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Temperature selectivity and movement patterns of speckled trout

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Executive Summary

Speckled trout (*Cynoscion nebulosus*) is the focus of an important recreational fishery in the southeastern United States**.** Speckled trout in Virginia has been cited as both a transitional population and as a mostly non-migratory population. The degree of residency is important to understand for the effective management of the species. Management of speckled trout has also been marred by cold-stun events which can kill a significant portion of the stock and have detrimental localized effects. Virginia is the northern extent of speckled trout populations and is the most likely portion of its range to experience cold-stun events. Virginia water temperatures can reach 0 °C during some winters, well below lethal temperatures for speckled trout. The primary objective of this project was to provide managers and recreational fishermen with information regarding speckled trout movements. This study used acoustic telemetry to better understand how speckled trout react to declining water temperatures and begin to assess what proportion of the population is subject to cold stun events. An array of acoustic receivers and temperature loggers were placed throughout the Corrotoman and Lynnhaven Rivers. Speckled trout were tagged with VEMCO V13T acoustic transmitters (n=43 fish) that broadcast the identity and internal temperature of the fish and VEMCO V9 acoustic transmitters (n=16 fish) that only broadcast the identity of the fish. Fish were detected at every receiver in both river systems, but acoustic receiver stations East Corrotoman 2, East Corrotoman 3, East Lynnhaven, and Linkhorn Bay had the most detections. Temperatures relayed from fish tagged with V13T tags ranged from 1.6–24.2 °C. Speckled trout that emigrated out of the river systems (~42.4% of tagged fish) left when water temperatures were between 13 - 15 °C. These fish were significantly smaller than the speckled trout that remained all winter. The speckled trout that remained in the Corrotoman and Lynnhaven Rivers typically were detected by the acoustic receiver stations East Corrotoman 5, East Corrotoman 6, or Linkhorn Bay when water temperatures dropped below 10 °C. The water temperature dropped below 5 °C in both river systems between January 7th and January 12th, 2017. All tagged speckled trout that swam within detection range during this time had body temperatures from 1.6 to 5.0 °C. One out of seven speckled trout from the Corrotoman River and six out of eleven speckled trout from the Lynnhaven River were never detected again after January 12th and presumed to have died. The behaviors of speckled trout from Virginia during the fall and winter months enable survival of the population through the colder conditions that exist at the extent of their range. The population of speckled trout in Virginia cycles between high abundance following several years of mild winters and low abundance following continuous years of winter mortality events. Most of the speckled trout smaller than 340 mm left these minor estuarine systems when temperatures hit a critical point in search of thermal refuges in the larger water bodies. These individuals likely sustain the population during mass mortality events associated with extreme cold temperatures. Mild winters allow for both resident and migrating speckled trout to survive and the population increases substantially. Managers should use previous winter water temperatures and notifications of mass mortality events to establish current catch limits.

Introduction

Speckled trout (*Cynoscion nebulosus*) is the focus of an important recreational fishery in the southeastern United States. Recreational harvest nationally and within Virginia far exceeds commercial harvest (Jensen 2009). Recreational landings in Virginia were estimated to be 226,556 lbs in 2012 (NOAA MRIP data). This generates over $6 million in income and $10 million in sales (Duberg et al. 2006). A coast-wide stock assessment of speckled trout has not been conducted because it is recognized as a largely non-migratory species. However, speckled trout do make some coastal movements, although there is a severe lack of information regarding the patterns and scale related to migration in this species. Speckled trout in Virginia has been cited as both a transitional population and as a mostly non-migratory population. Historical studies have shown an average of 15% of the population may migrate to North Carolina (Jensen 2009). Even the most recent North Carolina speckled trout Fisheries Management Plan included speckled trout landings from Virginia. More recent data indicates that only approximately 4% population moves between Virginia and North Carolina (S. Musick, pers. comm.). Genetic work is currently being performed to determine if two (or more) stocks exist within these states, and there is some indication that several rivers in Virginia are genetically unique (J. McDowell pers. comm.). Tagging studies outside of Virginia and North Carolina have also indicated that speckled trout are largely resident to their natal estuaries and often do not make coastal migrations (Iverson and Tabb 1962; Music 1981; Moulton et al. 2016). The sparse data on speckled trout movements within Virginia hinders management practices for both Virginia and North Carolina fishery managers.

Management of speckled trout has also been marred by cold-stun events which can kill a significant portion of the stock and have detrimental localized effects. Ellis et al. (2017) measured an increase in weekly mortality with declining temperature. Virginia is the northern extent of speckled trout populations and is the most likely portion of its range to experience cold-stun events. Virginia water temperatures can reach 0 °C during some winters. Lethal temperatures for adult speckled trout have been reported to be from 0 - 7 °C (Storey and Gudger 1936; Tabb 1958; Moore 1976; Anweiler et al. 2014; Ellis et al. 2017). Speckled trout populations in Virginia suffered cold mortality events in 2013 and 2014, with the last episode resulting in a closure of the speckled trout fishery. Although cold-stun events are not under the

control of fishery managers it is possible to include them into fishery management plans if managers had a better understanding of speckled trout behavior during the colder months. This requires information on how speckled trout react during the winter months to dramatic decreases in water temperature and long stretches of extremely cold conditions.

The primary objective of this project was to provide managers and recreational fishermen with information regarding speckled trout movements. This study used acoustic telemetry to better understand how speckled trout react to declining water temperatures and begin to assess what proportion of the population is subject to cold stun events. We hypothesized that an individual's behavior could be categorized as either emigration at a certain temperature threshold or remaining without regard to water temperature. The individuals that emigrate were hypothesized to move to deeper adjacent water bodies.

Methods

Monitoring Stations

In 2015, we deployed seven acoustic receivers (VEMCO VR2W) throughout the Corrotoman River (Figure 1) and two acoustic receivers within the southern branch of the Elizabeth River (Figure 2). These two rivers represented northern and southern Virginia populations of speckled trout. Acoustic receivers record information from fish tagged with acoustic transmitters along with the date and time the information was received. Acoustic receivers have a range of at least a half-mile radius and in all deployment locations the receiver was able to detect acoustic tags the entire width of the river (i.e., there were no acoustic shadows). Temperature loggers (HOBO Water Temperature Pro v2 Data Logger) were placed alongside each acoustic receiver. The temperature loggers recorded water temperature 0.5 meter off the bottom every 15 minutes. Unfortunately after extensive effort with hook and line and gillnets in October-November, 2015, only one speckled trout was caught and tagged in each of the Corrotoman and Elizabeth Rivers. The lack of speckled trout was most likely related to winter mortality events in both 2013 and 2014 and a decision was made to delay the project until the fall of 2016.

In 2016, tagging operations were more successful on the Corrotoman River, but zero fish were caught in the southern branch of the Elizabeth River. In October, the decision was made to move the southern portion of the tagging operation from the Elizabeth River to the Lynnhaven River. The two acoustic receivers from the Elizabeth River and two acoustic receivers from the Corrotoman River (West Corrotoman 1 and East Corrotoman 1; Figure 1) were deployed in the Lynnhaven River (Figure 3). The two receivers from the Corrotoman River were chosen based on which receivers had the least impact on the ability to track speckled trout movements. The temperature loggers were also redeployed with each receiver and continued to record temperature every 15 minutes. Other institutions manage additional acoustic receivers in the Atlantic Ocean off Virginia Beach, at the mouth of Chesapeake Bay, from the mouth of the James River to Richmond, in Chesapeake Bay near York spit, from the mouth of the York River to West Point, at the mouth of Mobjack Bay, from the mouth of the Rappahannock River to Fredericksburg, in the Potomac River, in the Patuxent River, and across the northern portion of Chesapeake Bay in Maryland waters. Most of these receivers were deployed for a 10-year study involving the movements of Atlantic sturgeon and all were in place for the current study on speckled trout.

The acoustic detection data in this report consists of data from 10/31/2015 to 1/29/2016 in the Corrotoman, Rappahannock, Piankatank, and York Rivers and 10/14/2016 to 1/25/2016 in the Lynnhaven River. Data from acoustic receivers maintained by non-Virginia Institute of Marine Science personnel will be acquired by the fall of 2017 and will be included on a future scientific paper and an associated webpage reporting the results.

Acoustic Tagging

Two different types of acoustic transmitters were used in this project. VEMCO V13T tags are acoustic transmitters that broadcast the identity and internal temperature of the fish. Because fishes are ectothermic, the internal temperature of the fish should approximate the water temperature. To support the weight of the V13T tags (weight in water = 6.5 g) fish had to be a minimum weight of 325 g or total length (TL) of 343 mm. VEMCO V9 tags (weight in water = 2.9 g) are acoustic transmitters that do not have an extra sensor on it, but can be put inside smaller fish (minimum weight = 150 g; minimum TL = 255 mm).

All tagged fish were caught via hook and line and immediately placed in a tank of water until an anesthetic bath and surgical supplies were ready. The anesthetic bath consisted of 20L of ambient river water, 26.6g of sodium bicarbonate, and 15ml of acetic acid. This produced a solution with high levels of CO_2 which acted as the anesthetic. Fish were placed in the anesthetic bath until stage 5 of anesthesia was reached (i.e., the fish loses movement in the fins and gill covers). Speckled trout were then placed on a surgical table with water flowing continuously into the mouth and over the gills. An approximately 20mm incision was made on the ventral surface half way between the pelvic and anal fins. The tag was inserted into the abdominal cavity and the incision was closed with simple interrupted sutures (Ethicon Endo-Surgery, Inc.; coated vicryl absorbable suture in 3-0 thread size with PS-2 reverse cutting needle). Finally, a small section of the anal fin was taken for genetic analysis, an external dorsal tag was inserted into the fish on the left side directly below the dorsal fin, and the fish was placed into a recovery tank. Once the effects of the anesthetic and surgical procedures were not evident, the fish was released at approximately the same location it was caught.

Analyses

Data from the temperature loggers was graphed and analyzed for trends within each river system. The temperature logger data was also compared to the temperatures of each fish tagged with a V13T tag to reveal if thermal refuges exist. If thermal refugees were not apparent, then temperature logger data was assigned to detections for fish implanted with V9 tags. Detection data was mapped with ArcGIS and analyzed for trends in movement patterns. Movement patterns were examined with regards to time of year, water temperature, and total length of tagged fish. T-tests were performed with Microsoft Excel to determine if TL of tagged fish differed between the two river systems and if TL correlated with emigration from their original tagged river system.

Results

Tagging data

Sixty speckled trout were caught and tagged during the fall of 2015 and 2016. Data from the Elizabeth River was removed from all analyses because the one fish tagged was never recorded by an acoustic receiver. The fish was recaptured by a recreational fisherman eight days after being tagged and reportedly released in healthy condition. The fish's lack of detections was probably due to either tag malfunction or the sutures did not hold the tag inside the body cavity before the wound healed. The other 59 fish that were tagged all had at least one detection and combined had over 92,000 detections.

Speckled trout tagged in the Corrotoman River (n=21; 11 V13T tags; 10 V9 tags) averaged (range) 344.5 mm TL (300 - 464 mm). In 2015, one speckled trout from the Corrotoman River was tagged on October 21st. In 2016, twenty fish were tagged between September 28th and December 13th. Speckled trout tagged in the Corrotoman River were recorded by a receiver an average (range) of 2027.1 detections (104 – 6044 detections). The average time between the day the fish was tagged and the last day detected for speckled trout in the Corrotoman River was 36.8 days (Table 1).

In the Lynnhaven River, tagged speckled trout (n=38; 32 V13T tags; 6 V9 tags) averaged (range) 407.2 mm TL (300 - 521 mm). The length of speckled trout tagged from the Lynnhaven River was significantly larger than the fish tagged from the Corrotoman River (t-test, df = 57, $p < 0.01$). All of the speckled trout from the Lynnhaven River were caught in 2016 from October 12th to November 17th. These fish were recorded by a receiver an average (range) of 1303.0 detections (2 – 8131 detections). The average time between the day the fish was tagged and the last day detected for speckled trout in the Lynnhaven River was 57.3 days (Table 1).

Temperature data

Water temperature patterns during the fall and winter of 2015 and 2016 in the Corrotoman River ranged from 1.5 to 30.5 °C (Figures 4 and 5). The temperature patterns in the Lynnhaven River in 2016 were very similar and ranged from 0 to 24°C (Figure 6). Both rivers experienced a decrease in temperature from October through December and then temperatures cycling around approximately 7°C. In the Corrotoman River, the stations upriver were warmer than the stations closer to the mouth. In the Lynnhaven River, water temperatures at each station were often within 1 or 2°C except during sudden cold and warming events. Water temperatures

in the eastern and western branches of the Lynnhaven cooled and warmed faster than water temperatures in Linkhorn Bay or at the mouth of the river.

Temperatures relayed from fish tagged with V13T tags ranged from 1.6–24.2°C. However, fish swimming in water below 3.9°C were never detected again and were presumed to have died. The temperatures from the V13T tags were always within 0.5°C of the temperature logger associated with the acoustic receiver that detected the tag. From these data, there does not appear to be a thermal refuge within 0.5 the detection radius of the acoustic receivers. Therefore, we assigned temperatures from the temperature loggers to fish tagged with V9 tags. Temperatures recorded at the same time a V9 tag was recorded ranged from 7–25°C. One fish tagged with a V13T tag had its internal temperature change from approximately 10°C to a steady 35.0°C. This tag proceeded to move quickly between receivers in the Lynnhaven River for 2 days before its last detection. The temperature during those two days never changed from 35.0°C, which leads us to believe this fish was consumed by a marine mammal, most likely a common porpoise.

Movement patterns

In the Corrotoman River, fish were detected 40,712 of times. Fish were detected at every acoustic receiver and appeared to utilize the entire river system. However, acoustic receiver stations East Corrotoman 2 (n = 11,239) and East Corrotoman 3 (n = 27,026) had the most detections and may be a location of higher speckled trout densities (Figure 7 and 8). In the Lynnhaven River, fish were also detected at every receiver for a total of 50,373 detections. The acoustic receiver stations Linkhorn Bay (n = 22,993) and East Lynnhaven (n = 22,250) had the most detections (Figure 9).

In the Corrotoman River, fourteen fish were detected moving out of the system between October 4th and December 1st (Figure 10). The average temperature during this egress was 15.5°C (Figure 11). Eleven fish were detected leaving the Lynnhaven River between October 22nd and January 7th at an average temperature of 14.4°C (Figures 10 and 11). The river temperatures of the Corrotoman and Lynnhaven Rivers at the time of egress were not significantly different (t-test, df = 23, p=0.57). Speckled trout that left the Corrotoman River were later detected in the Rappahannock (n = 5 fish), Piankatank (n = 3 fish), York (n = 1 fish),

James (n=1 fish, but could be greater due to unreported 2016 data), Elizabeth River (n=1) and Lynnhaven (n = 1 fish) Rivers. The speckled trout that moved from the Corrotoman River to the Lynnhaven River swam a minimum of 60 miles in 6 days. Speckled trout that moved out of the Lynnhaven River most likely moved to North Carolina, the lower Chesapeake Bay, or James River. VIMS staff does not maintain any of these receivers and as of the completion of this report we have not received data from receivers in those areas.

Speckled trout that remained in the systems were significantly larger than tagged speckled trout that emigrated in both the Corrotoman (t-test, $df = 19$, $p < 0.01$) and the Lynnhaven (t-test, $df = 36$, $p = .01$) Rivers. The speckled trout that remained in the Corrotoman River typically were detected by the acoustic receiver stations East Corrotoman 5 or 6 when water temperatures dropped below 10°C. In the Lynnhaven River, tagged speckled trout were more often detected at the acoustic receiver station Linkhorn Bay when water temperatures dropped below 10°C. The water temperature dropped below 5°C in both river systems between January 7th and January 12th, 2017. All tagged speckled trout that remained in these systems experienced this temperature drop and the fish that swam within detection range had body temperatures from 1.6 to 5.0°C. One out of seven speckled trout from the Corrotoman River and six out of eleven speckled trout from the Lynnhaven River were never detected again after January 12th and presumed to have died.

Discussion

In 2015, the current study and many recreational fishermen experienced a poor fishing season for speckled trout. The winters of 2013 and 2014 were very cold and many of the rivers and parts of Chesapeake Bay iced over. Thousands of dead speckled trout were described by many fisherman and the mass winter mortality events appeared to have impacted the population levels in these rivers. In contrast, the winter of 2015 was very mild and temperatures in the Corrotoman River rarely went below 5°C. This reprieve from deadly cold temperatures improved population numbers and we were able to complete the proposed acoustic study in 2016. Speckled trout greater than 400 mm were more abundant in the Lynnhaven River than the Corrotoman River. The significant size difference between the populations may be due to the more northern

Corrotoman River experienced larger winter mortality events and the population has not fully recovered.

This was the first time carbon dioxide was used as an anesthetic for sedating speckled trout. All fish successfully recovered from sedation and the surgical procedure. Carbon dioxide has the benefit of being the only approved anesthetic by the Food and Drug Administration for use in food fishes that will be immediately released in the wild. Future studies are warranted to determine if carbon dioxide can be used as an anesthetic on other estuarine species and how it compares to the use of other common anesthetics, i.e. MS-222 which has a 30-day wait period before release.

Speckled trout utilized the entire extant of the acoustic array in both the Corrotoman and Lynnhaven Rivers. Many fish would often remain around an acoustic receiver for several days to weeks and then move to a different stretch of river (detected by a different receiver). These fish may have been looking for prey or relocating to find warmer water. Virginia has the most northern population of resident speckled trout and because of their location this population is the most vulnerable to winter mortality events. The water temperatures in the fall and winter of 2016-2017 were a mix of seasonally warm temperatures (~10°C) and lethally cold temperatures (< 5°C). This provided a great platform to analyze which speckled trout moved in response to temperature and how many decide to remain and survive the colder temperatures.

Most of the speckled trout that emigrated moved out of both river systems during November when water temperatures were between 13 and 15°C. The emigrating fish were significantly smaller in length than the fish that remained in each river system. Smaller fish may not have the capacity to thermoregulate compared to larger speckled trout. They may leave areas of higher prey densities to seek out a thermal refuge in deeper areas of adjacent rivers or bays. A few speckled trout moved to non-adjacent river systems and were detected 25 to 68 miles away from their original tagging location. Previous acoustic tagging studies have shown speckled trout to have site fidelity to one river system, but a portion of speckled trout in this study moved to another river system(s) that were not adjacent to the original tagging location. An ongoing genetic study may improve our understanding of the connectivity of speckled trout between Virginia river systems.

Tagged speckled trout that did not emigrate in the Corrotoman River moved or remained upstream around stations East Corrotoman 2 and 3, while non-emigrating fish in the Lynnhaven

River moved or remained around the station Linkhorn Bay. The water temperatures at these three stations were typically a few degrees warmer than the other stations in each river system. This was most evident during cold events when temperatures would drop by a several degrees. The upriver locations on the Corrotoman River and Linkhorn Bay are shallower then the other stations and may increase in temperature faster during daylight hours. Speckled trout used these locations to survive the duration of cold events. Several tagged fish (39% of the speckled trout that did not emigrate) were presumed to have died during one particularly cold event when temperatures were below 5°C from January 5th to the 12th. Laboratory results for hatchery reared speckled trout have shown significant mortality to occur below 4°C (Anweiler et al. 2014). Ellis et al. (2017) found speckled trout to be tolerant of a water temperature of 5°C for a few days, but significant mortality occurred after 5 days of exposure. They also found that exposure at 3°C for 2 days resulted in 100% mortality. In spite of some tagged fish dying during the 5-day cold event, greater than 60% survived. These fish may have found a thermal refuge outside of detection range where temperatures were not lethal or been able to burrow into the mud or leaf litter to escape the lethal water temperatures (Hales and Able 2001).

The behaviors of speckled trout from Virginia during the fall and winter months enable survival of the population through the colder conditions that exist at the extent of their range. The population of speckled trout in Virginia cycles between high abundance following several years of mild winters and low abundance following continuous years of winter mortality events. Speckled trout that did not migrate with temperature and remained in the river systems regardless of lethal temperatures were significantly larger than those fish that emigrated. Most of the speckled trout smaller than 340 mm left these minor estuarine systems when temperatures hit a critical point in search of thermal refuges in the larger water bodies. These individuals likely sustain the population during mass mortality events associated with extreme cold temperatures. Mild winters allow for both resident and migrating speckled trout to survive and the population increases substantially. Managers should use previous winter water temperatures and notifications of mass mortality events to establish current catch limits.

Speckled trout are a fun and delicious fish to catch via hook and line fishing. This study shows a large portion of the population remain within the river system until mid to late November. After water temperatures drop below 13°C, many of the undersized (<14 inches) speckled trout will emigrate out of the river systems, but some of the legal-sized fish will remain.

This should increase the percentage of legal-sized fish caught, but may decrease the overall numbers of fish caught per day. These large fish appear to overwinter within the estuary, but may not be available to catch. Many fish during very cold water temperatures will stop eating and moving to help sustain them until temperatures increase again. The best chance of catching the larger fish during the winter months would be to choose a warm day and fish upriver in shallower areas.

The data from this study is useful and important for both fishery managers and recreational fisherman. However, this study only concerned speckled trout from two river systems and it is unknown how speckled trout in other bodies of water behave. The Corrotoman and Lynnhaven Rivers are both smaller tributaries and behavior may differ from speckled trout that reside in one of the major rivers with deep thermal refuges. All acoustic tags that were deployed in this study are still active and several agencies have yet to report their receiver detections. In the coming months, additional data should be made available to help interpret the winter movements of speckled trout. These results will be published online in a series of maps and graphs that will describe speckled trout movement in relation to season and temperature. These results will also be included in a scientific publication to be completed after the lifespan of the acoustic tag batteries has passed (February 2018).

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Table 1. Identification number, date, location, total length, number of detections, number of days between tagging and last detection, and lowest associated water temperature of tagged speckled trout.

Fish ID	Date tagged	Tagging location	Total length (mm)	Detections	Days relocated	Days between tagging and last detection	Lowest water temperature (°C)
23360	10/31/2015	Corrotoman	310	2290	31	78	19
23366	9/28/2016	Corrotoman	300	1413	37	57	15.1
23367	9/28/2016	Corrotoman	305	2978	37	37	17.4
23365	10/1/2016	Corrotoman	303	104	2	4	24
15618	10/5/2016	Corrotoman	343	107	4	5	22.8
23364	10/13/2016	Corrotoman	340	232	13	40	13
23350	10/18/2016	Corrotoman	305	2633	32	34	13.6
15628	10/18/2016	Corrotoman	350	226	4	6	24
23351	10/18/2016	Corrotoman	305	166	5	5	20.5
44010	10/25/2016	Corrotoman	318	2658	20	20	15.1
15616	10/30/2016	Corrotoman	355	1543	17	17	13.8
15617	11/1/2016	Corrotoman	381	1135	22	46	7.9
15669	11/2/2016	Corrotoman	349	4667	38	70	4.9
44011	11/4/2016	Corrotoman	308	1479	13	18	11.8
44012	11/4/2016	Corrotoman	318	1345	25	42	13.6
15611	11/4/2016	Corrotoman	350	1691	22	33	9.4
15610	11/4/2016	Corrotoman	362	2322	20	25	10.7
15667	11/18/2016	Corrotoman	343	1458	22	73	6.5
15668	12/5/2016	Corrotoman	464	4311	36	56	6
15660	12/13/2016	Corrotoman	457	3768	27	58	5.2
15659	12/13/2016	Corrotoman	369	6044	45	48	5.5
15619	10/12/2016	Lynnhaven	445	102	5	33	17.8
23363	10/12/2016	Lynnhaven	343	10	1	11	19.4
23362	10/12/2016	Lynnhaven	336	2	1	11	19.6
15627	10/12/2016	Lynnhaven	470	1263	22	88	3.5
15621	10/12/2016	Lynnhaven	407	2950	34	96	4.7
15623	10/12/2016	Lynnhaven	521	3324	31	94	5.4
15620	10/12/2016	Lynnhaven	432	1539	20	97	3.9
15626	10/20/2016	Lynnhaven	343	275	9	58	6.8
23358	10/20/2016	Lynnhaven	330	428	11	33	11.5
23357	10/20/2016	Lynnhaven	305	419	20	33	11.8
23359	10/20/2016	Lynnhaven	300	787	26	88	7
15625	10/20/2016	Lynnhaven	343	1935	25	51	8.3
23356	10/20/2016	Lynnhaven	340	70	4	16	17.5

Fish ID	Date tagged	Tagging location	Total length (mm)	Detections	Days relocated	Days between tagging and last detection	Lowest water temperature (°C)
15622	10/22/2016	Lynnhaven	406	3	1	11	22.1
15636	10/26/2016	Lynnhaven	407	1321	37	74	4.3
15630	10/26/2016	Lynnhaven	356	1888	13	16	13.6
15643	10/26/2016	Lynnhaven	483	2397	13	42	11.1
15638	10/26/2016	Lynnhaven	413	2903	41	84	5.6
15633	10/26/2016	Lynnhaven	407	1310	26	74	5.1
15640	10/26/2016	Lynnhaven	445	1340	21	82	6.77
15632	10/26/2016	Lynnhaven	444	566	13	73	4.3
15629	10/26/2016	Lynnhaven	457	1370	38	71	6.8
15634	10/26/2016	Lynnhaven	457	1858	35	72	6.3
15635	10/26/2016	Lynnhaven	483	2020	25	55	9
15639	10/26/2016	Lynnhaven	432	177	10	66	9.7
15642	10/26/2016	Lynnhaven	458	913	20	77	1.6
15641	10/26/2016	Lynnhaven	458	740	13	89	7.3
15624	10/26/2016	Lynnhaven	407	8131	49	73	6.7
15637	10/26/2016	Lynnhaven	407	1600	31	83	6.9
15615	10/29/2016	Lynnhaven	356	365	11	23	12.4
15614	10/29/2016	Lynnhaven	351	2116	26	81	6.9
15609	10/29/2016	Lynnhaven	349	1538	24	35	8.8
15612	11/17/2016	Lynnhaven	445	802	16	70	6.1
15664	11/17/2016	Lynnhaven	356	1561	20	50	6.9
15666	11/17/2016	Lynnhaven	438	236	4	44	9.6
15665	11/17/2016	Lynnhaven	455	777	16	58	6.3
15613	11/17/2016	Lynnhaven	419	446	4	49	7.7

Figure 1. Location of acoustic receivers and temperature loggers in the Corrotoman River.

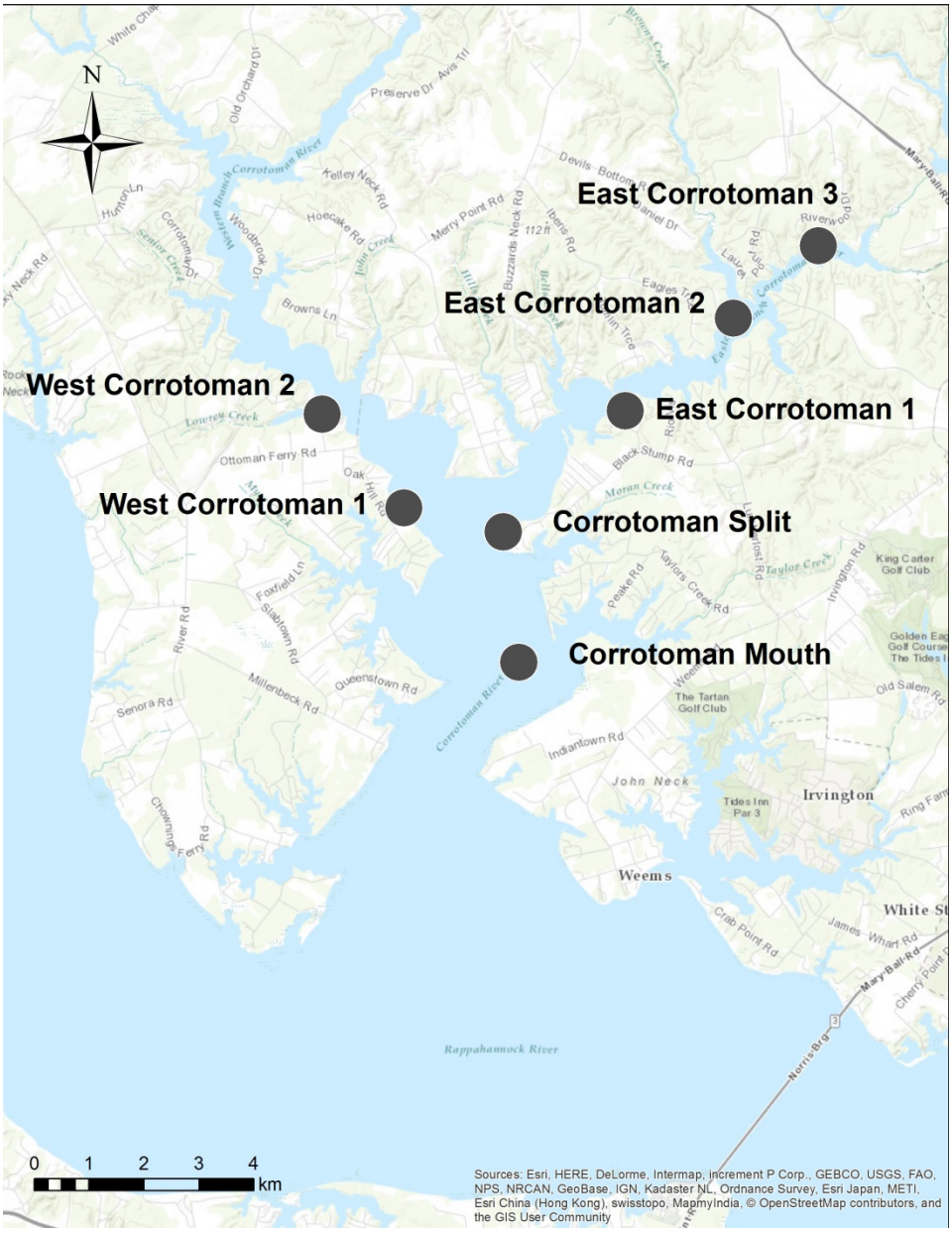

Figure 2. Location of acoustic receivers and temperature loggers in the Elizabeth River.

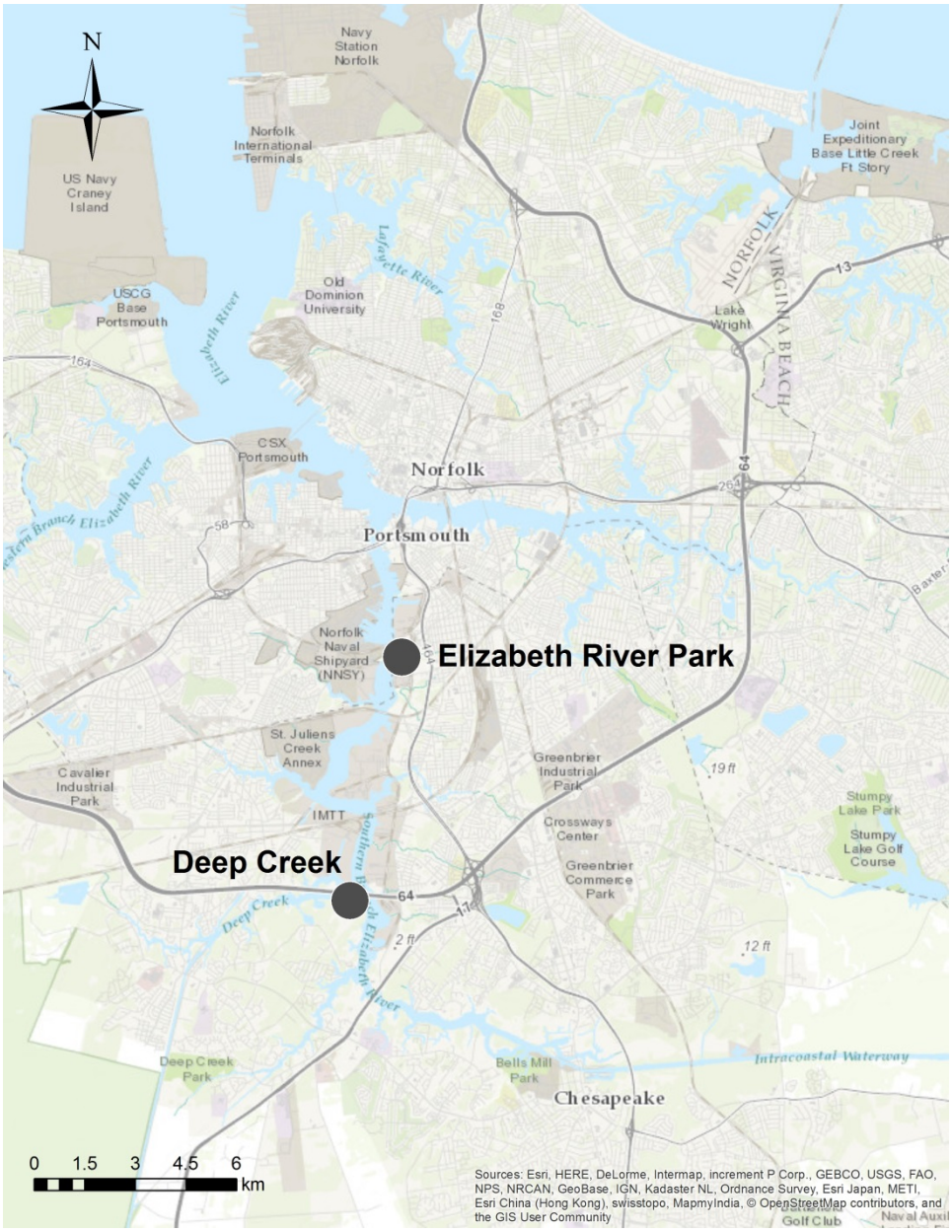

Figure 3. Location of acoustic receivers and temperature loggers in the Lynnhaven River.

Figure 4. Water temperature profiles of the Corrotoman River from 10/31/2015 to 3/15/2016.

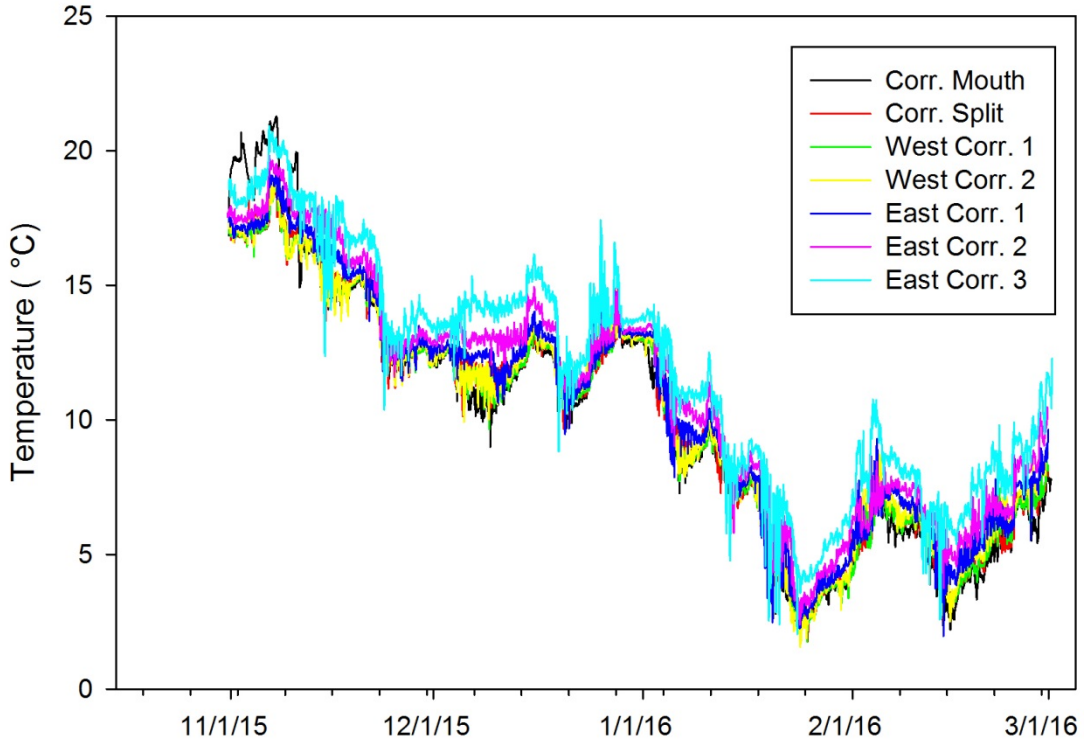

Figure 5. Water temperature profiles of the Corrotoman River from 9/15/2016 to 1/29/2017.

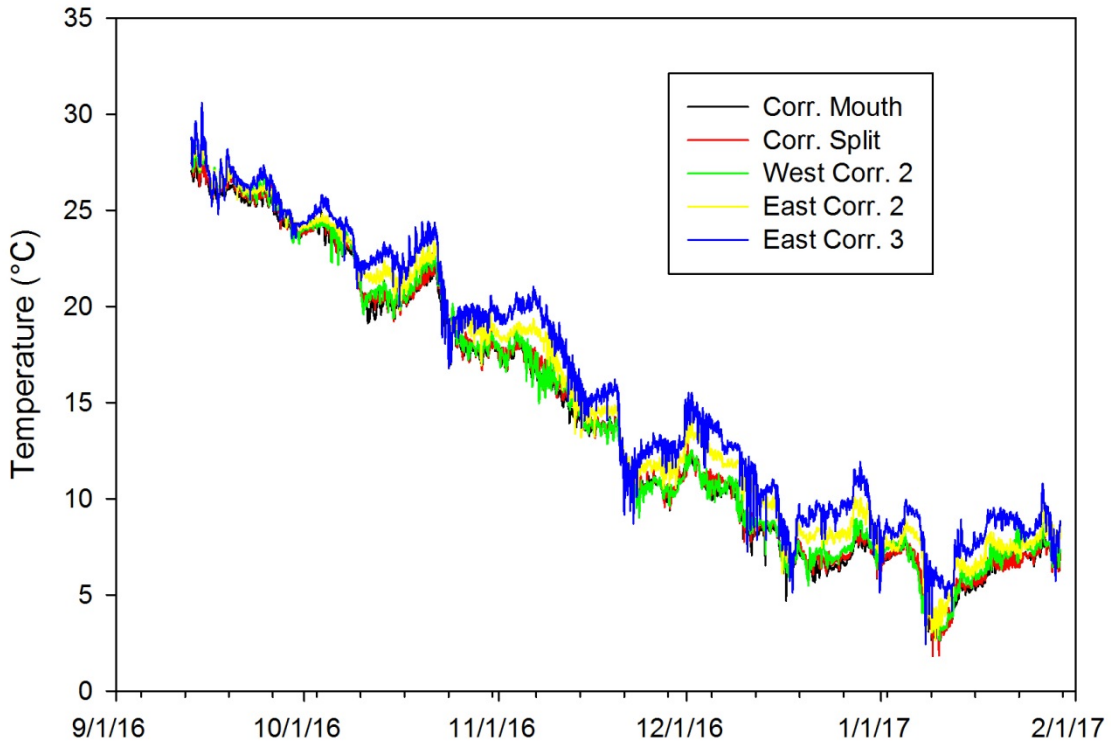

Figure 6. Water temperature profiles of the Lynnhaven River from 10/15/2016 to 1/24/2017

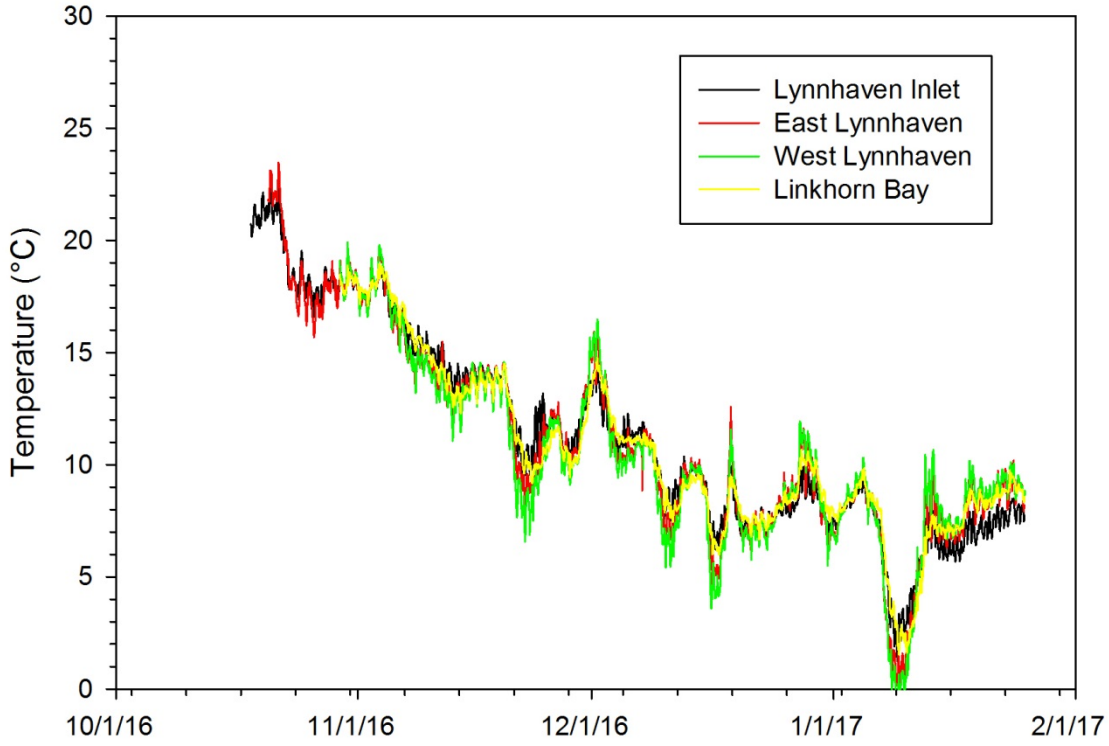

Figure 7. Density of detections for speckled trout tagged in the Corrotoman River not including movements outside the river system.

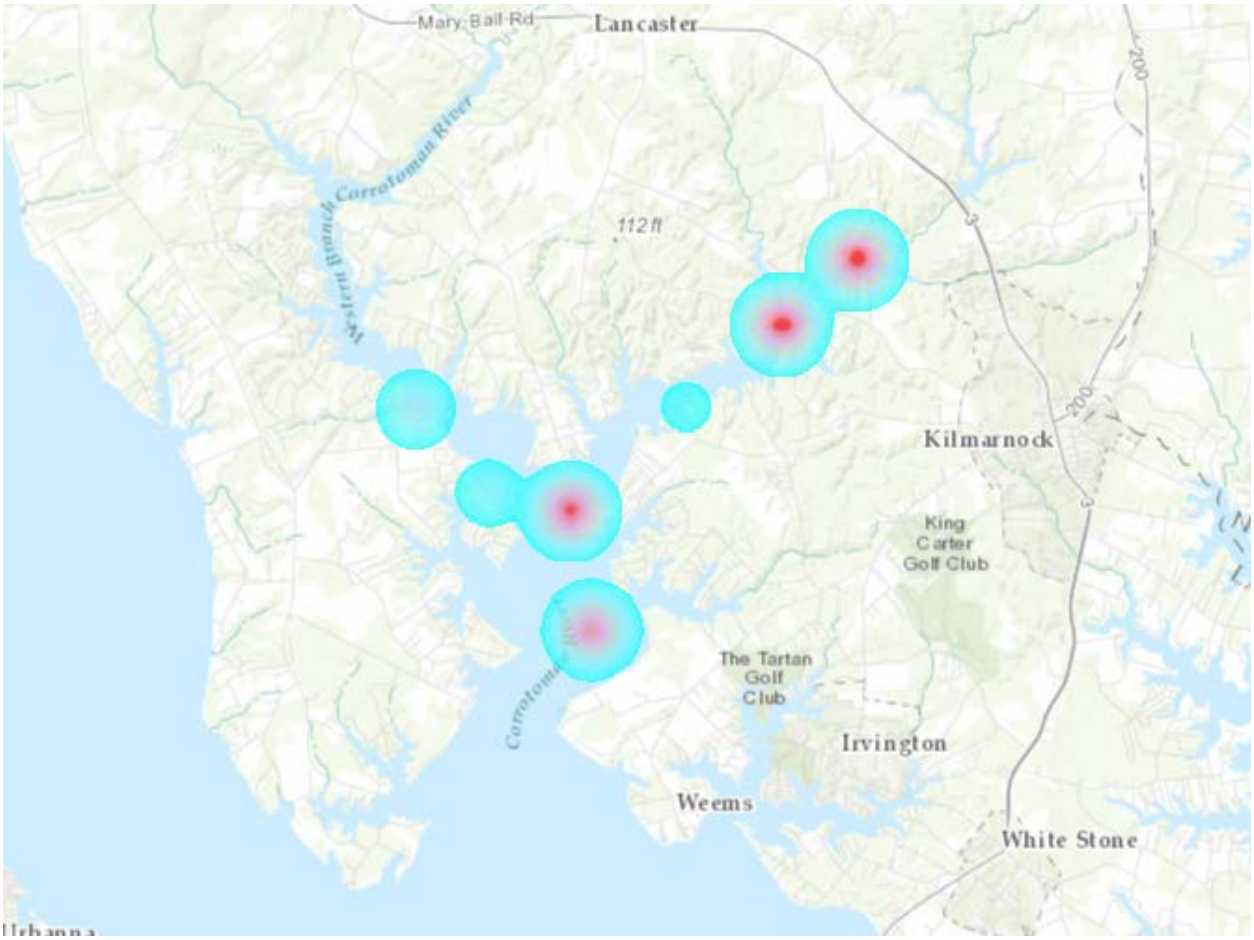

Figure 8. Density of detections for speckled trout tagged in the Corrotoman River including movements outside the river system.

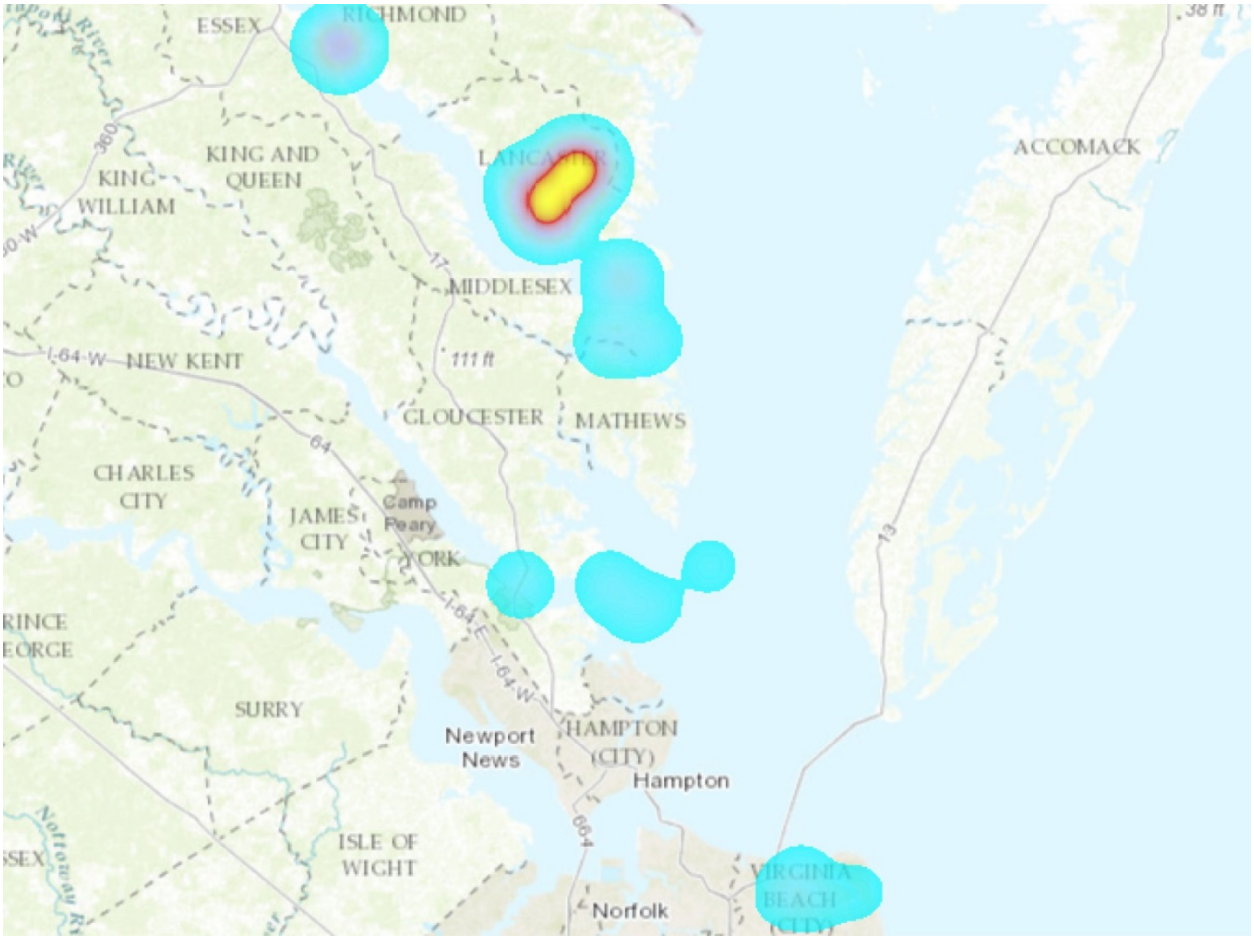

Figure 9. Density of detections for speckled trout tagged in the Lynnhaven River.

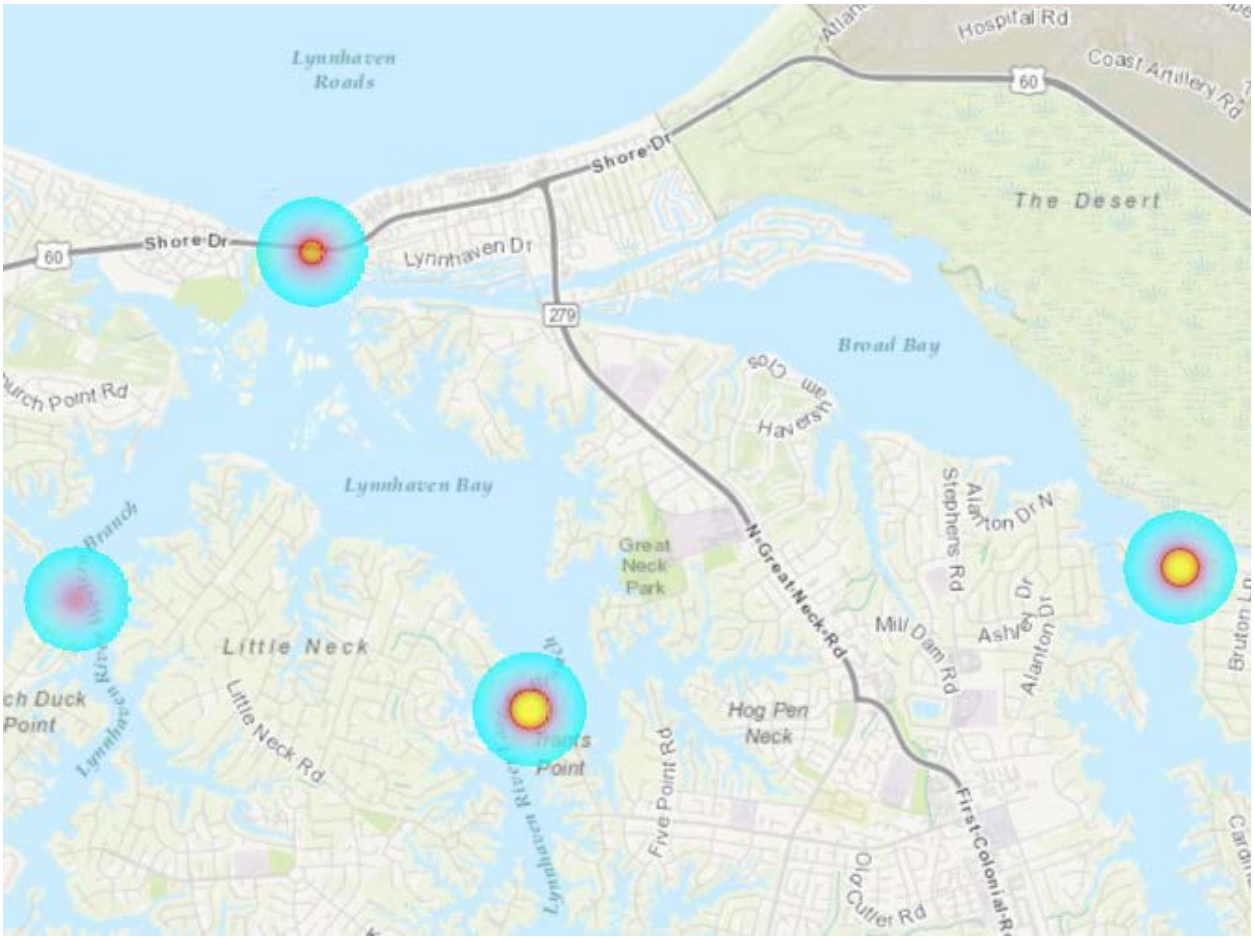

Figure 10. The percentage of the emigrating speckled trout from the Corrotoman and Lynnhaven Rivers versus day of the year.

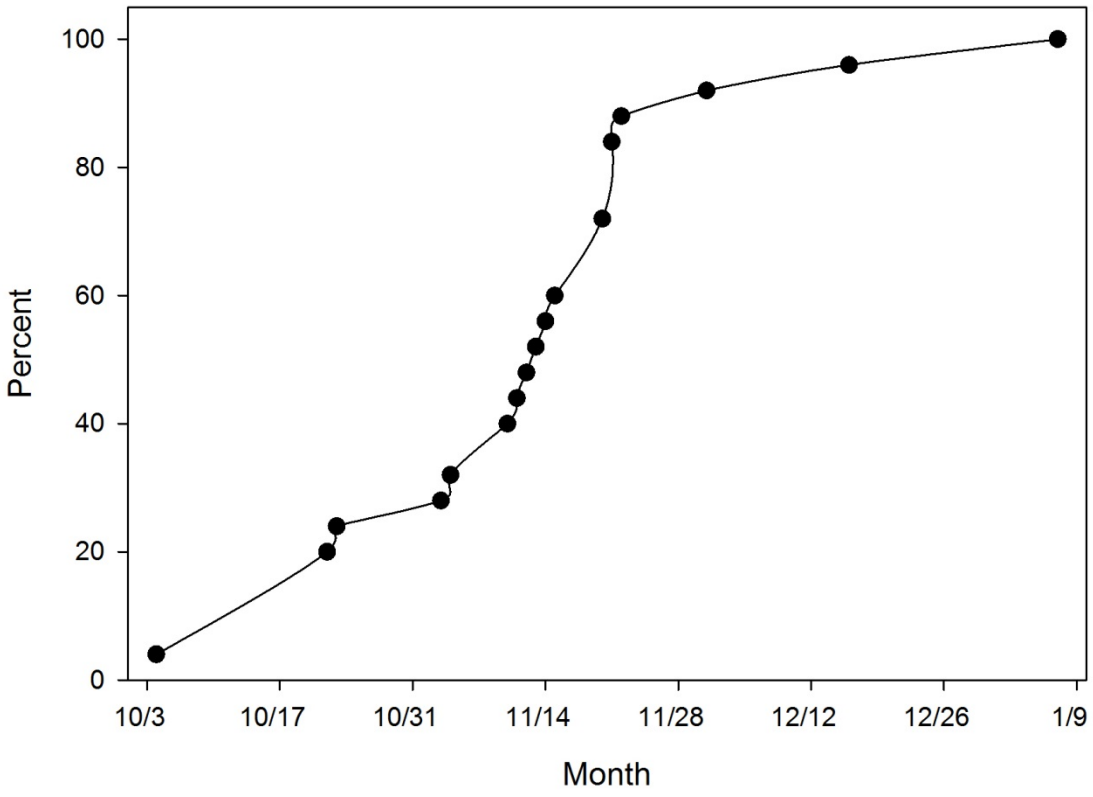

Figure 11. Temperature range of when speckled trout were detected leaving the Corrotoman and Lynnhaven Rivers.