls NOAA's only continual upriver gauge, analysis will proceed. River attribute data was requested from VCU in late summer 2010 and is supposed to be in the process of being queried. As of December 28th nothing has been received. Luckily, since this is the first year, time is available to attain the necessary data.

One of the main objectives of this first year report is to proof the GIS data analyses approaches. A preliminary discussion of migration trends over several years of tracking data and correlations

with other researcher's observations and the species' metabolic threshold as it relates to temperature (Niklitschek, 2000) is presented in the discussion. This discussion is based on comparing trends between various sturgeon tracking studies (ASMFC, 2009).

Results and Discussion

It is easy to determine, based on 2010 maps alone, where new abundance data for that year should have been collected or could be expanded and how appropriate time/area regulations could have been formulated. Any meaningful discussion of guidelines for time/area regulations and improving area based abundance models should consider habitat use patterns in relation to the factors that motivate temporal and spatial shifts in habitat occupation, so that resulting models are predictive. It is our hope that with enough years of data, we can determine which physical parameters are motivating seasonal habitat selection and annual shifts in that selection (task 5). Guidelines for time/area regulations and improved area based abundance models can then be determined, based upon the physical parameters that motivate a biological response.

Captive and field based behavioral research illustrate that the fish will actively select habitats in order to maximize their energetic budget (Hager, 2004; Secor and Niklitschek, 2010). Bioenergetic data (Niklitschek, 2000) leaves little doubt that environmental factors like temperature, dissolved oxygen (DO) and to a lesser degree salinity are important physical parameters that affect Atlantic sturgeon metabolism and motivate habitat selection. Physiological research on captive fish suggests that temperature is one the most important factors influencing habitat selection by Atlantic juveniles (Niklitschek, 2000). Juveniles actively select for temperatures between 12-20° C and avoid temperatures nearing 28° C (Secor and Niklitschek, 2010) in the lab and field. Others have also found that seasonal migrations of juveniles appear to be motivated by temperature gradients between fresh and brackish waters (Van Den Ayle, 1984). Physiological thresholds due to temperature and other potential factors motivate habitat selection to a varied degree across temporal scales, leading to active selection of habitats within a river or estuary on a short term basis and latitudinal migration patterns seasonally.

Because temperature is so physiologically important, observed temporal spatial aspects of migrations and habitat occupation are discussed in terms of water temperature. This physical basis of habitat segregation is suitable to river mechanics and array distribution. Receiver number limits station distribution and result in an average of less than one receiver per river mile segment and no coverage across numerous river mile sections. However, thermodynamics operate across a much larger scale than river mile and thus numerous stations are contained within a given thermocline. Therefore, receiver distribution does not limit segmentation of the river by water temperature gradients. The relatively homogeneous nature of thermal dynamics across multiple river miles and stations is evident in slide 58 and 61. A temperature based approach (task 5) is thus more appropriate for examination of habitat use patterns, determination of guidelines for time/area regulations and the improvement of area based abundance models (task 4). The results of task two, four and to some degree five will be addressed congruently. A thermal segregation of river habitats appears, at this point, to correlate with observed fish behavior.

Juvenile Atlantic sturgeon are thought to occupy fresh water portions of their natal rivers for at least the first year of life before moving into higher salinity waters and then to the sea (Secor et al., 2000). This emigration to the ocean generally occurs between age two and six (Smith, 1985). A transient life stage will continue until the fish begins to mimic adult spawning runs or maturity is reached and subsequent participation in spawning occurs.

No YOY have been collected and thus none tracked. One age one (528 mm fork length) was collected and tracked in 2009. This data will be individually examined and discussed in a later paper. A discussion of what we do know about pre-migratory sub-adults through other efforts over the years is attached (Attachment 1).

Task two GIS maps (slides 1-29 in the power point appendix) delineate habitat use patterns by life stage (YOY<550, sub-adults 550 to 1500, and adults>1500 mm TL) on a monthly and annual basis. Of the 33 sub-adults released, 29 were detected and 28 of the 32 adults released were subsequently tracked within the array (88%).

Habitat use by sub-adults is more complex than that of adults (Figure 2). This observation is based not only on expanded temporal and spatial distribution patterns but on a greater diversity of depth occupation within sites. Depth selection within a site can be used to deduce behavior by examining depth alterations over time (standard depth deviation) given a sufficient occupancy period. Conversely, if the period of occupancy is not sufficient, this suggests that the fish was simply migrating through the site on its way to more suitable habitat. Alternatively, rapid movement between sites by sub-adults over short time periods (a day) may suggest that they must cover a significant amount of ground in search of food sources within a given river segment. Rapid movements between sites by adults especially during suitable water temperatures (13° to 26°) likely suggest that they are searching for other adults, i.e. a spawning congregation.

Life stage	Temporal period	Mean depth (m)	Standard depth deviation	Min. Depth (m)	Max. Depth (m)
Adults	09-11	9.33	4.93	0.0002	51.55
Sub-adults	09-11	13.51	8.78	0.0002	90.37
Adults	April-May 09-11	8.35	3.53	3	51.5
Sub-adults	April-May 09-11	15.72	8.91	0.0002	60.65
Adults	August-Oct 09-11	9.43	5.06	0.0002	51.5
Sub-adults	August-Oct 09-11	16.57	9.48	0.0002	82.48

Figure 2. Figure two contains depth data by life stage for 2009-Sept. 2011.

Sub-adults make use of a similar depth range and exhibit similar depth occupancy patterns during periods of highest occupancy (spring and fall). Adults exhibit very different depth occupancy patterns seasonally. Though average depth and depth range is similar between seasons of occupancy, the frequency of depth alteration and minimum depth are not. Standard

depth deviation of adults is reduced in the spring and no apparent breaching occurs. Adult migration patterns in the spring are often characterized by large scale rapid movements (in excess of 20 river miles a day) within like temperature gradients with repetition of these movements over a period of days or even weeks while such gradient persist. Depth deviation of adults is exaggerated in the late summer, which is according to depth sensors, a product of breaching. It is also important to keep in mind that the upriver regions occupied during this period, are greatly reduced in depth variation, and thus given identical depth use patterns, a reduced standard depth deviation should result. Active tracking of tagged fish has collaborated that rapid alterations in depth, like those recorded on passive receivers, are due to breaching activities.

Seasonal migration and habitat occupancy patterns of sub-adult sturgeon in the James River are similar to those described by other investigators. The population of fish increases congruently with temperature in the spring and peaks for the season in May. When the water temperature approaches 26° C (end of May or in early June) in the middle river (USCG buoy 91) the population within the array decreases rapidly. This may be because temperatures in excess of 28° C have been found to have significant sub-lethal effects on Atlantic sturgeon metabolic function (Niklitschek, 2001; Niklitschek and Secor, 2005). As temperatures rise further, the sub-adult population continues to wane, reaching its lowest value in August congruent with the warmest water temperatures of the year (slide 62). Though the population is greatly reduced in August, the quantity of receptions per fish actually increases. This finding may suggest that fish cease their normal searching behavior during this physiologically stressful period and simply hold up in a preferred location (potentially a thermal refuge) awaiting the return of more favorable environmental conditions. This behavior as a reaction to extreme temperatures has also been documented by other researchers (Fisher, DEDNR personal communication; Moser and Ross, 1995).

The array population begins to rebuild in September as the river cools, reaching its annual apex in October. Sub-adults begin to move downriver and out of the array for the winter in mid-October (~ 20° C) and by November the population of resident fish has returned to mid-winter levels. Secor et al., (2000) found similar seasonal shifts in estuarine habitat occupancy based on the behavior of hatchery reared fish (Hudson origin) released into the upper Chesapeake. A portion of sub-adult James River fish has been recorded residing within the lower river in deep waters downriver of Hog Island below our original gate. A second array gate has been placed in Hampton Roads in order to better define true riverine residence times of adults and sub-adults alike and in an effort to determine what percentage sub-adults over winter locally. Some sub-adults are also recorded migrating to offshore holes located off of the North Carolina banks, where they join adult fish and may reside until as late as early April.

The characteristics of sub-adult habitat occupation in the James River are very different than that of adults. Sub-adults populations are much larger (slide 19) and residence time and distribution within the river much greater seasonally (slides 1-17) and annually (slide 19). Sub-adults appear to be more physiologically suited for estuarine occupancy. Sub-adults do not congregate within what appear to be confined physical refuges in the upper river during the warmest season, instead the majority of sub-adults seem to disperse and exit the array. The few that do not exit, exemplify similar patterns of reduced activity. Sub-adults use the Chickahominy River, but with

limited frequency. No adult fish have thus far been recorded using this tributary. On numerous years, larger sub-adults have immigrated into the James River in the fall from the Delaware and subsequently spent the coldest months of the year far upriver around RM 48. This region is completely fresh and contains very deep habitats with complex benthic composition and topography. This sub-adult winter holding area is located far above those selected by smaller juveniles that appear to occupy slightly brackish waters near RM 25 during the same period.

In numerous river systems, other investigators have documented seasonal migration patterns of sub-adults that are similar to those we observed (Brundage and Meadows, 1982; Smith et al., 1982; Dovel and Berggren, 1983; Gilbert, 1989). Reduced extents of movement are correlated with decreasing latitude. Since habitat selection is most often influenced by a desire to remain within a bioenergetically beneficial temperature range, a reduction in the extent of migration in more temperately moderate environments is inherent. Engaging in habitat selection behavior in order to maximize bioenergetics is in full concurrence with the findings of other investigators based on laboratory (Niklitschek, 2000) and field based models (Hager, 2004). Biotelemetry studies by Kieffer and Kynard (1993) in the Connecticut and Merrick Rivers found that juveniles did not enter the rivers until mid-May when temperatures were between 14.8° and 18° C. Downriver movements of sub-adults began around 20° C and peak activity was observed between 12°-18° C (Dovel and Berggren, 1983). Similar migration patterns where noted by researchers in the Hudson and Delaware (Dovel, 1979; Brundage and Meadows, 1982). Other researchers have also recorded juvenile Atlantic sturgeon congregating in deep waters (Moser and Ross, 1995; Bain et al., 2000, Savoy and Pacileo, 2003). Within the Hudson, Bain et al., (2000) found that juvenile sturgeon that did not migrate out to sea during the winter, inhabited deep water habitats within the Hudson. Savoy and Pacileo (2003) found similar deep water habitat occupation patterns within Long Island Sound during the winter. Additionally, Moser and Ross (1995) recorded juveniles in North Carolina preferentially occupying deeper cooler water habitats as thermal refuges in the summer.

Adult sturgeon appear to partake in two seasonal migrations within the James. They occupy the river in the spring (April-May) and again in the late summer through early fall (August –Oct). Most adults immigrate into the middle river (RM 18) in the spring when water temperature is approximately 17° C. After a short occupancy within down river stations most of these fish make repetitive and rapid up and down river runs into and within the upriver habitats that Bushnoe et al. (2005) described as being suitable for spawning (Appendix Figure 3). A smaller number make only one run, which may represent spawning behavior more characteristic of females. In 2010, adults congregated around RM 48 (Fort Pocahontas) during the spring a region identified as moderately suitable for spawning due to the seasonal variability of its physical characteristics (Bushnoe et al., 2005). Data from other years illustrates that adults do not consistently stop their upriver migrations at this mid-river site but often make it farther upriver. Incursions have included several fish entering what has been characterized as suitable spawning habitat in the upper James and Appomattox Rivers. No fish have been recorded passing above RM 67 in the James during the spring and this season is characterized by short residence times. Adults exit the array periodically throughout the spring and any remaining adults exit the river concurrently with the majority of sub-adults when the water temperatures reach 24° C in early June.

During the late summer and early fall (August-September) some adults that were present in the spring reappear. They are joined by other adults that were not present in the spring. It is unclear where these fish reside from June until August, but it appears to be below our Hampton gate. Adults may be transients from other river systems or, as returning fish suggest, the period outside the array may have been spent within the bay or near shore waters. Down river residence time appears to be reduced on this fall immigration. Fish ascend the river, rapidly congregating in upriver sites between RM 48 (Fort Pocahontas) and the fall line. Extended residence times and reduced activity at upriver stations during this period are so extreme that they overwhelm annual adult habitat occupancy charts as evidenced by receiver receptions (pie charts).

During late summer, a preference for the river section where the upper James and Appomattox Rivers meet is evident annually. Significant salinity differences between the upper and middle river sections does not exist nor does hypoxia (< 4 mg/L), nor an increase in food availability seem to be evident (Fenster 2010). In the lower bay and river, environmental conditions (salinity, DO and temperature) are physiologically stressful at this time (Niklitscheck, 2001, Secor and Niklitschek , 2010). Physiological stress motivates habitat selection (Secor and Gunnerson, 1998, Niklitscheck, 2001) and results in the migrations and extended resident time within the upper river during this season. Adults prefer the narrow confluences in the upper river due to reduced temperatures, and to a lesser degree increased DO (see slide 60 and 61). Differences of 5° C and 1 mg/l between river segments during this period do not at first seem significant. However, sturgeon require highly oxygenated environments (Niklitscheck, 2001) and the combined effect of decreased oxygen levels and temperatures in the middle river, close to, or exceeding the 26° C sublethal effects threshold, are enough to motivate migration and to encourage reduced behavior upon occupancy of these upriver refuge sites. In addition, less active fish receive a reduced benefit from ram ventilation, which would normally occur during increased swimming speeds. Perhaps the increased flow rates within the upper river also assist in respiratory exchange.

Standard depth deviation of adults (Figure 2) during late summer upriver occupancy does not reflect a reduction in activity, because breaching is regularly occurring. Depth data records and observations during active tracking of tagged fish confirm this hypothesis. Since Atlantic sturgeon are a physostomous fish that contains a pneumatic duct which connects its gas bladder to its gut, it is possible that an additional physiological benefit can be attained by breaching and forcing oxygen rich air into the air bladder periodically. From there oxygen could be diffused or forced into the circulatory system, thus additionally aiding in osmotic regulation. Whatever the reason, the fish do not appear to breach actively in the spring period when spawning is hypothesized to occur. Once temperatures decline in late September or early October, adults disperse through downriver sites and begin to move out of the river. By November, adults occupy only lower river sites and are out of the array by December.

PIT and T tag returns (our tags 2005-2010 reported to USFWS reported by Eyler et al., 2003)) show that migratory sub-adults join adults in near shore coastal migrations that move inshore and northerly in the spring and offshore and southerly in the winter. A significant number of our sonically tagged adults and sub-adults have been recorded congregating off Cape Hatteras, North Carolina. Where they arrive as early as late December and reside into early April. Some of these same fish have reentered the James the following year; again around the 17° C mark in late

April/ early May. These receptions and other offshore tag returns suggest that sturgeon from the Chesapeake stock gather in deep offshore sloughs south of the Virginia North Carolina border (Jim Gartland VIMS, NEMAP survey data, Wilson Laney USFWS, NMFS survey personal communications).

Task three

Atlantic sturgeon have been known to spawn in waters ranging from 13° to 26° C across there range (Borodin, 1925; Huff, 1975; Smith, 1985a; Bain et al., 2000; Caron et al., 2002; Hatin et al., 2002), however, spawning most often occurs between 13° and 21° C (Ryder, 1888; Scott and Crossman, 1973; Bain et al., 2000; Caron et al., 2002). Though temperature appears to be a universal determining factor in spawning, an increased tolerance for warmer water has, surprisingly, been recorded in more northern rivers (Hudson 14°-26° C, Bain et al., 2000 and St. Lawrence 14.5 -23.4° C, Hatin et al., 2002). The Delaware is the geographically closest river system to the James, and thus it is reasonable to assume that James River fish spawn within a similar temperature range. The Delaware stock's preferred spawning temperature range has been documented as being between 12.8° and 18.3° C (Ryder, 1888). To be inclusive rather than exclusive, maps of potential adult spawning were constructed for the period when temperatures were between 13-26° C (based on USGS temp. data attained from buoy 91, ~RM 56, James River).

Task three also cross references adult occupancy during this temperature range with numerous sources of benthic habitat maps. Receiver sites that existed during the entire 2010 year were selected and overlapped with benthic maps to examine habitat preference by benthic composition (slides 52-53). Benthic habitats within reception buffers were thus delineated and a percentage of known habitats determined (slides 54 and 55).

There appears to be more suitable spawning substrate in the upper river based on the increased presence of complex hard bottom. However, these regions are not occupied every year during the spring while lower river sites around RM 48 and 49 are. Perhaps as Smith (1985b) suggests, the annual spawning migration follows the salt wedge upriver progressing until it finds the first suitable spawning habitats above this region. This mechanism implies that the spawning ground shifts over time according to the prevailing physical conditions. Sites between RM 48-49 contain significant portions of hard bottom with complex topography and without sediment. Because different river sites were assessed by different benthic investigators using different scales and ground truthing techniques it is hard to assure that equal comparisons between each site compositions exist. Based on Gulf sturgeon research, Atlantics probably select regions of high conductivity that are above the salt wedge but below fall line waters containing low conductivity (Sulak and Clugston, 1999; Fox et al., 2000). Differences in conductivity may contribute to preferential occupation of the RM 48-49 region in the spring. Upriver regions receive large fresh water discharges which decrease already low conductivity measures in the spring (Fenster, 2010). Downriver sites would be buffered from such rapid declines. However, due to other physical attributes these lower river sites may not offer consistently beneficial spawning or nursery conditions. This may force upriver site selection or result in increased variability between spawning success due to environmental conditions.

Late summer tracking suggests that life stages of Atlantic sturgeon are physiologically dissimilar. Some age specific physiology for the species is well documented; differences between DPS and between juveniles and adults are not. In some regions, metabolic stress due to environmental conditions, may be a more important motivator for adult habitat occupation than previously recognized. Adult fish annually migrate to and occupy the upper James for an extended period in late summer to presumably inhabit the cooler more oxygen rich waters found there. For much of the time that adults appear to be forced to seek refuge and remain in a confined upriver region with fresh water inputs, sub-adults occupy a much wider distribution of habitats with higher temperatures. A reduced occupation of the river by adults near the Hatcher Island power plant's warm water input (RM 72), supports the assertion that temperature is the primary factor limiting adult habitat availability during this season.

Adult males collected during this period in the upper river are often expressing milt which has resulted in some proposing that these fish are spawning during the late summer. Most recently an egg-bearing female and a recently spawned female were also collected by a student. No data on the eggs' stage or confirmation of the female's recent spawning activity has been confirmed or made available to the partnership. And though egg mats are being run congruently over hard bottom habitats associated with the netting site, these collections have failed to collect any sturgeon eggs. If reproduction is occurring during late summer early fall, the timing this event is critical because the appropriate spawning temperature window for successful reproduction and larval survival is very short. Water temperatures are close to or exceed the highest reported spawning temperature of 26° C for most of September. Once temperatures drop to within the preferred range between 13° and 21° C (Ryder, 1888; Scott and Crossman, 1973; Bain et al., 2000; Caron et al., 2002) they usually decrease rapidly to a level far below that favored for incubation (20-21° C) and which lead to prolonged hatching and an increased risk of fungal infection (Mohler 2003). If larval sturgeon are produced within this short window, which most likely occurs in early October, it remains a question as to whether adequate growth could be attained to survive, since a temperature range of 15 to 19° C has been required to successfully rear larvae in captivity (Kelly and Arnold, 1999; Mohler, 2003). Fifteen degrees seems to be the suggested threshold for successful hatching with impending warmer temperatures (Bath et al., 1981). It appears likely that poor hatching and low to no survival of larvae would occur below this temperature.

Recognized habitat areas of special concern for Atlantic sturgeon include spawning grounds, nursery areas, inlets and wintering grounds (ASMFC 2009). Our research suggests that environmental refuge sites should be added to this list. Both adults and sub-adults occupy restricted thermal refuge sites seasonally and reduce activity while in these sites.

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Appendix Figures

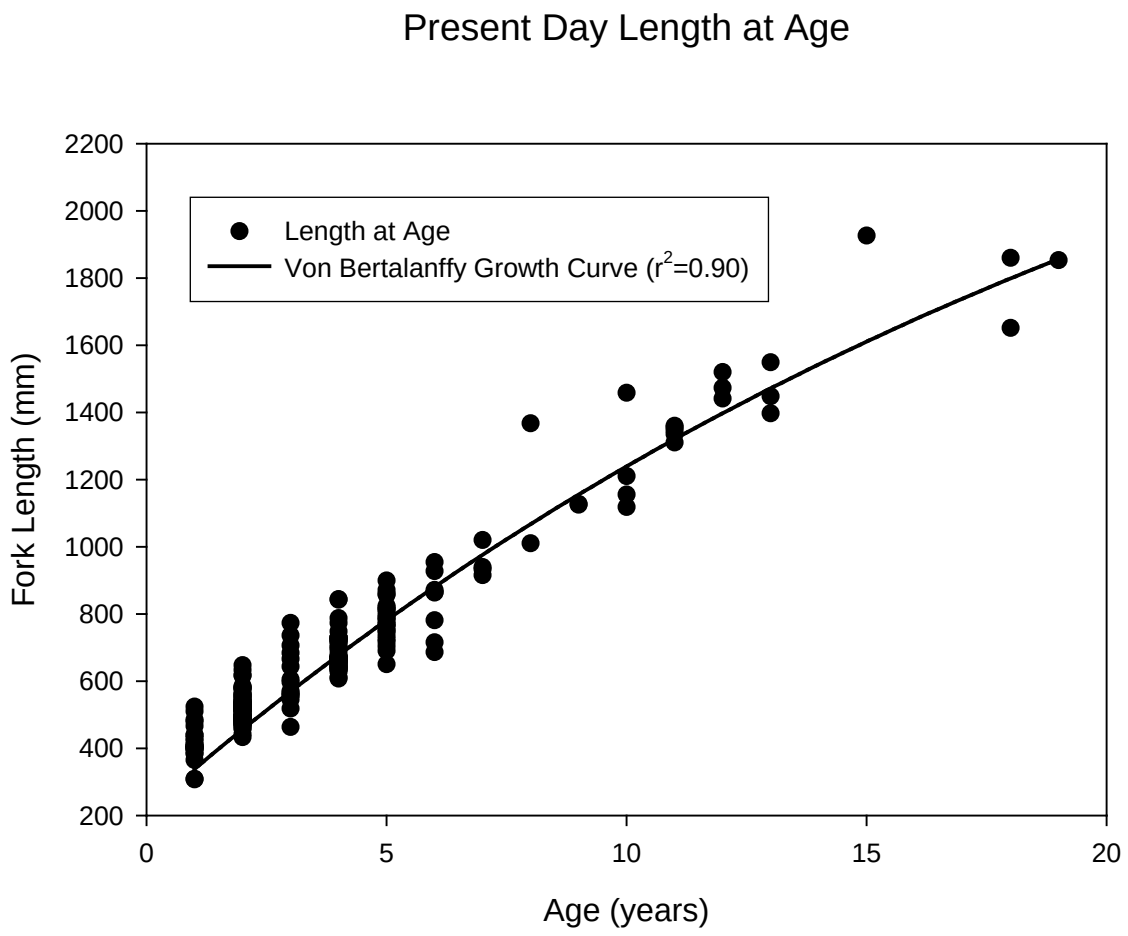

Figure 1. Figure one is an age growth regression of fish collected in the James River through the FRG program 2005-2007 (Balazik 2008).

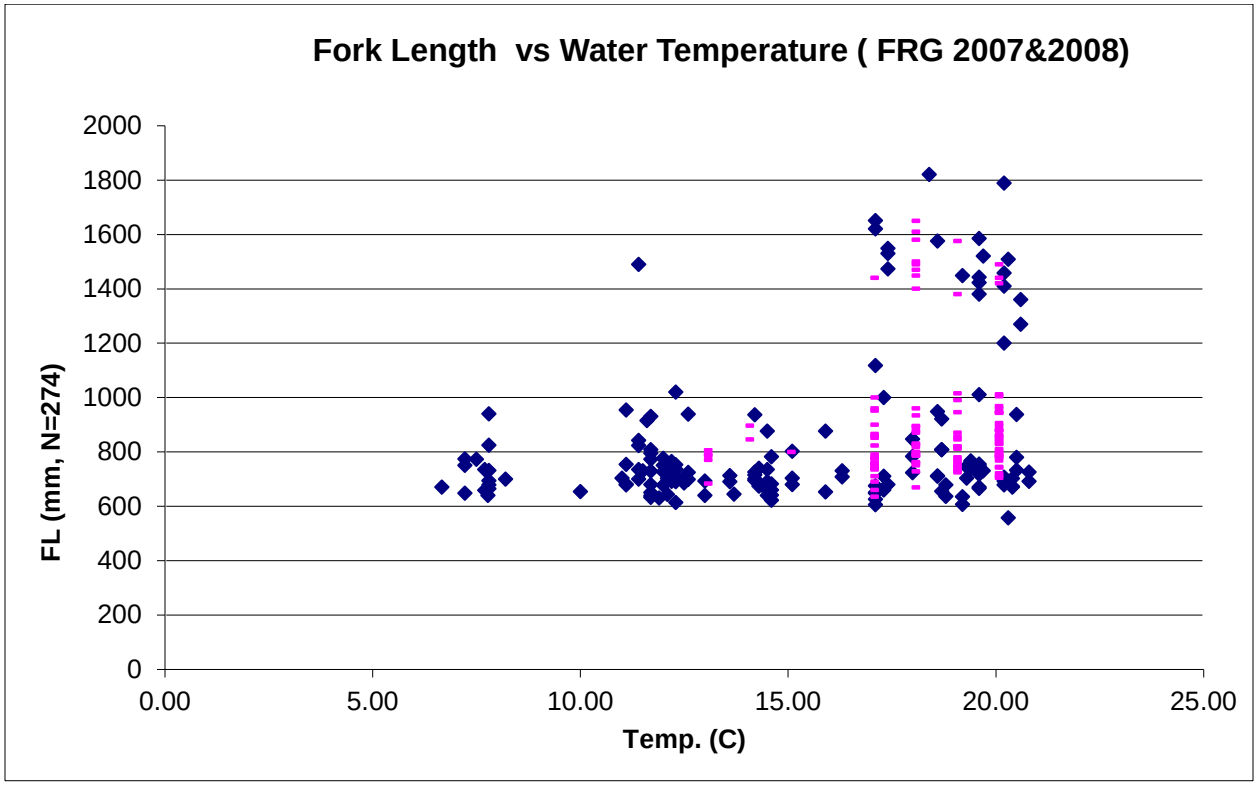

Figure 2. Figure two illustrates the temperature of capture at the down river survey site (RM 18) for 2008 and 2009. Notice the influx of adult fish occurring after 17° C. This immigration persists through May but not all fish partake in upriver migrations.

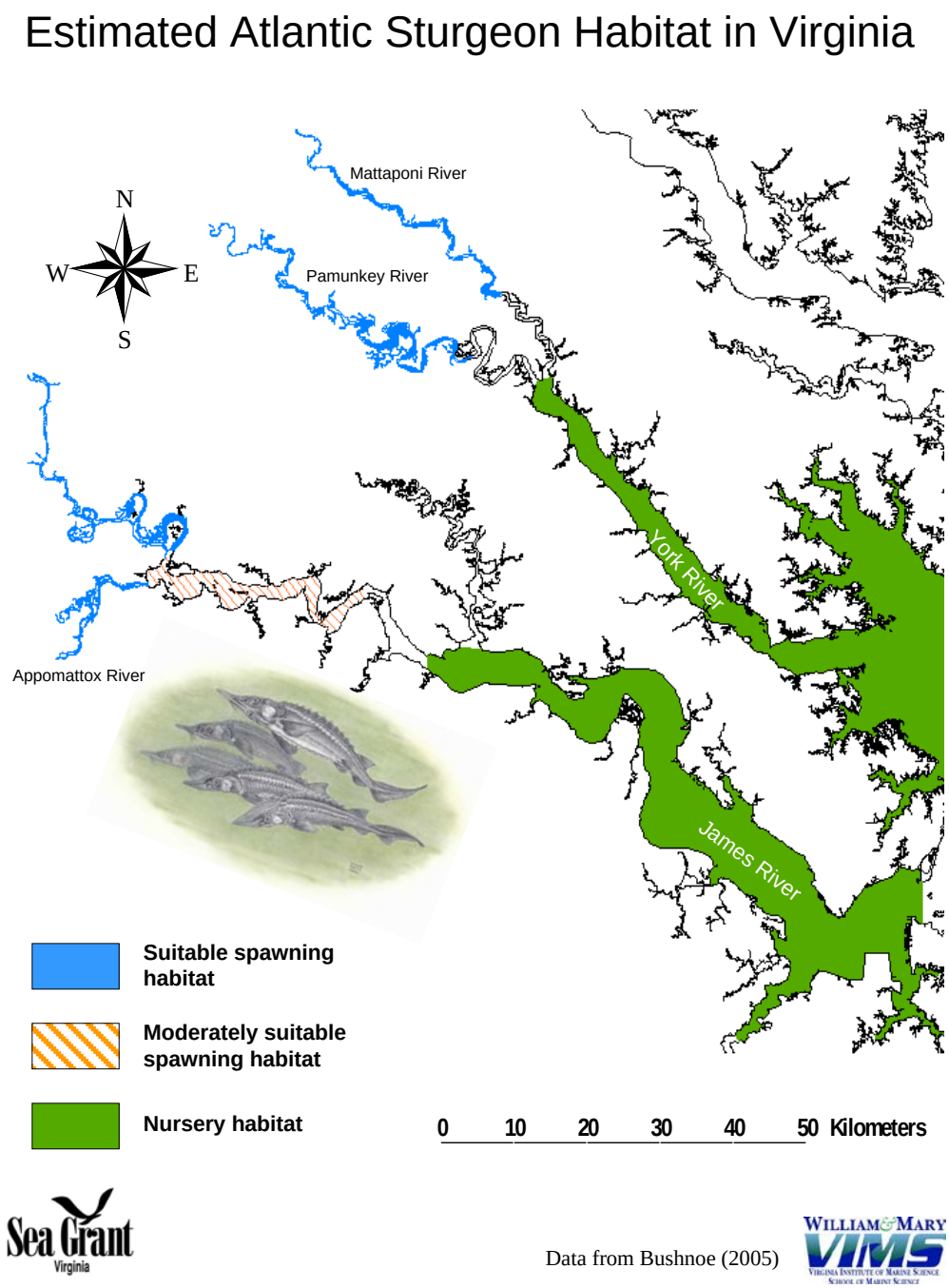

Figure 3. Figure three is from Bushnoe et al. 2005. It delineates potential spawning habitats by river mile based upon the average characteristics of numerous physical parameters. Notice moderately suitable spawning habitats occur as far down river as RM 48 (Fort Pocahontas), a region that records consistent occupation each spring and fall. In contrast sites within suitable habitat do not see annual use in the spring.

Attachment 1.

Comments on Pre-migratory juvenile sturgeon in the James and lower Bay

The Atlantic sturgeon is highly mobile, long lived and uses a wide diversity of habitats at varied life stages. We have not attained any young of the year (YOY) fish through our netting efforts related to transmitter implantation although they are known to reside within their native estuary for several years (Murowski and Pachero 1977; Smith 1985a). This occupation pattern has been confirmed in the James River numerous times through VIMS juvenile finfish survey's collection of YOY, which have been concentrated around the mouth of the Chickahominy River. This lack of collection by our survey gear is thus not indicative of YOY absence but rather the result of the gear and site selection we are implementing. The experimental nets used by our partners consist of 5-14" mesh which is not designed to capture YOY or even age one fish. Therefore, due to a lack of available specimens very little is known about how pre-migratory age classes use the James River or the estuary.

The majority of what we do know is based on our collaborative work with fishermen in 2005-2006. This work suggested that these pre-migration life stages seek out thermal refuge in deeper waters in the middle James below the salt water interface in late winter. Tag recoveries in Virginia also suggest that James River juveniles (genetic ID by King, unpublished) move into preferred habitats within the bay before becoming coastal wanderers when they reach a total length of approximately 510 – 710 mm TL or around age two (aged by Balazik 2008, appendix 1). Previous researchers have suggested that such a coastal emigration does not occur until fish were 760-920 mm (Murowski and Pachero 1977; Smith 1985a) and none have mentioned down river movements into preferred higher salinity feeding habitats prior to such a transition. Recapture data in both the James and York Rivers suggest that pre-migratory sturgeon show site fidelity within and outside of their native tributaries in the spring. Small juveniles recaptured in the James (January-April) occurred within 6 miles of the original capture location in brackish water near the freshwater interface. Approximately fifty juveniles of this size captured at the mouth of the York River were held (~ 96 hours) in late March to late April of 2006 in an upriver facility. The fish were of James River genetic origin according to King (unpublished) and of unique genotype according to Wirgen, et al. (2007). All were released in a central location near the mouth of the York River after capture. Of these fish, 9% were recaptured, with 66% of these recaptures occurring at the original capture site. In 2005, one fish was captured five times (April 8 to May 18) in this same habitat, located near expansive SAV covered benthos known to contain a diversity of benthic infauna. Interestingly, local fishermen also mentioned that iron slag had been dumped in deeper waters in close proximity to this habitat and that this site provided by far the most consistent catches. Extended residence times and multiple recaptures of numerous fish after release suggest that this region may contain preferred habitat. However, highly variable catches at this site reflect the temporal nature of the species occupation.