Draft Final Report for
Title: Comprehensive Estuarine Fish Inventory Program: Great Bay-Mullica River: Year Three

Investigator names and institution: Kenneth W. Able and Thomas M. Grothues, Rutgers the State University of New Jersey

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Problem Statement and Needs Assessment:

Estuaries are important spawning, nursery, and harvest areas for fish and invertebrates of recreational, commercial, and ecological importance in the temperate waters of the northeastern U. S., including New Jersey (Able and Fahay 1998, 2010a). Our knowledge of the life history and ecology of fishes in estuaries has been improving in recent years, in part, because the information on these topics is in increasing demand by ichthyologists, estuarine ecologists, pollution biologists and resource managers at local, state, federal and international levels (Able 2016). The fishes constitute one of the largest portions of the animal biomass and thus they are important to estuarine ecosystems. Sport and commercial fishermen are also becoming increasingly interested in fish life histories and ecology because they are beginning to play a larger advisory role where fish habitats and fish survival are concerned. This interest is extending to forage fishes.

Recently, these audiences have been further broadened by an increasingly informed general public, who are interested in (and alarmed by) the conflicting interests of aesthetic and recreational uses versus negative impacts resulting from human population pressures that bring habitat destruction and direct and indirect (non-point) sources of pollution. Some have estimated that up to 75% of economically important east coast fish populations are to some degree "estuarine dependent". A focus on estuarine fishes is also especially appropriate, largely because it is while they are in estuaries that they encounter several critical life history "bottlenecks" that can greatly affect survival rates and the resulting abundance of certain populations that we wish to harvest or conserve. Further, an understanding of long-term change is especially critical (e.g. Cody and Smallwood 1996, Ducklow et al. 2009, Sukhotin and Berger 2013) relative to their influence on recreational and commercial fisheries and their management. Our preliminary findings from sampling during 2016 and 2017 are available including some historical comparisons with earlier sampling programs (Able and Grothues 2017, Able and Grothues 2018).

Objectives:

Focus, for 2018, was on the determination of spawning and nursery areas of fishes and crabs with emphasis on those of commercial, recreational, and ecological importance in the Mullica River – Great Bay estuary. More specifically, we determined water quality, habitat characteristics, and distribution and abundance of fishes and ecologically important invertebrates such as crabs and jellyfishes. For fishes and crabs, we determined variation in habitat use across life history stages given the focus on larvae, juveniles, and adults across a variety of gear types and habitats.

Methods:

Study design and study site: In order to include all fish and most crab life history stages, we sampled with multiple gears across multiple seasons (Table 1). Further, we sampled with many of these gears along the salinity gradient from the vicinity of Little Egg Inlet to near the upper limits of saltwater intrusion (Figs. 1, 2).

The Great Bay – Mullica River is an exceptional location for these studies. The Mullica River and its tributaries drain an area of about 400,000 ha of relatively undeveloped pinelands and marshes in southern New Jersey. A portion of this watershed has been designated the Pinelands National Reserve and is relatively unaltered (Good and Good 1984). Waters from this extensive drainage enter into Great Bay from the Mullica River and other small tributaries (Psuty et al., 1993; Kennish, 2004). The shorelines total 283 km. They share qualities with those in many other estuaries in New Jersey, including a moderate tidal range of about 1.1 m near the mouth of Great Bay (Durand 1984, Able et al. 1992, Psuty et al. 1993). This estuary is a shallow (<2 m), salt marsh-fringed, drowned river valley (Fig. 1). Water temperature regimes follow temperate and seasonal patterns (<0°C in winter to > 30°C in summer) and salinity corresponds to an upriver gradient from polyhaline regions near Little Egg Inlet to the freshwater-saltwater interface near Lower Bank, approximately 30 km upstream (Able and Fahay 2010a). The Great Bay-Mullica River rarely approaches the low dissolved oxygen levels of hypoxic estuaries (<4 mg/L). This estuary is also unique in that it has relatively few impacts. The human population density is low, large portions of the watershed are in state and federal ownership, and it consists of largely unaltered, natural habitats (Good and Good 1984, Kennish 2004). As a result, it is considered to be the cleanest estuary in New Jersey and one of the cleanest on the east coast (Able 2015). Thus, it provides a baseline for comparison to other, more impacted estuaries in New Jersey.

An earlier literature review has summarized research activities for this and all other estuaries in New Jersey including the Mullica River-Great Bay estuary (Able and Kaiser 1995). Another advantage of this study estuary is that it is the site of several extensive and intensive monitoring sites for larval and juvenile fishes. These have been utilized in a number of ways including for larval fishes (Able et al. 2017). This approach has included species composition and annual timing of ingress for larval fish assemblages (Witting et al. 1999), analysis of population dynamics and biology of economically important species such as summer flounder (Keefe and Able 1993, Able et al. 2011b), winter flounder (Sogard et al. 2001; Chant et al. 2000), American eel (Sullivan et al. 2006, 2009), Atlantic menhaden (Warlen et al. 2002), and other ecologically important species such as Conger eels (Correia et al. 2004). Further, preliminary analysis of research done at Little Egg Inlet suggests that several changes in abundance of selected species are the result of climate change, recovery of local spawning stocks, or other factors that could only be detected with a long time series (Hare and Able 2007, Able and Fahay 2010a, Nickerson et al. 2018, Nickerson et al. In review). Other studies have compared aspects of fish biology across specific estuaries (Sogard et al. 2001, Able et al. 2001, Phelan et al. 2000, Wilson et al. 1990). Further, our own extensive research in estuaries includes comparisons to New York Harbor (Able and Fahay 2010a), Barnegat Bay (Able et al. 2014a), Beaufort Inlet, North Carolina, North Inlet, South Carolina (Able et al. 2011a) and Louisiana marshes (Able et al. 2014b). These comparisons will help support our proposed study of this “representative” estuary.

Environmental Data: Environmental data (salinity, temperature, water height, pH, dissolved oxygen) was summarized from four dataloggers across the estuarine salinity gradient on 15 minute intervals with some interruptions since 1996 through the JCNERR's System Wide Monitoring Protocol (SWMP) (Fig. 1) (Kennish 2004). Data from all four loggers is presented for 2018 to show tidal, seasonal, and spatial variability. This year, the SWMP series was compromised by the loss of the two lower bay (Buoy 126 and Buoy 139, see Fig. 1) data loggers to ice rafting in early January. These were not replaced until June. In their stead, a logger of the same type was deployed in the Rutgers University Marine Field Station (RUMFS) boat basin nearby and is representative of conditions in the lower bay that was previously sampled by the lost loggers. In addition, salinity from more spatially diverse locations throughout the watershed is derived from YSI measurements at some locations over time and from individual measurements.

Larval Fish Composition, Abundance, and Size: During 2018, larvae were collected with a 1 m-diameter (1 mm mesh) circular plankton net at the bridge over Little Sheepshead Creek (3.8 km from Little Egg Inlet) (Fig. 1). The site has been continuously in use with the same sampling protocol since 1989 (Able and Fahay 1998, Witting et al. 1999, Able et al. 2017). The net was deployed with a General Oceanics flow meter to a depth of approximately 1.5 m. Collections were during the night time flood tide for three consecutive 30 minute sets (see Witting et al. 1999 for more details). Fish abundance was standardized to effort as sample density (individuals/1000m^3) by calculating sample volume from the flow value and net diameter. Larval abundance at the Little Sheepshead Creek sampling site are indicative of larval supply because the larvae are annually available, abundant, and represented by all developmental stages (preflexion, flexion, postflexion) (Able and Fahay 2010a) including other southern New Jersey sites (Able et al. 2017). The late (postflexion) stages of development, which are likely to be indicators of year class strength (Houde 2008), are well represented and a source for settlement in the area (e.g. Chant et al. 2000, Sogard et al. 2001). This same sampling program has proven useful for assessing the late larval abundance of many estuarine resident species as well (Able et al. 2006, Able and Fahay 2010a, Able et al. 2011b) and as an earlier index of climate change (Able and Fahay 2010b). Physical variables (temperature, salinity, dissolved oxygen) were recorded at deployment and retrieval of collectors. Seasonality of the larval assemblage was portrayed as a time series plot using the sample amplitude of the first principal components analysis (PCA) as a proxy for assemblage. Only taxa identifiable to species were included, because different species of the same genus may have different spawning and arrival times and may thus obfuscate patterns. Larval abundance was expressed as density (individuals per 1000 L) and log(y+1) transformed for PCA.

Juvenile and Adult Fishes and Crab Composition, Abundance, and Size: During 2018, juvenile fishes and crabs were sampled with a long-term otter trawl program at a variety of stations/habitats located throughout the Great Bay - Mullica River estuary during March, May, July, September, and November (Table 1, Fig. 1). In addition, during July and September, additional stations were added from the RUMFS long-term otter trawl sampling program in order to provide enhanced spatial coverage. All stations were chosen based on their depth, substrate type, and amount and type of structured habitat. In this sampling program, fish were collected with three 2-minute tows with an otter trawl (4.9 m headrope, 19 mm mesh wings, 6.3 mm mesh liner) at each station during the daytime. From each tow, all fishes were identified and counted and twenty of each were randomly measured to the nearest mm total length (TL) or fork length (FL) (see Szedlmayer and Able 1996 for additional details).

Also during 2018, larger juvenile and adult fishes were sampled with gill nets (as we have done before, Able et al. 2009) along the salinity gradient as well (Table 1, Fig. 2). Anchored multi-mesh gill nets (15 m x 2.4 m with 5 panels of 5 mesh sizes [2.5, 3.8, 5.1, 6.4, and 7.6 cm box] and 91 m x 2.4 m with 6 panels of 3 mesh sizes [1.3, 1.9 and 2.5 cm box]) in the Great Bay - Mullica River estuary were used to sample in several areas (see Fig. 2). Gill nets were set at intervals at night during the spring, summer and fall in upper creek, creek mouth and nearshore bay habitats for approximately 60 minutes. Upon retrieval of each gill net, all fishes were identified, counted and measured. Several of the dominant species collected were represented by multiple age classes; thus, fish were divided into two age classes: young-of-the-year (age 0) and juveniles and adults (age 1+) based on available monthly size estimates (Able and Fahay 1998).

For each gill net sample, depth, surface temperature, salinity and dissolved oxygen were recorded with a hand-held YSI.

Results and Discussion:

Sampling by RUMFS during 2018 was based on ichthyoplankton (March-October, 57 tows), juvenile and adults with otter trawl (March-September, 135 tows) and large juveniles and adults with gill nets (March-September, 140 sets) efforts in the Mullica River – Great Bay watershed (Fig. 1, Table 1). Because biases associated with each sampling gear influence the size of animals captured, we compared the lengths across gears for the more commonly collected species.

Details of data management can be found in Appendix 1. A preliminary checklist of all species encountered to date is in Appendix 2. For completeness sake, ancillary studies of alewife spawning areas in the watershed based on visual observations are included as Appendix 3. A short synthesis/overview of underwater natural history in the watershed in an upcoming book is also included as Appendix 4.

Length composition of fishes and crabs in the Mullica River – Great Bay estuary: In order to further characterize the fishes and crabs in the Mullica River – Great Bay estuary we have compared their lengths as larvae (plankton net) or juveniles and adults (trawl and gill net). In addition, we have plotted their length, by sampling gear, across all sampling during 2018 for 22 species (Fig. 3). Of these, several were only collected in one gear (e.g. gill net, *Dorosoma cepedianum*). Others were collected in two gears (*Callinectes sapidus, Centropristis striata, Leiostomus xanthurus, Limulus Polyphemus, Paralichthys dentatus, Pomatomus saltatrix*) across more than one life history stage. All other species were collected in at least two gears (*Alosa pseudoharengus, Ameirus catus, Anchoa mitchilli, Bairdiella chrysoura, Cynoscion regalis, Libinia emarginata, Menidia menidia, Morone americana, Morone saxatilis, Opsanus tau, Pseudopleuronectes americanus, Syngnathus fuscus, Urophycis regia*).

These composite samples, because of the variety of gears, include, for some species larval <20mm (*A. mitchilli, B. chrysoura, B. tyrannus, C. sapidus, C. striata, C. regalis, Leiostomus xanthurus, Libinia emarginata, L. polyphemus, M. Menidia, Opsanus tau, P. dentatus, P. americanus, S. fuscus*) but also larger fish >400mm *(A.catus, C. regalis, D. cepedianum, M. saxatilis, P. dentatus, P. saltatrix*).

Environmental Variables: There is a distinct salinity gradient in the Mullica River-Great Bay estuary and the Wading River, a major tributary (Fig. 4). While salinity decreases upstream, the most marked changes typically occur above Hog Island. From that point and above salinities are typically less than 5, which is physiologically demanding for many marine fishes. The lowest salinities, typically less than 5 and as low as 0, occur near the confluence with the Batsto River. A possible exception to this obvious transition is in the Bass River, which has relatively high salinity throughout its measured length. The salinities at the lower end of the estuary near Little Egg Inlet are typically above 18 and often around 28. Seasonally, water temperatures fell to subzero in late January and mid-February in the saline portion of the estuary (Fig. 5, 6). SWMP data loggers were unavailable for most of January and February but the few temperature data collected there in January were near or below º0 C. (Fig. 7, 8). Temperatures peaked at all logger stations in mid-August at around 30 ºC except at Lower Bank where they briefly reached 32ºC (Fig. 5-8). Temperature variation was in phase on the seasonal scale, but on the daily scale was locally forced by tide. The two riverine stations (Chestnut Neck and Lower Bank) experienced the higher overall salinity range as flow from both event scale (storm and tide) and seasonal differences (e.g. spring freshet) is constrained to the narrow channel. The overall temperature/salinity profile of the Mullica River Great Bay estuary provides habitat at some point between 0 and 32ºC and 0 and 32 salinity (Fig. 9). Acidic waters (pH <5.3) typically occur in the freshwater portion of the Mullica River – Great Bay estuary due to the influence of tannins released from the oaks and pines in the Pine Barrens (Fig. 10). This is most evident in the tidal freshwaters in the Mullica River above Green Bank (Fig. 5, 6). Lower in the Mullica River, this pH becomes more basic as it is modified by higher salinity waters from the ocean. Great Bay has the highest (natural) pH values (Fig. 7, 8).

Larval Fish Composition, Abundance, and Size: During 2018, ichthyoplankton nets collected 10,056 fish of 70 taxa, although 14 taxa were identified only to genus or higher level and were likely to have been unidentifiable examples of taxa already collected and identified to species (e.g. *Anchoa* spp, were likely to have been *Anchoa mitchilli*, but may have included *Anchoa hepsetus*). Twenty-nine of the taxa were represented by three individuals or less (including four unknown to species) and ten by a single individual. The larvae were distinctly seasonally variable as depicted by principal components analysis (n = 47 species). The first principal component explained 38% of the variation and the second explained 25%, so it is important to view both these axes (Fig. 11). As in 2016 and 2017, there was clean separation of spring, summer, and fall samples in the coenospace when both major axes were considered together, although there was some overlap considering either major mode alone. Summer samples (June, July, August) was well represented by several goby species (*Gobiosoma bosc* and *G. ginsburgi*), anchovies (both *Anchoa mitchilli* and *A. hepsetus*), northern pipefish (*Syngnathus fuscus*), horseshoe crab (*Limulus polyphemus*) and black seabass (*Centropristis striata*). Spring samples (March, April, May) tended to have winter flounder (*Pseudopleuronectes americanus*), conger eel (*Conger oceanicus*), American eel (*Anguilla rostrata*), and Atlantic herring (*Clupea harrengus*). Fall samples (September, October, November) had Atlantic croaker (*Micropogonias undulatus*), darter goby (*Ctenogobius boleosoma*), and Atlantic menhaden (*Brevoortia tyrannus*) (Fig. 11, 12). Larval abundance (transformed to CPUE) also peaked in summer (Fig. 13) but was heavily weighted by *Anchoa mitchilli* and *Anchoa spp* (probably also *A. mitchilli*) and secondarily by emergent swimming phase larval horseshoe crabs (*Limulus polyphemus*).

Juvenile and Adult Fishes and Crab Composition, Abundance, and Size: During 2018, the juvenile and adult component of the fauna varied by seasonal and spatial variation in occurrence and distribution based on otter trawl catches. The highest catches, for all species combined, were found near Little Egg Inlet and up the Mullica River (Fig. 14). The spatial variation of many species captured with otter trawls during 2018 was strongly influenced by the salinity (Fig. 4). Several species were only found in the higher salinities of Great Bay and the lower Mullica River including *Opsanus tau* (Fig. 14), *Syngnathus fuscus*, *Bairdiella chrysoura, Centropristis striata*, and *Libinia emarginata* (Fig. 15) and *Urophycis regia, Menidia menidia*, and

Pseudopleuronectes americanus (Fig. 16). Others were most abundant in the Mullica River such as *Morone americana* and *Morone saxatilis* (Fig. 14). Some species were nearly ubiquitous such as *Brevoortia tyrannus* and *Anchoa mitchilli* although the latter was most abundant in the lower bay and upper river (Fig. 17). Other widely distributed species included *Callinectes sapidus* (Fig. 17).

During 2018, the distribution of the dominant species collected in gill nets varied by species. Several were more abundant in the upper, lower salinity portions of the sampled estuary including *Ameiurus catus*, *Dorosoma cepedianum*, *Brevoortia tyrannus*, *Cynoscion regalis*, *Morone americana*, *Morone saxatilis*, *Leiostomus xanthurus*, and *Callinectes sapidus* (Fig. 18, 19). Others occurred throughout the estuary (*Alosa pseudoharengus*) or only in the lower, higher salinity portions of the estuary such as *Mustelus canis*, *Pomatomus saltatrix* and *Limulus polyphemus* (Fig. 20).

Seasonal comparisons of distributions during 2018, as collected by gill net, varied by species. *Morone saxatilis* was collected primarily in the Mullica River and upper Great Bay in May, July, and September (Fig 21). *Morone americana* was fairly evenly distributed throughout the river in most months but with peaks in May, July, and September (Fig. 22). *Ameiurus catus* was not collected in March but in all other months it was collected in tributaries to the Mullica River (Fig. 23). *Dorosoma cepedianum* was most abundant in July and September from the upper Mullica River (Fig. 24). They were not available in March. The anadromous *Alosa pseudoharengus* were most abundant in March, presumably during their upstream migration to spawn in fresh waters and absent in all other months sampled (Fig. 25). *Pomatomus saltatrix* were absent in March, July, and November, but present in Great Bay and in the lower Mullica River during May and September (Fig. 26). *Brevoortia tyrannus* were most abundant in the Mullica River and its tributaries in July, and less abundant in March and November (Fig. 27). *Callinectes sapidus* were most abundant in upper Great Bay and the Mullica River in May, July, and September (Fig. 28). They were not collected in March and not very abundant in November.

Student Involvement/Outreach

During 2018, a variety of individuals associated with RUMFS participated in this project in the Mullica River-Great Bay as graduate and undergraduate students, and trainees. An intern from 2017, Christina Welsh, as the result of collaboration between RUMFS and Stockton University, was supported by a Stacy Moore Hagan Memorial Fellowship. Her project, in the study estuary, focused on the spatial distribution of "peat reefs", portions of marsh edge that calve off and become intertidal and subtidal habitat for fishes, decapod crustaceans, and bivalves. As a result of her continued work on this project during 2018, she is a co-author on a paper describing these findings (Able et al. 2018). Others gained valuable experience as graduate students by participating in the field sampling (Jessica Valenti, Rutgers University Ph. D. program in Oceanography). A large number of colleagues and current and former students made presentations at the American Fisheries Society 2018 meeting in Atlantic City based in part on data from the NJDEP Inventory Project.

Presentations (only presenters listed) at the 2018 American Fisheries Society meeting in Atlantic City included:

Fodrie, J. 2018, August. Assessing Summer Flounder Larval Poplulation Connectivity Via Geochemical Tagging. Presented at the 2018 American Fisheries Society meeting in Atlantic City.

Grothues, T.M. 2018, August. Evidence of Phenological Shifts in the Recruitment of Fishes from Long-Term Time Series in the Mullica River – Great Bay Estuary in Southern New Jersey. Presented at the 2018 American Fisheries Society meeting in Atlantic City.

Grothues, T.M. 2018, August. SWMP in Service of Fisheries: Coupling Long-Term Monitoring with Focused Fisheries Research at the Jacques Cousteau National Estuarine Research Reserve. Presented at the 2018 American Fisheries Society meeting in Atlantic City.

Musumeci, V. 2018, August. Estuarine Predator-Prey Interactions in the Early Life History of Two Eels (*Anguilla rostrata* and *Conger oceanicus*). Presented at the 2018 American Fisheries Society meeting in Atlantic City.

Schneider, A. 2018, August. What controls the Recruitment of Juvenile Blue Crabs in Southern New Jersey? Presented at the 2018 American Fisheries Society meeting in Atlantic City.

Valenti, J.L. 2018, August. Ichthyoplankton Supply to Estuarine Habitats. Presented at the 2018 American Fisheries Society meeting in Atlantic City.

Technician Training

Several technicians, including Maggie Shaw, Ryan Larum, Christine Welsh, Alexandra Schneider, Giselle Schreiber, and Thomas Johnson, participated in all aspects of the field sampling, identification, data entry, and data checking for each of the sampling programs as part of their training.

Volunteers/Outreach

Several volunteers and a citizen scientist (Pat Filardi) from the Jacques Cousteau National Estuarine Research Reserve assisted with field sampling and data entry. These individuals also serve as outreach ambassadors because they come from and interact with the local community.

Literature Cited

Able, K. W. 2015. Station 119: From Lifesaving to Marine Research. West Creek: Down The Shore.

Able, K. W. 2016. Natural history: An approach whose time has come, passed, and needs to be resurrected. ICES Journal of Marine Science 73(9):2150-2155.

Able, K. W., D. M. Allen, J. A. Hare, D. E. Hoss, K. E. Marancik, G. Bath-Martin, P. M. Powles, D. E. Richardson, J. C. Taylor, H. J. Walsh, S. M. Warlen, and C. Wenner. 2011a. Life history and habitat use of the speckled worm eel, *Myrophis punctatus,* along the east coast of the United States. Environmental Biology of Fishes 92:237-259.

Able, K.W. and M.P. Fahay. 1998. The First Year in the Life of Estuarine Fishes in the Middle Atlantic Bight. Rutgers University Press. 342 p.

Able, K. W. and M. P. Fahay. 2010a. Ecology of Estuarine Fishes: Temperate Waters of the Western North Atlantic. Johns Hopkins University Press, Baltimore, MD. 566 p.

Able, K. W., and M. P. Fahay. 2010b. Climate Change. Pp 116 - 125 *In* Able, K. W. and M. P. Fahay. 2010. Ecology of Estuarine Fishes: Temperate Waters of the Western North Atlantic. Johns Hopkins University Press, Baltimore, MD. 566 p.

Able, K.W., M.P. Fahay, D.A. Witting, R.S. McBride and S.M. Hagan. 2006. Fish settlement in the ocean vs. estuary: comparison of pelagic larval and settled juvenile composition and abundance from southern New Jersey, USA. Est. Coast. Shelf Sci. 66: 280-290.

Able, K.W. and T.M. Grothues. 2017. Comprehensive Estuarine Fish Inventory Program: Great Bay-Mullica River, Annual Report for 2016.

Able, K.W. and T.M. Grothues. 2018. Comprehensive Estuarine Fish Inventory Program: Great Bay-Mullica River, Annual Report for 2017.

Able, K. W., T. M. Grothues, and P. Jivoff. 2014a. Barnegat Bay Final Report – Assessment of Fish and Crab Responses to Human Alteration in Barnegat Bay. Report to the NJ Department of Environment Protection. 99 p.

Able, K. W., R. Hoden, D. A. Witting and J. B. Durand. 1992. Physical parameters of the Great Bay-Mullica River Estuary (with a list of research publications). Rutgers Univ. Inst. Mar. Coastal Sci. Tech. Rept. 92-06.

Able, K.W., K.M.M. Jones and D.A. Fox. 2009. Large nektonic fishes in marsh creek habitats in the Delaware Bay estuary. Northeastern Naturalist 16(1):27-44.

Able, K.W. and S.C. Kaiser. 1995. New Jersey estuaries finfish resource assessment, phase I: Literature Summary. IMCS Technical Report 95-01.

Able, K. W., P. C. Lopez-Duarte, F. J. Fodrie, O. P. Jensen, C. W. Martin, B.J. Roberts, J. Valenti, K. O'Connor, and S.C. Halbert. 2014b. Fish assemblages in Louisiana salt marshes: Effects of the Macondo oil spill. Estuaries and Coasts DOI: 10.1007/s12337-014-9890-6.

Able, K.W., D. Nemerson, R. Bush and P. Light. 2001. Spatial variation in Delaware Bay (U.S.A.) marsh creek fish assemblages. Estuaries 24(3): 441-452.

Able, K. W., M. C. Sullivan, J. A. Hare, G. Bath-Martin, J. C. Taylor, and R. Hagan. 2011b. Larval abundance of summer flounder (*Paralichthys dentatus*) as a measure of recruitment and stock status. Fisheries Bulletin 109:68-78.

Able, K.W., J.L. Valenti, and T.M. Grothues. 2017. Fish larval supply to and within a lagoonal estuary: Multiple sources for Barnegat Bay, New Jersey. *Environmental Biology of Fishes*. DOI: 10.1007/s10641-017-0595-0.

Able, K.W., C.J. Welsh, and R. Larum. 2018. Salt marsh peat dispersal: Habitat for fishes, decapod crustaceans, and bivalves. *In* Peat. Intech Ltd., Rijeka, Croatia.

Chant, R.J. M.C. Curran, K.W. Able and S.M. Glenn. 2000. Delivery of winter flounder (*Pseudopleuronectes americanus*) larvae to settlement habitats in coves near tidal inlets. Est. Coast. Shelf Sci. 51: 529-541.

Cody, M. L., and J. A. Smallwood. 1996. Long-term studies of vertebrate communities. Academic Press, San Diego, CA.

Correia, A.T., K.W. Able, C. Antunes, and J. Coimbra. 2004. Early life history of the American conger eel (*Conger oceanicus*) as revealed by otolith microstructure and microchemistry of metamophosing leptocephali. Mar. Biol. 145: 477-488.

Ducklow, H. W., S. C. Doney, and D. K Steinberg. 2009. Contributions of long-term research and time-series observations to marine ecology and biogeochemistry. Annual Review of Marine Science 1:279-302.

Durand, J. B. 1984. Nitrogen distribution in New Jersey coastal bays. Pp. 29-51 *in* M. J. Kennish and R. A. Lutz, eds. Ecology of Barnegat Bay, New Jersey. Lecture Notes on Coastal and Estuarine Studies. Springer, New York, NY.

Good, R. E., and N. F. Good. 1984. The Pinelands National Reserve: an ecosystem approach to management. Bioscience 34(3):169-173.

Hare, J. A., and K. W. Able. 2007. Mechanistic links between climate and fisheries along the east coast of the United States: explaining population outbursts of Atlantic croaker (*Micropogonias undulatus*). Fish. Oceanogr. 16(1):31-45.

Houde, E. D. 2008. Emerging from Hjort's Shadow. J. Northw. Atl. Fish. Sci. 41:53-70.

Keefe, M. and K.W. Able. 1993. Patterns of metamorphosis in summer flounder, *Paralichthys dentatus*. Journal of Fish Biology 42:713-728.

Kennish, M. J. 2004. Chapter 3. Jacques Cousteau National Estuarine Research Reserve. Pp. 59-115. *In:* M. J. Kennish (ed.) Estuarine Research, Monitoring and Resource Protection. CRC Press, New York.

Nickerson, K. J., T. M. Grothues, and K. W. Able. 2018. Sensitivity of a fish time-series analysis to guild construction: A case study of the Mullica River – Great Bay ecosystem. Marine Ecology Progress Series 598:113-129.

Nickerson K.J., T. M. Grothues, and K. W. Able. In review. Change in fish assemblages in a Mid-Atlantic Estuary: Analysis of a decades-long time series. Estuaries and Coasts.

Phelan, B.A., R. Goldberg, A.J. Bejda, J. Pereira, S. Hagan, P. Clark, A.L. Studholme, A. Calabrese and K.W. Able. 2000. Estuarine and habitat-related differences in growth rates of young-of-the-year winter flounder (*Pseudopleuronectes americanus*) and tautog (*Tautoga onitis*) in three northeastern US estuaries. J. Exp. Mar. Biol. Ecol. 247: 1-28.

Psuty, N. P., M. P. DeLuca, R. Lathrop, K. W. Able, S. Whitney, and J. F. Grassle. 1993. The Mullica River – Great Bay National Estuarine Research Reserve: A unique opportunity for research, preservation and management. Proceedings of Coastal Zone '93, July 1993. New Orleans, Louisiana.

Sogard, S. M., K. W. Able, and S. M. Hagan. 2001. Long-term assessment of settlement and growth of juvenile winter flounder (*Pseudopleuronectes americanus*) in New Jersey estuaries. Journal of Sea Research 45(3-4):189-204.

Sukhotin, A., and V. Berger. 2013. Long-term monitoring studies as a powerful tool in marine ecosystem research. Hydrobiologia 706:1-9.

Sullivan, M.C., K.W. Able, J.A. Hare and H.J. Walsh. 2006. *Anguilla rostrata* glass eel ingress into two U.S. east coast estuaries: patterns, processes and implications for adult abundance. Journal of Fish Biology 69:1081-1101.

Sullivan, M. C., M. J. Wuenschel and K. W. Able. 2009. Inter- and intra-estuary variability in ingress, condition, and settlement of the American eel *Anguilla rostrata*: implications for estimating and understanding recruitment. Journal of Fish Biology 74:1949-1969.

Szedlmayer, S.T. and K.W. Able. 1996. Patterns of seasonal availability and habitat use by fishes and decapod crustaceans in a southern New Jersey estuary. Estuaries 19(3): 697-707.

Warlen, S.M., K.W. Able and E. Laban. 2002. Recruitment of larval Atlantic menhaden (*Brevoortia tyrannus*) to North Carolina and New Jersey estuaries: evidence for larval transport northward along the east coast of the United States. Fish. Bull 100(3): 609-623.

Wilson, K.A., K.W. Able, and K.L. Heck Jr. 1990. Habitat use by juvenile blue crabs: a comparison among habitats in southern New Jersey. Bull. Mar. Sci. 46(1):105-114.

Witting, D. A., K. W. Able, and M. P. Fahay. 1999. Larval fishes of a Middle Atlantic Bight estuary: Assemblage structure and temporal stability. Can. J. Fish. Aquat. Sci. 56(2):222-230.

Table 1. Sampling effort during 2018 for larval, juvenile and adult fishes along an estuarine environmental gradient in the Mullica River-Great Bay (MR-GB) using plankton, otter trawl, and gill nets. See Fig. 1 and Fig. 3 for locations of sampling sites. Note that three 30-minute hauls are statistically treated as one 90-minute haul for ichthyoplankton.

Life History Stage	Sampling Gear Specifications	Sample Duration (min)	Year	Frequency	Total Number of Hauls	Total Number of Fishes	MR-GB Sites Sampled
Larvae	Plankton net (1.0 m, 1 mm mesh)	90	2018	Bi-weekly	19	10,103	Little Sheepshead Creek
Juveniles and Adults	Otter Trawl (4.9 m)	2	2018	1x/month, 3x/site: Mar, May, Jul, Sep, Nov	135	1,580	Grassy Channel, The Cut, Graveling Point, Buoy 139, Ballanger Creek Mouth, Turtle Creek Mouth, Landing Creek Mouth, Motts Creek Mouth, Holgate Cove
Juveniles and Adults	Gill nets (four 45' nets [5 panels: one each of 2”, 3”, 4”, 5”, 6” mesh])	60-144	2018	1x/mo, Mar, May, Jul, Sep, Nov	140	516	Ballanger Creek, Graveling Point, Landing Creek, Nacote Creek, The Cut, Turtle Creek, Wading River

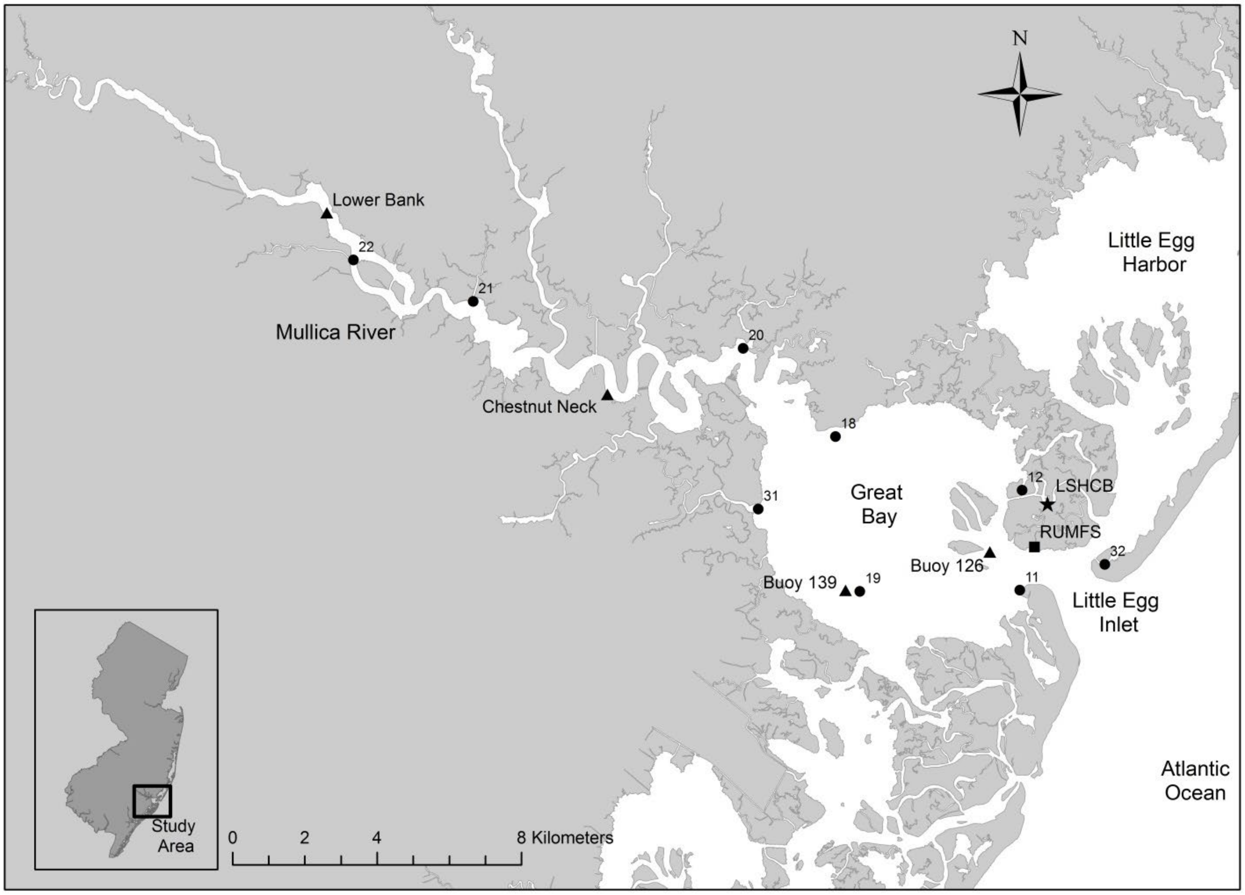


Figure 1. Sampling locations for larval (ichthyoplankton net) and juvenile (otter trawl) fishes in the Great Bay-Mullica River estuary during 2018. LSHCB indicates ichthyoplankton sampling site in Little Sheepshead Creek. Closed circles indicate otter trawl locations. Triangles indicate location of SWMP data loggers. See Table 1 for additional details.

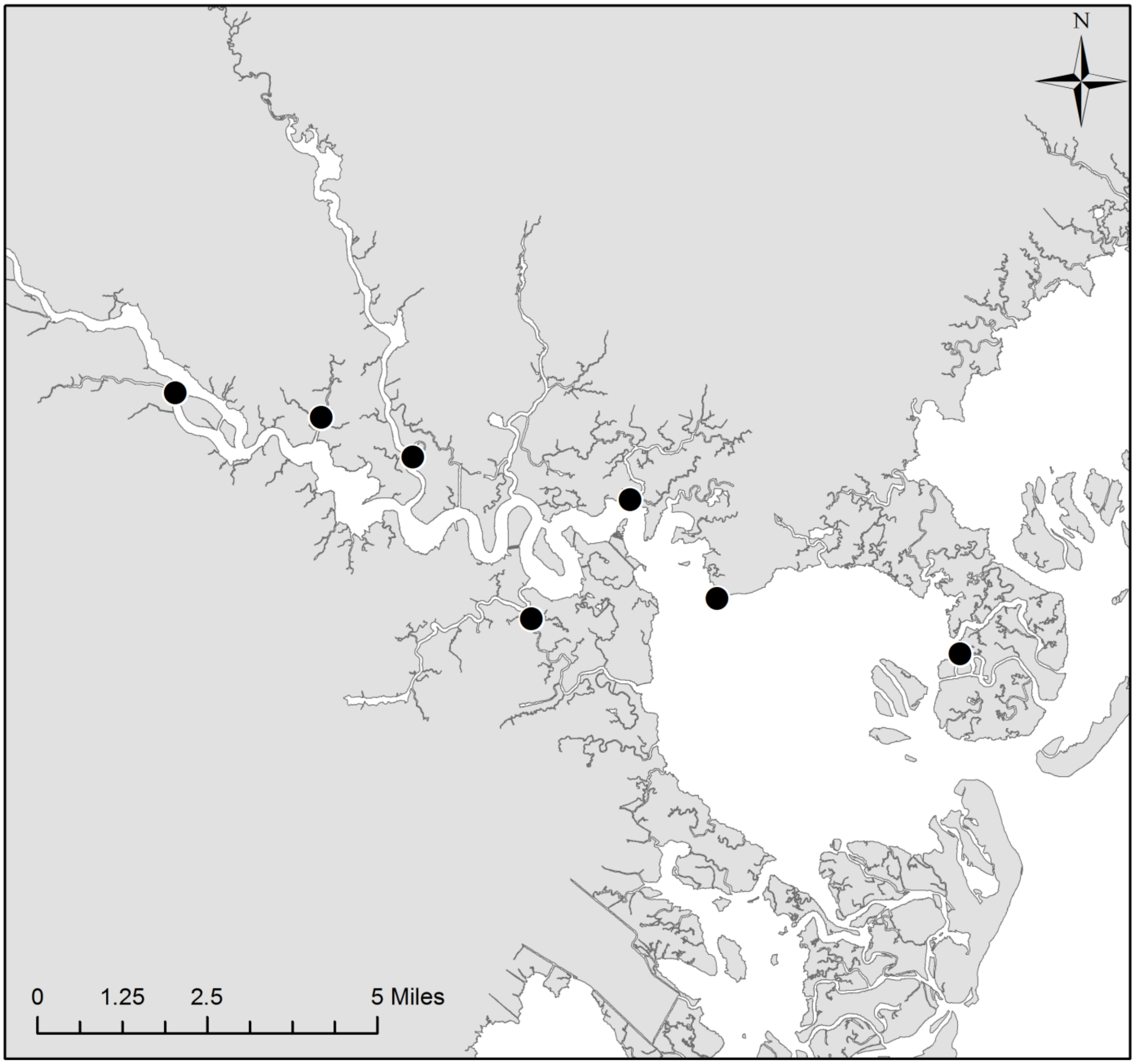


Figure 2. Gill net (black dots) sampling locations in the Great Bay-Mullica River estuary during 2018. See Table 1 for additional details.

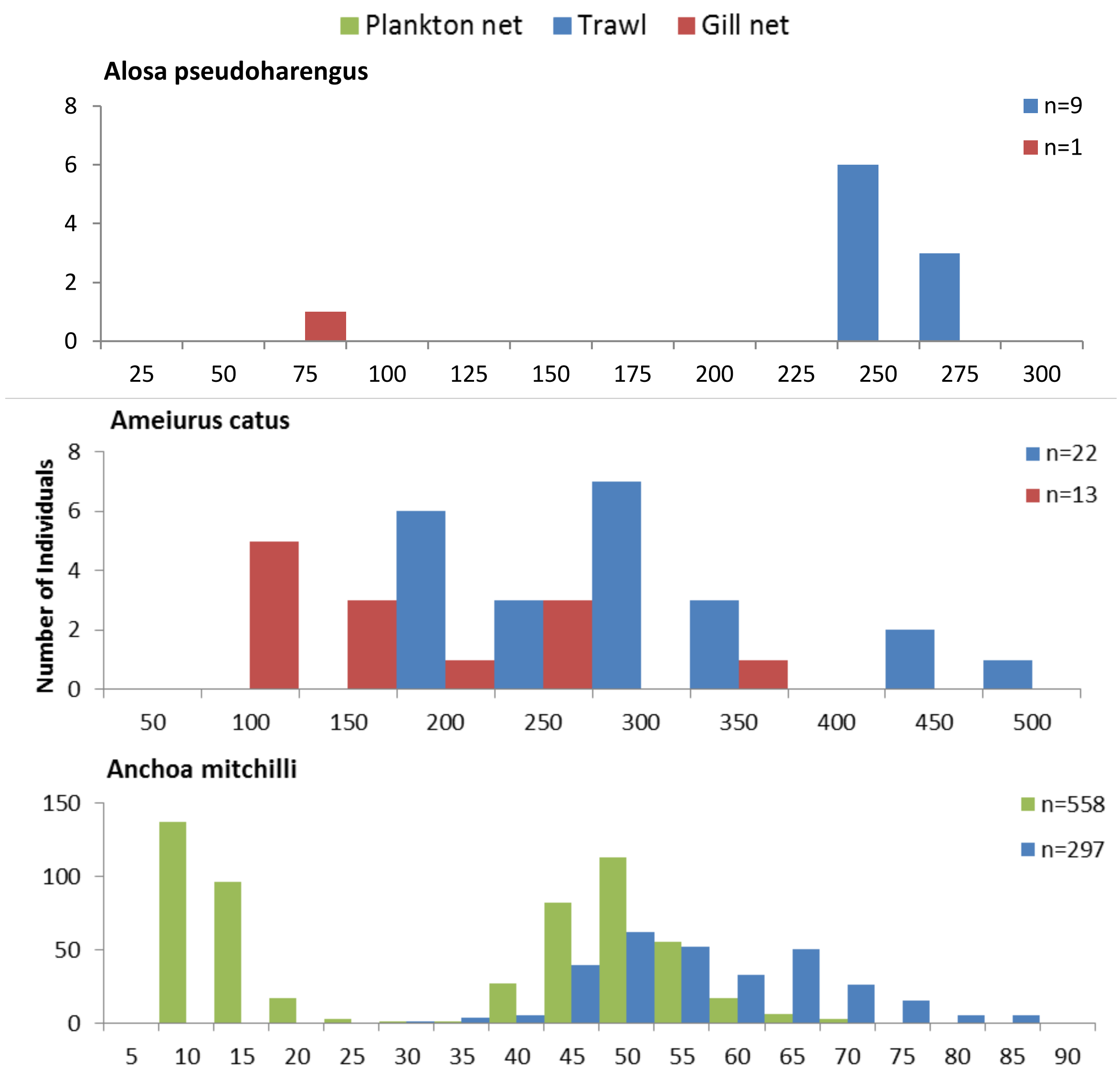


Figure 3. Composite length frequency of fishes, decapod crabs, and horseshoe crabs across all sampling periods and gears (by color) in the Mullica River-Great Bay during 2018. For *Brevoortia tyrannus* size classes in which >40 larval fish were collected: size class 20 mm, n=310; size class 30 mm, n=136. For *Limulus polyphemus* size class with maximum length (measured as carapace width) of 30 mm, n=87. Note dashed line through x-axis, which indicates a break in scale. For *Paralichthys dentatus* size class with maximum length of 15 mm, n=78. Note dashed line through x-axis, which indicates a change in scale. For *Syngnathus fuscus* size class with maximum length of 20 mm, n=138.

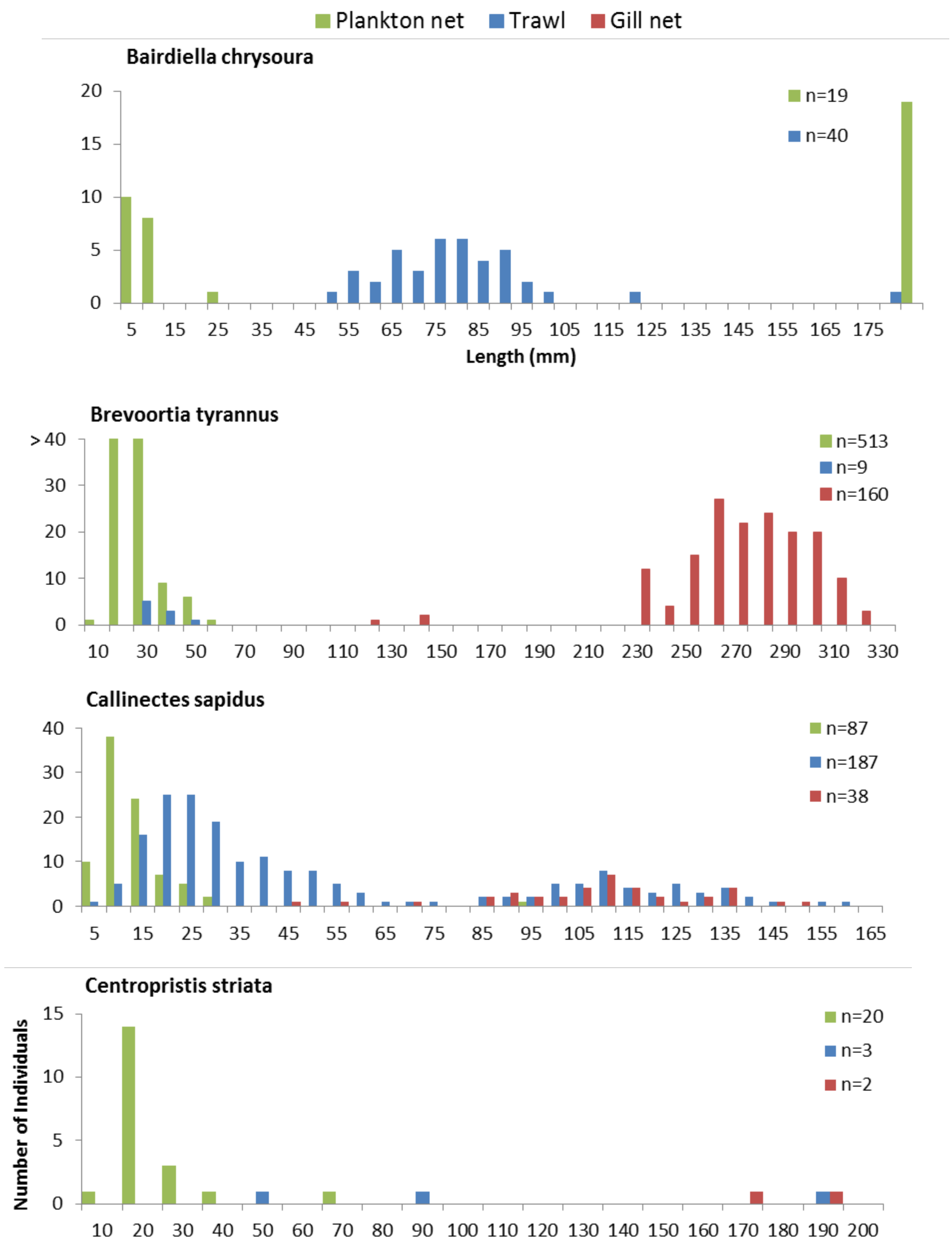
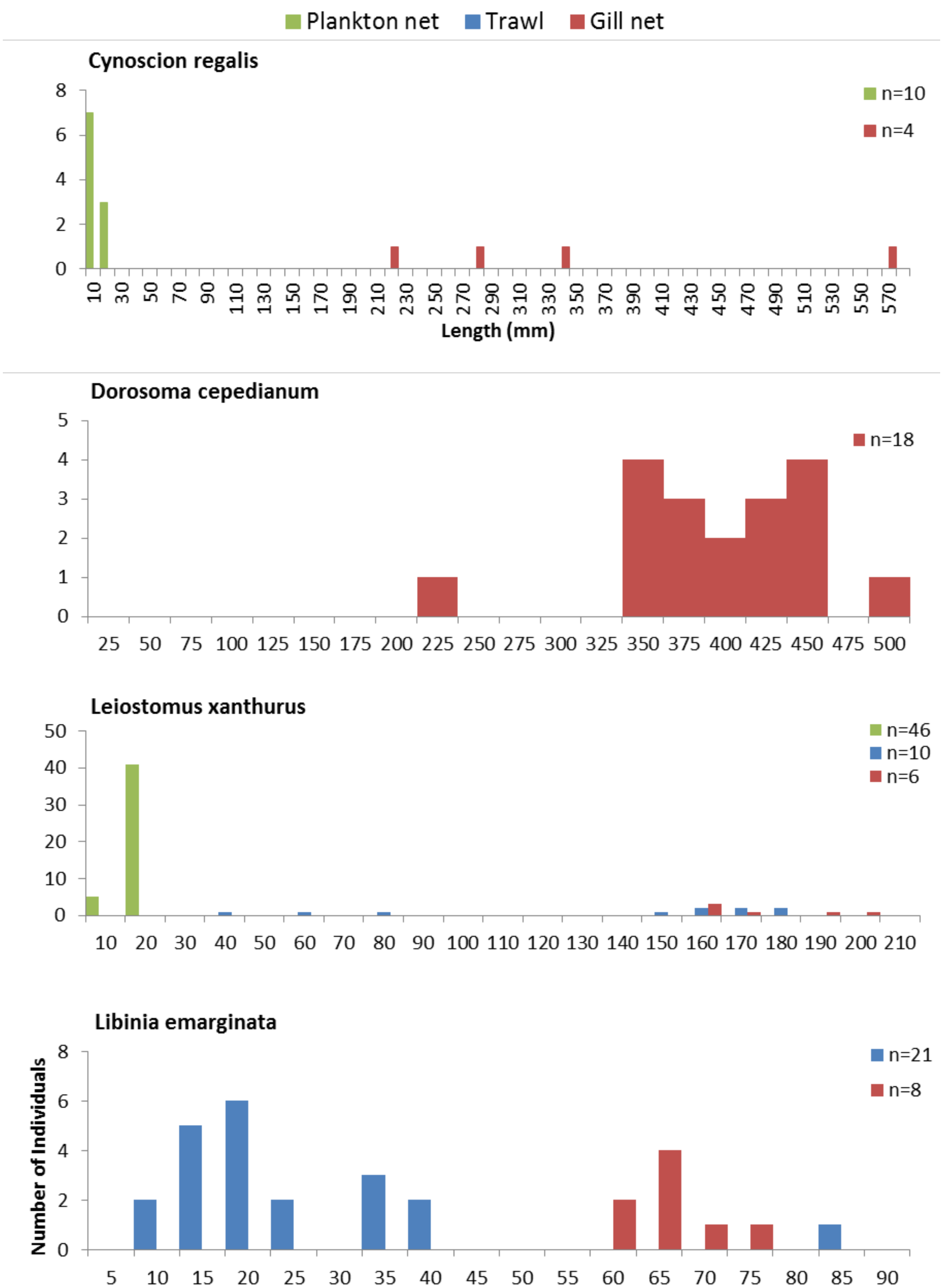


Figure 3 Continued



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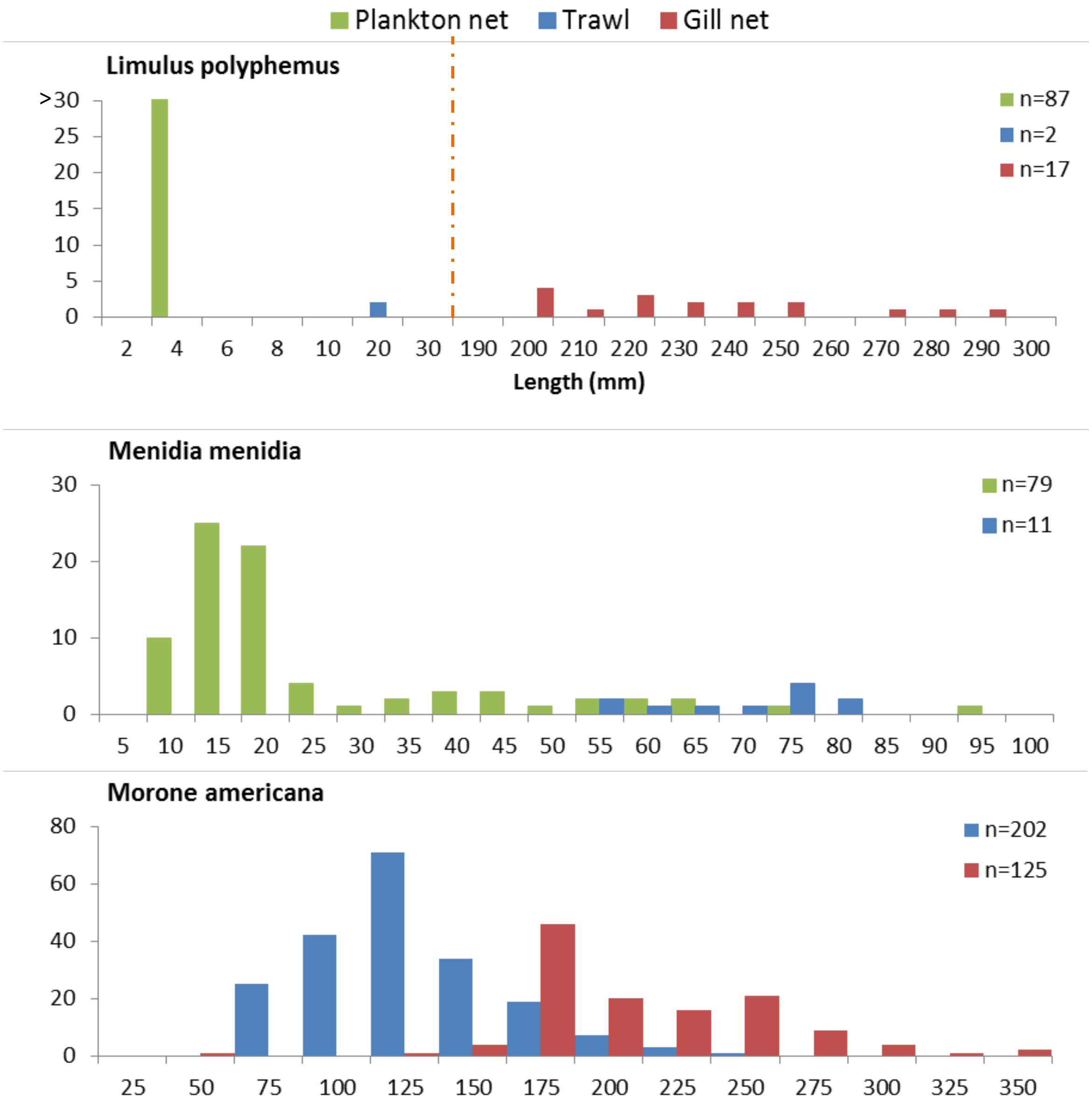

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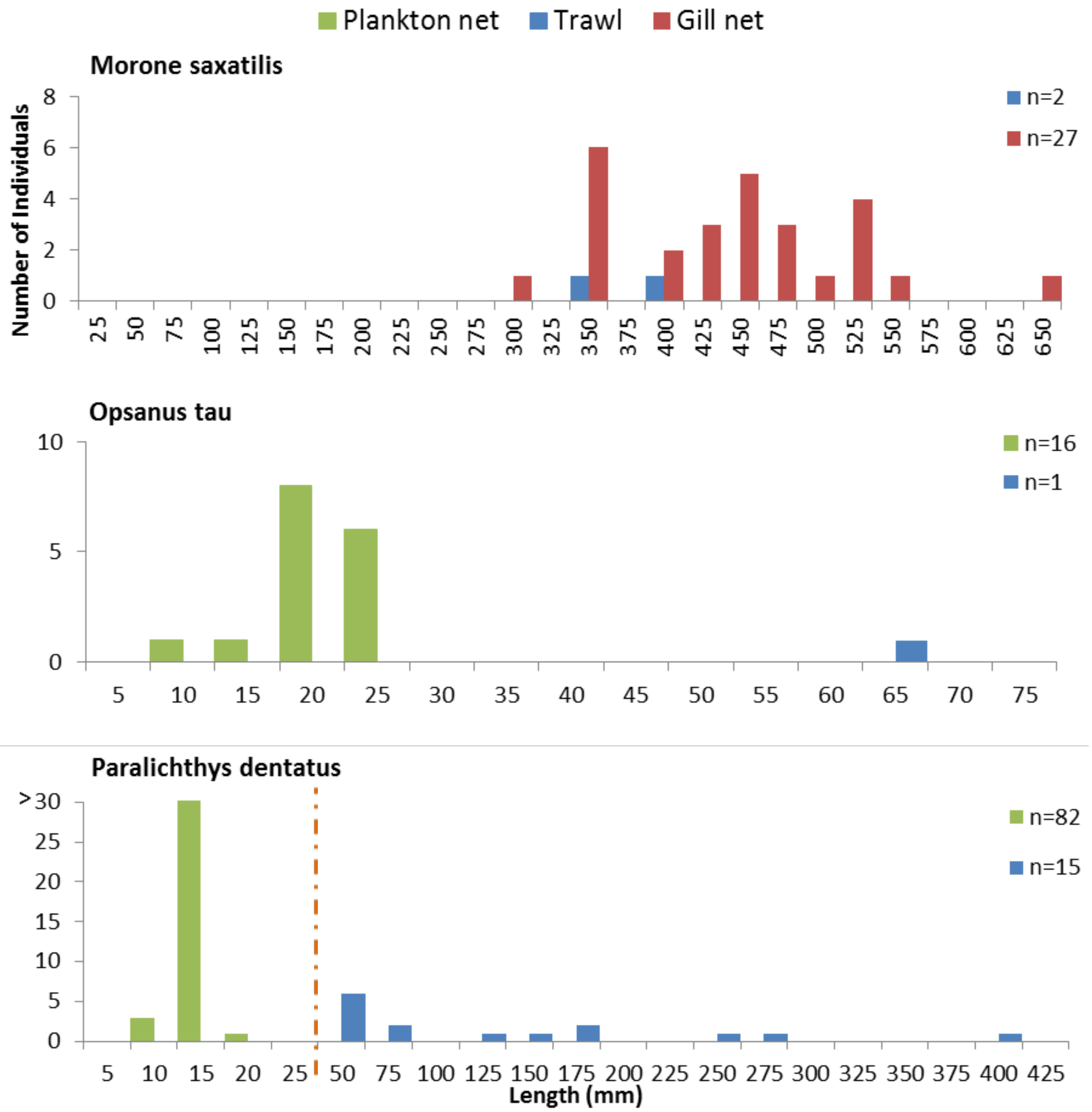

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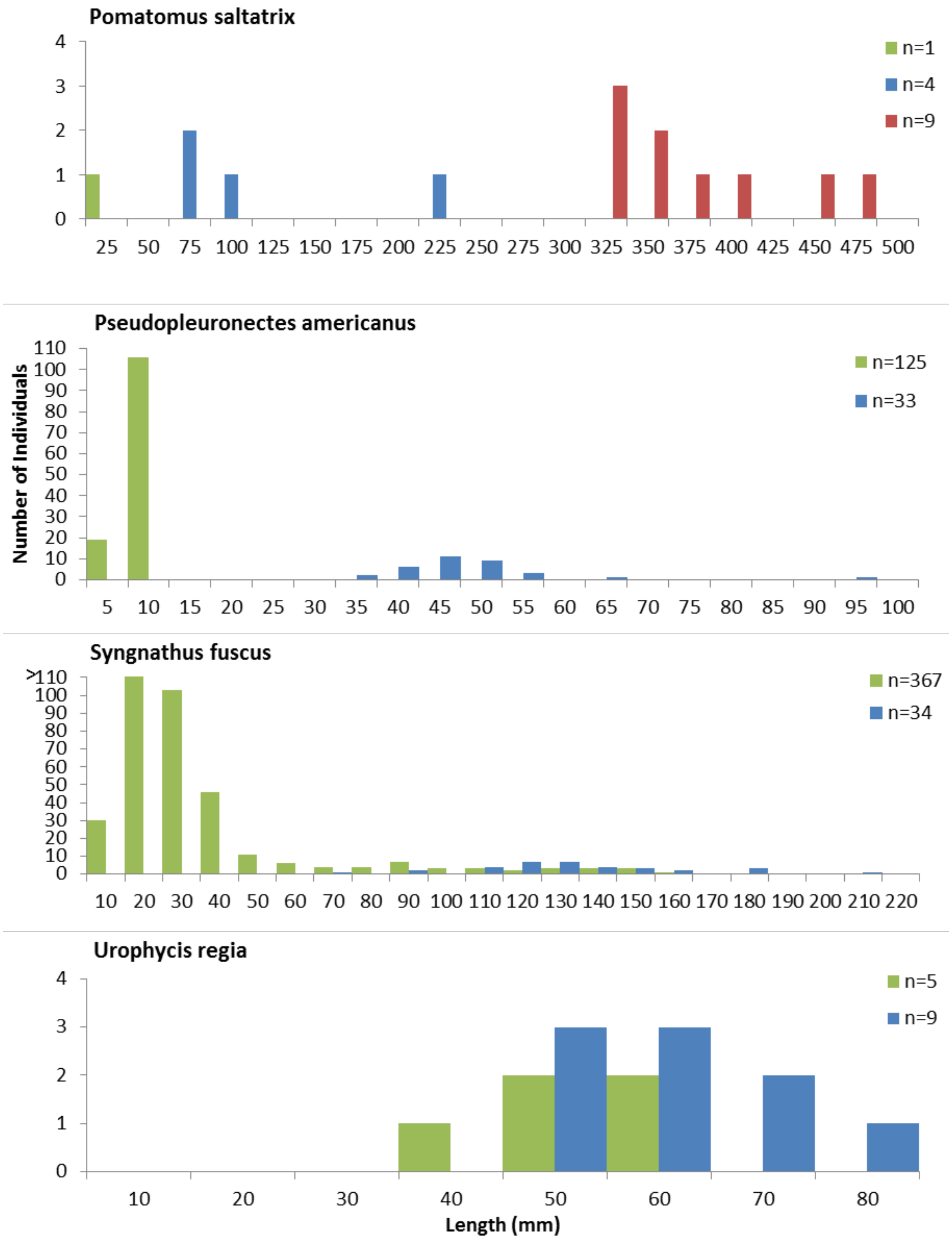


Figure 3 Continued

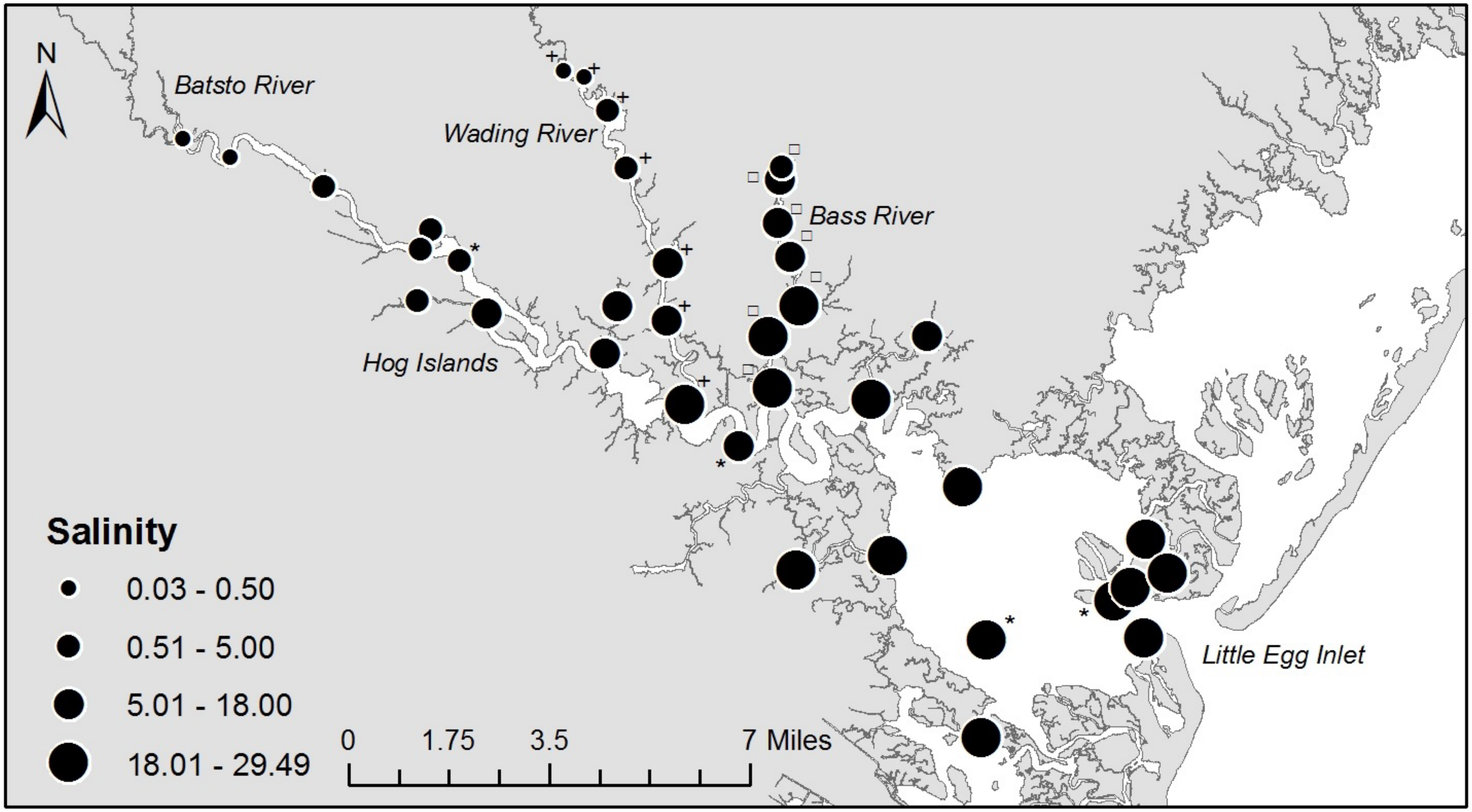


Figure 4. Average salinity from long term otter trawl samples 1988-2014. * indicates System-Wide Monitoring Program data values from 1996-2014. + indicates Wading River sites sampled on 22 September 2016. □ indicates Bass River sites samples on 18 November 2016.

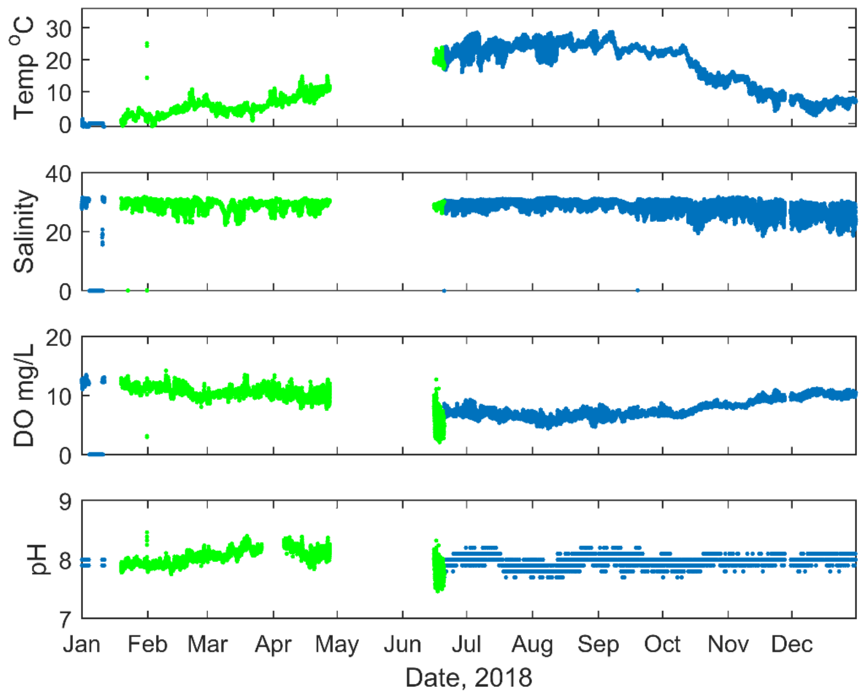


Figure 5. Temporal variability of water quality variables at Buoy 126 in 2018. Green symbols represent raw replacement data from the temporary logger at the RUMFS boat basin. See Fig. 1 for location of data logger.

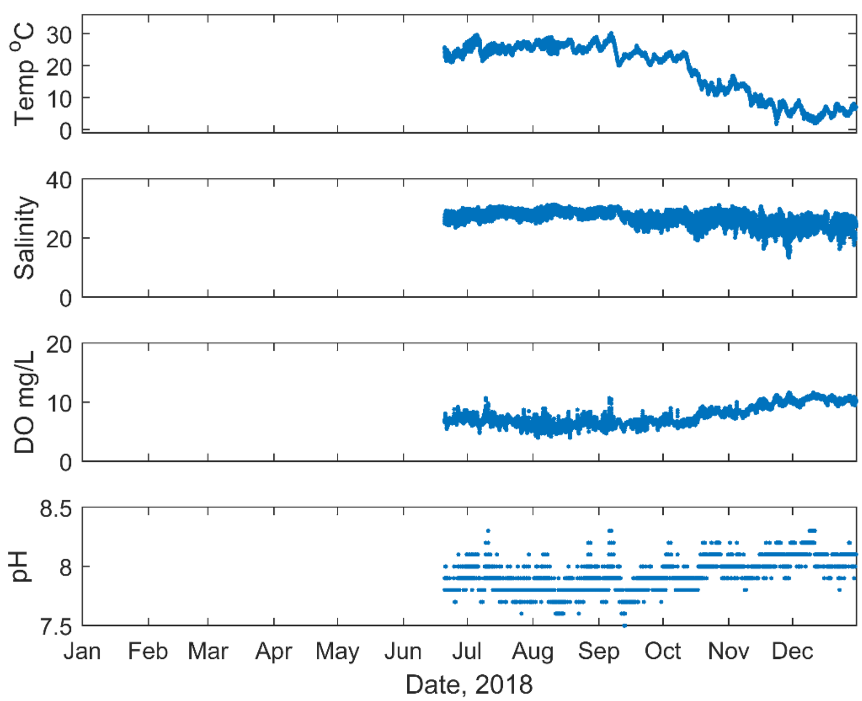


Figure 6. Temporal variability of water quality variables at Buoy 139 in 2018. See Fig. 1 for location of data logger

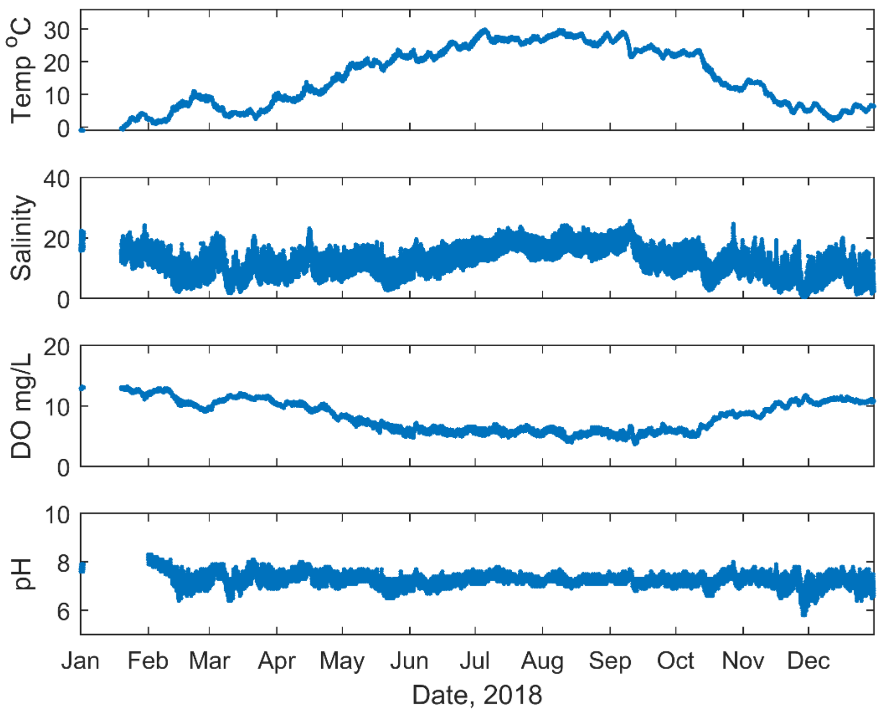


Figure 7. Temporal variability of water quality variables at Chestnut Neck in 2018. See Fig. 1 for location of data logger.

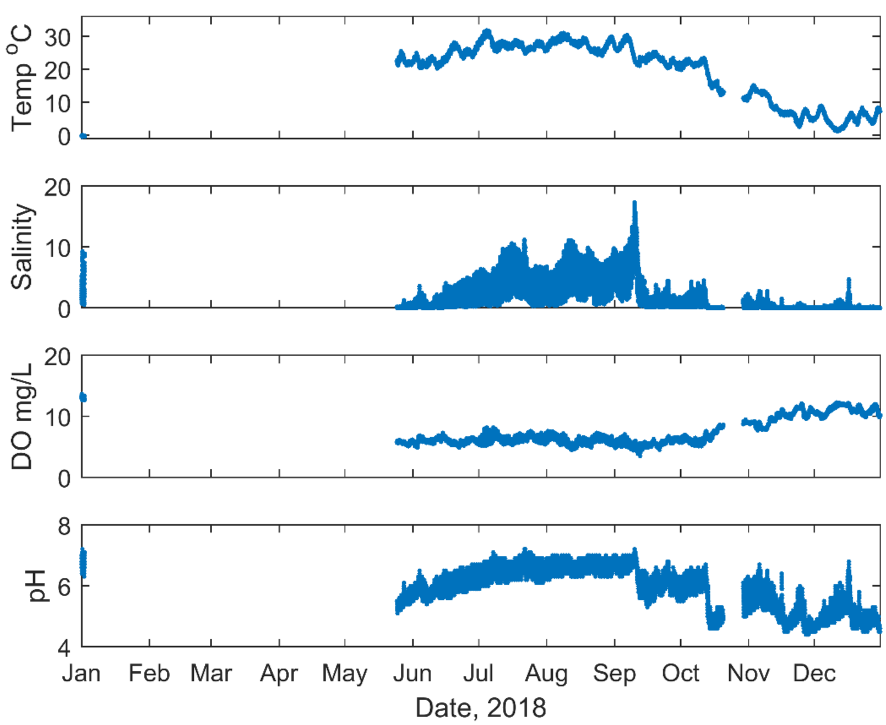


Figure 8. Temporal variability of water quality variables at Lower Bank in 2018. See Fig. 1 for location of data logger.

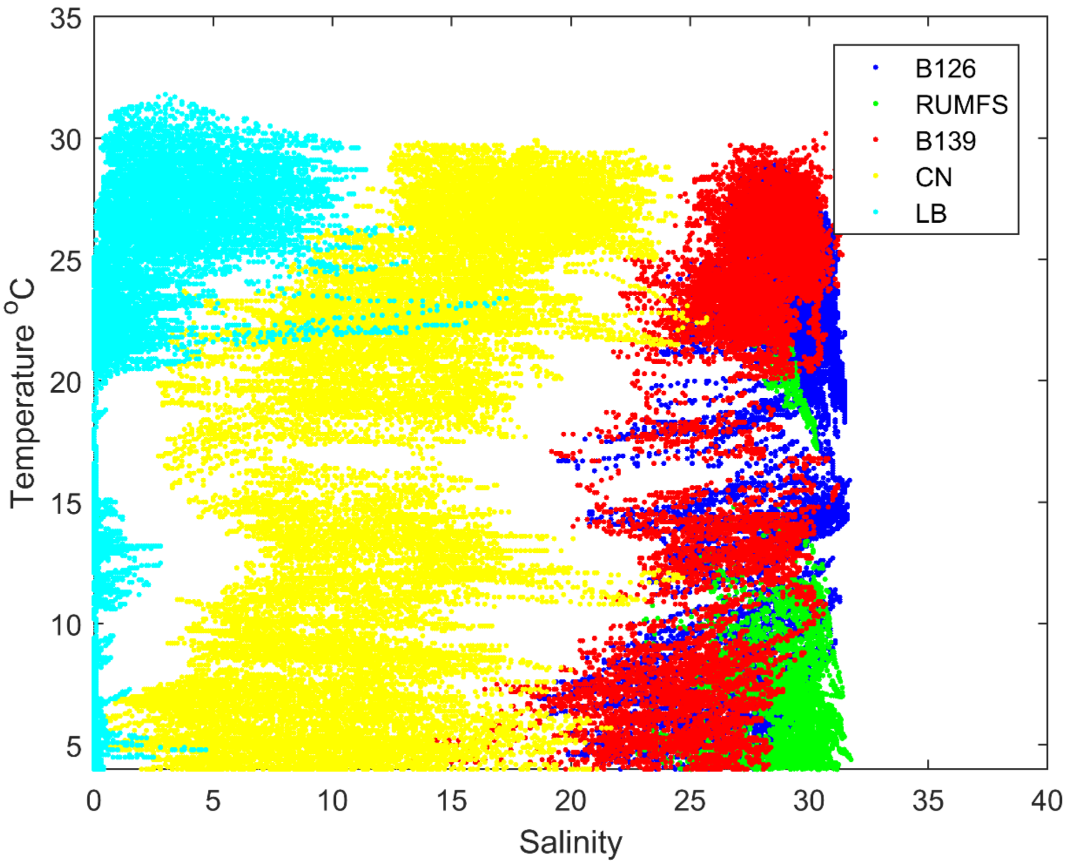


Figure 9. Temperature-Salinity diagram of all measures collected by JCNERR SWMP loggers in the Mullica River Great Bay Estuary, New Jersey, in 2017. B126 refers to Buoy 126, B139 to Buoy 139, CN to Chestnut Neck, and LB to Lower Bank. Note that data markers for B139 occlude those for 126, which has similar tidal and seasonal range. See Figure 1 for data logger locations. This graph includes replacement TS data from the temporary logger in the RUMFS boat basin as “B126”.

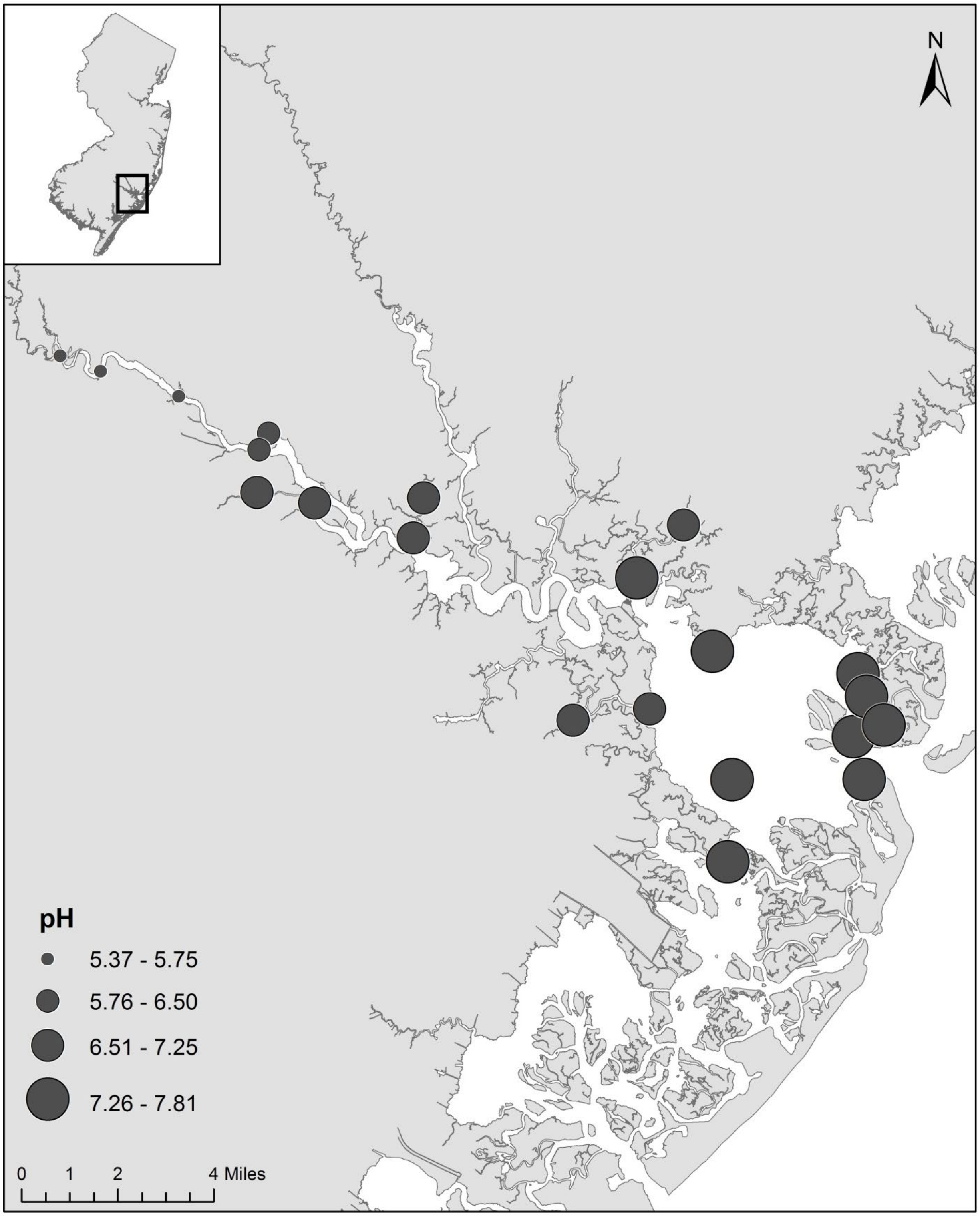


Figure 10. Average surface pH by site from long term otter trawl sampling 1988-2014 (range of 5.37 – 7.81).

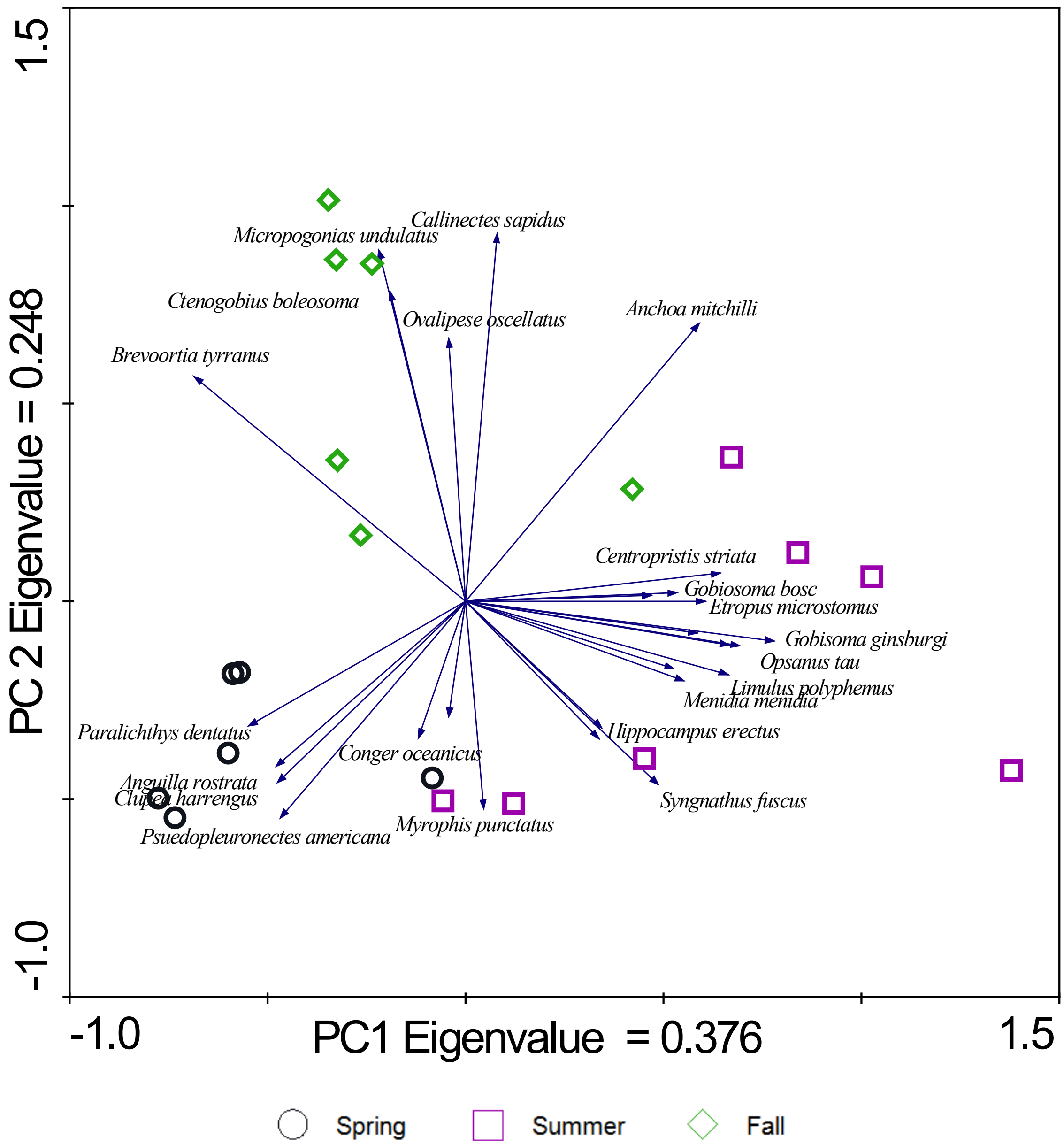


Figure 11. Biplot of sample and species scores for principal components analysis of larval fish and crab samples collected at Little Sheepshead Creek behind Little Egg Inlet. Species names are abbreviated as the first 3 letters of the genus and species each. Species plot coordinates are shown by their arrow points. Labels for *Leiostomus xanthurus*, (near *Conger oceanicus*), *Cynoscion regalis* (near *Hippocampus erectus*), *Menidia beryllina* (near *M. menidia*), *Bairdiella chrysura* and *Astroscopus gutatta* (both near *Opsanus* I) and *Anchoa hepsetus* (near *Gobiosoma bosc*) removed for clarity.

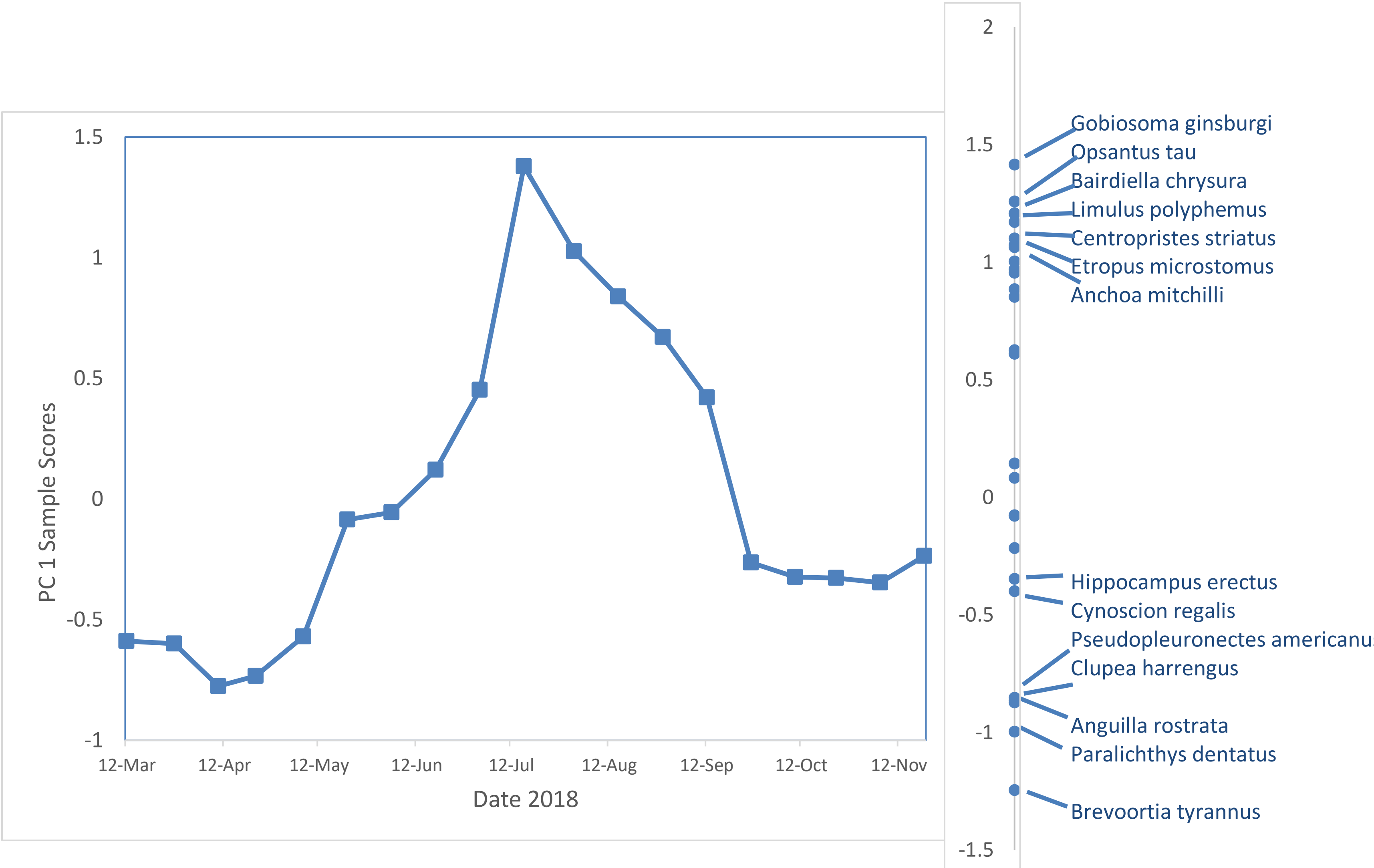


Figure 12. Sample score amplitude along the first principal component plotted as a time series to show larval fish and crab assemblage change over time. The second y-axis scales independently and shows the relative weight of several species in determining sample score. Not all species are shown.

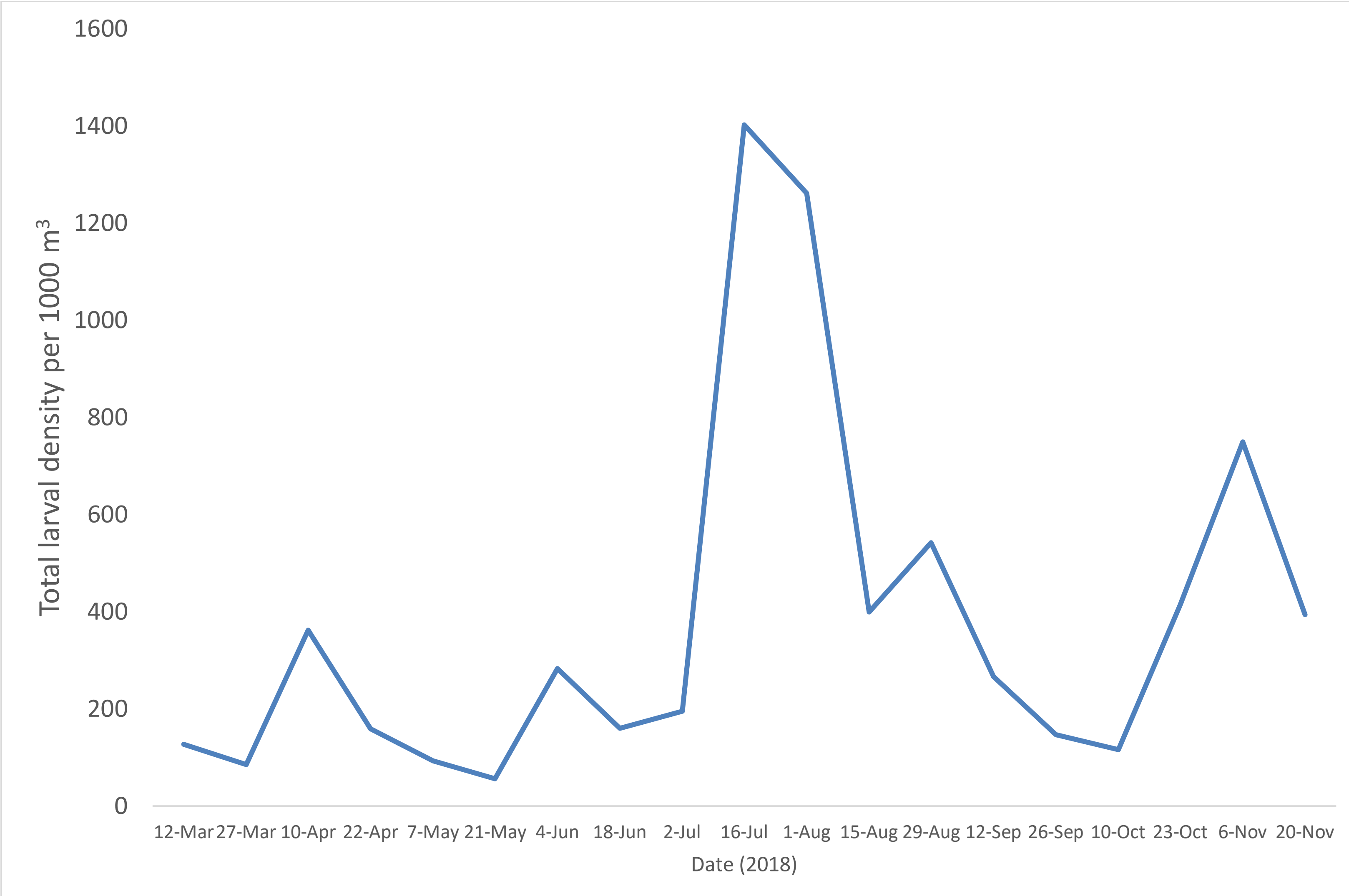


Figure 13. Density of all fish and crab larvae over time from sampling in Little Sheepshead Creek behind Little Egg Inlet in 2018.

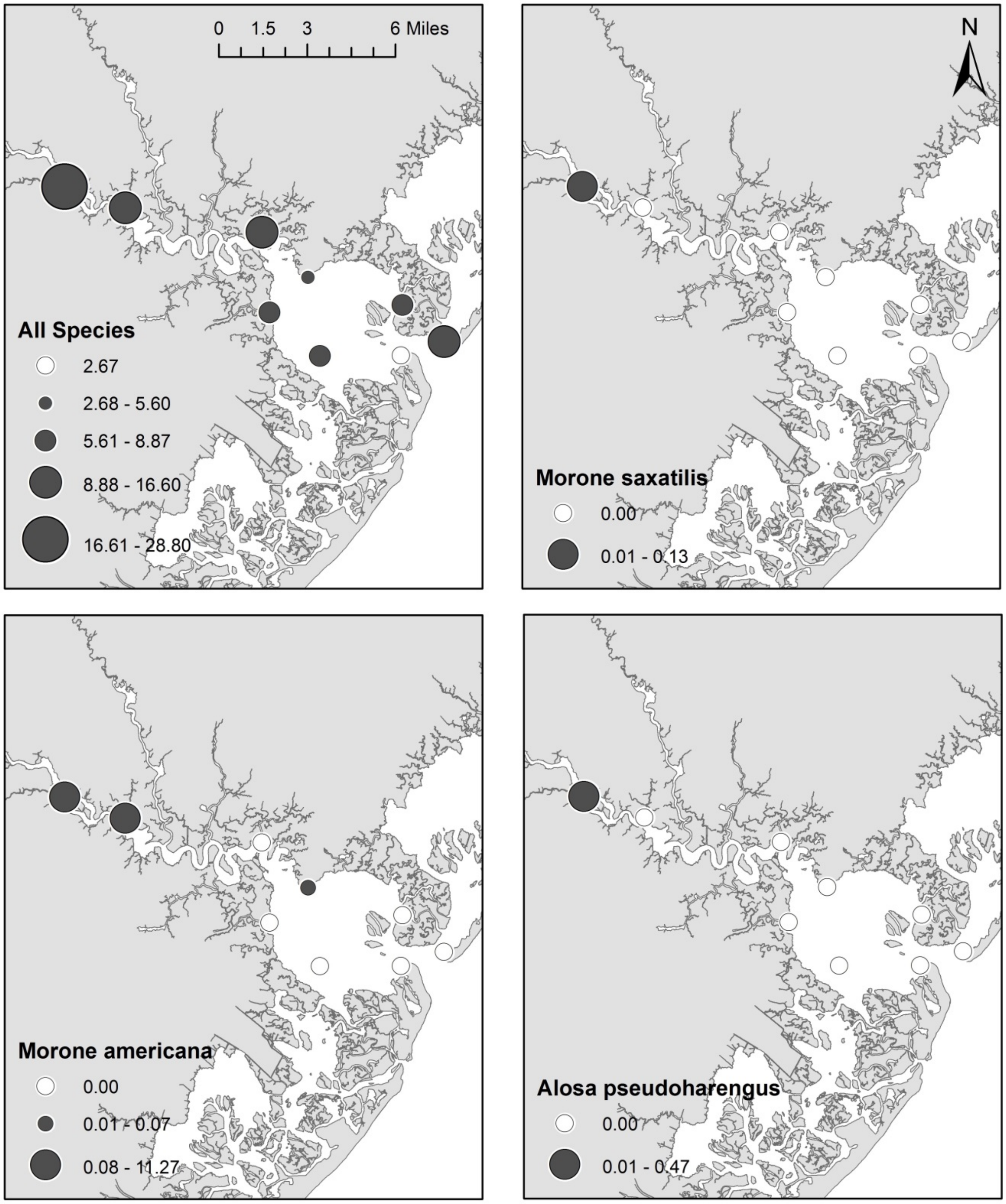


Figure 14. Spatial distribution of all and selected species from estuarine inventory trawl sampling during the months of March, May, July, September, and November in 2018. Symbols indicate average number caught per tow.

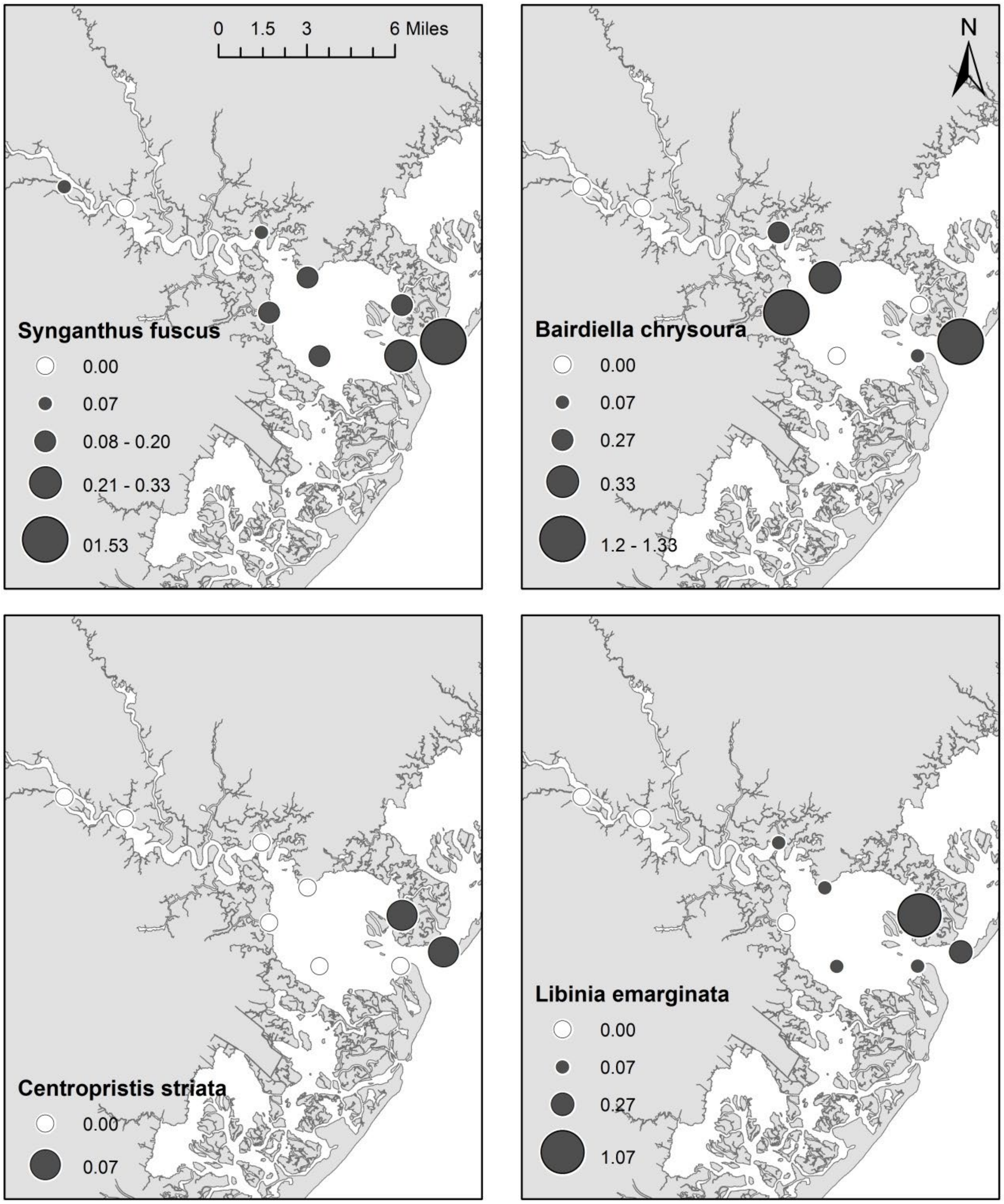
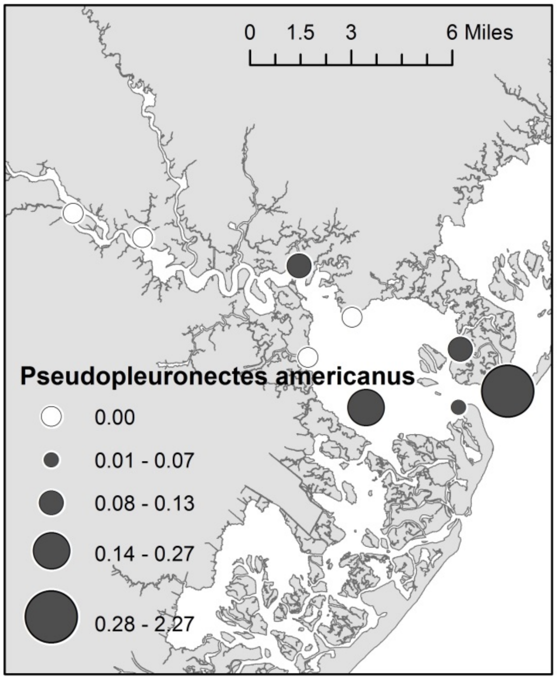
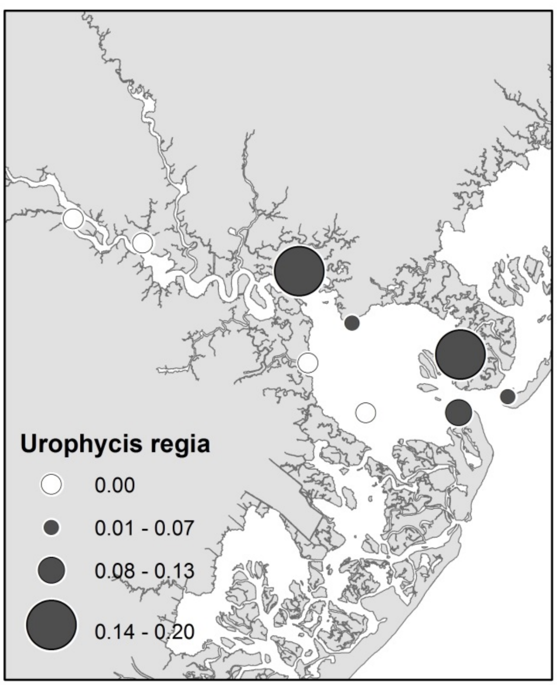


Figure 15. Spatial distribution of selected high salinity species from estuarine inventory trawl sampling during the months of March, May, July, September, and November 2018. Symbols indicate average number caught per tow.


0 1.5 3 6 Miles
Pseudopleuronectes americanus
0.00
0.01 - 0.07
0.08 - 0.13
0.14 - 0.27
0.28 - 2.27


Urophycis regia
0.00
0.01 - 0.07
0.08 - 0.13
0.14 - 0.20

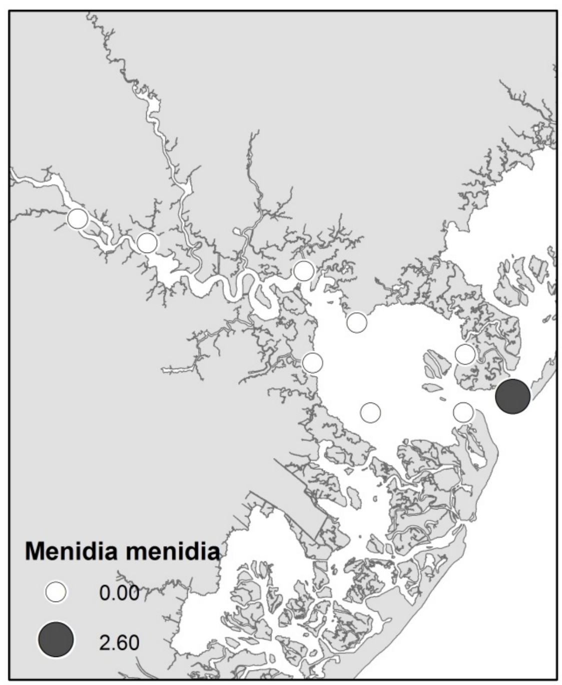

Menidia menidia
0.00
2.60

Figure 16. Spatial distribution of selected high salinity species from estuarine inventory trawl sampling during the months of March, May, July, September, and November 2018. Symbols indicate average number caught per tow.

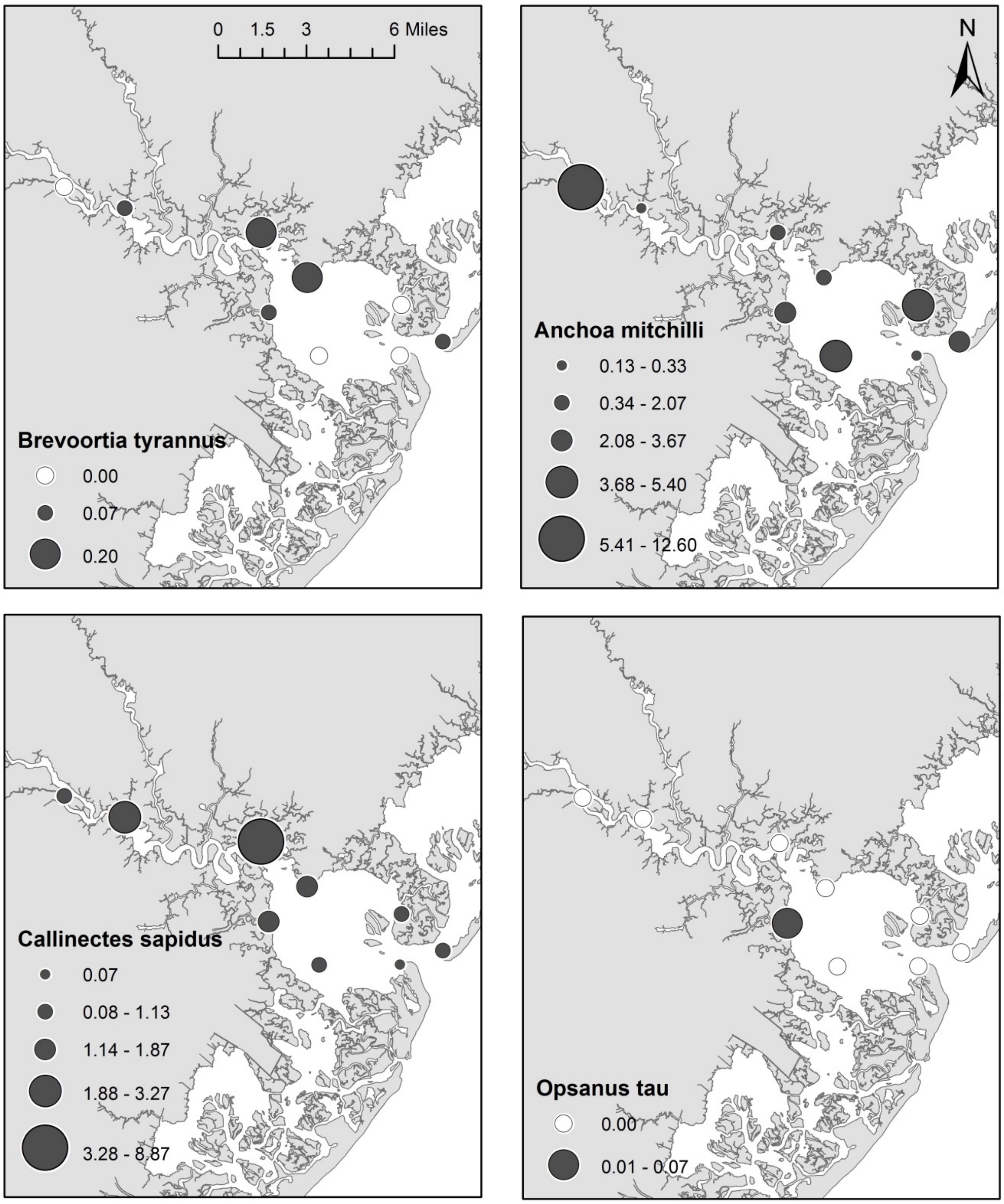


Figure 17. Spatial distribution of ubiquitously distributed species from estuarine inventory trawl sampling during the months of March, May, July, September, and November in 2018. Symbols indicate average number caught per tow.

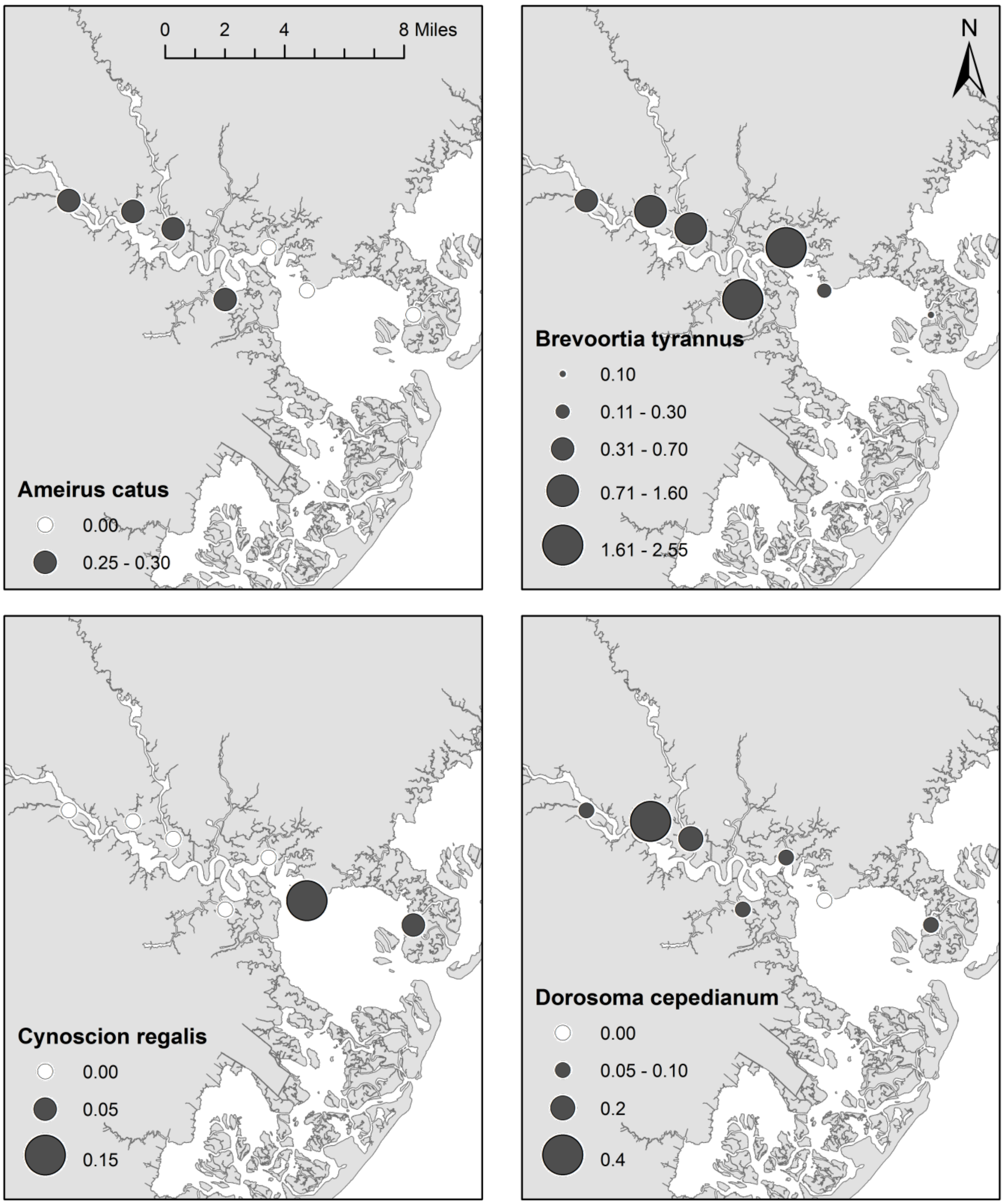


Figure 18. Abundance of selected species from estuarine inventory gill net sampling in the months of March, May July, September, and November in 2018. Closed circles represent total number of fish caught at each site. Open circles indicate no fish caught.

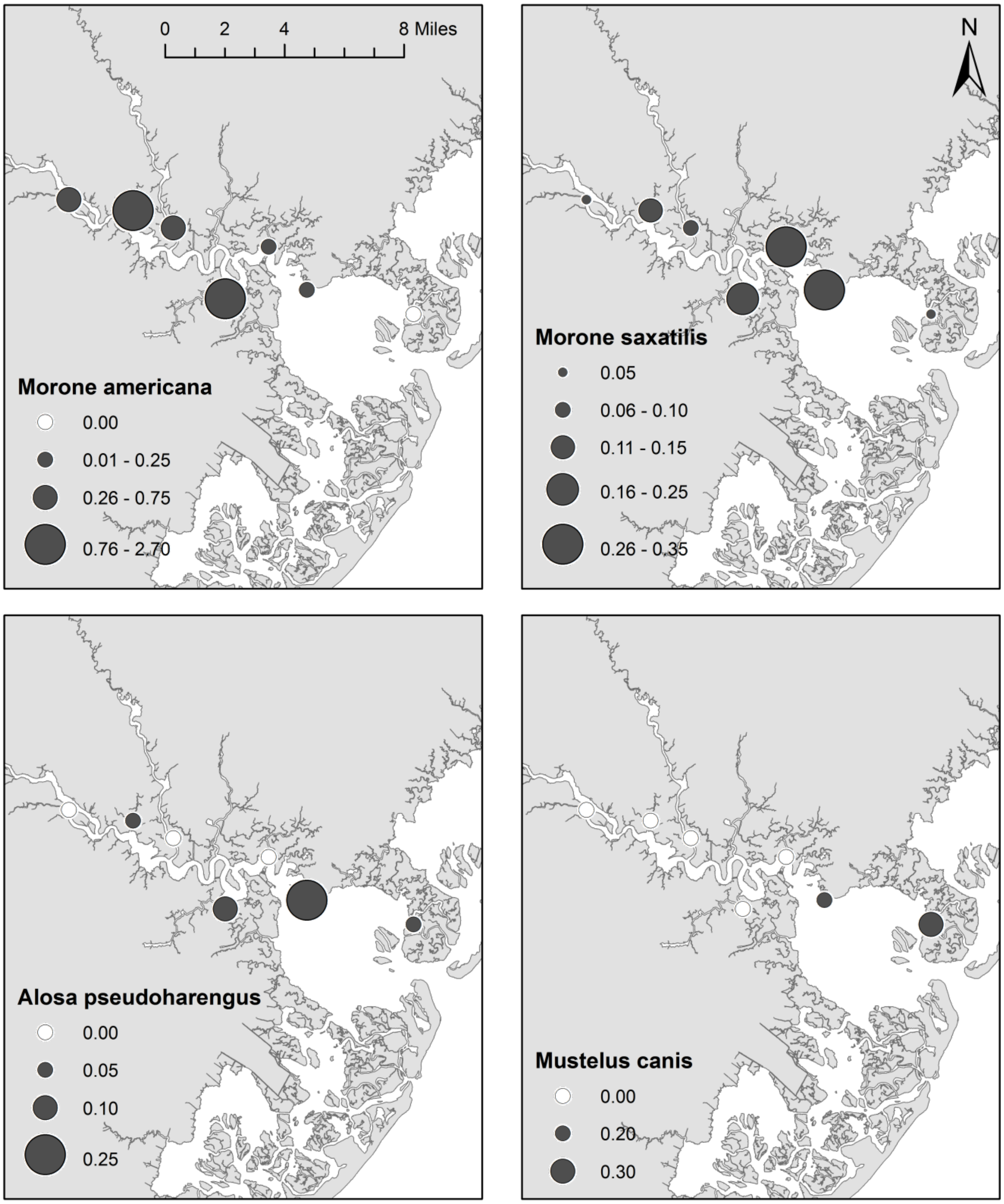


Figure 19. Abundance of selected species from estuarine inventory gill net sampling in the months of March, May July, September, and November in 2018. Closed circles represent total number of fish caught at each site. Open circles indicate no fish caught.

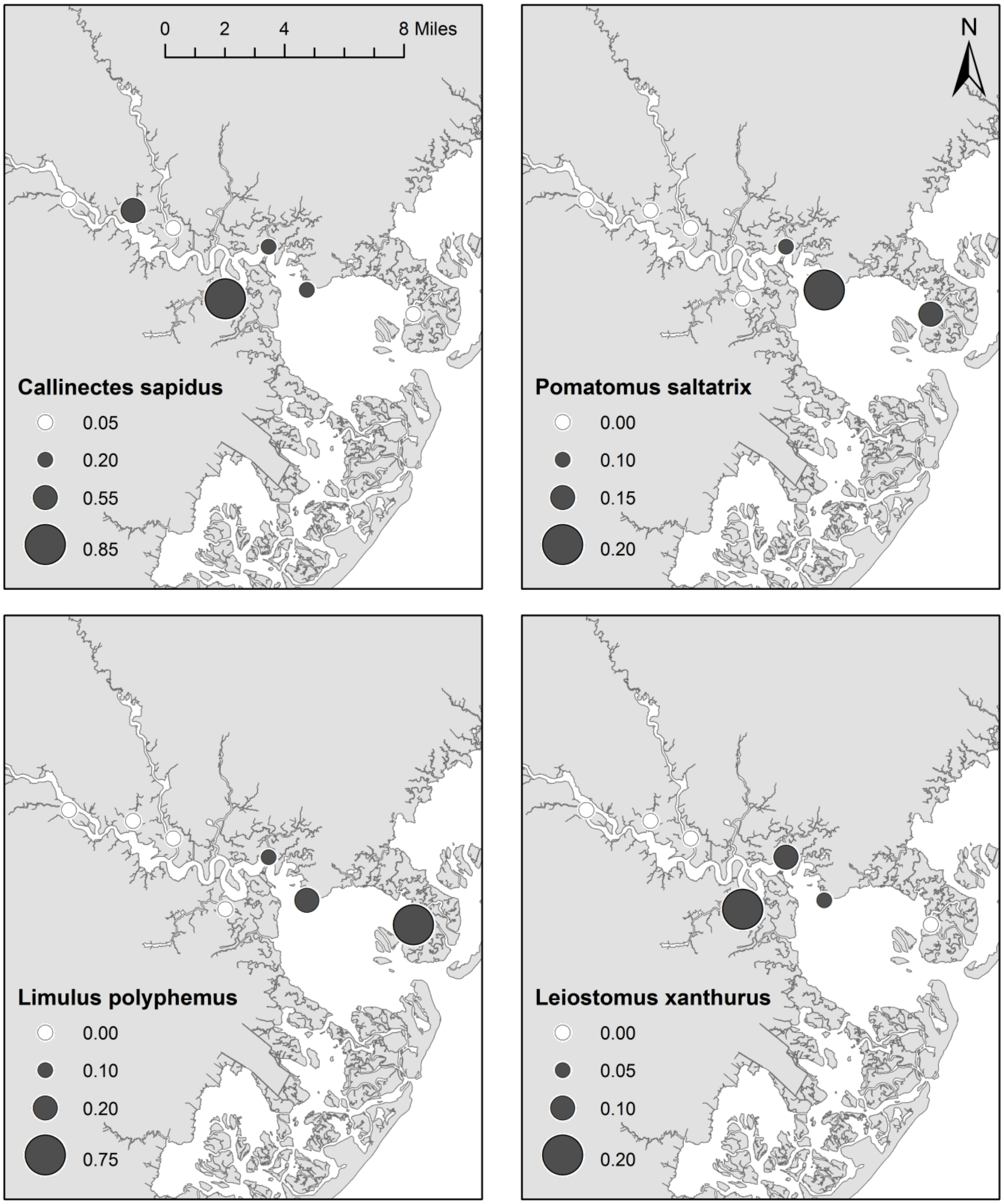


Figure 20. Abundance of selected species from estuarine inventory gill net sampling in the months of March, May July, September, and November in 2018. Closed circles represent total number of fish caught at each site. Open circles indicate no fish caught.

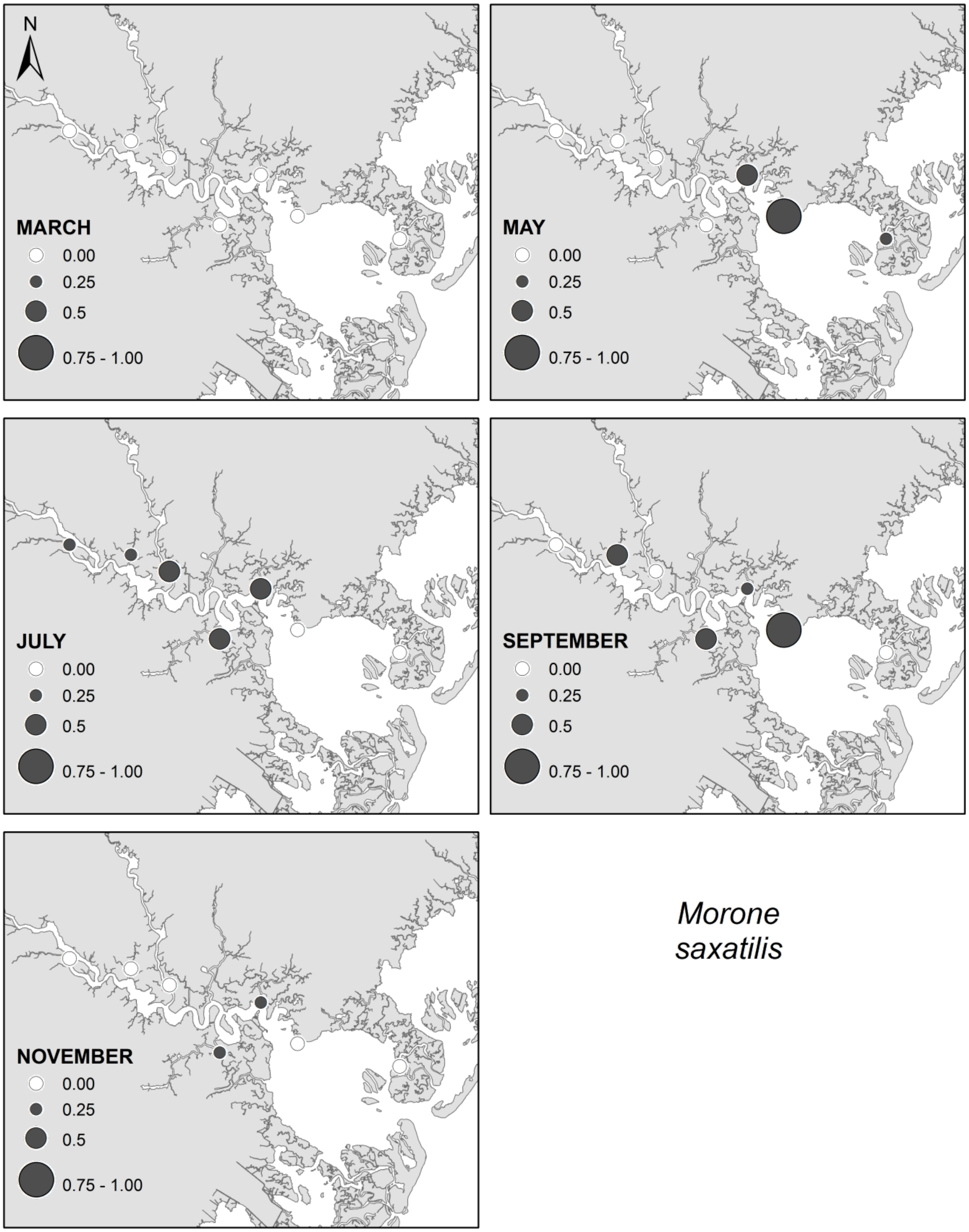


Figure 21. Seasonal distribution of *Morone saxatilis* from estuarine inventory gill net stations during 2018. Symbols indicate average number caught per set.

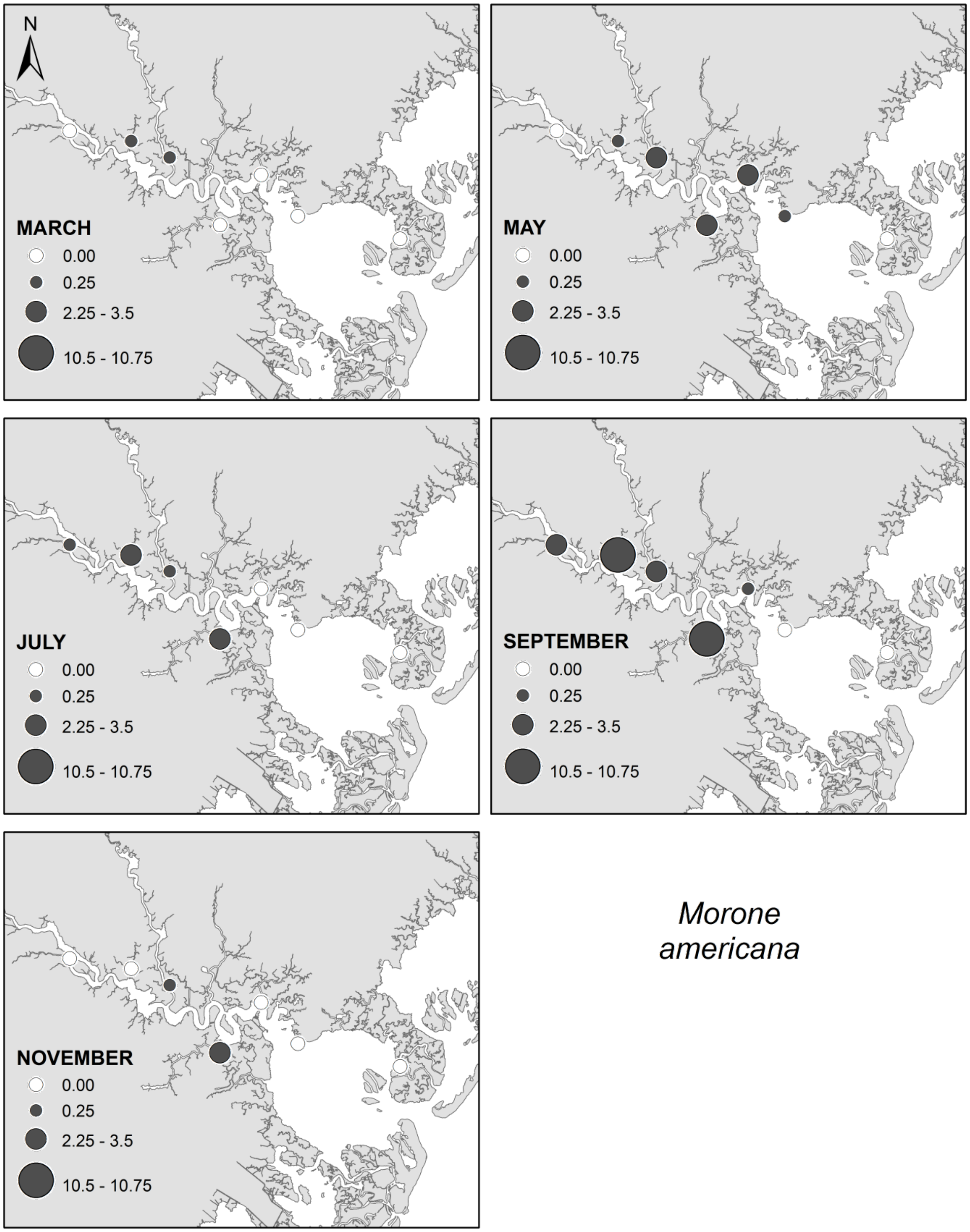


Figure 22. Seasonal distribution of *Morone americana* from estuarine inventory gill net stations during 2018. Symbols indicate average number caught per set.

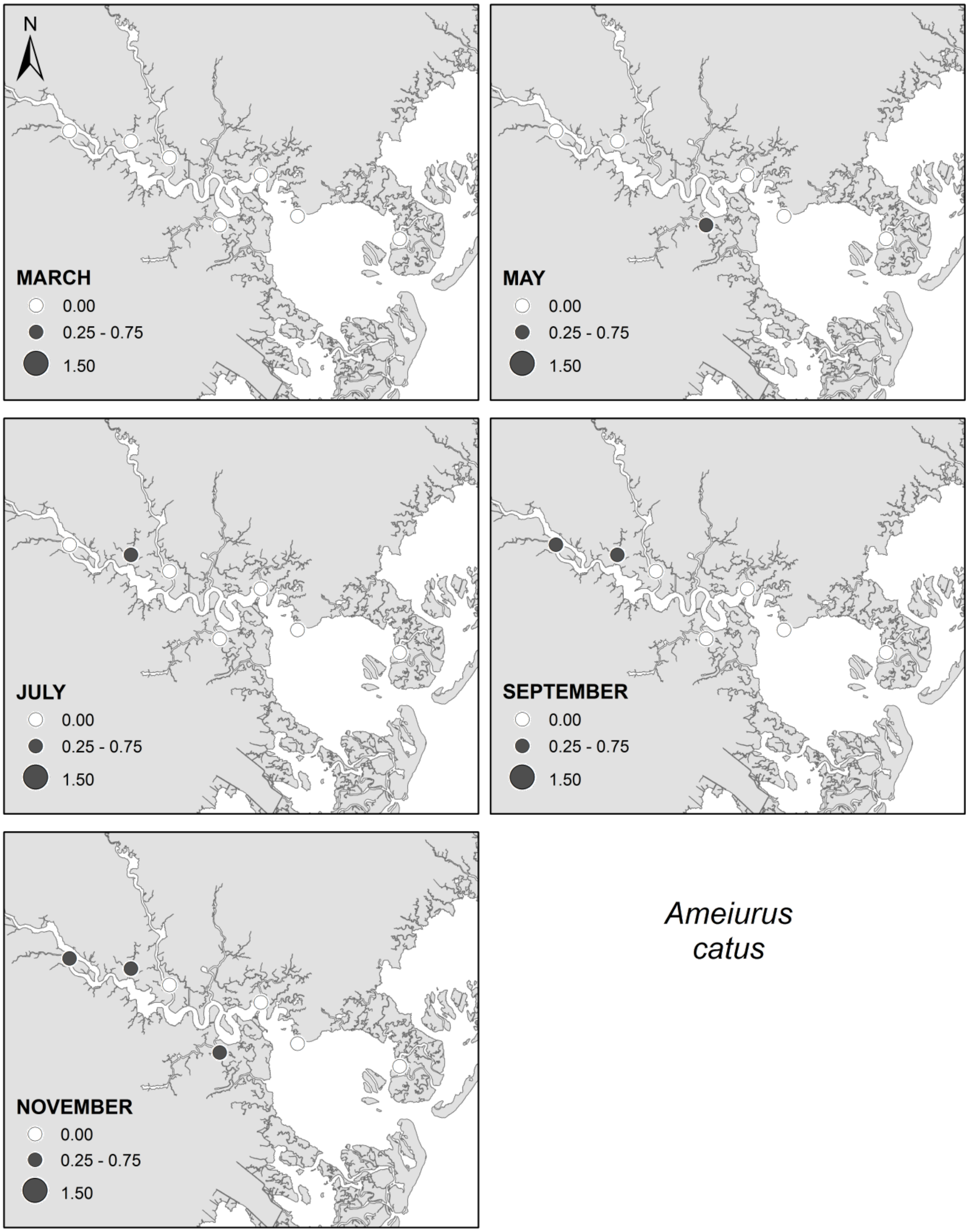


Figure 23. Seasonal distribution of *Ameiurus catus* from estuarine inventory gill net stations during 2018. Symbols indicate average number caught per set.

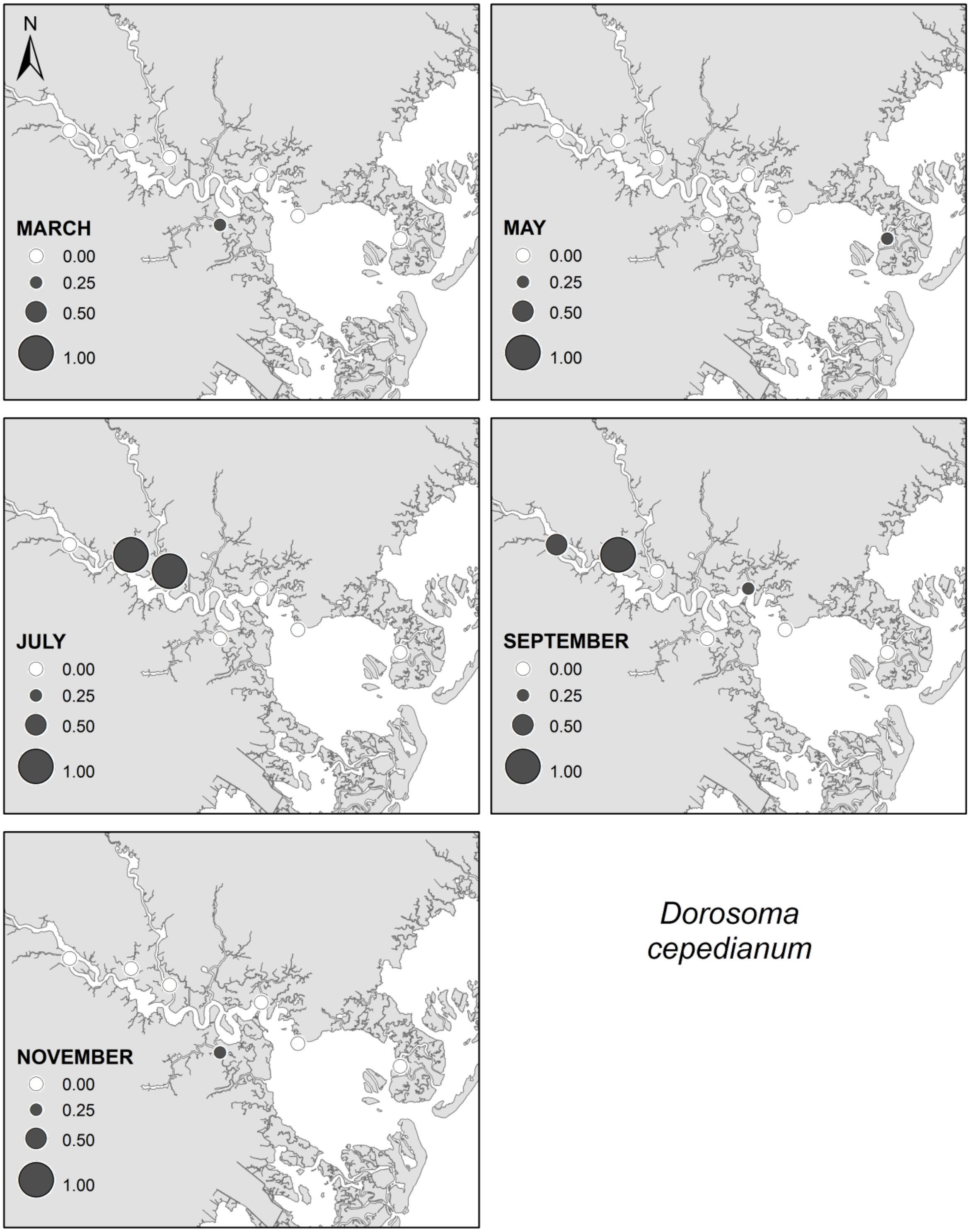


Figure 24. Seasonal distribution of *Dorosoma cepedianum* from estuarine inventory gill net stations during 2018. Symbols indicate average number caught per set.

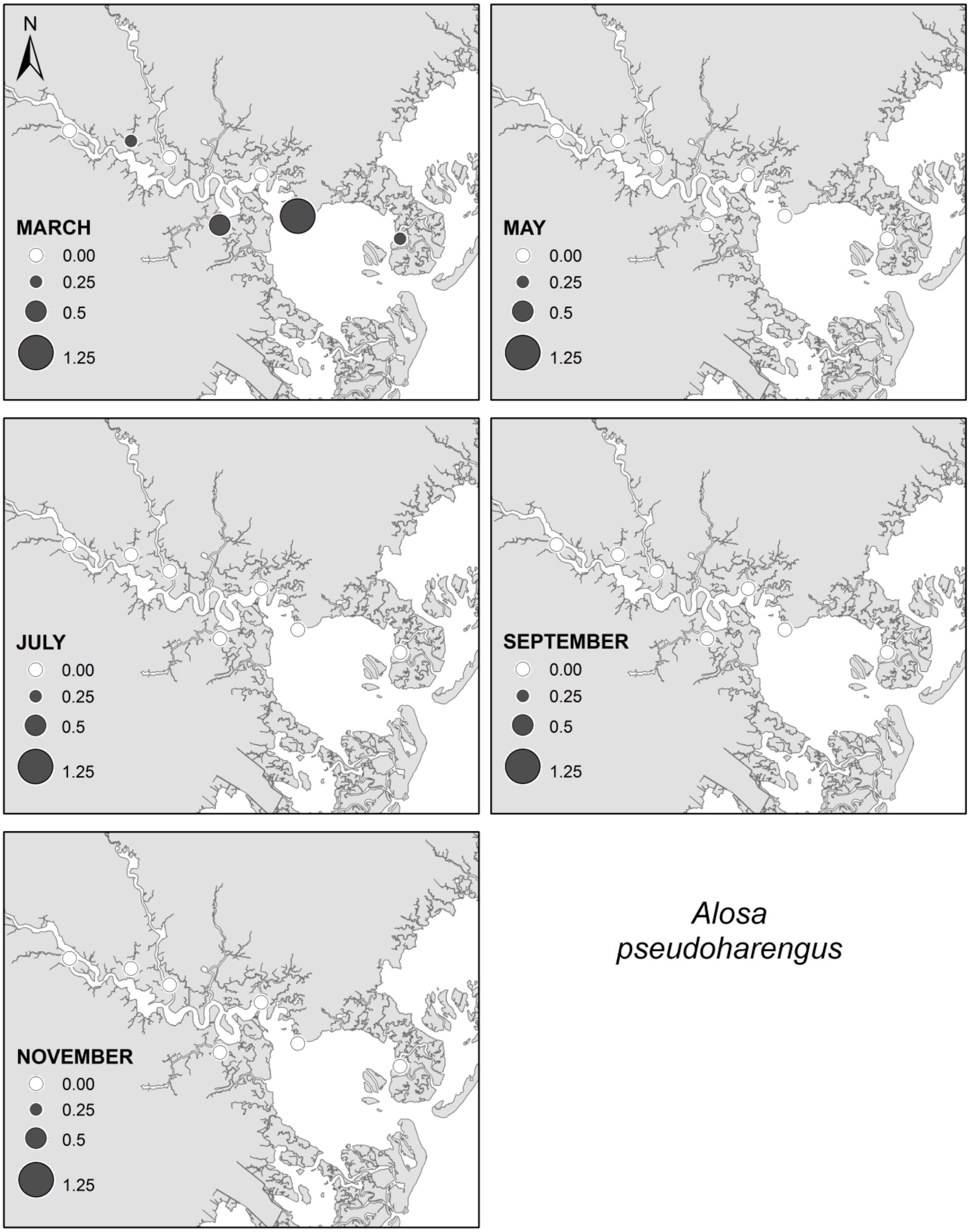


Figure 25. Seasonal distribution of *Alosa pseudoharengus* from estuarine inventory gill net stations during 2018. Symbols indicate average number caught per set.

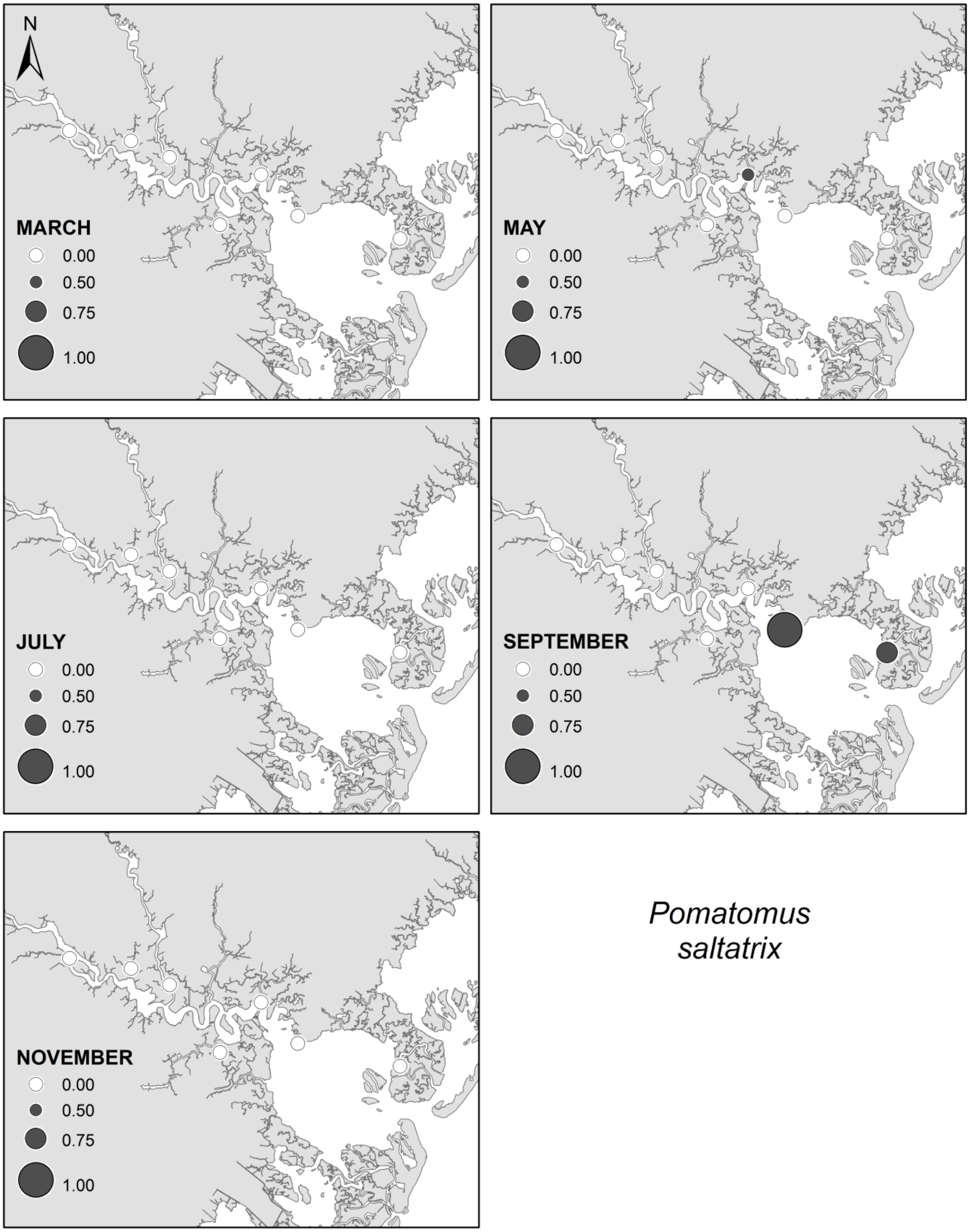


Figure 26. Seasonal distribution of *Pomatomus saltatrix* from estuarine inventory gill net stations during 2018. Symbols indicate average number caught per set.

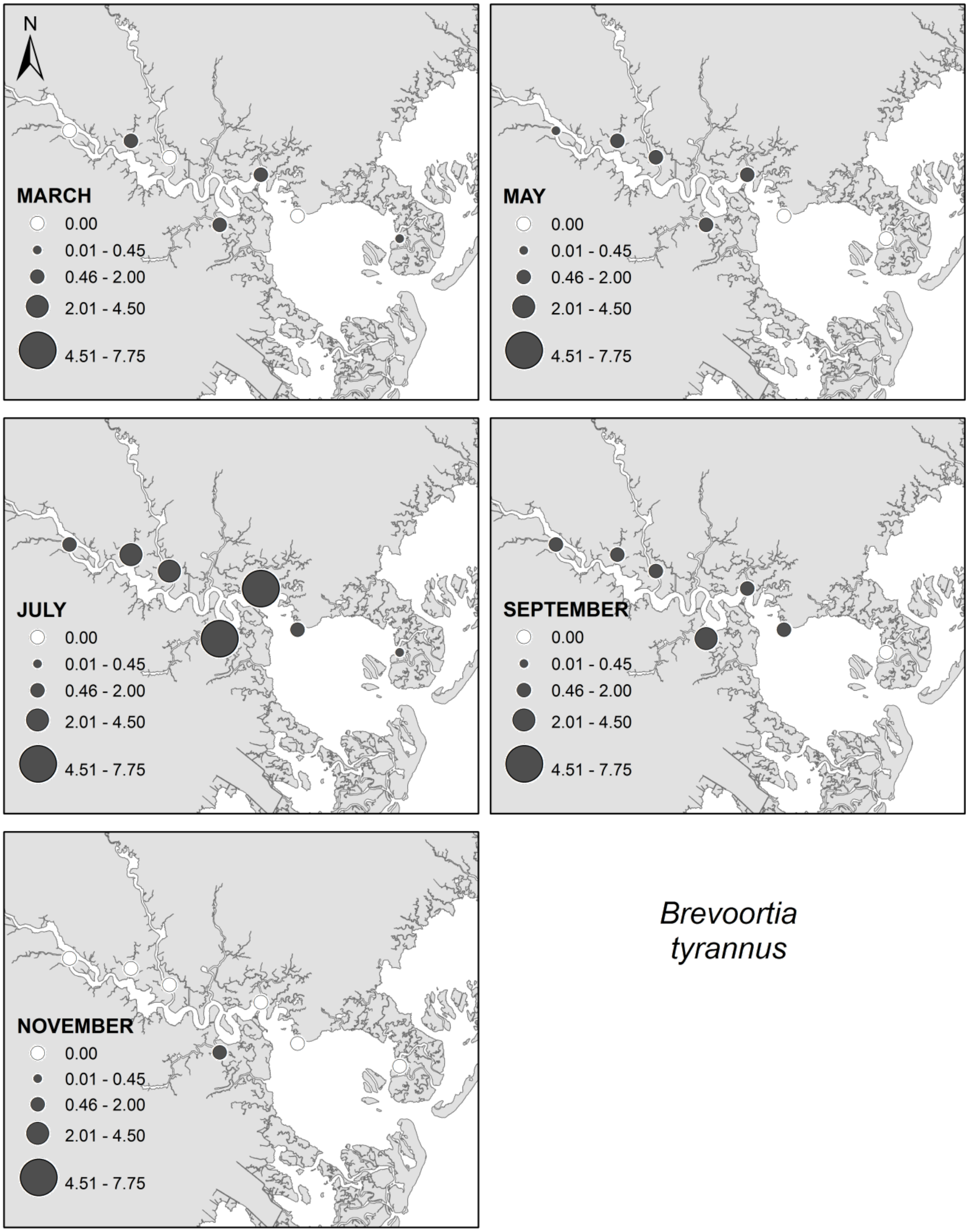


Figure 27. Seasonal distribution of *Brevoortia tyrannus* from estuarine inventory gill net stations during 2018. Symbols indicate average number caught per set.

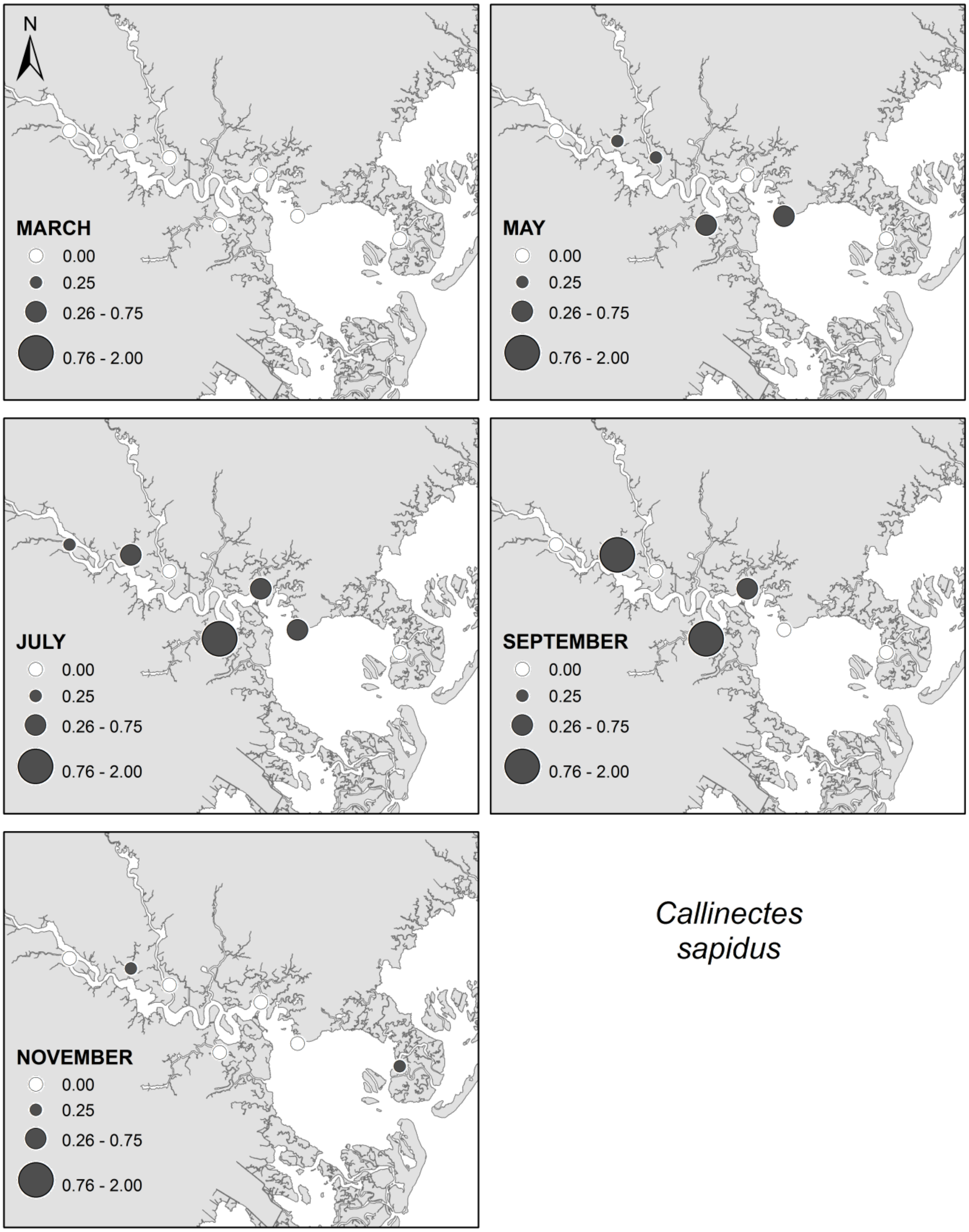


Figure 28. Seasonal distribution of *Callinectes sapidus* from estuarine inventory gill net stations during 2018. Symbols indicate average number caught per set.

Appendix 1:

Data Management Plan: Data management will be through TUCKFILE, a relational data-entry program written in MySQL. All biological and related environmental data will be entered simultaneously in the program and are separated into four files (environmental, unique sample attributes at a given location, fish abundance, fish length) that are linked through referential integrity. These four files are "nested" within each other. A recent technical report (Vasslides et al. 2011) provides a metadata manual for data management. Environmental data in the study area will be collected and managed in a standardized way through the NERR System Wide Monitoring Program (SWMP) under oversight of a Centralized Data Management Office (CDMO) and include a rigorous QA/QC protocol. Because of the standardization, data will be treated identically in initial upload and parsing and with identical treatment relative to issues of missing data treatment and filtering. Processed data will be stored as MATLAB files (*.mat) along with their metadata on the RUMFS server (Dellserver) which is backed up nightly off site, but these can be easily exported to ASCII text (*.txt, *csv) and XML files upon request.

Literature Cited

Vasslides, J. M., J. L. Rackovan, J. L. Toth, R. Hagan, and K. W. Able. 2011. Metadata manual for fish and environmental records at the Rutgers University Marine Field Station. IMCS Technical Report 2011-1.

Appendix 2:

Checklist of aquatic vertebrates and selected invertebrates of the Mullica River-Great Bay estuary, based on Able and Fahay (2010) and subsequent observations.

	Common Name	Scientific Name	Occurrence
Cartilaginous Fishes			
	Smooth dogfish	*Mustelus canis*	abundant
	Dusky shark	*Carcharhinus obscurus*	rare?
	Sandbar shark	*Carcharhinus plumbeus*	Rare?
	Tiger shark	*Galeocerdo cuvier*	rare
	Smooth hammerhead	*Sphyrna zygaena*	rare
	Spiny dogfish	*Squalus acanthias*	rare
	Smalltooth sawfish	*Pristis pectinata*	rare
	Clearnose skate	*Raja eglanteria*	abundant
	Little skate	*Leucoraja erinacea*	abundant
	Cownose ray	*Rhinoptera bonasus*	abundant
Ray-finned fishes			
	Ladyfish	*Elops saurus*	rare
	Bonefish	*Albula vulpes*	rare
	American eel	*Anguilla rostrata*	abundant
	Moray sp.	*Gymnothorax* sp.	rare
	Shrimp eel	*Opichthus gomesii*	rare
	Speckled worm eel	*Myrophus punctatus*	rare
	Conger eel	*Conger oceanicus*	common
	Bay anchovy	*Anchoa mitchilli*	abundant
	Silver anchovy	*Engraulis eurystole*	occasional
	Striped anchovy	*Anchoa hepsetus*	common
	Dusky anchovy	*Anchoa lyolepis*	rare
	Alewife	*Alosa pseutoharengus*	abundant
	Atlantic herring	*Clupea harengus*	common
	Atlantic menhaden	*Brevoortia tyrannus*	abundant
	Atlantic thread herring	*Opisthonema oglinum*	rare
	Blueback herring	*Alosa aestivalis*	abundant
	Gizzard shad	*Dorosoma cepedianum*	common
	Hickory shad	*Alosa mediocris*	common
	Spanish sardine	*Sardinella aurita*	occasional
	Common carp	*Cyprinus carpio*	rare
	Golden shiner	*Notemigonus crysoleucas*	abundant
	Goldfish	*Carassius auratus*	rare
	Ironcolor shiner	*Notropis chalybaeus*	status unknown
	Spottail shiner	*Notropis hudsonius*	rare

Common Name	Scientific Name	Occurrence
Ray-finned fishes (continued)		
Creek chubsucker	*Erimyzon oblongus*	abundant
White sucker	*Catostomus commersonii*	occasional
Brown bullhead	*Ameiurus nebulosus*	abundant
Tadpole madtom	*Noturus gyrinus*	common
White catfish	*Ameiurus catus*	common
Yellow bullhead	*Ameiurus natalis*	abundant
Chain pickerel	*Esox niger*	abundant
Redfin pickerel	*Esox americanus*	abundant
Eastern mudminnow	*Umbra pygmaea*	abundant
Brook trout	*Salvelinus fontinalis*	introduced-maintained by stocking
Brown trout	*Salmo trutta*	introduced-maintained by stocking
Rainbow trout	*Oncorhynchus mykiss*	introduced-maintained by stocking
Inshore lizardfish	*Synodus foetens*	occasional
Pirate perch	*Aphredoderus sayanus*	abundant
Crested cusk-eel	*Ophidion josephi*	rare
Striped cusk-eel	*Ophidion marginatum*	common
Fourbeard rockling	*Enchelyopus cimbrius*	occasional
Red hake	*Urophycis chuss*	common
Spotted hake	*Urophycis regia*	abundant
White hake	*Urophycis tenuis*	occasional
Silver hake	*Merluccius bilinearis*	occasional
Atlantic cod	*Gadus morhua*	rare
Pollock	*Pollachius virens*	juveniles common
Oyster toadfish	*Opsanus tau*	abundant
Striped mullet	*Mugil cephalus*	common
White mullet	*Mugil curema*	abundant
Atlantic silverside	*Menidia menidia*	abundant
Inland silverside	*Menidia beryllina*	abundant
Rough silverside	*Membras martinica*	occasional
Atlantic needlefish	*Strongylura marina*	common-summer
False silverstripe halfbeak	*Hyporhamphus meeki*	rare
Banded killifish	*Fundulus diaphanus*	abundant
Mummichog	*Fundulus heteroclitus*	abundant
Rainwater killifish	*Lucania parva*	common
Spotfin killifish	*Fundulus luciae*	common
Striped killifish	*Fundulus majalis*	abundant
Sheepshead minnow	*Cyprinodon variegatus*	abundant
Deepwater squirrelfish	*Sargocentron bullisi*	rare
Longjaw squirrelfish	*Neoniphon marianus*	rare

Common Name	Scientific Name	Occurrence
Ray-finned fishes (continued)		
Squirrelfish	*Holocentrus adscensionis*	rare
Blackspotted stickleback	*Gasterosteus wheatlandi*	rare
Fourspine stickleback	*Apeltes quadracus*	common
Ninespine stickleback	*Pungitius pungitius*	rare
Threespine stickleback	*Gasterosteus aculeatus*	common
Lined seahorse	*Hippocampus erectus*	common in summer and fall
Northern pipefish	*Syngnathus fuscus*	abundant
Northern searobin	*Prionotus carolinus*	abundant
Striped searobin	*Prionotus evolans*	abundant
Grubby	*Myoxocephalus aenaeus*	common
Inquiline snailfish	*Liparis inquilinus*	rare
Striped bass	*Morone saxatilis*	abundant
White perch	*Morone americana*	abundant
Black sea bass	*Centropristis striata*	abundant
Gag	*Mycteroperca microlepis*	rare
Banded sunfish	*Enneacanthus obesus*	abundant
Black crappie	*Pomoxis nigromaculatus*	rare
Blackbanded sunfish	*Enneacanthus chaetodon*	abundant
Bluegill	*Lepomis macrochirus*	abundant
Bluespotted sunfish	*Enneacanthus gloriosus*	abundant
Largemouth bass	*Micropterus salmoides*	abundant
Mud sunfish	*Acantharchus pomotis*	abundant
Pumpkinseed	*Lepomis gibbosus*	abundant
Redbreast sunfish	*Lepomis auritus*	rare
Rock bass	*Ambloplites rupestris*	status unknown
Smallmouth bass	*Micropterus dolomieu*	introduced-status unknown
Swamp darter	*Etheostoma fusiforme*	abundant
Tessellated darter	*Etheostoma olmstedi*	abundant
Yellow perch	*Perca flavescens*	occasional
Dusky cardinalfish	*Phaeoptyx pigmentaria*	rare
Bluefish	*Pomatomus saltatrix*	abundant
Cobia	*Rachycentron canadum*	rare
Atlantic moonfish	*Selene setapinnis*	occasional-summer
Banded rudderfish	*Seriola zonata*	occasional-summer
Bigeye scad	*Selar crumenophthalmus*	rare
Blue runner	*Caranx crysos*	occasional -summer and fall
Crevalle jack	*Caranx hippos*	common in summer and fall
Florida pompano	*Trachinotus carolinus*	occasional-summer
Lookdown	*Selene vomer*	occasional-summer

Common Name	Scientific Name	Occurrence
Ray-finned fishes (continued)		
Palometa	*Trachinotus goodei*	rare
Permit	*Trachinotus falcatus*	common-summer
Rough scad	*Trachurus lathami*	rare
Round scad	*Decapterus punctatus*	rare
Gray snapper	*Lutjanus griseus*	occasional
Mojarras	This group of fishes is possibly diverse in New Jersey waters (Able 1992) but the taxonomic difficulties are considerable (Matheson 2983) and require much more study. These fishes are rare to occasional.	
Pigfish	*Orthopristis chrysoptera*	rare
Pinfish	*Lagodon rhomboides*	rare
Scup	*Stenotomus chrysops*	common
Spottail pinfish	*Diplodus holbrooki*	rare
Atlantic threadfin	*Polydactylus octonemus*	rare
Atlantic croaker	*Micropogonias undulatus*	common
Banded drum	*Larimus fasciatus*	rare
Black drum	*Pogonias cromis*	rare
Northern kingfish	*Menticirrhus saxatilis*	common
Silver perch	*Bairdiella chrysoura*	common
Southern kingfish	*Menticirrhus americanus*	rare
Spot	*Leiostomus xanthurus*	common-abundant
Spotted seatrout	*Cynoscion nebulosus*	rare
Weakfish	*Cynoscion regalis*	abundant
Foureye butterflyfish	*Chaetodon capistratus*	rare
Spotfin butterflyfish	*Chaetodon ocelletus*	common
Sergeant major	*Abudefduf saxatilis*	rare
Cunner	*Tautogolabrus adspersus*	common
Tautog	*Tautoga onitis*	abundant
Daubed shanny	*Leptoclinus maculatus*	rare
Radiated shanny	*Ulvaria subbifurcata*	rare
Snakeblenny	*Lumpenus lumpretaeformis*	rare
Rock gunnel	*Pholis gunnellus*	occasional
American sand lance	*Ammodytes americanus*	abundant
Northern stargazer	*Astroscopus guttatus*	occasional
Crested blenny	*Hypleurochilus geminatus*	rare
Feather blenny	*Hypsoblennius hentz*	occasional
Striped blenny	*Chasmodes bosquianus*	occasional
Skilletfish	*Gobiesox strumosus*	occasional
Fat sleeper	*Dormitator maculatus*	occasional
Darter goby	*Ctenogobius boleosoma*	rare

Common Name	Scientific Name	Occurrence
Ray-finned fishes (continued)		
Green goby	*Microgobius thalassinus*	common
Highfin goby	*Gobionellus oceanicus*	rare
Naked goby	*Gobiosoma bosc*	abundant
Seaboard goby	*Gobiosoma ginsburgi*	occasional
Great barracuda	*Sphyreana barracuda*	rare
Northern sennet	*Sphyreana borealis*	common
Atlantic mackerel	*Scomber scombrus*	abundant
Spanish mackerel	*Scomberomorus maculatus*	occasional
Butterfish	*Peprilus triacanthus*	abundant
Harvestfish	*Peprilus paru*	rare
Twospot flounder	*Bothus robinsi*	rare
Windowpane	*Scopthalmus aquosus*	abundant
Bay whiff	*Citharichthys spilopterus*	rare
Fourspot flounder	*Paralichthys oblongus*	common
Fringed flounder	*Etropus crossotus*	rare
Smallmouth flounder	*Etropus microstomus*	common
Summer flounder	*Paralichthys dentatus*	abundant
Yellowtail flounder	*Limanda ferruginea*	common
Winter flounder	*Pseudopleuronectes americanus*	abundant
Witch flounder	*Glyptocephalus cynoglossus*	rare
Hogchoker	*Trinectes maculatus*	common
Blackcheek tonguefish	*Symphurus plagiusa*	rare
Gray triggerfish	*Balistes capriscus*	rare
Orange filefish	*Aluterus schoepfii*	rare
Planehead filefish	*Stephanolepis hispidus*	rare
Scrawled filefish	*Aluterus scriptus*	rare
Scrawled cowfish	*Lactophrys quadricornis*	rare
Northern puffer	*Sphoeroides maculatus*	common-summer
Striped burrfish	*Chilomycterus schoepfi*	occasional

Appendix 3:

Spatial Variation in Alewife Spawning in the Mullica Valley

Able, K.W.[1], Pat Filardi[2]

[1]Rutgers University Marine Field Station
800 c/o 132 Great Bay Boulevard
Tuckerton, New Jersey 08087-2004

[2]Jacques Cousteau National Estuarine Research Reserve

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Introduction

The decline in anadromous river herrings (*Alosa* spp.) along the east coast of the US (Limburg and Waldman 2009, Palkovacs et al. 2013, Ogburn et al. 2017) and our inability to help them recover points out the lack of understanding we have for the natural history of these important species (Able 2016). River herring are not only an important forage food source for other fish, birds, mammals, and herptiles (Loesch 1987, Wilson and Halupka 1995), but can also act as a nutrient source for freshwater systems and stimulate microbial activity that can increase overall food production of a lake as well as reducing the sedimentation rate of a lake (Durbin et al. 1979, West et al. 2010, Hall et al. 2012). What we do know has been summarized for the Middle Atlantic (Klauda et al. 1991, Mullen et al. 1986, Davis and Schultz 2009, Able and Fahay 2010, Hasselman and Limburg 2012) but much remains to be learned (Able 2016, Able and Grothues 2017, Able et al. 2017). To date, several factors are suspected of contributing to the decline of river herrings including habitat loss, offshore bycatch in pelagic fisheries (Bethoney et al. 2014, Hasselman et al. 2016), overfishing (Turner et al. 2015), and perhaps, all of these factors combined (Limburg and Waldman 2009). In addition, climate change induced temperature increases may induce earlier spawning migrations (Ellis and Vokoun 2009). Of certain importance to their decline is the history of dam creation since European settlement, as this has precluded spawning in many miles of upstream areas (Freeman et al. 2003, Walter and Merritts 2008, Mattocks et al. 2017). Besides these effects, dams may create "ecological hotspots" that force and enhance interactions between migratory fishes such as the anadromous alewife and the catadromous American eel (Able et al. 2017).

Despite the ease of human access to spawning sites in freshwater streams, we still lack a thorough understanding of many aspects of river herring reproduction and early life history. In New Jersey, prior surveys have attempted to determine utilization in the Mullica Valley (Hastings 1984) and spawning sites throughout the state (Zich 1978, NJDEP 2005). Other aspects of their reproduction in New Jersey are poorly known. In a 2016 effort, we defined some of the reproductive characteristics of the spawning population in the Batsto River (Able et al. 2016). During the spring of 2017, we elaborated on the natural history of river herrings in the Mullica Valley watershed by defining the reproductive seasonality and nursery areas in this relatively unaltered estuary (Able et al. 2017).

The purpose of this report is to 1) evaluate spatial variation in alewife spawning based on frequent observations during spring 2018 in the Mullica Valley, and 2) continued evaluation of the status of alewife based on occurrence of spawning relative to studies in the 1970's (Zich 1978). These foci are especially important because the Mullica Valley is a relatively undisturbed area that provides a useful baseline for this species.

Materials and Methods

Study Site

The Great Bay – Mullica River estuary is a relatively shallow (<2 m), salt marsh-fringed, drowned river valley system (Fig. 1). Watershed protection by the Pinelands National Reserve and state and federal management areas makes it one of the least impacted systems in the northeastern United States (Good and Good 1984; Kennish et al. 2004). Water temperature regimes follow temperate seasonal patterns (<0 °C in winter to >30 °C in summer) and salinity corresponds to an upriver gradient from polyhaline regions near Little Egg Inlet (salinity 32) to the freshwater-saltwater interface near Lower Bank, and into tidal freshwater habitats further upstream (Fig. 1). Atypical of other northeastern U.S. estuaries, the Mullica River-Great Bay rarely approaches hypoxic dissolved oxygen levels (<4 mg/L) (System Wide Monitoring Program, unpublished data). The upper regions of the estuary are relatively unaltered with low human population density (Kennish et al. 2004) and are acidic (pH 4–6) due to tannins leached from the surrounding natural pine/oak-dominated watershed.

The Batsto River, a tributary to the Mullica River, is approximately 16 miles long and drains approximately 67 square miles of southern Burlington County (USACE 2003). A dam at Batsto Village divides the study area into Batsto Lake and the continuation of the river below the dam. Semidiurnal tides can reach the base of the dam. The distance from the dam to Rt. 542 is approximately 152 m, while the distance from Rt. 542 to its confluence with the Mullica River is a little over 1600 m. The current concrete dam was built in 1958 but some kind of dam has been present at the site since 1776 (Budd Wilson, pers. comm., Pearce 2000).

Nescochogue Creek is another tributary that enters the Mullica River a few miles above where the Batsto River enters the same river. It drains a relatively undeveloped portion of the Great Swamp. A portion of the creek has been diverted and drains into Lake Nescochogue. The observation points are behind the church in Pleasant Mills at the former bridge and in the adjacent flood plain.

Temporal Occurrence of Adult Alewives

The earliest observations in the Mullica Valley watershed locations were based on those by Zich (1978) during the early 1970's (Fig. 1). The selection of other sites for our 2018 studies were based on our prior experience and accounts of others. In order to determine the timing and duration of spawning, we made frequent visual observations in the shallow, clear waters at the study sites during spring 2018 (Fig. 2). The detection of reproducing river herring was augmented by audible and visual observations of splashing while spawning in the shallows. We were also alerted to the presence of adult river herring by personnel at Batsto Village on several occasions. Both of these other sources were used in our prior studies (Able et al. 2016, 2017; Able and Grothues 2017).

Visual Survey of Spawning

The duration of the survey period occurred during the same general period of prior efforts in the spring of 2016 and 2017 (Able et al. 2016, 2017; Able and Grothues 2017). Each survey consisted of visiting a site to visually identify if river herring were present and roughly estimate their numbers. Their presence was also evident by frequent splashing during spawning events on the edge of a stream or among tree limbs or roots that had fallen into the stream. On occasion, these were also verified by a second observer.

These surveys in the freshwaters of the Mullica Valley included sites in the Bass River (3), Wading/Oswego (1), Wading (7), and Mullica (10). At most sites, water temperature was measured with a stem thermometer. In addition to these, the upper Mullica River from the Atsion Lake dam to three miles below the dam (Fig. 2) was sampled by visual observations from a kayak for approximately 50-75 hours over the alewife spawning season.

Results and Discussion

During the period between mid-March and mid-May 2017 we made 196 individual observations at 22 locations in the Mullica Valley to determine the presence of spawning river herring (Fig. 2,3). Priority sites were visited between 17 and 24 times while other sites ranged from 2 – 14 times. In addition, the Mullica River below the Lake Atsion dam was examined by kayak for the presence of spawning river herring during the same period (Fig. 3). We assumed that all river herring observed were alewife based on 1) visual observations of deep bodied *Alosa* spp. with large eyes relative to snout length and 2) prior extensive collecting efforts in 2016 and 2017 at the Batsto Dam that only found this species (Able et al. 2016, 2017).

Location of Spawning

Despite extensive observations at numerous locations we only identified alewife at freshwater streams at the Batsto Village Dam in the Batsto River and Nescochogue Creek in the Mullica River drainages (Fig. 2, 3). These same sites were identified during the 1970s as spawning sites (Fig. 1, Zich 1978). Other sites identified by Zich (1978) during that study did not appear to support spawning in 2018 including Mullica River at Constable Bridge, Nacote Creek at Mill Pond, and Wading River above Rt. 542 (Fig. 1, 2). Thus, the number of spawning sites has been reduced since the 1970s based on these surveys.

Timing of Spawning

Spawning during spring 2018 was infrequent but concentrated. At the Batsto Dam we estimated hundreds of alewife were present on April 23 and 25. At Nescochogue Creek the number present varied from low (2 individuals on April 5 and 12 individuals on March 31) to higher abundances (100s on April 1, 23, 25 and 26 to 100s to 1000 on April 2). In the three instances in which we observed spawning we observed them in discrete waves lasting approximately 4 -6 days at Nescochogue Creek and 3 days at Batsto Dam (Fig. 3).

Overall, spawning occurred during a period of rising water temperatures at both of these sites (Fig. 4). The spawning at Nescochogue Creek occurred at the same time as elevated temperatures here in late March – early April. We cannot account for the occurrence of higher temperatures in early April at Nescochogue Creek. The spawning at both sites at the same dates in late April occurred at similar temperatures.

The general patterns of alewife life history in the Mullica Valley mirror those of other alewife spawning and nursery areas in the northeastern U.S. (Thunberg 1971). Spawning in the spring, for these anadromous fishes is common although the occurrence in waves, as we observed in 2016 (Able et al. 2016) and 2018 (this study), is less frequently reported. The occurrence of these waves on the spawning grounds has been reported elsewhere in Rhode Island, when the presence of these spawning fish lasted 1-5 days (Cooper 1961). Elsewhere, the temporal occurrence has been reported for longer time periods, but this was calculated as time spent in a lake where spawning occurred (Kissil 1974) or over entire spawning seasons (Ogburn et al. 2017).

Spawning in discrete but temporally isolated waves may allow herring to retreat to deeper waters between reproductive events. This may be advantageous in that it could prevent predation by eagles and ospreys and other predators in shallow water between spawning events. Perhaps spawning in waves is consistent with asynchronous oocyte development in alewife (Ganias et al. 2015) and the closely related blueback herring (McBride et al. 2010). This interpretation has been reevaluated for river herring in Massachusetts streams (Rosset et al. 2017).

Pattern Relative to Decline in Population

A comparison of alewife spawning areas in the Mullica Valley in the 1970's relative to 2018 suggests continued decline in spawning. Several of the sites indicating earlier spawning (Constable Bridge, in the Mullica, Bass River State Forest, Mill Pond dam in the Nacote Creek, above Rt. 542 in the Wading River based on Zich (1978) (Fig. 1)) did not have any evidence of spawning in 2018. Unfortunately some sites in Zich (1978) were misidentified as being in the Mullica Valley (Lucas Branch, Merrygold Lake). These are actually part of the Great Egg Harbor River watershed. Other sites investigated in the 1970's (Ballanger Creek above Polly Ditch, Jobs Creek (Fig. 1)) were not evaluated in 2018.

The status of alewives in the Mullica Valley may reflect the condition of populations in the northeastern US, which are declining (Limburg and Waldman 2009, Palkovacs et al. 2013), perhaps because of environmental effects (Tommasi et al. 2015, Lynch et al. 2015). Others have suggested offshore bycatch in pelagic fisheries (Hasselman et al. 2016) and perhaps climate change, as it affects timing of spawning runs (Ellis and Vokoun 2009, Hall et al. 2011), and overfishing (Hall et al. 2012, Turner et al. 2015), as causes for the decline. Most would agree that habitat loss contributes significantly to their decline, especially through dam creation since European settlement because it eliminates the possibility of spawning many miles upstream of a dam (Freeman et al. 2003, Walter and Merritts 2008, Hall et al. 2012, Mattocks et al. 2017, Januchowski-Hartley et al. 2013). This certainly occurs at the dam in Batsto Village and other locations in adjacent Barnegat Bay (Able et al. 2017). This has occurred at the Batsto dam despite the fact that a fish ladder for river herring runs has been installed there. Our personal observations indicate that while hundreds of alewife congregate in the river below the dam, they have not been observed in the fish ladder during the same period.

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References

Able, K.W. 2016. Natural history: An approach whose time has come, passed, and needs to be resurrected. ICES Journal of Marine Science, doi: 10.1093/icesjms/fsw049.

Able, K.W., C. Denisevich, R.K. Hagan, M.J. Shaw, and S.M. VanMorter. 2016. Reproductive Characteristics of Alewife in the Batsto River, New Jersey: Aspects of Timing, Size, Sex and Behavior. Rutgers University Marine Field Station Report.

Able, K.W. and M.P. Fahay. 2010. Ecology of Estuarine Fishes: Temperate Waters of the Western North Atlantic. Johns Hopkins University Press, Baltimore, MD. 566 p.

Able, K.W. and T.M. Grothues. 2017. Comprehensive Estuarine Fish Inventory Program: Great Bay – Mullica River Year Two. Report to the NJ Department of Environment Protection.

Able, K.W., M.J. Shaw, S.M. VanMorter, M.C. Sullivan, and T.M. Grothues. 2017. Interactions between Alewife and American eel in the Mullica Valley. Appendix to NJDEP Inventory Annual Report.

Able, K.W., J.L. Valenti, and T.M. Grothues. 2017. Fish larval supply to and within a lagoonal estuary: Multiple sources for Barnegat Bay, New Jersey. Environmental Biology of Fishes doi: 10.1007/s10641-017-0595-0.

Anonymous. 2003. Environmental Assessment: Batsto River fishway restoration project section 206, ecosystem restoration Burlington County, New Jersey. Philadelphia District, U.S. Army Corps of Engineers and New Jersey Field Office, U.S. Fish and Wildlife Service. 36 p.

Bethoney, N. D., K.D.E. Stokesbury, B.P. Schondelmeier, W.S. Hoffman, and M.P. Armstrong. 2014. Characterization of river herring bycatch in the Northwest Atlantic midwater trawl fisheries. North American Journal of Fisheries Management 34:828-838.

Cooper, R.A. 1961. Early life history and spawning migration of the alewife, Alosa pseudoharengus. M.S. Thesis, Univ. of Rhode Island, Kingston, Rhode Island. 58 p.

Davis, J.P. and E.T. Schultz. 2009. Temporal shifts in demography and life history of an anadromous alewife population in Connecticut. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 1:90-106.

Durbin, A.G., S.W. Nixon, and C.A. Oviatt. 1979. Effects of the spawning migration of the alewife, *Alosa pseudoharengus*, on freshwater ecosystems. Ecology 60:8-17.

Ellis, D. and J.C. Vokoun. 2009. Earlier spring warming of coastal streams and implications for alewife migration timing. North American Journal of Fisheries Management 29:1584-1589.

Freeman, M.C., C.M. Pringel, E.A. Greathouse, and B.J. Freeman. 2003. Ecosystem-level consequences of migratory faunal depletion caused by dams. American Fisheries Society Symposium. 35:255-266.

Ganias, K., J.N. Divino, K.E. Gherard, J.O. Davis, F. Mouchlianitis, and T. Schultz. 2015. A reappraisal of reproduction in anadromous alewives: Determinate versus indeterminate fecundity, batch size, and batch number. Transactions of the American Fisheries Society. 144: 1143-1158.

Good, R.E. and N.F. Good. 1984. The Pinelands National Reserve: An ecosystem approach to management. BioScience 34(3):169-173.

Hall, C.J., A. Jordaan, and M.G. Frisk. 2011. The historic influence of dams on anadromous fish habitat with a focus on river herring and hydrologic longitudinal connectivity. Landscape Ecology 26:95-107.

Hall, C. J., A. Jordann, and M.G. Frisk. 2012. Centuries of anadromous forage fish loss: Consequences for ecosystem connectivity and productivity. BioScience 62(8):723-731.

Hasselman, D.J., E.C. Anderson, E.E. Argo, N.D. Bethoney, S.R. Gephard, D.M. Post, B.P. Schondelmeier, T.F. Schultz, T.V. Willis, and E.P. Palkovacs. 2016. Genetic stock composition of marine bycatch reveals disproportional impacts on depleted river herring genetic stocks. Can. J. Fish. Aquat. Sci. 73:951-963.

Hasselman, D.J. and K.E. Limburg. 2012. Alosine restoration in the 21st Century: Challenging the Status Quo. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 4:174-187.

Hastings, R.W. 1984. The fishes of the Mullica River, a naturally acid water system of the New Jersey Pine Barrens. Bull. N.J. Acad. Sci. 29(1):9-23.

Januchowski-Hartley, S.R., P.B. McIntyre, M. Diebel, P.J. Doran, D.M. Infante, C. Joseph, and J.D. Allan. 2013. Restoring aquatic ecosystem connectivity requires expanding inventories of both dams and road crossings. Front. Ecol. Environ. 11(4):211-217.

Kennish, M.J., S.M. Haag, G.P. Sakowicz, and J.B. Durand. 2004. Benthic macrofaunal community structure along a well-defined salinity gradient in the Mullica River-Great Bay estuary. Journal of Coastal Research. 45:209-226.

Kissil, G.W. 1974. Spawning of the anadromous alewife, *Alosa pseudoharengus*, in Bride Lake, Connecticut. Trans. Amer. Fish. Soc. 2:312-317.

Klauda, R.J., S.A. Fischer, L.W. Hall Jr., and J.A. Sullivan. 1991. Alewife and blueback herring, *Alosa pseudoharengus* and *Alosa aestivalis*. Pp 10.1-10.29. *In:* Habitat Requirements for Chesapeake Bay Living Resources. Chesapeake Research Consortium, Inc. Solomons, Maryland.

Limburg, K.E. and J.R. Waldman. 2009. Dramatic declines in North Atlantic diadromous fishes. BioScience. 59(11):955-965.

Loesch, J.G. 1987. Overview of life history aspects of anadromous alewife and blueback herring in freshwater habitats. American Fisheries Society Symposium. 1: 89–103.

Lynch, P.D., J.A. Nye, J.A. Hare, C.A. Stock, M.A. Alexander, J.D. Scott, K.L. Curti, and K. Drew. 2015. Projected ocean warming creates a conservation challenge for river herring populations. ICES Journal of Marine Science 72(2):374-387.

Mattocks, S., C.J. Hall, and A. Jordaan. 2017. Damming, lost connectivity, and the historical role of anadromous fish in freshwater ecosystem dynamics. BioScience 67:713-728.

McBride, R.S., J.E. Harris, A.R. Hyle, and J.C. Holder. 2010. The spawning run of blueback herring in the St. Johns River, Florida. Transactions of the American Fisheries Society. 139: 598-609.

Mullen, D.M., C.W. Fay, and J.R. Moring. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (North Atlantic)-alewife/blueback herring. U.S. Fish Wildl. Serv. Biol. Rep. 82(11.56). U.S. Army Corps of Engineers, TR EL-82-4. 21 pp.

NJDEP (New Jersey Department of Environmental Protection). 2005. Locations of anadromous American shad and river herring during their spawning period in New Jersey's freshwaters including known migratory impediments and fish ladders. NJ DEP, Division of Fish and Wildlife, Bureau of Freshwater Fisheries.

Ogburn, M.B., J. Spires, R. Aguilar, M.R. Goodison, K. Heggie, E. Kinnebrew, W. McBurney, K.D. Richie, P.M. Roberts, and A.H. Hines. 2017. Assessment of river herring spawning runs in a Chesapeake Bay coastal plain stream using imaging sonar. Transactions of the American Fisheries Society 146:22-35.

Palkovacs, E.P., D.J. Hasselman, E.E. Argo, S.R. Gephard, K.E. Limburg, D.M. Post, T.F. Schultz, and T.V. Willis. 2013. Combining genetic and demographic information to prioritize conservation efforts for anadromous alewife and blueback herring. Doi:10.1111/eca.12111

Pearce, J.E. 2000. Heart of the Pines: Ghostly Voices of the Pine Barrens. Batsto Citizens Committee, Inc. Hammonton, New Jersey. 903 p.

Rosette, J., A.H. Roy, B.I. Gahagan, A.R. Whiteley, M.P. Armstrong, J.J. Sheppard, and A. Jordaan. 2017. Temporal patterns of migration and spawning of river herring in coastal Massachusetts. Transactions of the American Fisheries Society 146:1101-1114.

Thunberg, B.E. 1971. Olfaction in parent stream selection by the alewife (*Alosa pseudoharengus*). Animal Behavior 19:217-225.

Tommasi, D., J. Nye, C. Stock, J.A. Hare, M. Alexander, and K. Drew. 2015. Effects of environmental conditions on juvenile recruitment of alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*) in fresh water: a coastwide perspective. Can. J. Fish. Aquat. Sci 72:1037-1047.

Turner, S. M., J. P. Manderson, D. E. Richardson, J. J. Hoey and J. A. Hare. 2015. Using habitat association models to predict Alewife and Blueback herring marine distributions and overlap with Atlantic herring and Atlantic mackerel: can incidental catches be reduced? ICES Journal of Marine Science 73(7):1912-1924.

USACE (US Army Corps of Engineers). 2003. Environmental Assessment: Batsto River Fishway Assessment Project. Philadelphia District, US Army Corps of Engineers and New Jersey Field Office, US Fish and Wildlife Service.

Walter, R. C. and D. J. Merritts. 2008. Natural streams and the legacy of water-powered mills. Science. 319:299-304.

West, D.C., A.W. Walters, S. Gephard, and D.M. Post. 2010. Nutrient loading by anadromous alewife (*Alosa pseudoharengus*): Contemporary patterns and predictions for restoration efforts. Can. J. Fish. Aquat. Sci. 67:1211- 1220.

Wilson, M.F. and K.C. Halupka. 1995. Anadromous fish as keystone species in vertebrate communities. Conservation Biology 9(3):489-497.

Zich, H.E. 1978. Information on anadromous clupeid spawning in New Jersey. NJ DEP, Division of Fish and Wildlife. Misc. Rept. No. 41, 28 p.

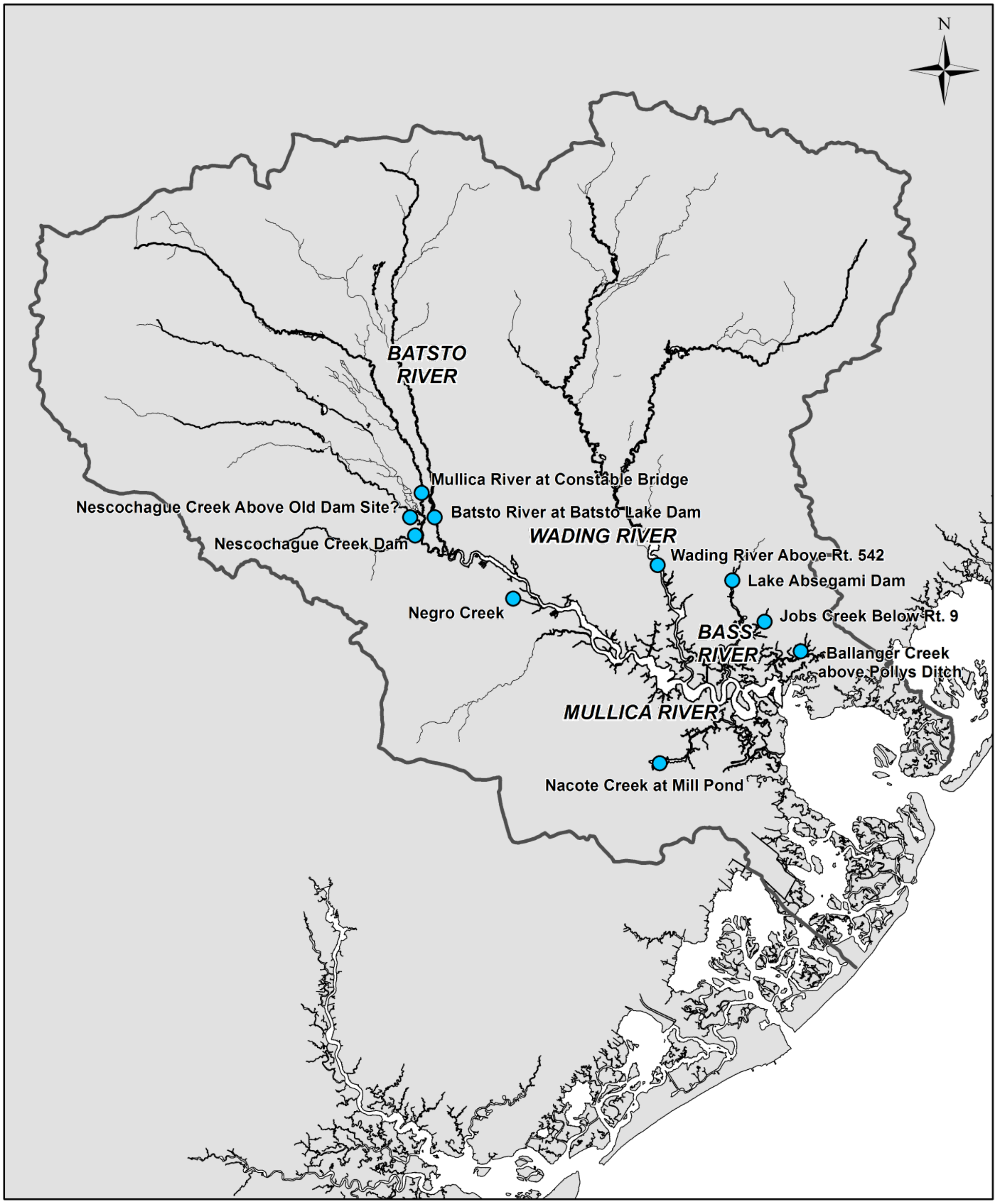

Figure 1. Locations of river herring monitoring sites for spawning activity in the Mullica Valley based on Zich (1977).

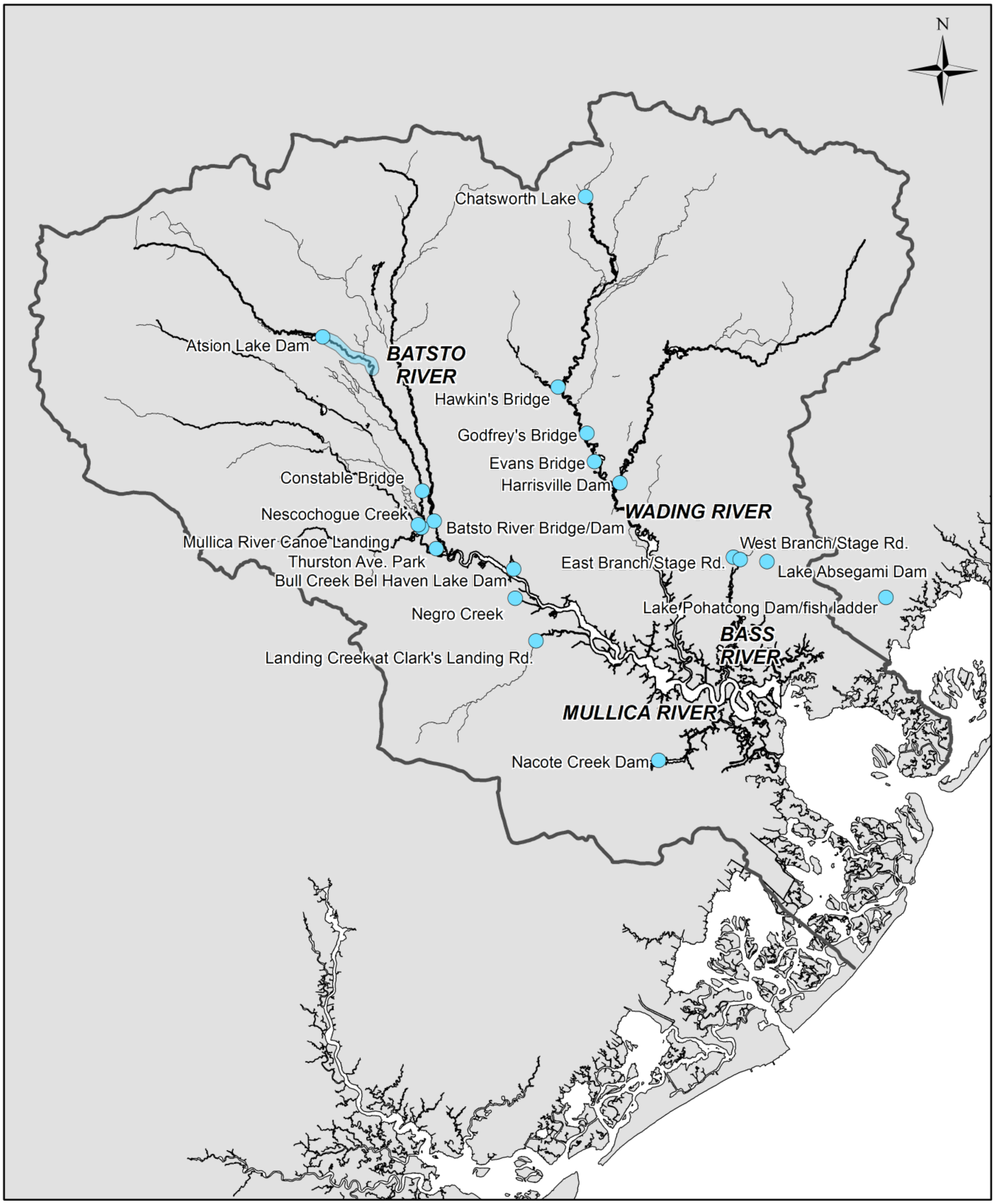

Figure 2. Locations of river herring monitoring sites for spawning activity in the Mullica Valley during spring 2018.

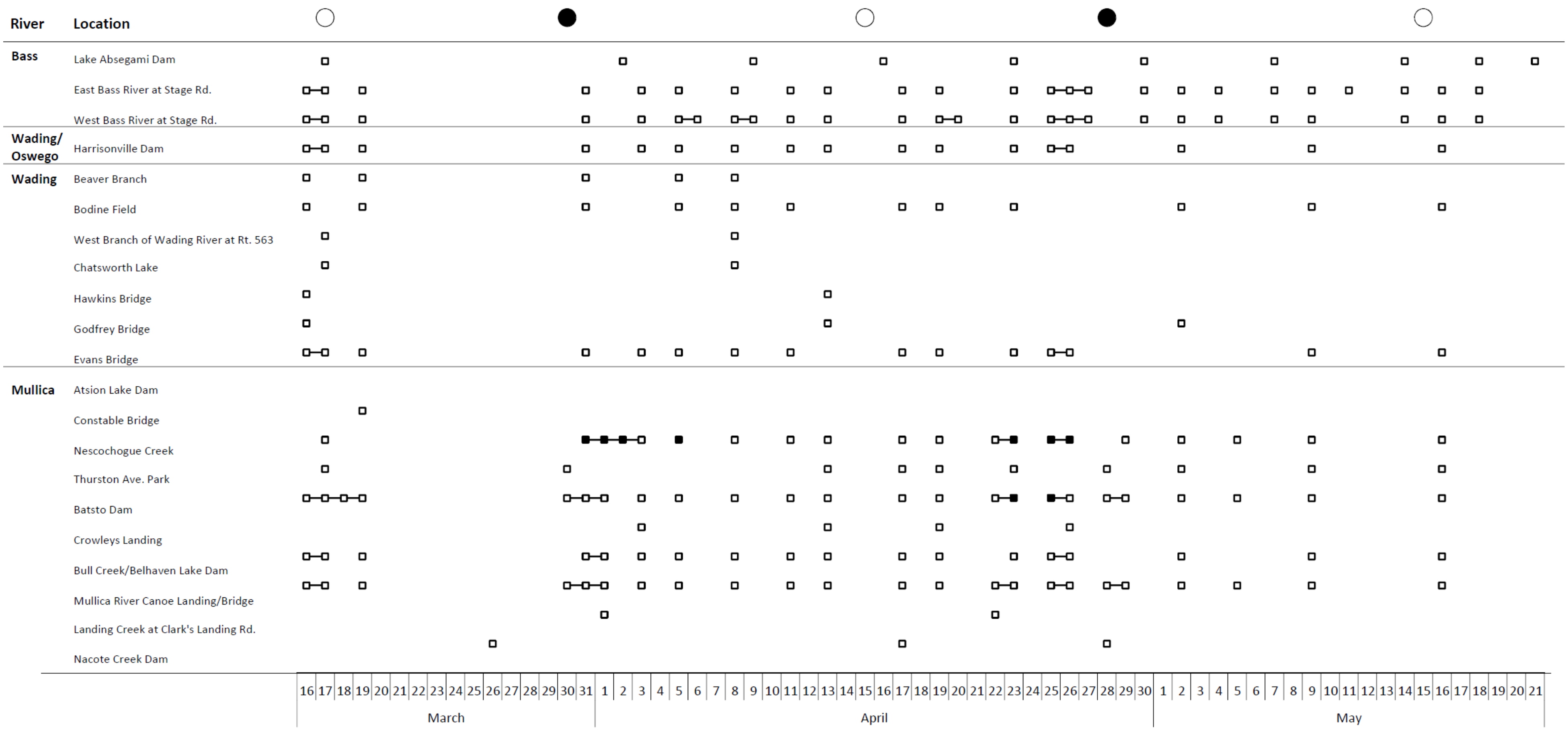

Figure 3. Timeline for occurrence (presence/absence) of river herring in the Mullica Valley by date and site during spring 2018. Presence (■) and absence (□) of spawning river herring at sampling sites within the Bass, Wading, and Mullica rivers, New Jersey. No symbol for a date/location indicates that no observations were made. Circles above the chart indicate new (○) and full (●) moon phases.

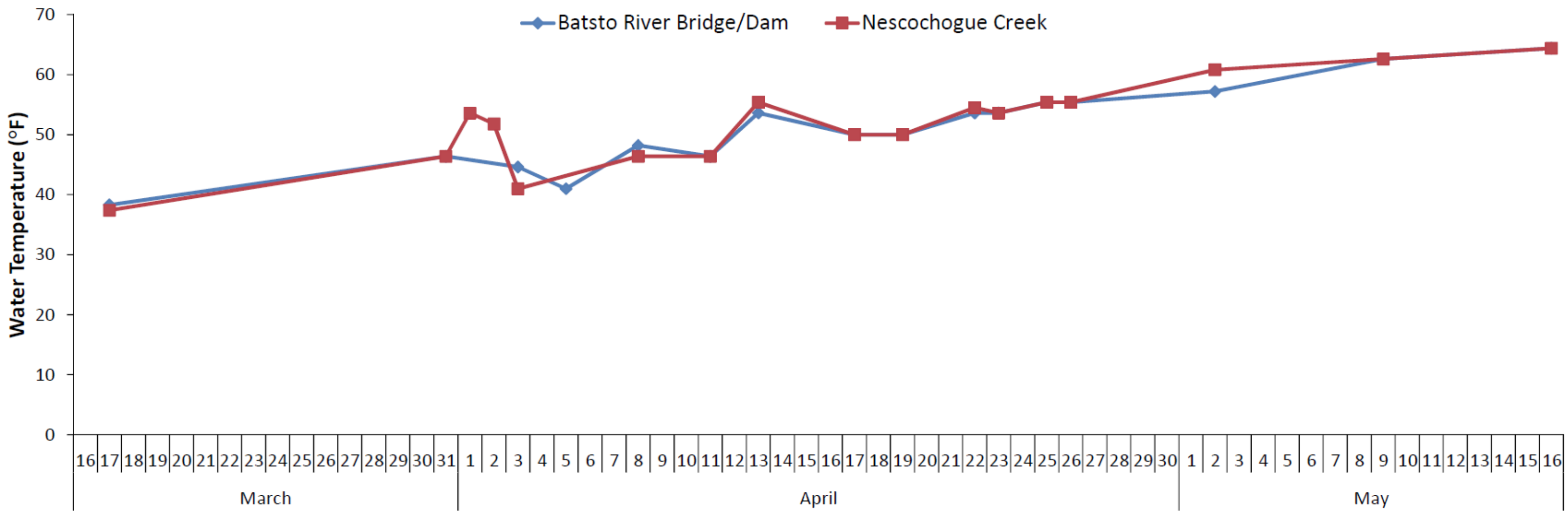

Figure 4. Water temperature of two regularly sampled sites, Batsto River Bridge/Dam and Nescochogue Creek, over the sampling period in spring 2018.

Appendix 4: Beneath the surface: Underwater Natural History in the Mullica Valley

Kenneth W. Able

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Synopsis/Overview

This view of the Mullica Valley estuary will expose the reader to an invisible part of the planet, the underwater estuary that few people see or understand. The various chapters will allow the reader to penetrate the surface and gain insights into the kinds of habitats (e.g. salt marshes, creeks, oyster beds, peat reefs, sand bars) and the animals and plants that live there. For the first time, they will get a better understanding of the importance of these shallow waters, how the amount of salt in the water determines where animals and plants are found in estuaries, the day-night, seasonal, and annual variation in their occurrence, and how change is occurring as the result of a changing climate. A unifying theme will be the kinds and importance of the animals and plants that live beneath the surface of this unique estuary. Scattered throughout the various chapters will be insightful sidebars that tell intimate stories of where the fishes, crabs, mammals, etc. came from and where they are going as they travel through the estuary on their way to and from other portions of the east coast of the U.S. These seasonal occurrences will be captured in an underwater natural events calendar.

This estuary, as for others, is a location where freshwaters from the land meet and mix with the salty waters from the ocean. This drowned river valley is unusual and unique for several reasons. This estuary and its watershed is a moderately large system, about 365,000 acres, and of this, approximately 115,000 acres are protected as part of the above holdings. This combination of protected watershed, low human population density, and general lack of extensive development makes this the cleanest estuary in New Jersey and one of the cleanest estuaries along the east coast of the U.S. Further, this watershed is likely to remain that way into the future because of numerous federal and state holdings that provide protection from development.