Inshore Fish and Blue Crab Survey of Rehoboth Bay, Indian River Bay, and Little Assawoman Bay

For 2016
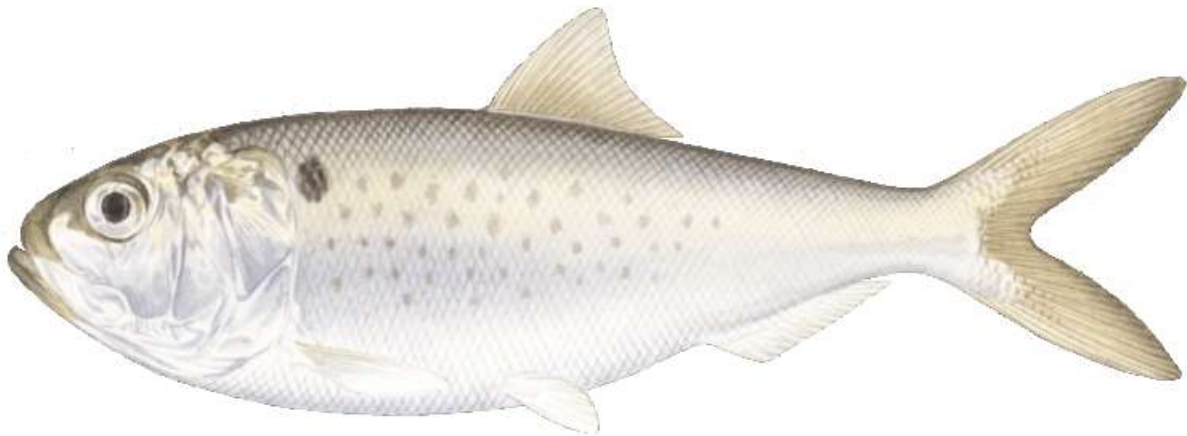
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Cover Illustration: "Atlantic Menhaden – *Brevoortia tyrannus,* by Val Kells ©. Val Kells, Marine Science Illustration, www.valkellsillustration.com

The Delaware Center for the Inland Bays is a non-profit organization and a National Estuary Program. It was created to promote the wise use and enhancement of the Inland Bays watershed by conducting public outreach and education, developing and implementing restoration projects, encouraging scientific inquiry and sponsoring needed research, and establishing a long-term process for the protection and preservation of the Inland Bays watershed.

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EXECUTIVE SUMMARY

The inshore waters of the Delaware Inland Bays are important nursery areas for many species of fish. Monitoring these areas annually provides data on current fish abundances and trends over time, along with species specific information on distribution within the Inland Bays and the associated physical factors responsible for this distribution. The information derived from this study can be used to assess the status and trends of inshore fish species in the Inland Bays, and predict future changes in fish abundance due to changes from shoreline modification, water quality, and climate change.

Fixed sites along the shoreline of the Inland Bays were sampled in 2016 from the last two weeks of April through October using similar methodologies to previous reports (McGowan et al. 2016). Sampling effort consisted of a single 100-ft seine haul made parallel to shore with a 30-ft long bag seine. Sampling effort has been remained consistent throughout the six years of the study. A total of 207 samples at 16 sites yielded 5,133 total Blue Crabs, along with 54,377 total fish, comprised of 46 species. The catch per unit effort for fish was the third highest recorded by this survey, while the catch per unit effort for Blue Crabs was the highest recorded by this survey to date. The most abundant species collected in 2016 were Atlantic Silverside, Mummichog, Striped Killifish, Atlantic Menhaden, and Bay Anchovy, which together represented over 92% of the overall fish catch. Catches of the 14 target species (Atlantic Croaker, Atlantic Menhaden, Atlantic Silverside, Bay Anchovy, Bluefish, Mummichog, Silver Perch, Spot, Striped Bass, Striped Killifish, Summer Flounder, Weakfish, White Mullet, and Winter Flounder) were examined individually. Blue Crabs were categorized into size classes. Of the 5,133 Blue Crabs caught in 2016, 3,446 (67%) were small (0 – 40 mm carapace length), 1,541 (30%) were medium (41 – 140 mm), and 146 (3%) were large specimens (>141 mm).

INTRODUCTION

The 2016 Inshore Fish and Blue Crab Survey was the sixth annual volunteer seining study of the near-shore areas of Rehoboth Bay, Indian River and Bay, and Little Assawoman Bay, managed by the Delaware Center for the Inland Bays. Shallow, inshore areas are important to the aquatic community as they may be preferentially utilized by juvenile fish and crabs. While the annual Delaware Department of Natural Resources and Environmental Control (DNREC) offshore bottom trawl surveys are informative, and are the best method for assessing populations for many species, the trawl survey may fail to adequately characterize species that prefer the inshore areas during parts or all of their life cycle. Therefore, understanding how these environments are related in terms of species assemblages and habitat utilization, in order to accurately assess species populations, is important. This survey represents the first comprehensive, long-term survey of these inshore areas in the Inland Bays.

The main objective of the current study was to generate comparative average catch data for all inshore fish species, with an emphasis on 14 target species (seven forage and seven predator species) as well as Blue Crabs. From these data, trends in species abundance and distribution for each species can be monitored through time. The annual Inland Bays survey reports are distributed to state and federal regulatory organizations, academic institutions, and interested environmental organizations. Summary data are available to the above entities and the public through the annual reports. Complete data sets are available by request to the Center for the Inland Bays.

METHODS AND MATERIALS

A total of 207 inshore seine samples were collected in 2016 at 16 fixed sites in Indian River and Bay, Rehoboth Bay, Little Assawoman Bay and tributaries (Figure 1) from the end of April through October. Detailed site descriptions are available in the 2014 annual report (Kernehan et al. 2016). One sampling event was collected during the second half of April, while two monthly sampling events were collected during the first and second halves of each month from May through October.

Each study site occurred within close proximity to a road or parking lot for ease of access by volunteers in motor vehicles. Sites were selected that have an open shoreline area of at least 100 feet in length, with a flat bottom and substrate firm enough to safely sample at all tidal stages. Four sites are located in Rehoboth Bay, seven in Indian River and Bay, and five in Little Assawoman Bay and it's tributaries (Figure 1). These sites have been sampled since 2011.
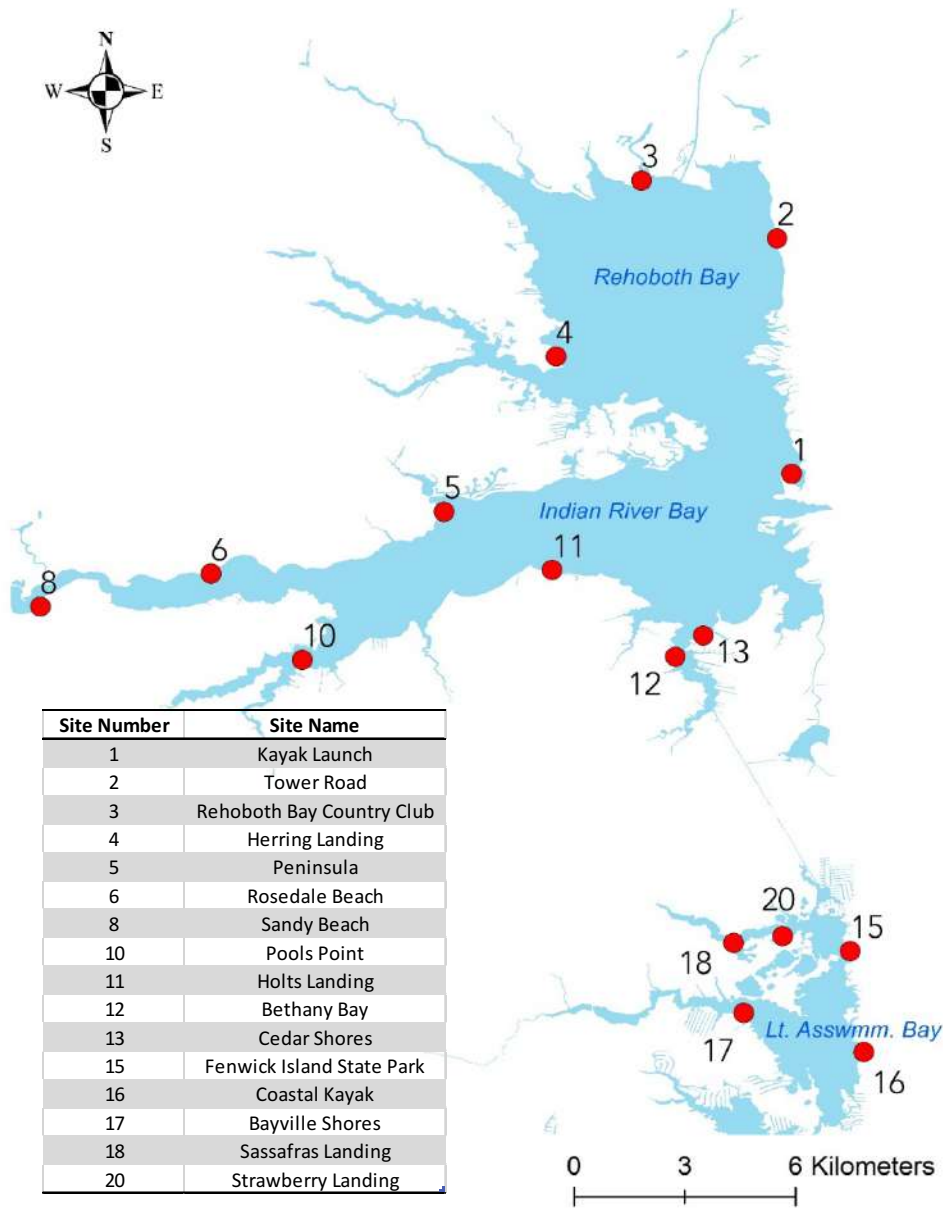
Site Number	Site Name
1	Kayak Launch
2	Tower Road
3	Rehoboth Bay Country Club
4	Herring Landing
5	Peninsula
6	Rosedale Beach
8	Sandy Beach
10	Pools Point
11	Holts Landing
12	Bethany Bay
13	Cedar Shores
15	Fenwick Island State Park
16	Coastal Kayak
17	Bayville Shores
18	Sassafras Landing
20	Strawberry Landing

Figure 1. Map of the 16 sites seined in 2016.

At each location, a single haul was made using a 30-foot long by 4-feet high bag seine with ¼-inch mesh. The bag is 4-feet long, 4-feet wide and 4-feet deep, located in the center of the net. One volunteer wades off the shoreline into deeper water, while another volunteer remains closer to shore, usually in a foot or less of water. The net was drawn between them, fully extended, perpendicular to the shore, and is then walked parallel to the shore for 70 feet, when the deeper water volunteer swings inshore and both volunteers walk the net onto shore thereby seining 100 feet of shoreline. The only exception to this procedure was at Rosedale Beach (Site 6), where two 50- foot hauls were made because a pier, too low to walk under, is located across the middle of the area. All fish were removed from the net, identified and counted. At least 25 specimens of each fish species were placed in buckets of water as quickly as possible to be measured to the nearest millimeter. The first 25 fish of each species that are scooped out of the holding bucket are measured for total length (mm). The selection procedure for length frequency data may bias measurements. However, since the selection procedure is standardized across space and time, our data remains consistent for analyzing spatial and temporal comparisons within the survey. All other fish and crabs were immediately counted and returned to the water to minimize mortality. When air temperature was extremely high, bottles of frozen water and aerators were placed in the buckets to reduce mortality for those specimens retained for measurement. Blue Crabs were counted and categorized as small (less than 40 mm carapace width, less than 1-year old), medium (41-140 mm, 1-2 years old) or large (greater than 140 mm, adults more than 2 years old).

Fish were identified to the species level. The authors were present for most of the surveys to verify identifications. When questionable species were encountered in other samples, pictures or preserved specimens were transmitted to the authors for identification or verification. Scientific names for species identified during 2016 are listed in Appendix A.

Each seine sample was designated as one unit of effort. The two 50-feet hauls at Rosedale Beach were combined and counted as one unit of effort. The arithmetic catch-per-seine was calculated for both the total fish catch, and total Blue Crab catch for 2016, by dividing the total number of fish or Blue Crab by the total number of seines in 2016 (207). Arithmetic catch-per-seine for each month and each site were calculated using the same approach. Species specific percent composition was calculated by dividing the total catch by the annual total number of each species. Percentage calculations for each species of fish do not include the annual number of Blue Crabs collected in the survey.

The 14 target fish species chosen for individual analyses, results, and discussion sections included seven important forage species that occur throughout the Inland Bays, and seven recreationally and commercially important species in Delaware and other states. These species include: Atlantic Croaker, Atlantic Menhaden, Atlantic Silverside, Bay Anchovy, Bluefish, Mummichog, Silver Perch, Striped Bass, Striped Killifish, Summer Flounder, Weakfish, White Mullet, and Winter Flounder. Blue Crabs are also considered a target species.

Differences in abundance between the three bays were calculated for each target species during the 2016 season using pairwise Wilcoxon rank sum tests with a Bonferroni correction (α = 0.05).

Physical parameters of water temperature (measured to 0.1 degree centigrade, ^{0}C), dissolved oxygen (to 0.1 milligram per liter, mg/l), and salinity (to 0.1 part per thousand, ppt) were measured with a YSI Pro 2030 meter at the beginning of each survey. The weather and wind conditions were noted for each sample as well as the stage of the tide. Tidal stages were categorized as low ebb or low flood if sampling began within 2 hours of low tide, mid-flood or mid-ebb if sampling began within 2 to 4 hours of low or high tide, and high ebb or high flood if sampling began within 2 hours of high tide.

Correlations between the abundance of each target species and the measured dissolved oxygen, water temperature, and salinity values since the start of the survey in 2011 were assessed using Kendall's tau correlation tests (α = 0.05) for each species. Additionally, pairwise Wilcoxon rank sum tests with Bonferroni corrections (α = 0.05) were run to assess the influence of tidal stage on each target species' abundance since 2011. We chose to use data from 2011 through the current year since individual species' abundances vary widely, and therefore if we only included a single year's worth of data for these analyses, some species' correlations would be based on only a handful of individuals.

Due to the large annual fluctuations in fish abundance, statistical trends of species populations are not yet appropriate, however, the geometric mean catch for each year of the survey are presented for each target fish species to better visualize the data. In addition, the geometric mean was calculated for each previous season, then the arithmetic mean and median of these values were calculated and plotted to show how the previous year compared to the time series averages.

RESULTS

Physical Parameters

Mean dissolved oxygen concentration ranged from a low of 4.04 mg/L at Sandy Beach (Site 8) in August, to a high of 15.10 mg/L at Strawberry Landing (Site 20) in April (Table 1). Rehoboth bay sites (1-4) and Little Assawoman bay sites (15-20) had generally homogenous dissolved oxygen concentrations among sites within a given month, while Indian River sites (5-13) exhibited greater variation among sites in the monthly mean.

Mean water temperature ranged from a low of 13.2 degrees Celsius in October at Sandy Beach (Site 8) to a high of 32.3 degrees Celsius at Pools Point (Site 10) in August (Table 2). Like dissolved oxygen, Indian River sites exhibited a wider range of temperatures within a given month than the Rehoboth bay and Little Assawoman bay sites.

Salinity ranged from a low of 1.3 ppt at Sandy Beach (Site 8) in October to a high of 30.7 ppt at Kayak Launch (Site 1) in August (Table 3). Again, Indian River Bay sites showed greater variability among sites within a given month, while sites in the other bays were fairly homogenous.

Correlations for each target species to dissolved oxygen, water temperature, and salinity since 2011 are presented in Table 4. It should be noted that while statistically significant, many of these correlations are weak, which suggests that additional unmeasured variables such as food availability, habitat type, and predation risk also influence fish distribution and abundance. A majority of species were correlated with salinity, though the direction of this correlation was species dependent. All species except Atlantic Croaker, Winter Flounder, and Weakfish were significantly positively correlated with water temperature, while Atlantic Croaker was the only species significantly negatively correlated with water temperature. This is in line with this species' life cycle, as the young-of-the-year enter the estuary in the fall once water temperatures have cooled (Pacheco and Grant 1973; Rhode 2008), overwinter in the estuary (Able and Fahay 2010), and are therefore present in the inshore areas in the spring before water temperatures have warmed. Surprisingly, a majority of species were negatively correlated with

dissolved oxygen. While in general fish need healthy dissolved oxygen levels to survive, the sampling times in this study are primarily in the mid-morning to early afternoon, well into the upwards swing of the diel cycle, and therefore the oxygen levels encountered in this study are consistently within the healthy range for the species of fish encountered in this study. Surveys rarely take place with oxygen levels falling below 4mg/L. Therefore, while the negative correlations represent affinities for lower oxygen, they are ultimately still within the healthy limits for these species, and should be interpreted as such.

Influence of tidal stage on fish and crab abundance was examined by first simplifying the tidal variables into three categories; High tide (high ebb and high flood), Mid tide (mid ebb and mid flood), and Low tide (low ebb and low flood). Then a series of pairwise Wilcoxon tests with Bonferroni corrections were run for each species.

Catch totals during the three tidal stages were not significantly different for Atlantic Croaker, Atlantic Menhaden, Silver Perch, Spot, Striped Bass, Summer Flounder, White Mullet, or Winter Flounder. Atlantic Silverside had a greater catch during high tide and mid tides than during low tides ($p < 0.01$, $p < 0.001$). Bay Anchovy had a greater catch at high tide compared to low tide and mid tide ($p < 0.001$, $p < 0.01$), and a greater catch at mid tide than low tide ($p < 0.01$), demonstrating a preference for deeper waters within the nearshore area. In support of this, Bay Anchovy are often collected in greater numbers by the DNREC open water trawl survey (Greco 2016), which samples areas that are frequently deeper than the areas sampled by this survey. Bluefish had a greater catch during the high tide than the low tide or the mid tide ($p < 0.001$, $p < 0.05$). This may be a response to the preferences of their prey (Bay Anchovy and Atlantic Silverside) which showed a greater abundance during higher tides as well. Weakfish had a greater catch at the high tide compared to the mid tide ($p < 0.05$). Mummichog had a greater catch during low tide than both high and mid tides ($p < 0.001$, $p < 0.001$), and a greater catch during mid tides than high tides ($p < 0.001$). Striped Killifish demonstrated the a similar pattern as Mummichog, with a greater catch at low tide compared to high and mid tides ($p < 0.001$, $p < 0.001$), and a greater catch at mid compared to high tide ($p < 0.05$). Lastly, Blue Crab showed a similar pattern to both Striped Killifish and Mummichog, with a greater catch during low tide compared to high and mid tides ($p < 0.001$, $p < 0.001$). These last three species are all known to inhabit the marsh surface, with Mummichog and Striped Killifish often spawning in intertidal pools (Able and Fahay 2010). Therefore, it is unsurprising that these species all show an ability to tolerate low tides.

Table 1. Mean dissolved oxygen concentration (mg/L) for each site per month during 2016.

Site	Site Name	Bay	Apr	May	Jun	Jul	Aug	Sep	Oct
1	Kayak Launch	Rehoboth	9.50 +/- NA	8.18 +/- 1.31	4.44 +/- 0.21	6.71 +/- 1.00	4.75 +/- 0.07	5.04 +/- 0.37	7.88 +/- 0.83
2	Tower Rd	Rehoboth	10.10 +/- NA	8.50 +/- 0.42	6.44 +/- 0.33	6.20 +/- 0.42	7.43 +/- 2.65	4.75 +/- 1.06	9.13 +/- 0.43
3	Rehoboth Beach CC	Rehoboth	9.70 +/- NA	12.40 +/- 2.83	8.55 +/- 1.74	7.15 +/- 1.13	7.60 +/- 0.99	5.77 +/- 1.33	8.46 +/- 1.56
4	Herring Landing	Rehoboth	10.17 +/- NA	11.27 +/- 1.66	7.44 +/- 0.24	5.94 +/- 1.33	8.80 +/- 0.28	6.90 +/- 0.98	8.94 +/- 0.76
5	Peninsula	Indian River	5.40 +/- NA	7.60 +/- 0.99	8.12 +/- 0.46	6.35 +/- 0.35	6.43 +/- 0.18	7.23 +/- 1.10	10.54 +/- 2.67
6	Rosedale Beach	Indian River	7.50 +/- NA	5.40 +/- 1.27	7.44 +/- 2.32	7.03 +/- 1.59	6.55 +/- 3.32	4.87 +/- 0.19	8.46 +/- 2.92
8	Sandy Beach	Indian River	10.00 +/- NA	5.29 +/- 2.57	6.12 +/- 0.40	4.10 +/- 0.85	4.04 +/- 0.35	4.89 +/- 0.29	8.45 +/- 2.58
10	Pools Point	Indian River	8.60 +/- NA	9.25 +/- 0.07	10.39 +/- 1.96	8.18 +/- 0.59	6.86 +/- 2.06	6.78 +/- 0.11	8.10 +/- 0.99
11	Holts Landing	Indian River	9.30 +/- NA	9.65 +/- 0.07	8.85 +/- 2.19	9.10 +/- 1.85	8.70 +/- 1.55	7.76 +/- 1.48	8.40 +/- 0.57
12	Bethany Bay	Indian River	12.40 +/- NA	12.20 +/- 2.26	14.03 +/- 1.09	6.27 +/- 2.02	7.91 +/- 2.11	6.75 +/- 0.78	8.61 +/- NA
13	Cedar Shores	Indian River	10.00 +/- NA	10.70 +/- 0.85	8.81 +/- 1.25	7.40 +/- 0.42	8.64 +/- 1.07	7.85 +/- 1.20	8.93 +/- 1.37
15	Fenwick Island	Lt. Asswmn.	10.00 +/- NA	12.71 +/- 6.09	9.19 +/- 0.16	7.95 +/- 1.35	7.21 +/- 0.13	7.59 +/- 0.55	8.58 +/- 3.94
16	Coastal Kayak	Lt. Asswmn.	10.70 +/- NA	9.43 +/- 0.61	10.65 +/- 1.91	8.20 +/- 0.28	9.20 +/- 1.41	10.04 +/- 1.43	8.93 +/- 1.73
17	Bayville Shores	Lt. Asswmn.	11.60 +/- NA	10.36 +/- 2.40	8.00 +/- 0.00	7.35 +/- 0.07	7.46 +/- 0.76	7.93 +/- 0.75	8.74 +/- 4.72
18	Sassafras Landing	Lt. Asswmn.	10.00 +/- NA	8.75 +/- 0.07	8.25 +/- 0.35	7.65 +/- 0.49	6.75 +/- 0.49	6.80 +/- 1.70	8.56 +/- 3.49
20	Strawberry Landing	Lt. Asswmn.	15.10 +/- NA	10.7 +/- 1.70	8.91 +/- 1.29	7.80 +/- 0.99	8.16 +/- 2.48	7.74 +/- 1.47	8.80 +/- 4.81

Table 2. Mean water temperature (Celsius) for each site per month during 2016.

Site	Site Name	Bay	Apr	May	Jun	Jul	Aug	Sep	Oct
1	Kayak Launch	Rehoboth	15.6 +/- NA	16.8 +/- 4.0	22.9 +/- 0.6	26.2 +/- 0.7	28.0 +/- 1.1	23.6 +/- 0.4	14.0 +/- 2.2
2	Tower Rd	Rehoboth	15.9 +/- NA	18.4 +/- 4.4	24.0 +/- 1.2	27.9 +/- 1.5	26.7 +/- 1.1	27.5 +/- 5.3	14.0 +/- 3.3
3	Rehoboth Beach CC	Rehoboth	16.8 +/- NA	18.8 +/- 4.9	26.2 +/- 0.2	29.3 +/- 2.6	30.3 +/- 1.0	25.5 +/- 1.9	15.9 +/- 2.1
4	Herring Landing	Rehoboth	18.0 +/- NA	18.5 +/- 4.9	24.5 +/- 1.9	30.0 +/- 1.7	30.7 +/- 0.8	24.6 +/- 1.5	15.4 +/- 2.9
5	Peninsula	Indian River	16.1 +/- NA	19.0 +/- 6.2	23.9 +/- 1.7	28.0 +/- 1.9	27.7 +/- 1.2	23.7 +/- 0.4	16.1 +/- 2.0
6	Rosedale Beach	Indian River	16.3 +/- NA	19.9 +/- 5.8	24.2 +/- 0.5	27.9 +/- 1.6	27.6 +/- 0.4	24.5 +/- 1.2	15.2 +/- 1.2
8	Sandy Beach	Indian River	16.0 +/- NA	20.2 +/- 5.1	23.9 +/- 0.4	28.1 +/- 1.9	26.4 +/- 2.0	24.9 +/- 1.8	13.2 +/- 2.9
10	Pools Point	Indian River	17.8 +/- NA	17.2 +/- 1.4	25.1 +/- 5.2	30.7 +/- 2.6	32.3 +/- 1.9	25.3 +/- 1.8	21.0 +/- 1.2
11	Holts Landing	Indian River	18.2 +/- NA	16.2 +/- 2.1	21.7 +/- 2.9	28.6 +/- 2.4	29.5 +/- 3.4	25.3 +/- 1.5	20.5 +/- 1.0
12	Bethany Bay	Indian River	19.9 +/- NA	18.0 +/- 3.3	26.0 +/- 5.5	27.4 +/- 0.2	30.2 +/- 4.0	25.9 +/- 1.2	20.7 +/- NA
13	Cedar Shores	Indian River	19.5 +/- NA	18.1 +/- 5.5	26.1 +/- 6.5	28.4 +/- 0.2	30.2 +/- 3.7	26.2 +/- 2.1	20.8 +/- 0.1
15	Fenwick Island	Lt. Asswmn.	16.1 +/- NA	17.5 +/- 1.0	27.5 +/- 0.7	30.7 +/- 1.8	30.5 +/- 0.5	25.4 +/- 3.2	20.7 +/- 2.1
16	Coastal Kayak	Lt. Asswmn.	15.9 +/- NA	17.3 +/- 1.0	28.2 +/- 0.7	31.1 +/- 1.9	30.5 +/- 0.3	25.5 +/- 3.1	20.9 +/- 2.4
17	Bayville Shores	Lt. Asswmn.	19.8 +/- NA	18.1 +/- 1.7	28.0 +/- 0.5	31.0 +/- 1.3	30.4 +/- 0.7	26.0 +/- 3.2	21.1 +/- 4.7
18	Sassafras Landing	Lt. Asswmn.	16.6 +/- NA	18.5 +/- 2.4	29.4 +/- 0.7	31.8 +/- 1.4	31.0 +/- 0.0	26.6 +/- 3.4	21.1 +/- 4.8
20	Strawberry Landing	Lt. Asswmn.	17.3 +/- NA	18.0 +/- 2.0	28.8 +/- 0.3	31.9 +/- 2.2	30.9 +/- 0.1	25.8 +/- 3.6	20.9 +/- 4.1

Table 3. Mean salinity (ppt) for each site per month during 2016.

Site	Site Name	Bay	Apr	May	Jun	Jul	Aug	Sep	Oct
1	Kayak Launch	Rehoboth	28.3 +/- NA	28.4 +/- 0.2	28.2 +/- 0.0	29.9 +/- 0.2	30.7 +/- 0.0	29.0 +/- 2.0	25.4 +/- 2.2
2	Tower Rd	Rehoboth	28.5 +/- NA	26.3 +/- 0.7	26.0 +/- 0.7	28.7 +/- 0.2	29.6 +/- 0.7	27.4 +/- 1.7	24.7 +/- 0.7
3	Rehoboth Beach CC	Rehoboth	28.4 +/- NA	24.4 +/- 4.5	26.2 +/- 0.0	27.7 +/- 0.3	29.2 +/- 0.0	27.5 +/- 0.8	23.6 +/- 3.1
4	Herring Landing	Rehoboth	28.6 +/- NA	27.9 +/- 0.7	28.6 +/- 0.0	29.4 +/- 0.5	30.0 +/- 0.2	28.7 +/- 2.1	23.0 +/- 5.1
5	Peninsula	Indian River	23.3 +/- NA	26.0 +/- 1.1	26.4 +/- 1.0	24.8 +/- 4.2	28.5 +/- 0.4	17.7 +/- 15.5	18.1 +/- 10.2
6	Rosedale Beach	Indian River	21.2 +/- NA	20.4 +/- 1.4	19.8 +/- 1.3	20.9 +/- 2.4	22.9 +/- 0.0	24.2 +/- 2.7	11.1 +/- 7.8
8	Sandy Beach	Indian River	13.7 +/- NA	10.0 +/- 1.7	11.3 +/- 5.2	13.1 +/- 3.2	14.2 +/- 3.1	19.2 +/- 4.2	1.3 +/- 1.3
10	Pools Point	Indian River	20.5 +/- NA	15.9 +/- 2.6	24.1 +/- 4.0	25.7 +/- 2.4	25.1 +/- 0.2	25.1 +/- 1.6	11.9 +/- 10.8
11	Holts Landing	Indian River	25.9 +/- NA	23.3 +/- 0.9	26.5 +/- 0.3	28.0 +/- 0.3	29.2 +/- 0.0	28.3 +/- 0.5	25.0 +/- 2.6
12	Bethany Bay	Indian River	27.1 +/- NA	25.9 +/- 1.5	27.0 +/- 0.4	29.0 +/- 0.1	23.1 +/- 8.7	28.4 +/- 1.9	18.3 +/- NA
13	Cedar Shores	Indian River	27.9 +/- NA	27.4 +/- 0.3	27.3 +/- 1.5	28.7 +/- 0.8	29.5 +/- 0.1	28.9 +/- 1.6	26.8 +/- 3.1
15	Fenwick Island	Lt. Asswmn.	20.4 +/- NA	14.9 +/- 4.5	18.6 +/- 0.0	17.6 +/- 2.6	23.9 +/- 2.2	24.5 +/- 2.9	13.5 +/- 11.3
16	Coastal Kayak	Lt. Asswmn.	23.3 +/- NA	19.7 +/- 0.7	21.6 +/- 1.4	22.2 +/- 1.1	24.4 +/- 2.6	22.6 +/- 6.5	10.9 +/- 7.2
17	Bayville Shores	Lt. Asswmn.	17.7 +/- NA	13.4 +/- 4.4	17.3 +/- 0.9	18.9 +/- 0.4	21.9 +/- 4.1	16.0 +/- 13.2	4.2 +/- 1.5
18	Sassafras Landing	Lt. Asswmn.	19.0 +/- NA	11.5 +/- 3.3	14.2 +/- 1.6	17.3 +/- 0.4	21.2 +/- 2.4	17.6 +/- 11.3	6.6 +/- 5.9
20	Strawberry Landing	Lt. Asswmn.	10.7 +/- NA	13.9 +/- 3.5	17.1 +/- 1.2	18.5 +/- 0.1	23.4 +/- 2.4	18.5 +/- 10.9	9.31 +/- 1.4

Table 4. Correlations for each species to physical parameters since 2011 as assessed by Kendall's tau correlation tests (α = 0.01).

Species	Salinity p value	Salinity tau	Dissolved Oxygen p value	Dissolved Oxygen tau	Water Temperature p value	Water Temperature tau	Number of Specimens
Atlantic Croaker	< 0.001	-0.091	0.0814	-0.0407	< 0.01	-0.0646	765
Atlantic Menhaden	< 0.001	-0.103	0.1672	-0.0317	< 0.001	0.0956	14137
Atlantic Silverside	< 0.001	0.1271	0.0361	-0.041	< 0.001	0.1119	103050
Bay Anchovy	0.0256	-0.0503	< 0.001	-0.1689	< 0.001	0.0826	5384
Bluefish	0.3118	0.0234	< 0.001	-0.127	< 0.001	0.1128	250
Mummichog	< 0.001	-0.0679	0.2390	0.0242	< 0.001	0.1188	78700
Silver Perch	< 0.01	0.0693	< 0.001	-0.1488	< 0.001	0.1444	4947
Spot	0.0253	-0.0498	< 0.01	-0.064	< 0.001	0.1296	8970
Striped Bass	0.3615	-0.0213	< 0.01	-0.0711	< 0.01	0.0604	120
Striped Killifish	< 0.001	0.1164	0.0166	-0.049	< 0.001	0.0853	44122
Summer Flounder	< 0.001	-0.1685	< 0.001	-0.1086	< 0.001	0.0922	1151
Weakfish	< 0.01	-0.0687	< 0.01	-0.0641	0.0110	0.0592	598
White Mullet	< 0.001	0.0836	< 0.001	-0.1199	< 0.001	0.1853	4076
Winter Flounder	0.0103	0.0594	< 0.001	-0.0798	0.1003	-0.038	544
Blue Crab Small	< 0.001	-0.1101	0.0462	0.0409	< 0.001	0.1285	13978
Blue Crab Medium	< 0.01	-0.0561	0.1335	-0.0312	< 0.001	0.2223	7161
Blue Crab Large	< 0.001	-0.0886	0.0267	-0.0506	< 0.001	0.1284	763
Blue Crab (total)	< 0.001	-0.086	0.3929	0.0172	< 0.001	0.1761	21902

Fish and Crab Catch Results

A total of 54,377 fish and 5,133 Blue Crabs were caught in 2016. The total arithmetic catch-per-seine for 2016 was 262.69 fish per seine, less than the 2015 catch-per-seine of 290.39, but above the survey average of 219.55 fish per seine. The total arithmetic catch-per-seine for crabs in 2016 was 24.79 crabs per seine, greater than 2015 catch-per-seine of 21.67, and above the survey average of 20.25. A total of 46 fish species were collected in 2016, which is above the survey average of 43, and greater than the 45 species collected during 2015.

The top five species for 2016 were Atlantic Silversides (33.63%), Mummichog (23.20%), Striped Killifish (19.82%), Atlantic Menhaden (12.09%), and Bay Anchovy (3.90%). These species comprised over 92% of total fish catch for 2016. This is a slight departure from previous years, with the addition of Bay Anchovy to the top five, while Sheepshead Minnow dropped to the seventh most abundant species behind Silver Perch.

Seasonally, there were departures from the patterns seen in 2015. Previously August was the most productive month for both fish and Blue Crabs, in 2016 however, the most productive month in terms of catch-per-seine was June for both fish and Blue Crabs (Figures 2-3).
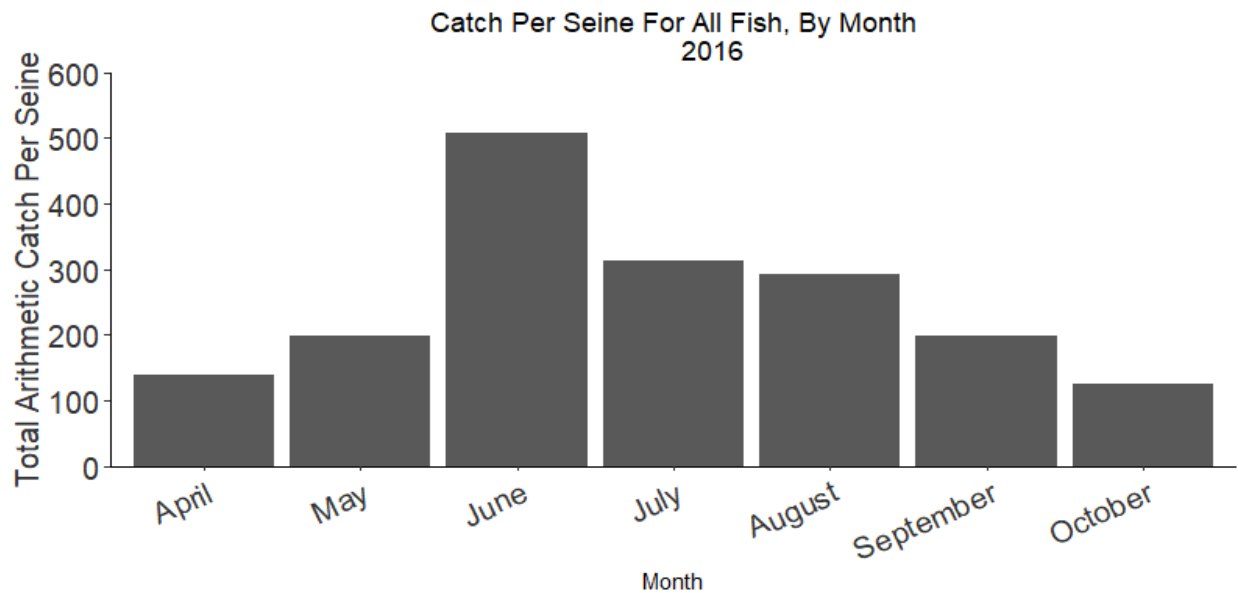
Figure 2. Fish catch per month during 2016.
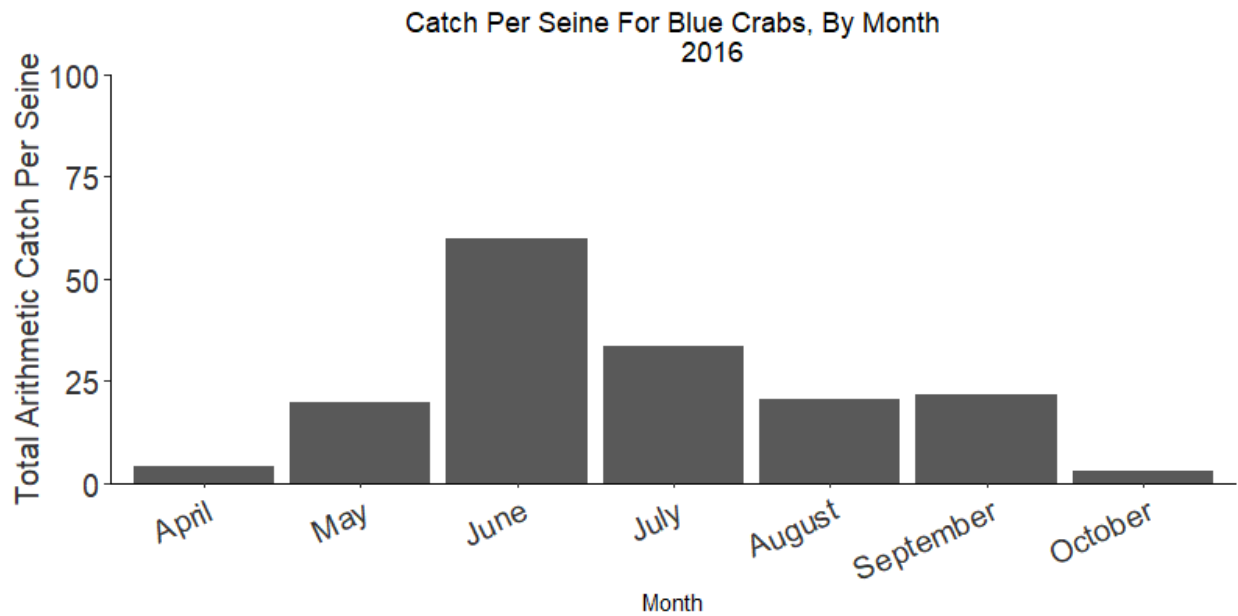
Figure 3. Blue Crab catch per month during 2016.

As in 2014 and 2015, Kayak Launch (Site 1) was the most productive site for numbers of fish, while Sandy Beach (Site 8) was the most productive site for Blue Crabs (Figures 4-5). No other site came close to the number of Blue Crabs caught at Sandy Beach, demonstrating the importance of that site and its mid-salinity waters to the Blue Crab population in the Inland Bays.
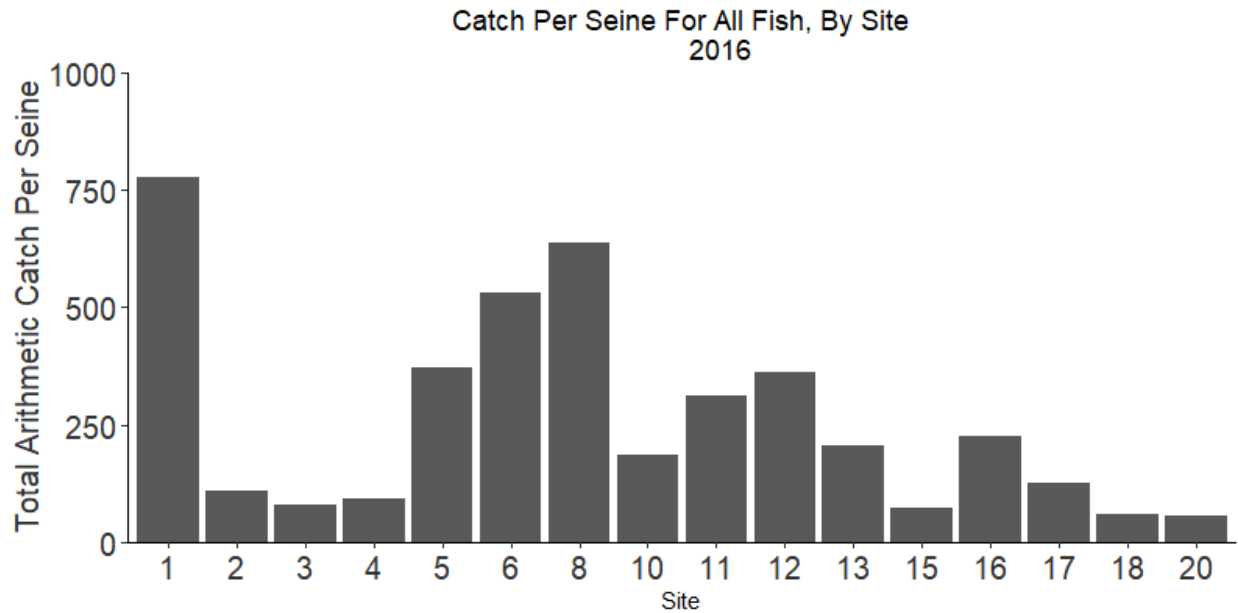
Figure 4. Catch per unit effort for fish per site during 2016.
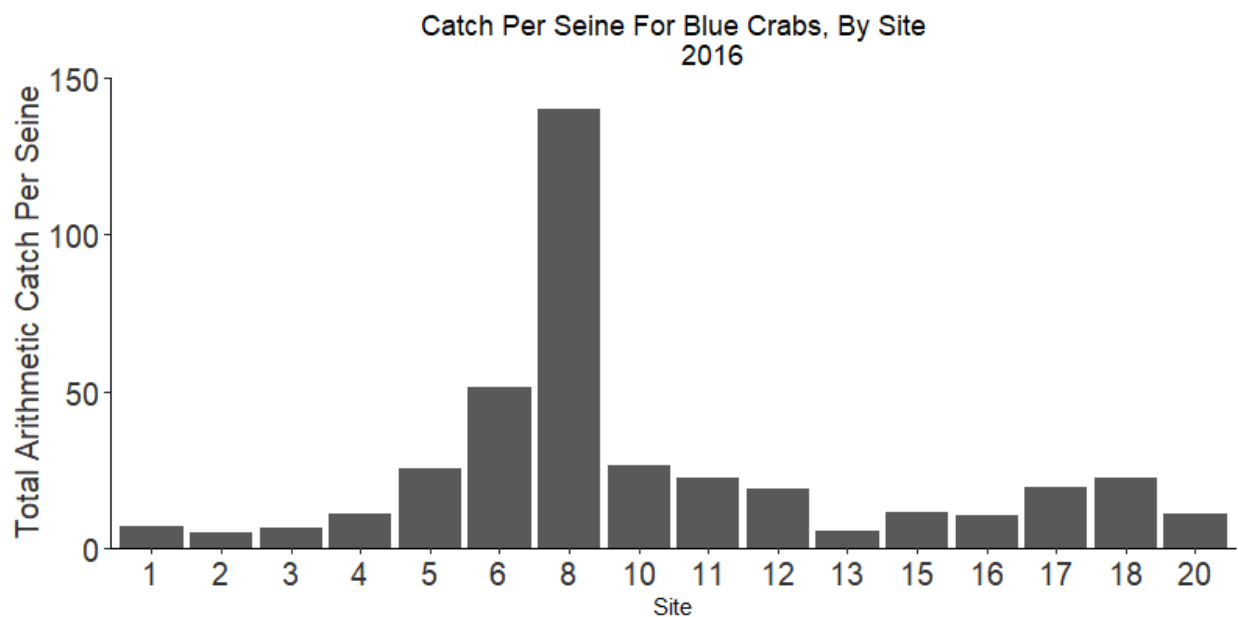
Figure 5. Catch per unit effort for crabs per site during 2016.

The most species rich sites were Peninsula (Site 5) with 24 fish species collected, and Holts Landing and Sandy Beach (Site 11 and 8; Figure 6) both with 22 fish species collected. Both Peninsula and Holts Landing sites have been in the top five most species rich sites since the start of the program in 2011. Sandy Beach is the

furthest up river site in the survey, with occasional occurrences of freshwater fish species during 2016.
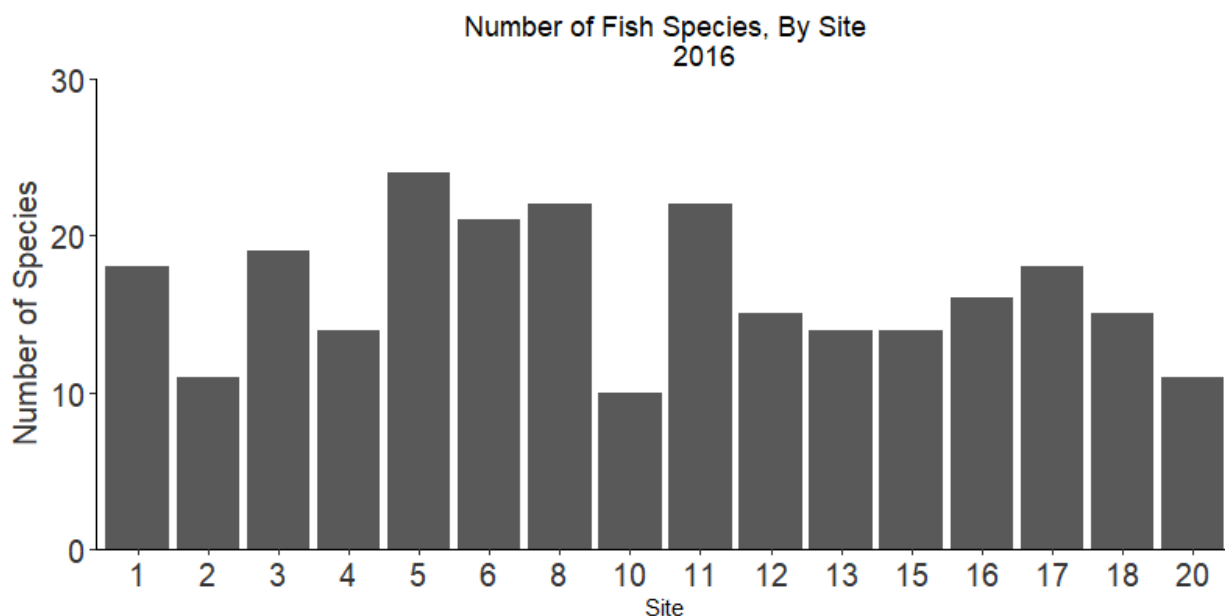
Figure 6. Number of species of fish caught per site during 2016.

Target Species

Target species are species of special concern, due either to their importance for commercial or recreational fisheries, or to their importance as food for larger species. Seven predator, seven forage species, and one invertebrate species have been defined as target species; Atlantic Croaker, Atlantic Menhaden, Atlantic Silverside, Bay Anchovy, Bluefish, Mummichog, Silver Perch, Spot, Striped Bass, Striped Killifish, Summer Flounder, Weakfish, White Mullet, Winter Flounder, and Blue Crabs.

The 2016 survey marked a record year for Atlantic Menhaden, which had a record high catch-per-seine value in 2016. Length distributions of fish target species are depicted in Figure 7. The lengths of predatory species caught by this survey do not represent the full length distributions for these species, and suggest that the specimens utilizing the inshore areas are typically juveniles, and as these species grow they become less frequent in inshore waters and are therefore utilizing deeper waters. In contrast, species such as Mummichog and Atlantic Silverside are

caught frequently at their maximum and minimum total lengths, indicating these species typically inhabit the inshore waters at all stages of their life cycle.
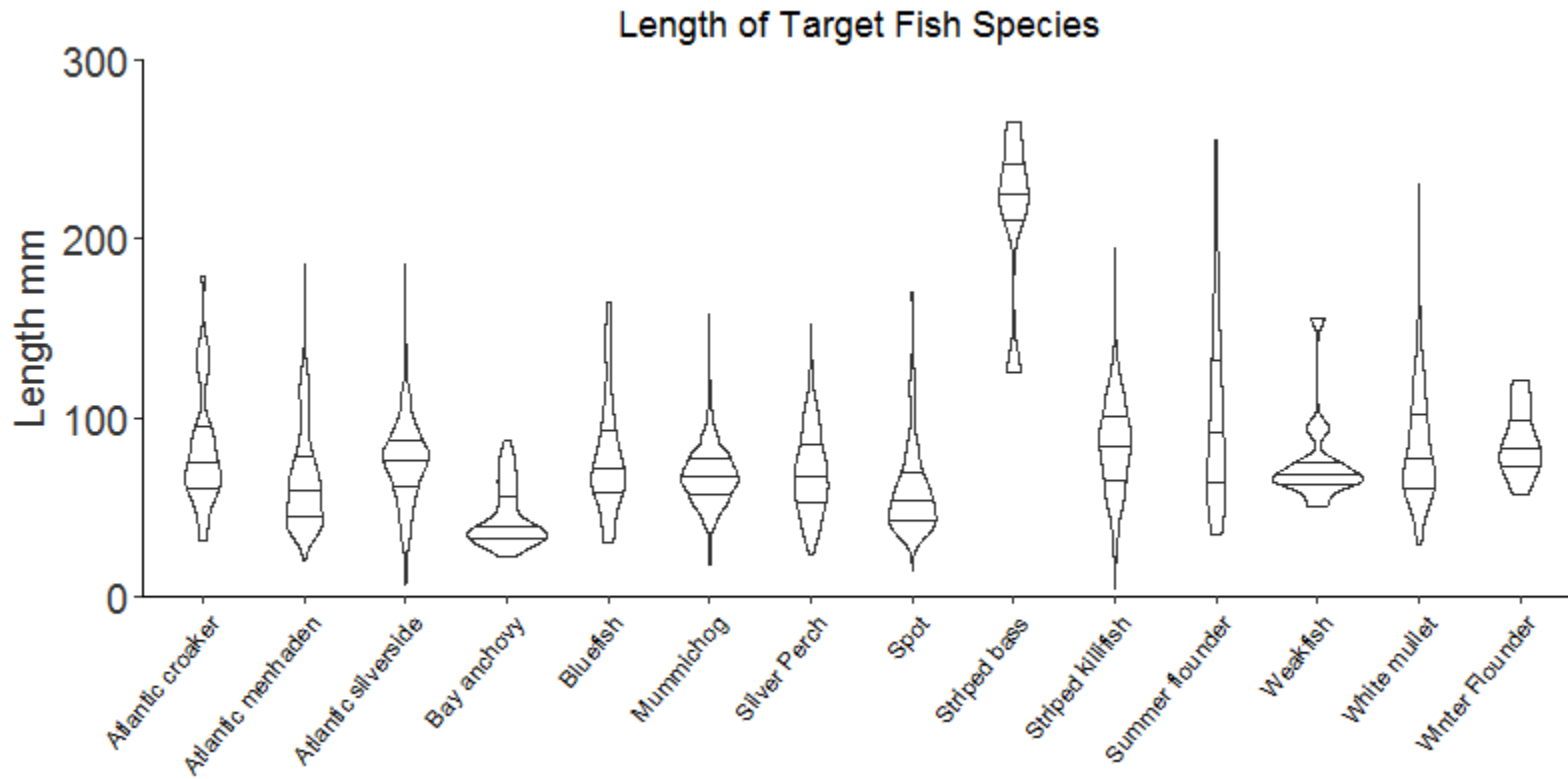
Figure 7. Fish Length by species for specimens captured during 2016. Horizontal lines represent the 25th, 50th, and 75th quartiles. Striped Bass lengths are capped at 300 mm.

Atlantic Croaker

64 Atlantic Croaker were caught in 2016, for a geometric mean catch of 0.043 fish per seine, up from the dramatic decline in croaker seen in 2015, but still below the time series mean and median (Figure 8). As in previous years most croaker were less than 100 mm in length, demonstrating the specimens that do utilize the inshore areas are primarily young-of-the-year. Unlike 2014 and 2015, the peak occurrence of croaker in 2016 was May (Figure 9), rather than September. Ingress of croaker larvae into the estuary typically occurs in the late fall with a peak in November or December (Pacheco and Grant 1973; Rhode 2008). In previous years, particularly during 2014 when croaker were caught in greater numbers, the majority of croaker caught were less than 60 mm in length, indicating those captured were larvae and young-of-the-year fish entering the estuary that were spawned in the fall. The slightly larger sizes and springtime peak in 2016 suggest that the croaker captured this year were spawned during the fall of 2015, and that the ingress of larvae from the fall spawning in 2016 was either minimal, or occurred after the October seine events. Atlantic Croaker catch did not differ between any of the three bays during 2016, though upper Indian River Bay sites continued to have greater catch numbers than other areas, a pattern seen over the last 5 years (Figure 10; McGowan et al. 2017).
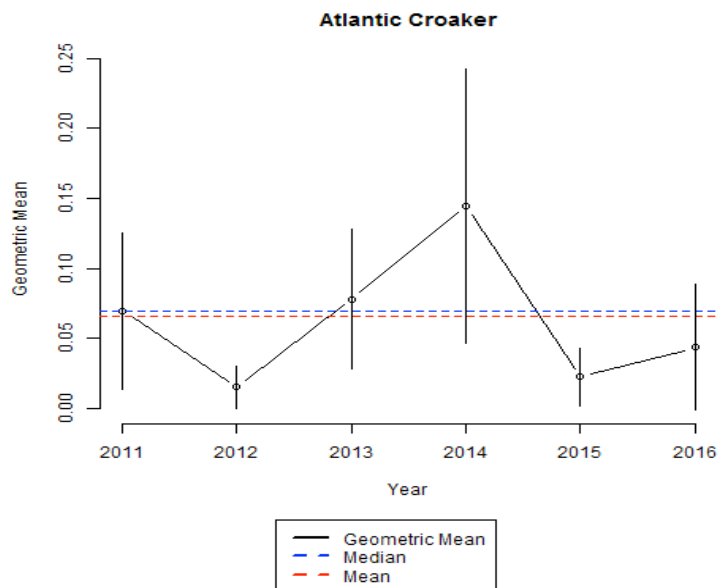
Figure 8. Geometric mean catch-per-seine for Atlantic Croaker, with the time series mean and median.
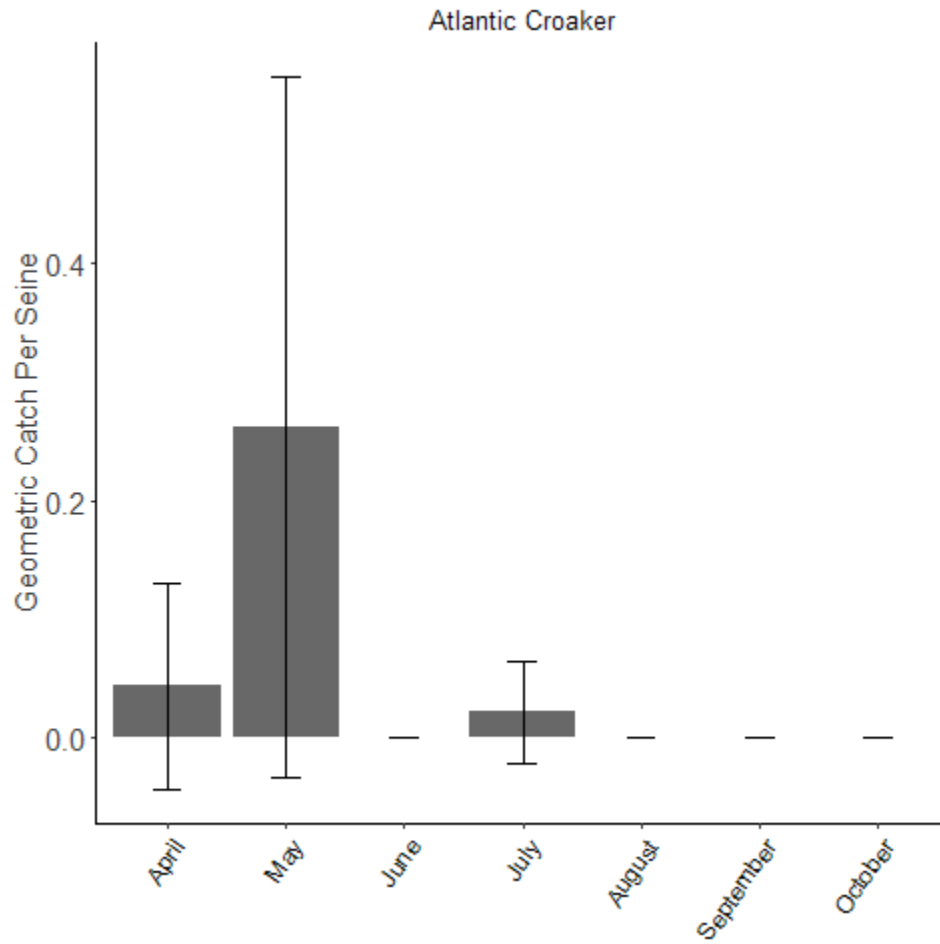
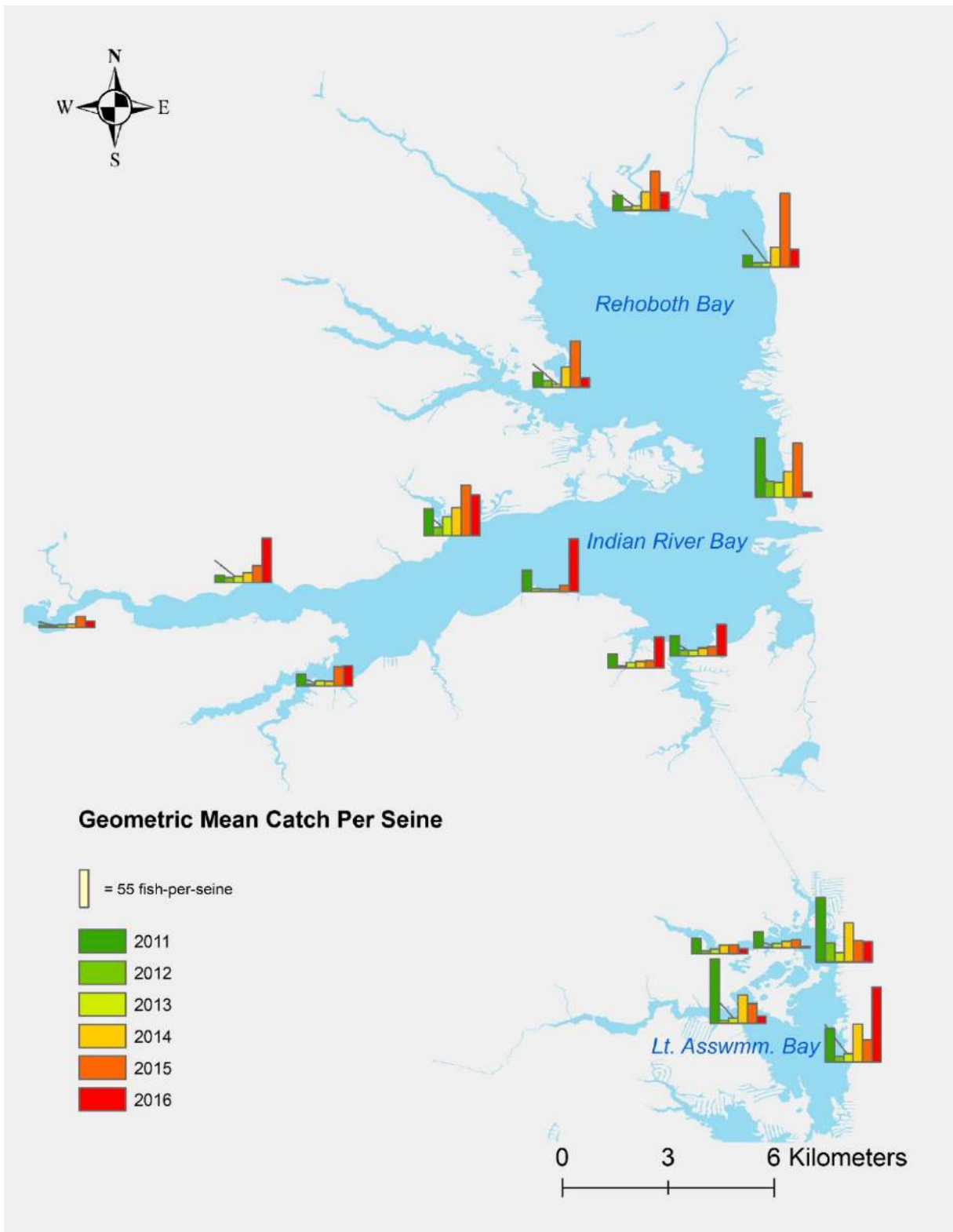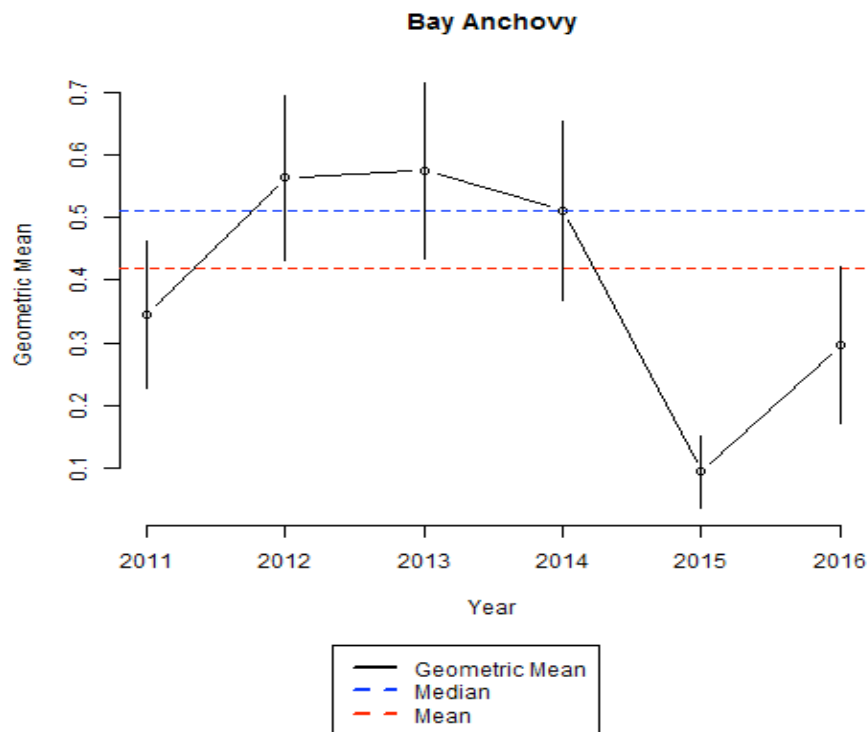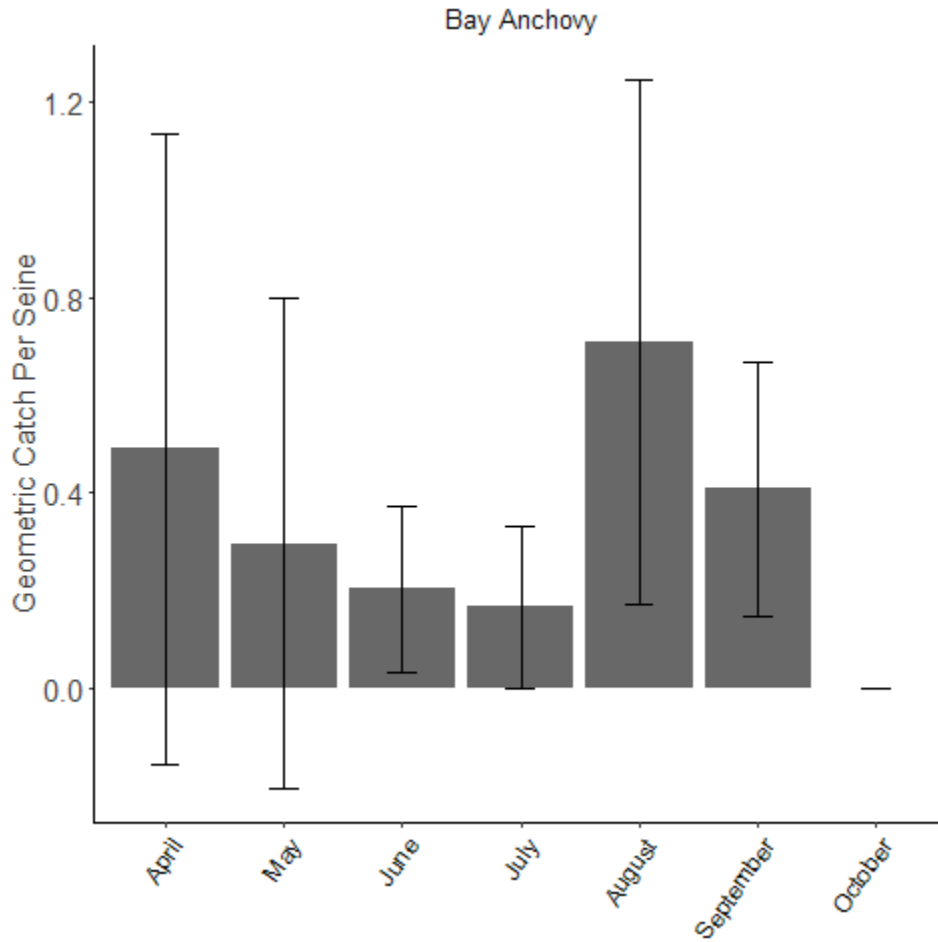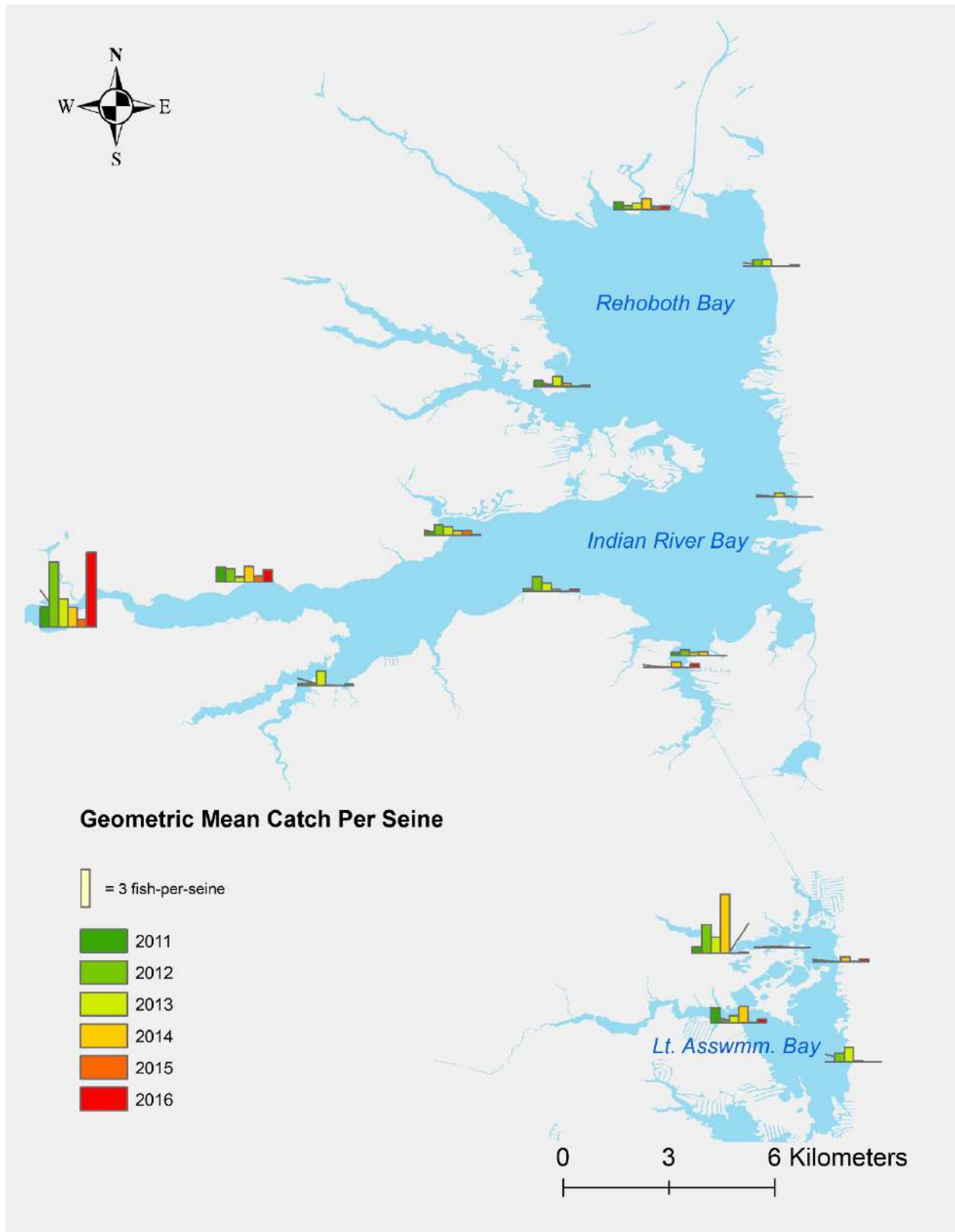**Figure 9. Geometric mean catch-per-seine during 2016 for Atlantic Croaker by month.**
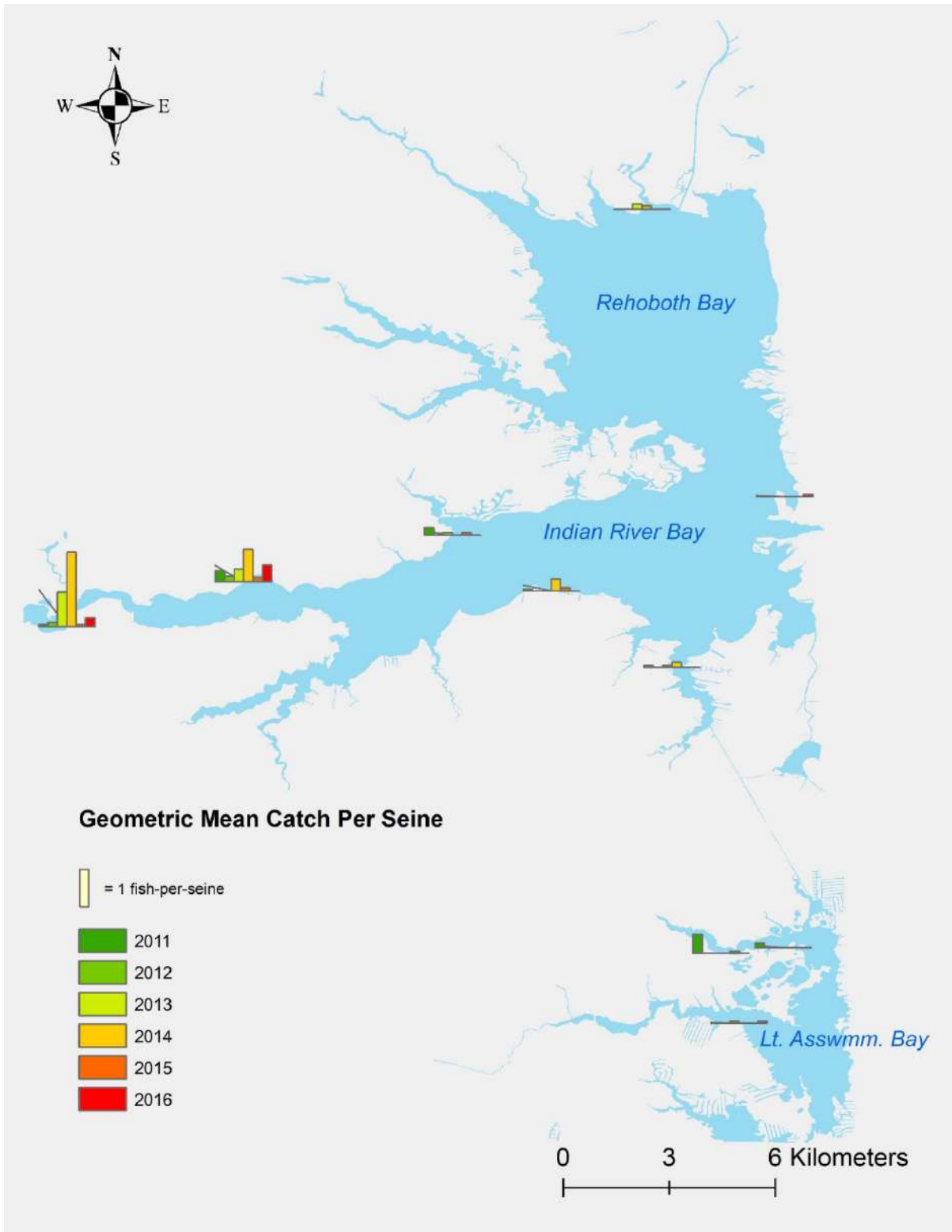
Figure 10. Geometric mean catch-per-seine since 2011 for Atlantic Croaker by site.

Atlantic Menhaden

A total of 6,575 Atlantic Menhaden were caught in 2016, for a geometric mean catch of 0.593 fish per seine, the highest of any year thus far and above the time series mean and median (Figure 11). Seasonally, June was the peak month of occurrence for Menhaden (Figure 12), similar to the results from 2014 and 2015 (Kernehan et al. 2016; McGowan et al. 2017). The majority of Menhaden caught in 2016 were approximately 50 mm in length. Menhaden were more abundant in Indian River Bay than in Rehoboth Bay (p < 0.05; Figure 13), and Menhaden catch was higher at the upper Indian River sites than at other locations, indicating the importance of the up river sites for Atlantic Menhaden. In support of this pattern Menhaden catch from 2011 through 2016 has been negatively correlated with salinity (p < 0.001; Table 4).
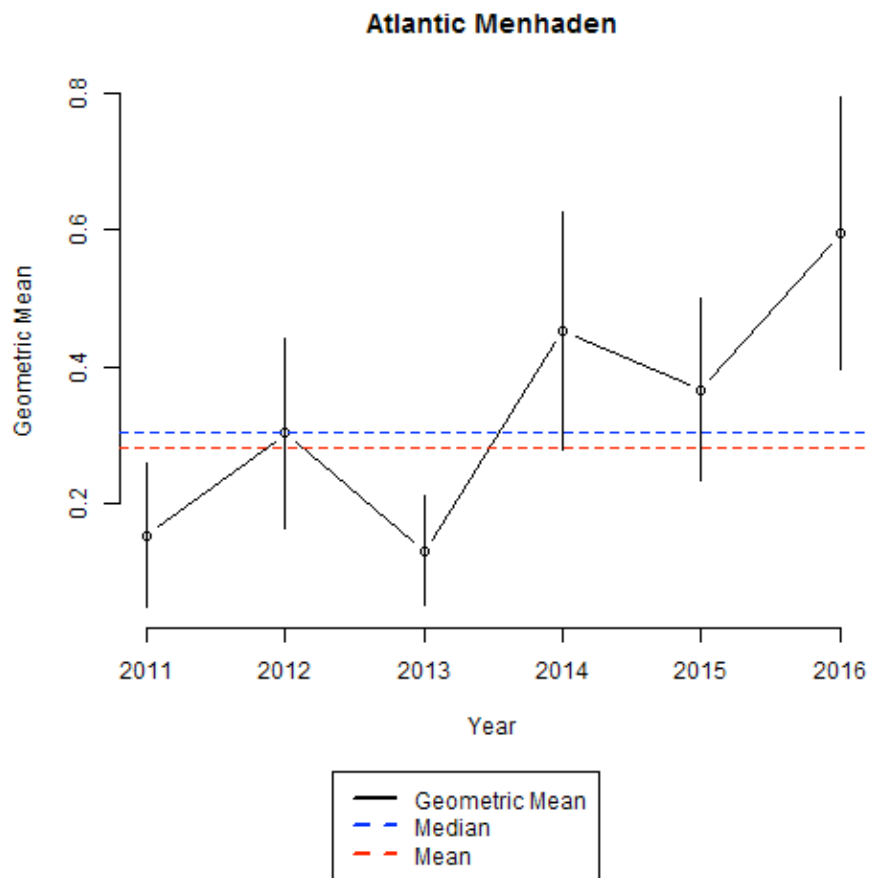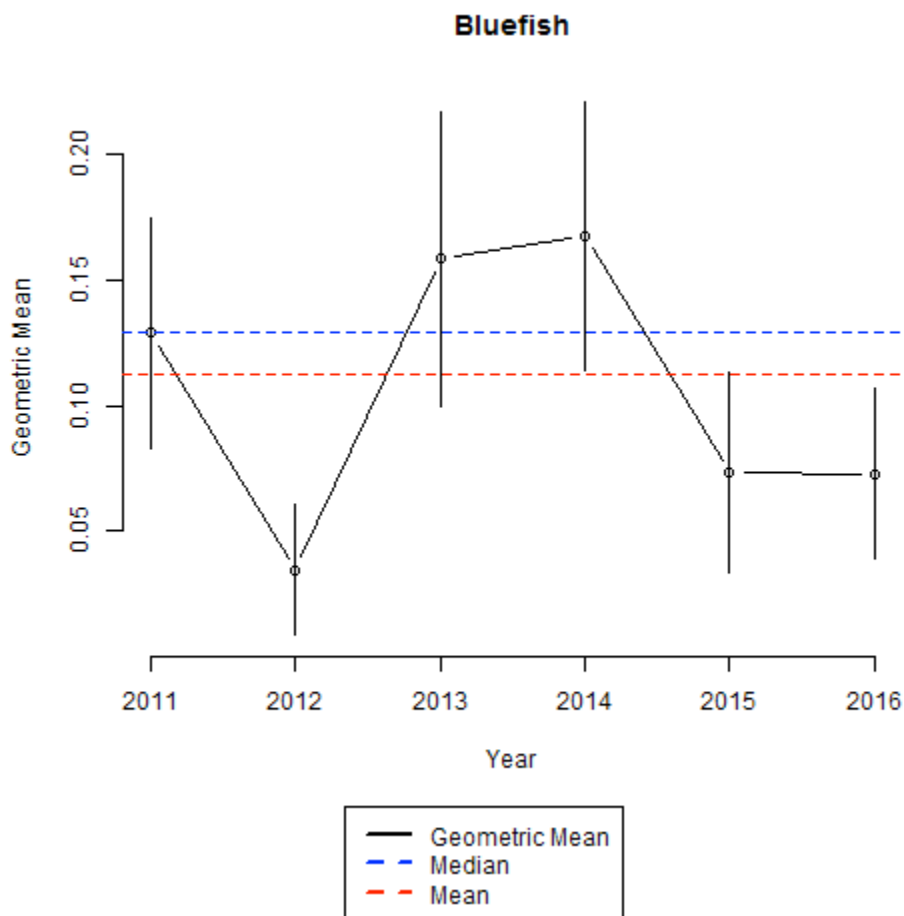

Figure 11. Geometric mean catch-per-seine for Atlantic Menhaden, with the time series mean and median.
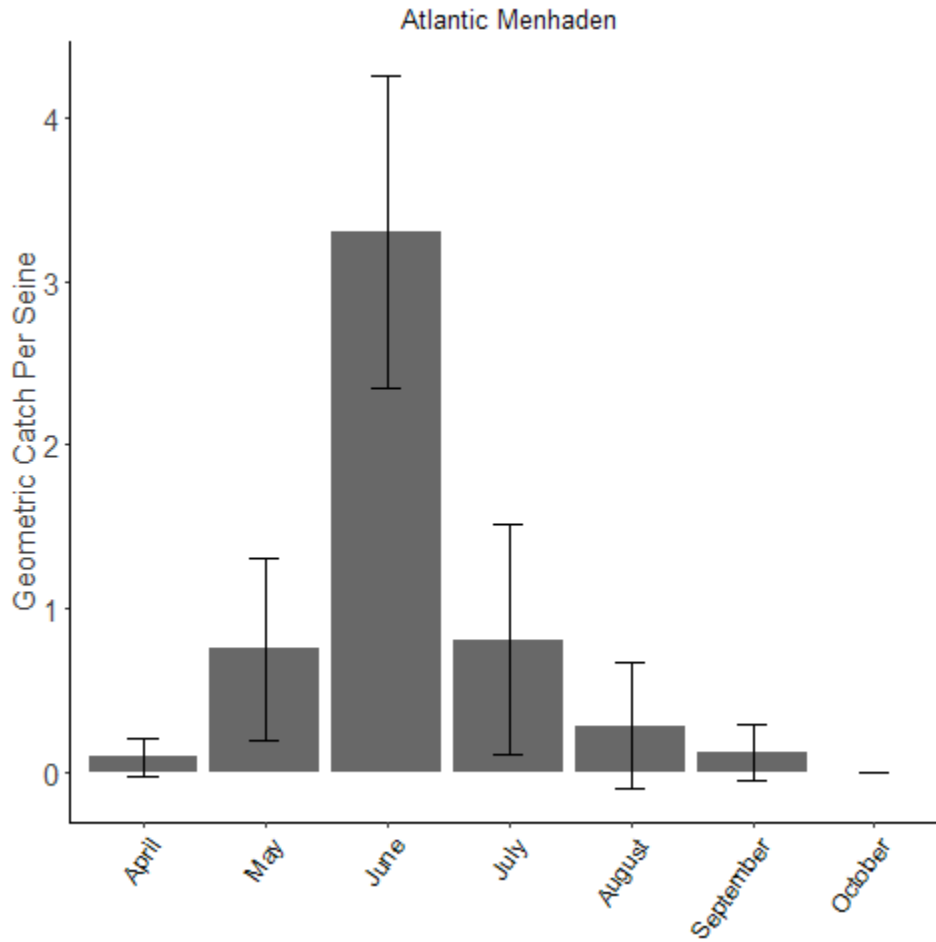
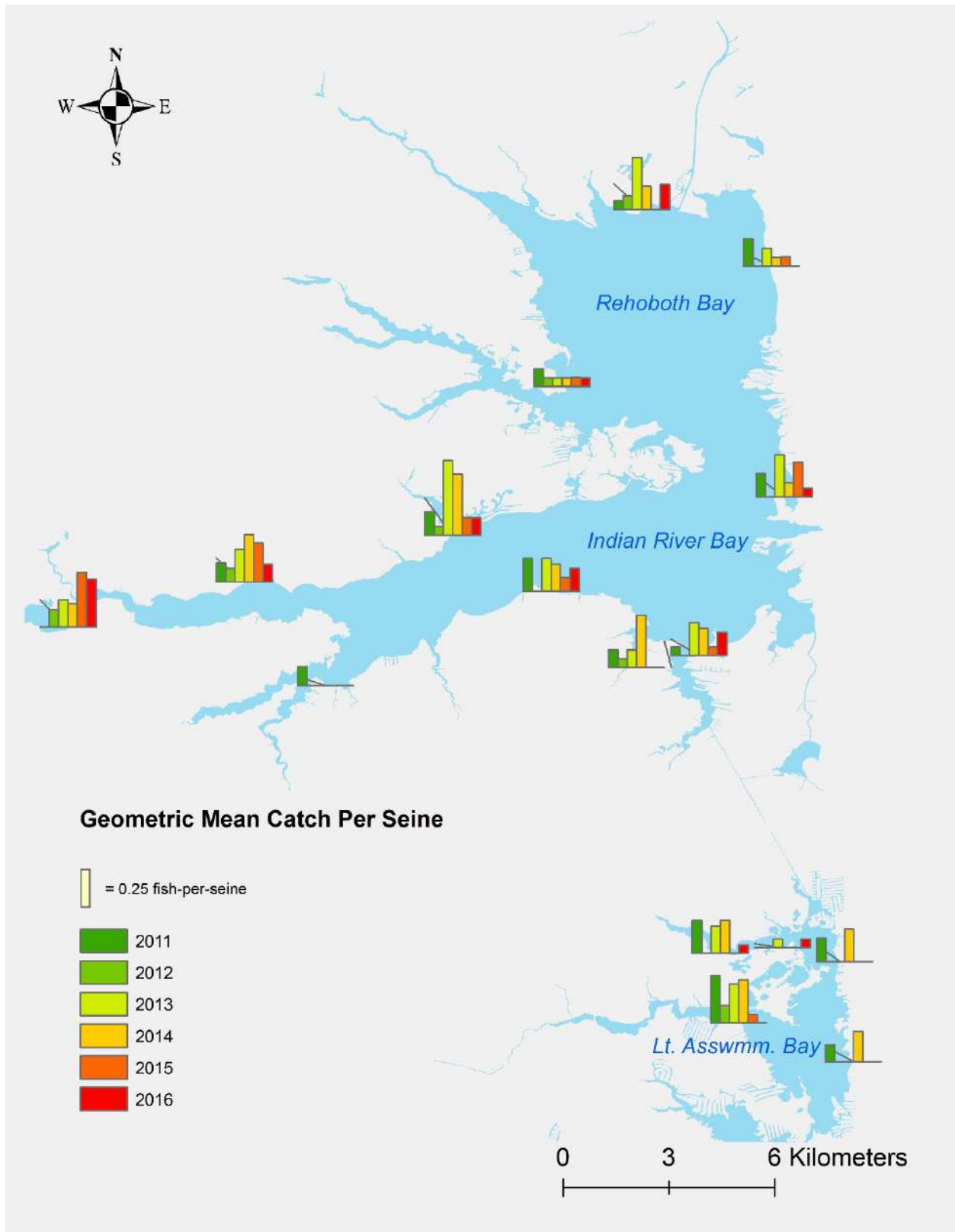**Figure 12. Geometric mean catch-per-seine during 2016 for Atlantic Menhaden by month.**
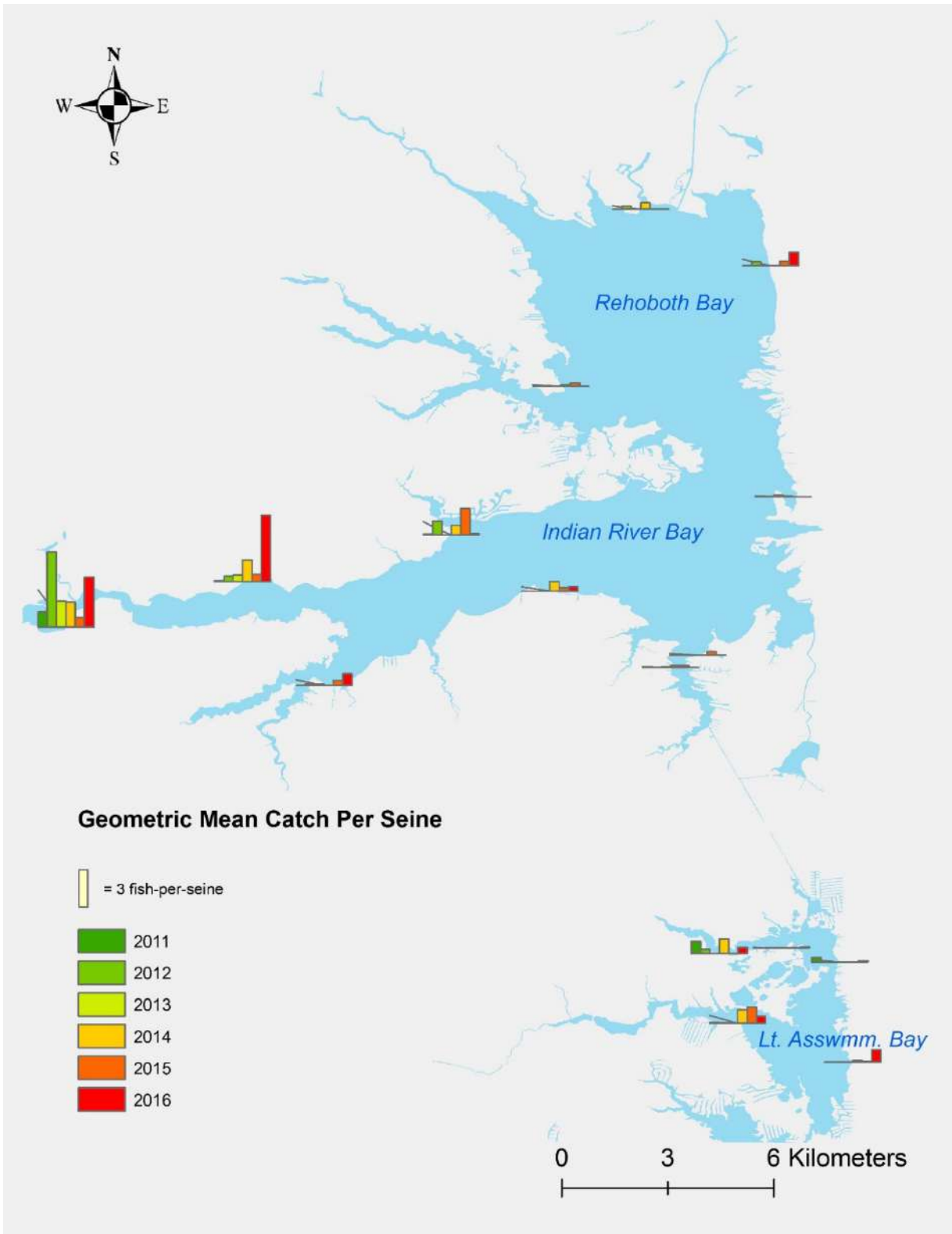
Figure 13. Geometric mean catch-per-seine since 2011 for Atlantic Menhaden by site.

Atlantic Silverside

A total of 18,287 Atlantic Silversides were caught in 2016, for a geometric mean catch of 24.15 fish per seine, down from 2015, but greater than the time series mean and median (Figure 14). Atlantic Silversides are a critical forage species in the Inland Bays, and are consistently one of the top five most abundant species in this survey. The most productive month was August (Figure 15), but the species is abundant and widespread throughout the Inland Bays during all survey months. This species utilizes the inshore areas throughout its life cycle, with large numbers of Silversides caught at all size classes for this species (Figure 7). Significantly, more Silverside were caught in Indian River Bay than were caught in Little Assawoman Bay ($p < 0.01$) and Rehoboth Bay ($p < 0.05$) during 2016 (Figure 16). Silverside abundance was also positively correlated with both water temperature and salinity ($p < 0.001$, $p < 0.001$; Table 4).
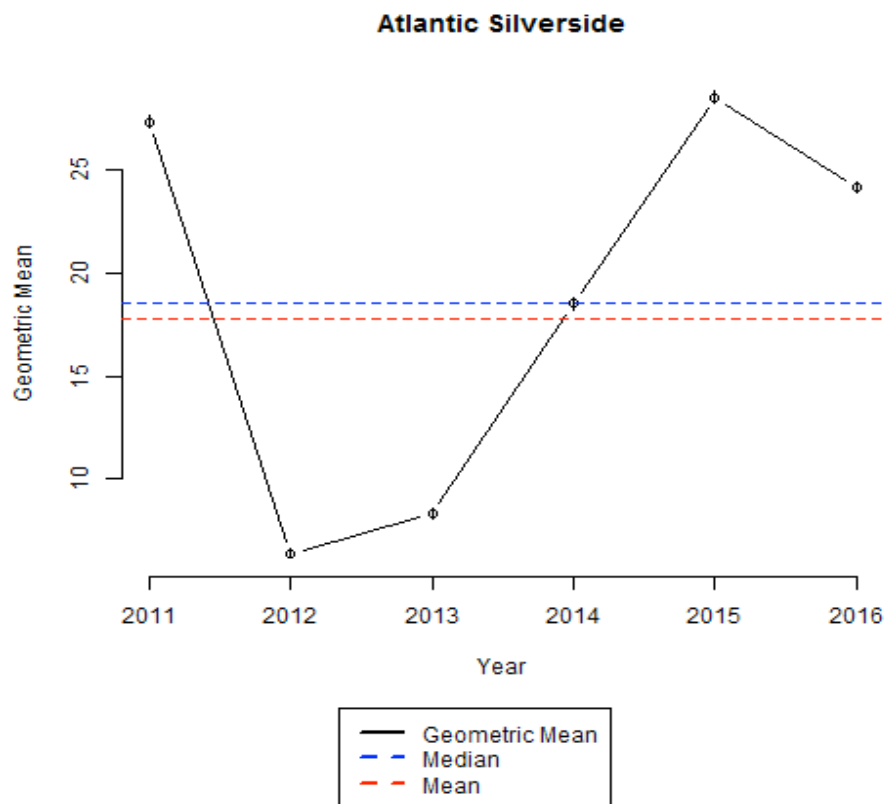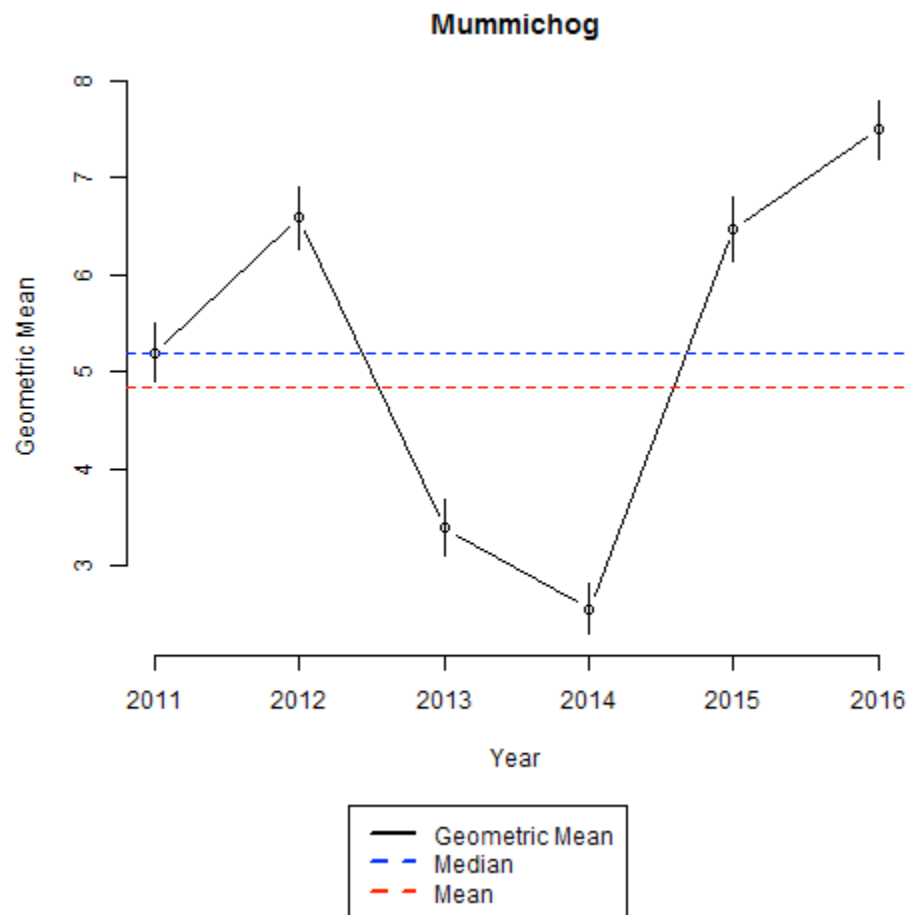

Figure 14. Geometric mean catch-per-seine for Atlantic Silverside, with the time series mean and median.
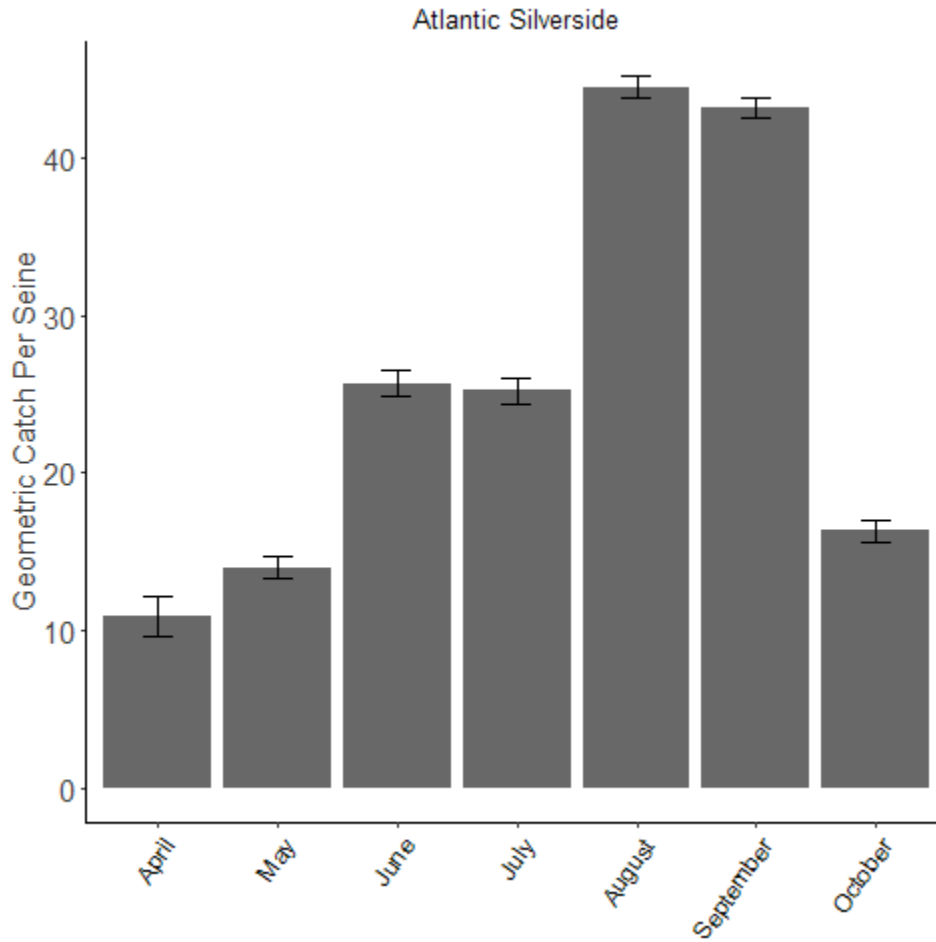
Figure 15. Geometric mean catch-per-seine during 2016 for Atlantic Silverside by month.

Figure 16. Geometric mean catch-per-seine since 2011 for Atlantic Silverside by site.

Bay Anchovy

2,122 Bay Anchovy were caught in 2016 for a geometric mean catch of 0.295 fish per seine, below the time series mean and median (Figure 17). The number of Bay Anchovy caught during 2016 was numerically the largest amount caught by this survey to date, however, the catch was composed of a handful of seines with large amounts of Bay Anchovy, and therefore resulted in a reduced geometric mean. The consistently greater catch numbers from the DNREC study suggest that while Bay Anchovy are an important inshore species based on relative abundance to other fish, the majority of Bay Anchovy utilize the open waters sampled by DNREC, as opposed to the inshore habitats sampled in this study. As in previous years, the peak month for Bay Anchovy abundance was August (Figure 18; Kernehan et al. 2016; McGowan et al. 2017). The majority of Bay Anchovy caught were between 30 and 65 mm in length. Bay Anchovy abundance was greater in Indian River Bay than Little Assawoman Bay during 2016 ($p < 0.05$), and Bay Anchovy continued to show a preference for upper tributary or up river sites during 2016 (Figure 19).
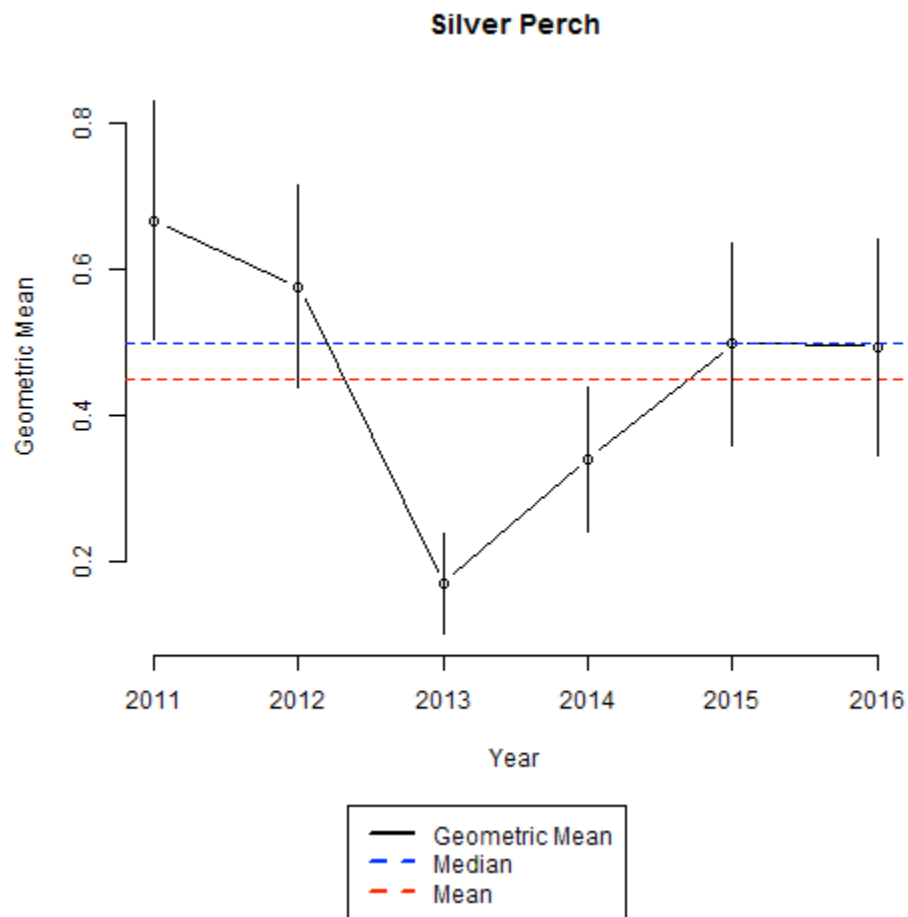

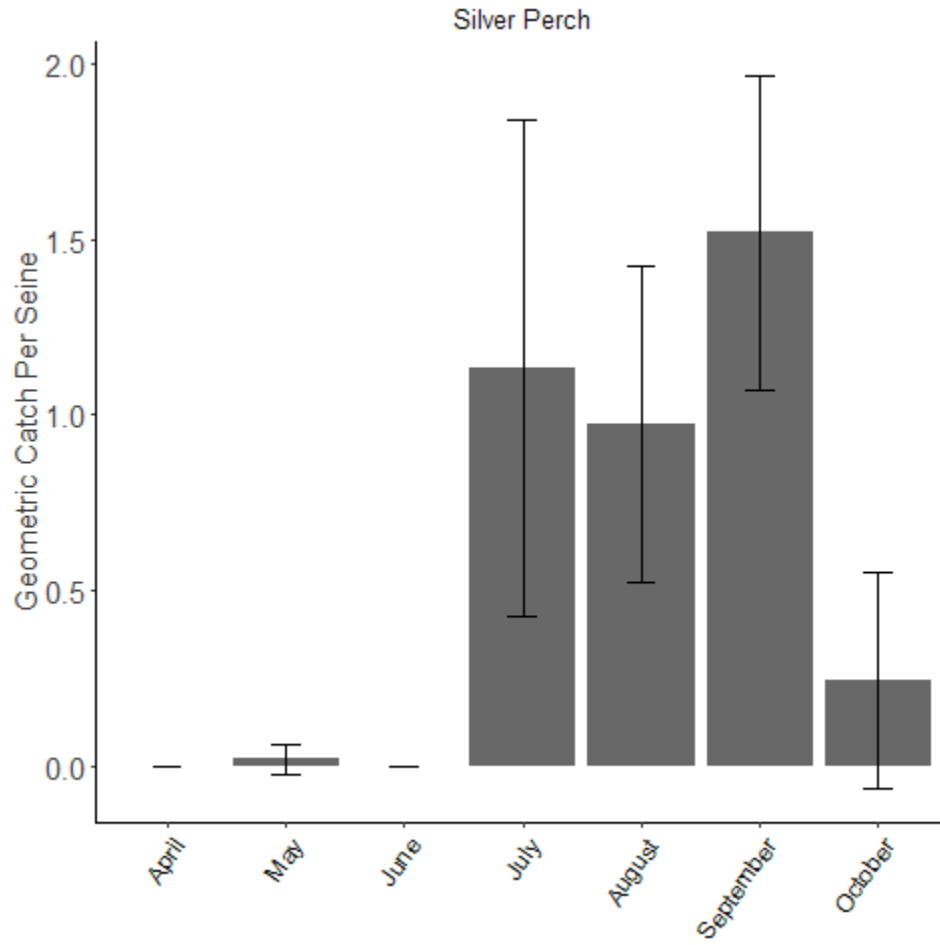Figure 17. Geometric mean catch-per-seine for Bay Anchovy, with the time series mean and median.

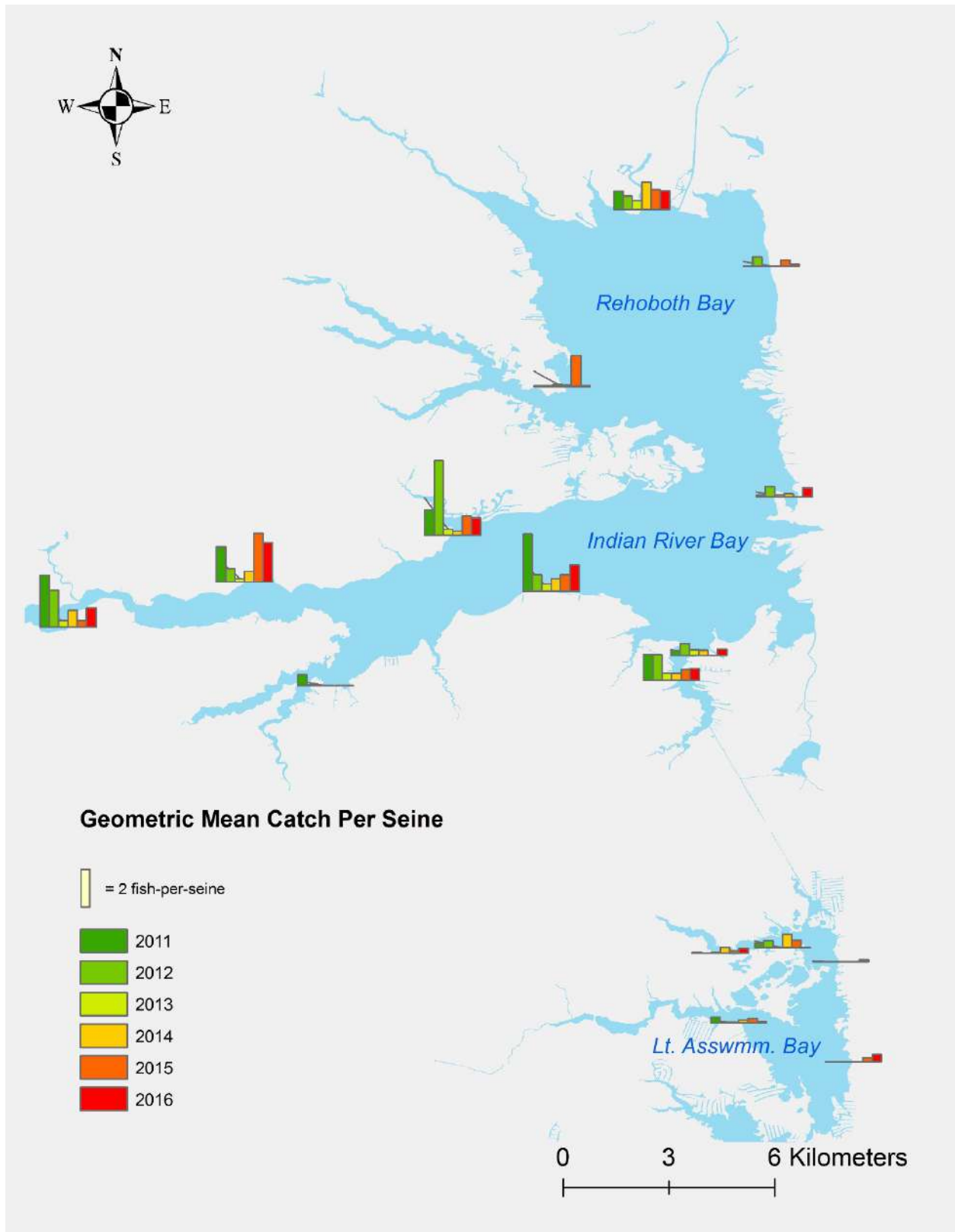**Figure 18. Geometric mean catch-per-seine during 2016 for Bay Anchovy by month.**

Figure 19. Geometric mean catch-per-seine since 2011 for Bay Anchovy by site.

Bluefish

A total of 25 Bluefish were captured in 2016, for a geometric mean catch of 0.072 fish per seine, below the time series mean and median (Figure 20). The majority of Bluefish were caught in June, a seasonal pattern seen every survey year so far (Figure 21; McGowan et al. 2017). No Bluefish exceeded 170 mm in length, suggesting that adults and larger juveniles do not use the inshore areas sampled in this study or are unable to be captured by the gear employed.
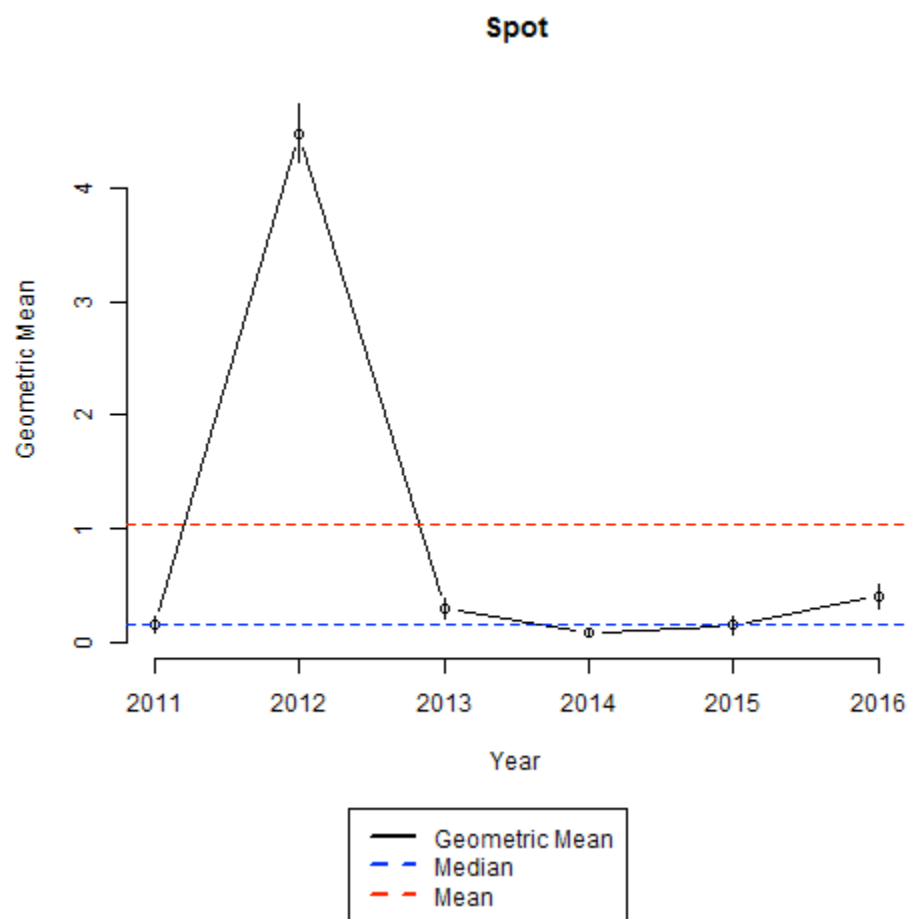

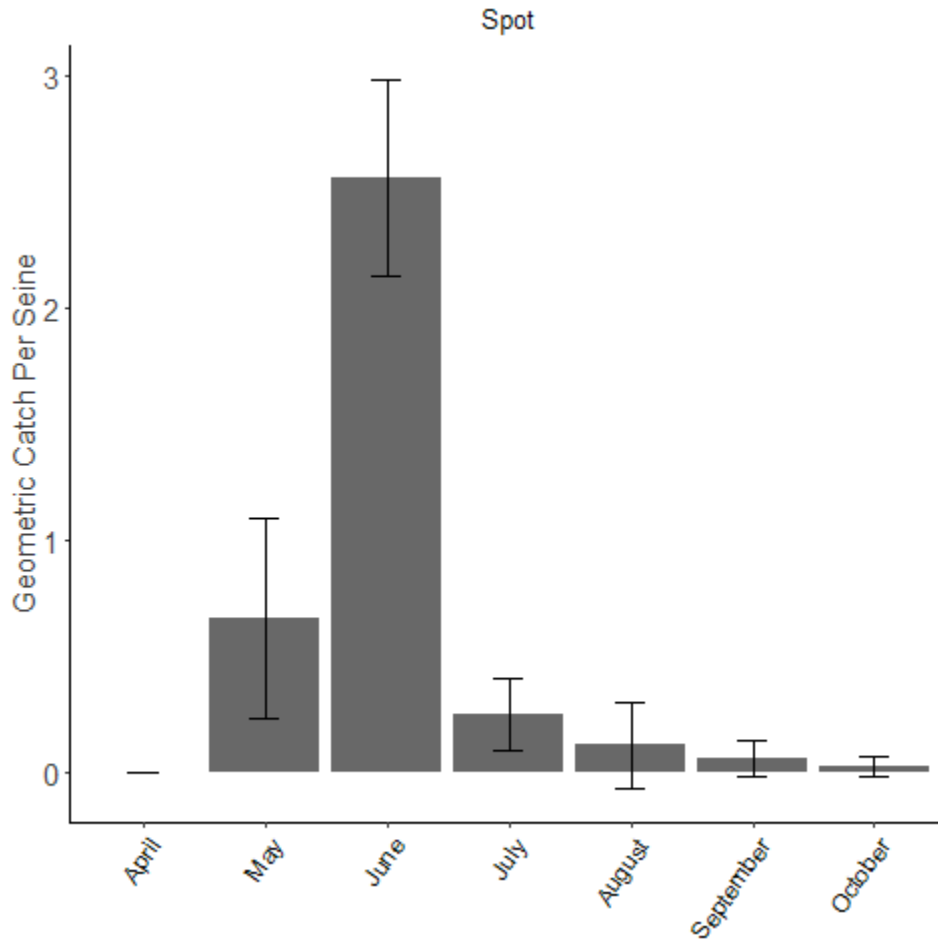Figure 20. Geometric mean catch-per-seine for Bluefish, with the time series mean and median.
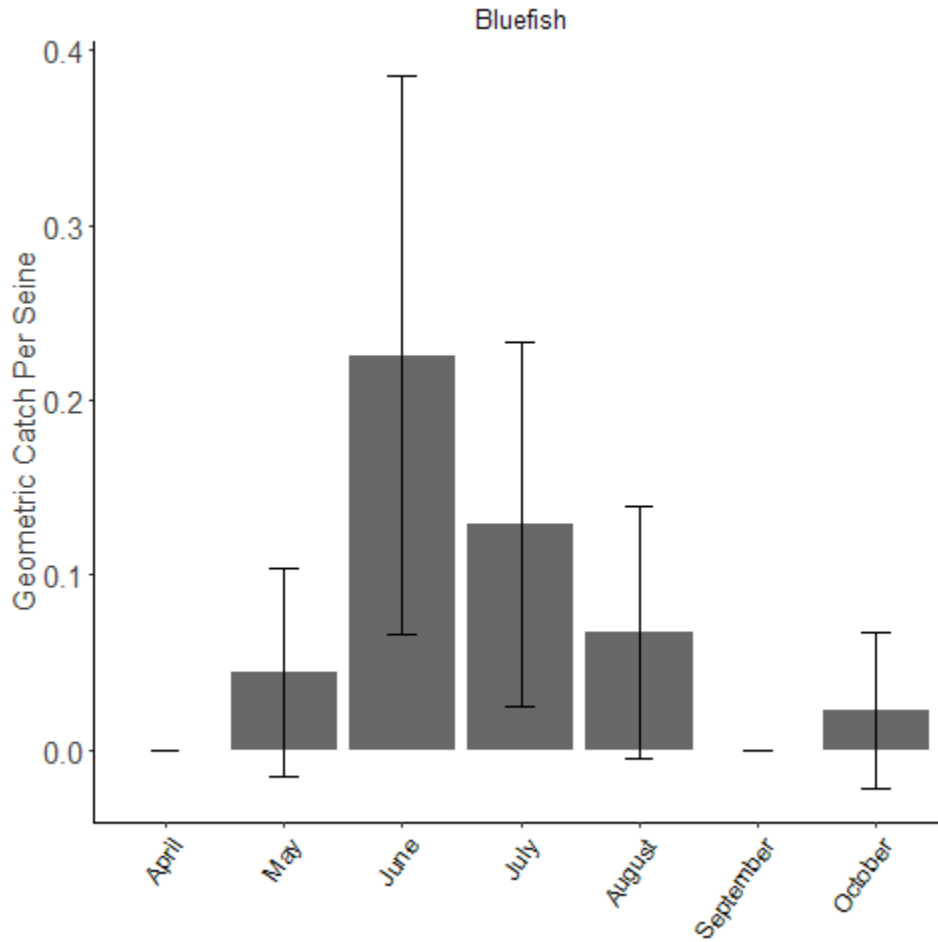
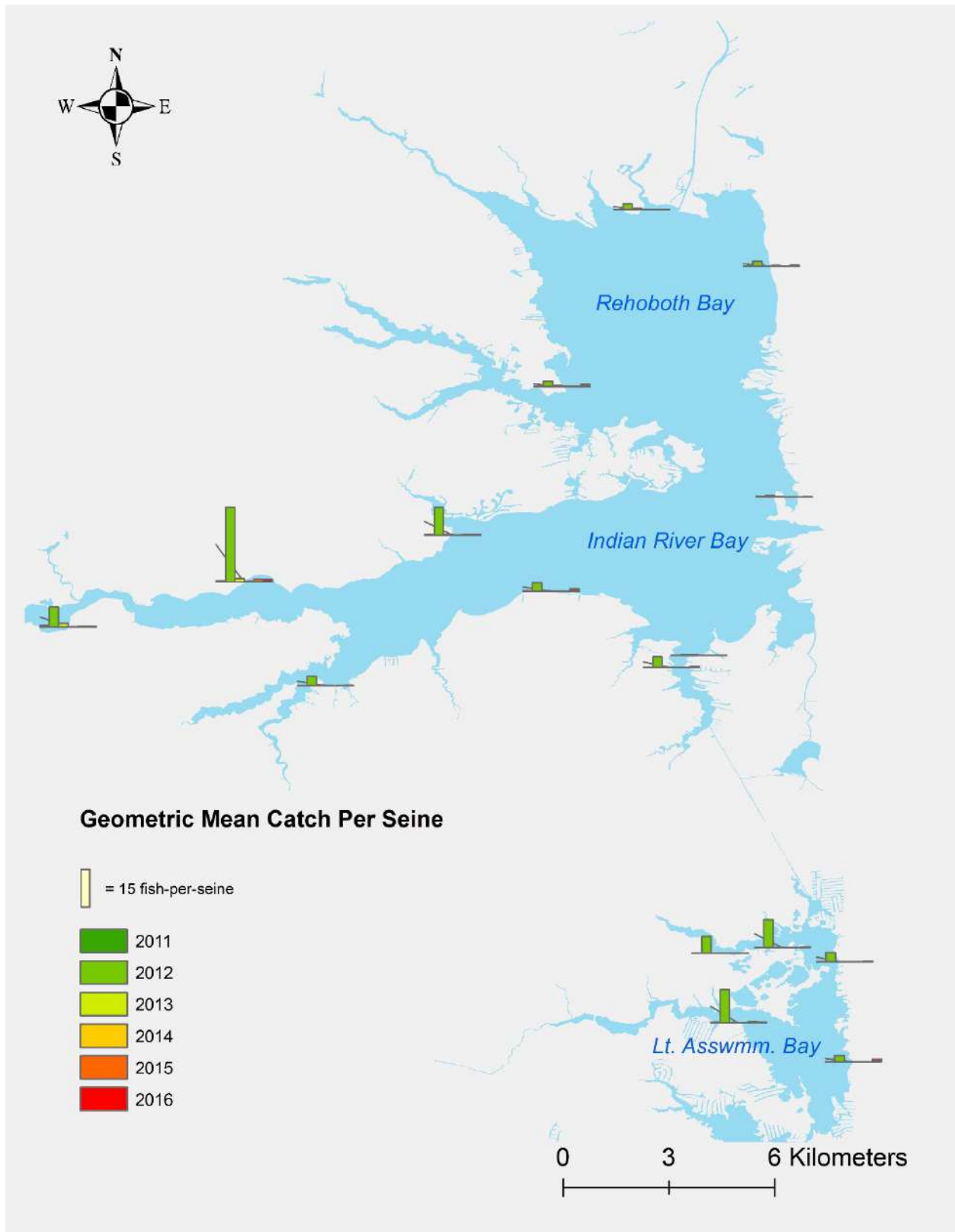**Figure 21. Geometric mean catch-per-seine during 2016 for Bluefish by month.**

Figure 22. Geometric mean catch-per-seine since 2011 for Bluefish by site.

Mummichog

A total of 12,617 Mummichog were caught in 2016, for a geometric mean 7.48 fish per seine, up from 2015 and above the time series mean and median (Figure 23). Mummichog were present in large numbers every month, but a noticeable peak in abundance occurred during June, and a noticeable reduction in abundance occurred during September and October (Figure 24). This pattern has also been observed cumulatively over the previous 5 years (McGowan et al. 2017). All size classes of Mummichog were present, confirming the importance of inshore areas to this species. Mummichog abundance was not significantly different between the three bays but activity was lower in the northern and eastern sites in Rehoboth Bay (Figure 25).
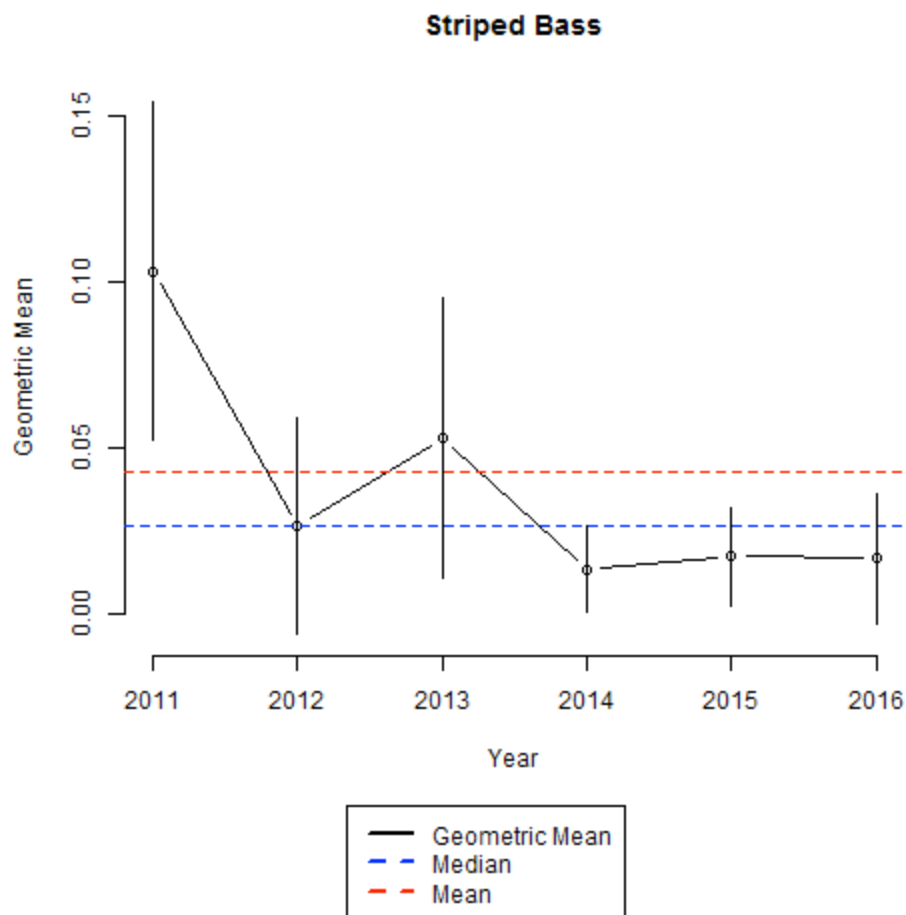

Figure 23. Geometric mean catch-per-seine for Mummichog, with the time series mean and median.
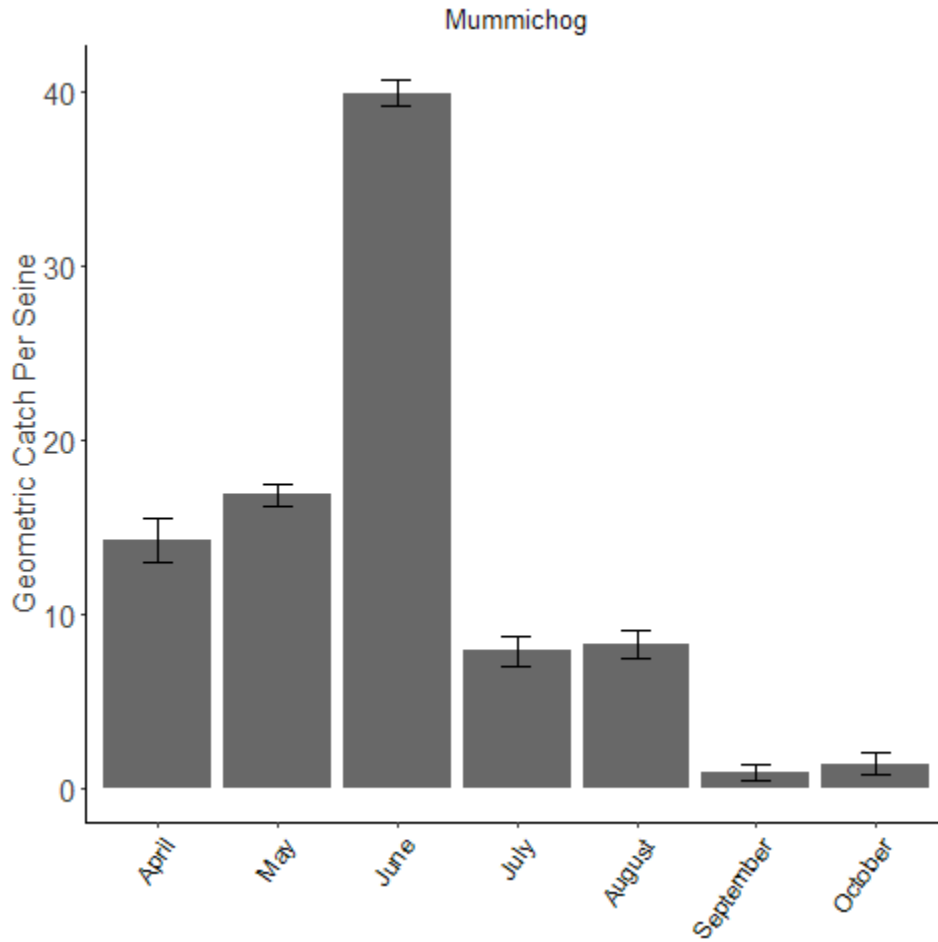
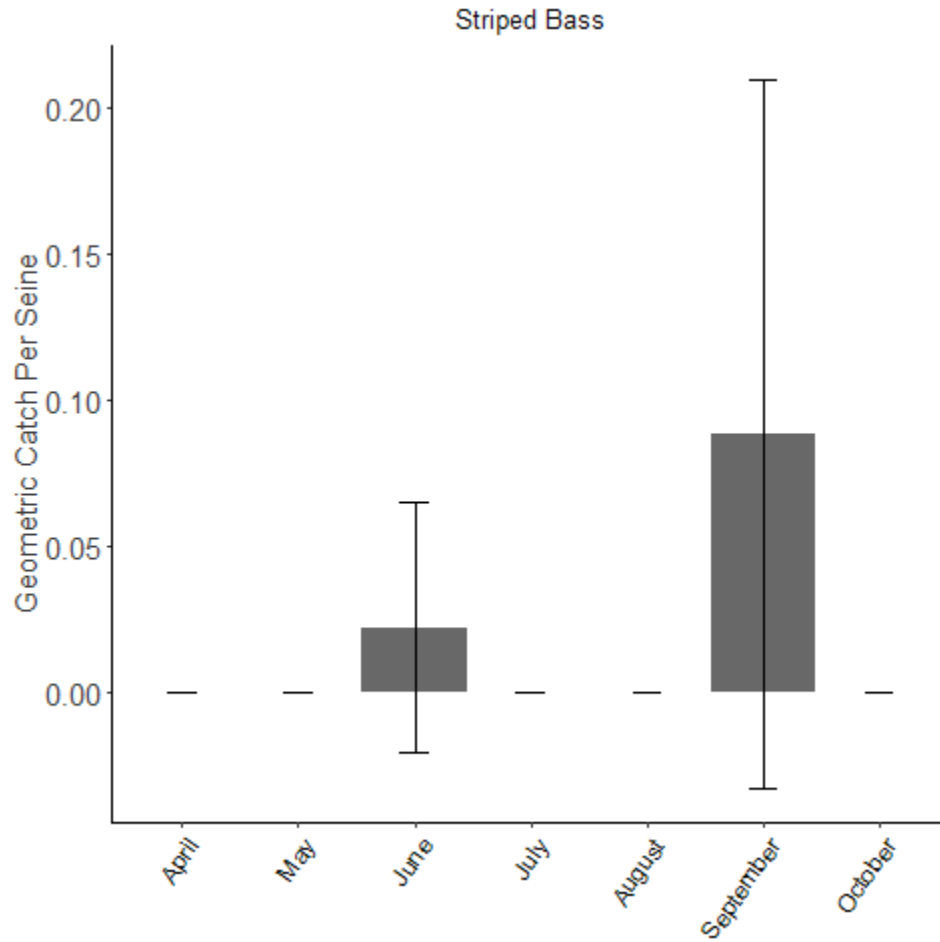**Figure 24. Geometric mean catch-per-seine during 2016 for Mummichog by month.**
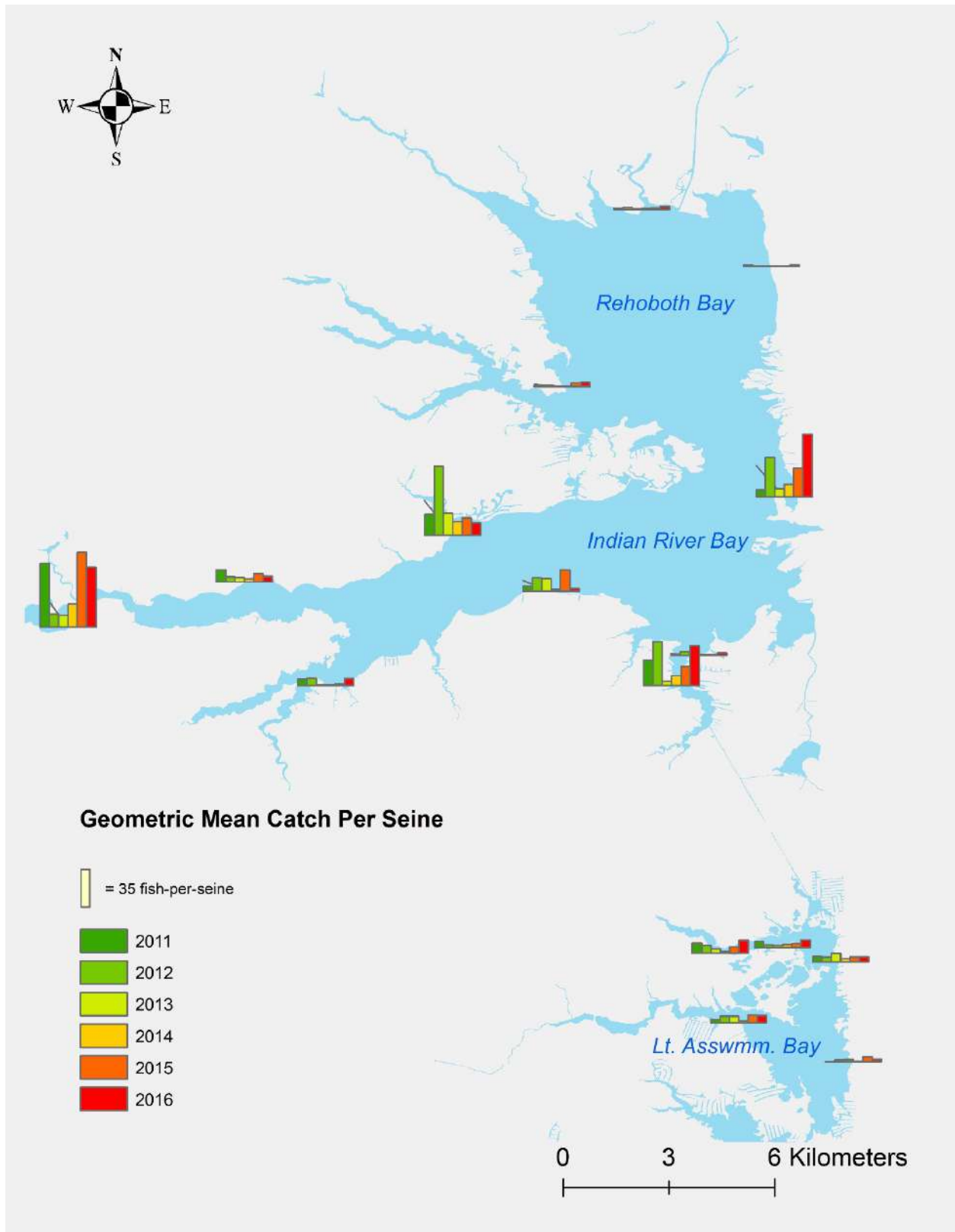
Figure 25. Geometric mean catch-per-seine since 2011 for Mummichog by site.

Silver Perch

1,533 Silver Perch were caught in 2016, for a geometric mean of 0.49 fish per seine, less than 2015 and below the time series mean but above the time series median (Figure 26). Unlike the previous 5 years, the most productive month for Silver Perch was September, rather than August (Figure 27). The majority of Silver Perch caught were less than 100 mm in length, indicating that young-of-the-year utilize inshore areas, but juveniles and adults move to deeper portions of the estuary. Silver perch abundance did not differ between the bays, but activity is in general higher in Indian River than in Rehoboth or Little Assawoman Bays (Figure 28).

Figure 26. Geometric mean catch-per-seine for Silver Perch, with the time series mean and median.

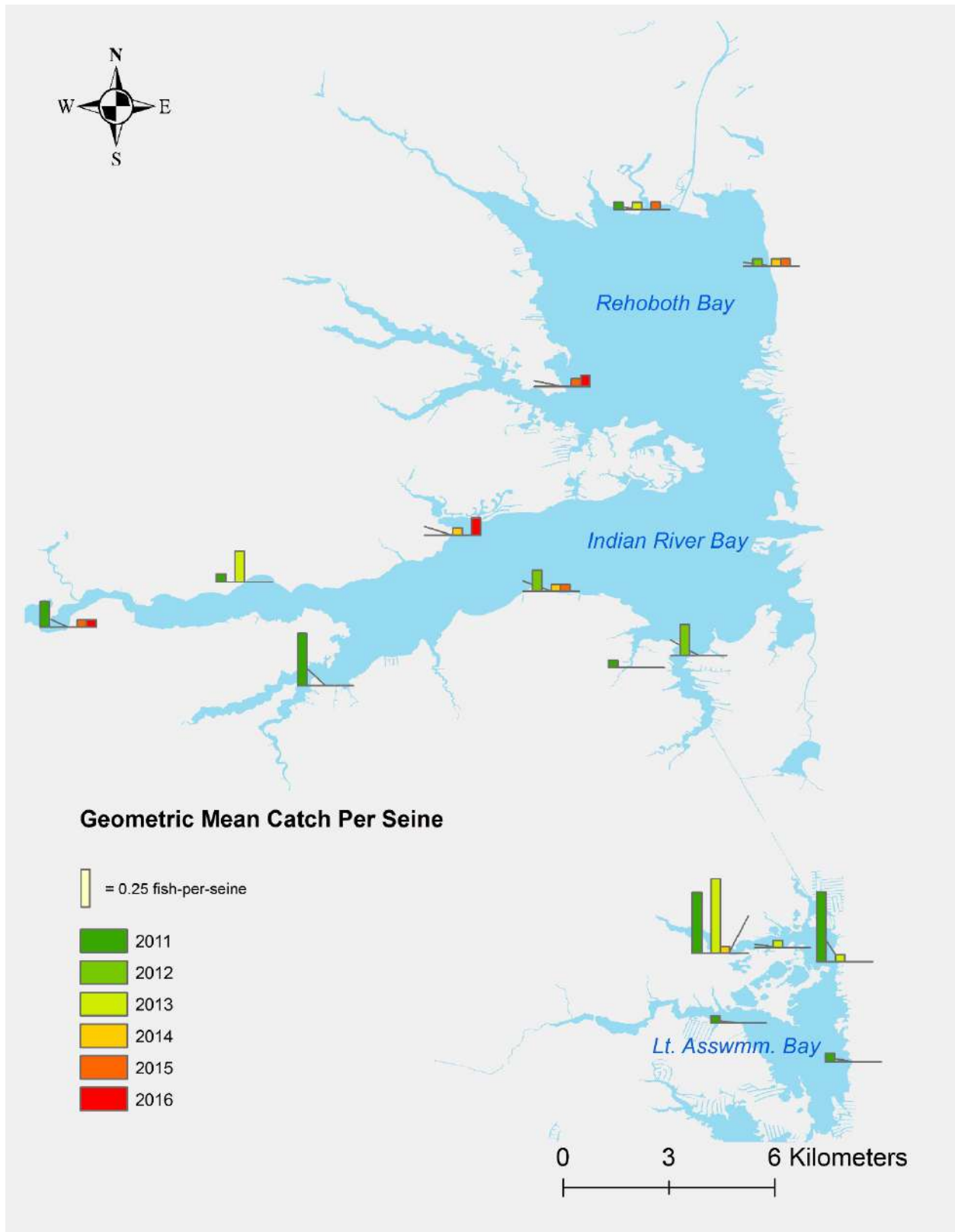**Figure 27. Geometric mean catch-per-seine during 2016 for Silver Perch by month.**

Figure 28. Geometric mean catch-per-seine since 2011 for Silver Perch by site.

Spot

A total of 371 Spot were caught in 2016, for a geometric mean of 0.40 fish per seine, more than 2015 and above the time series median but below the mean (Figure 29). Spot exhibit dramatic annual differences in abundance of young-of-the-year (Pacheco and Grant 1973; Able and Fahay 2010). June was the peak month for Spot in 2016 (Figure 30), corresponding to the seasonality seen in previous years (McGowan et al. 2017). The majority of Spot were less than 75 mm in length. Spot abundance did not differ between the three bays (Figure 31).
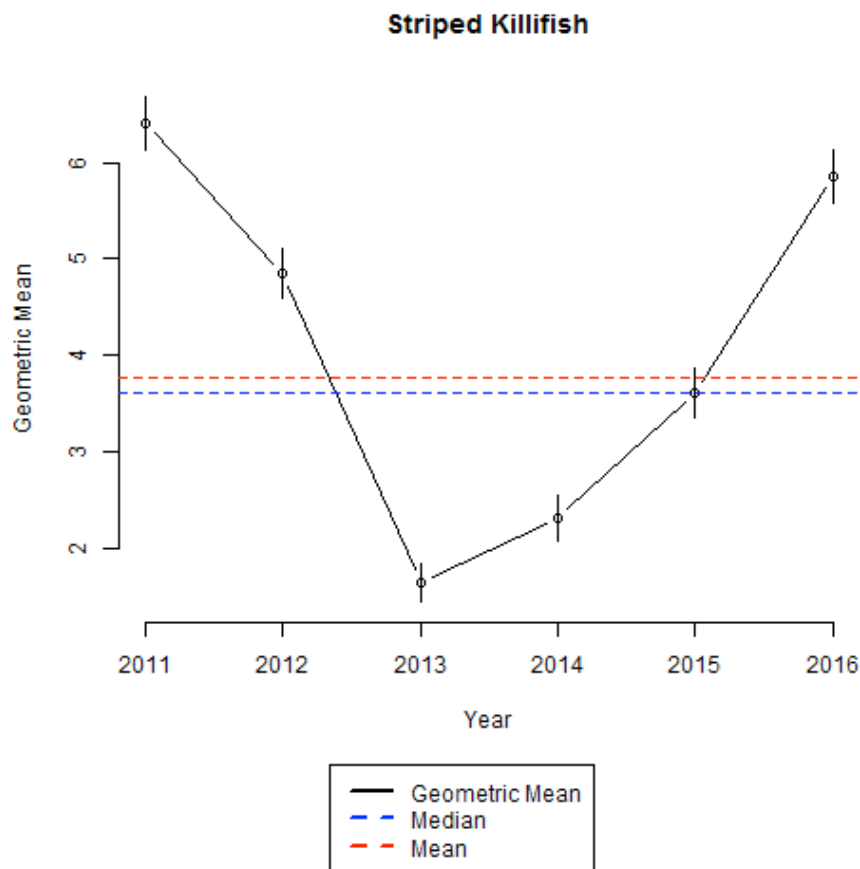

Figure 29. Geometric mean catch-per-seine for Spot, with the time series mean and median.

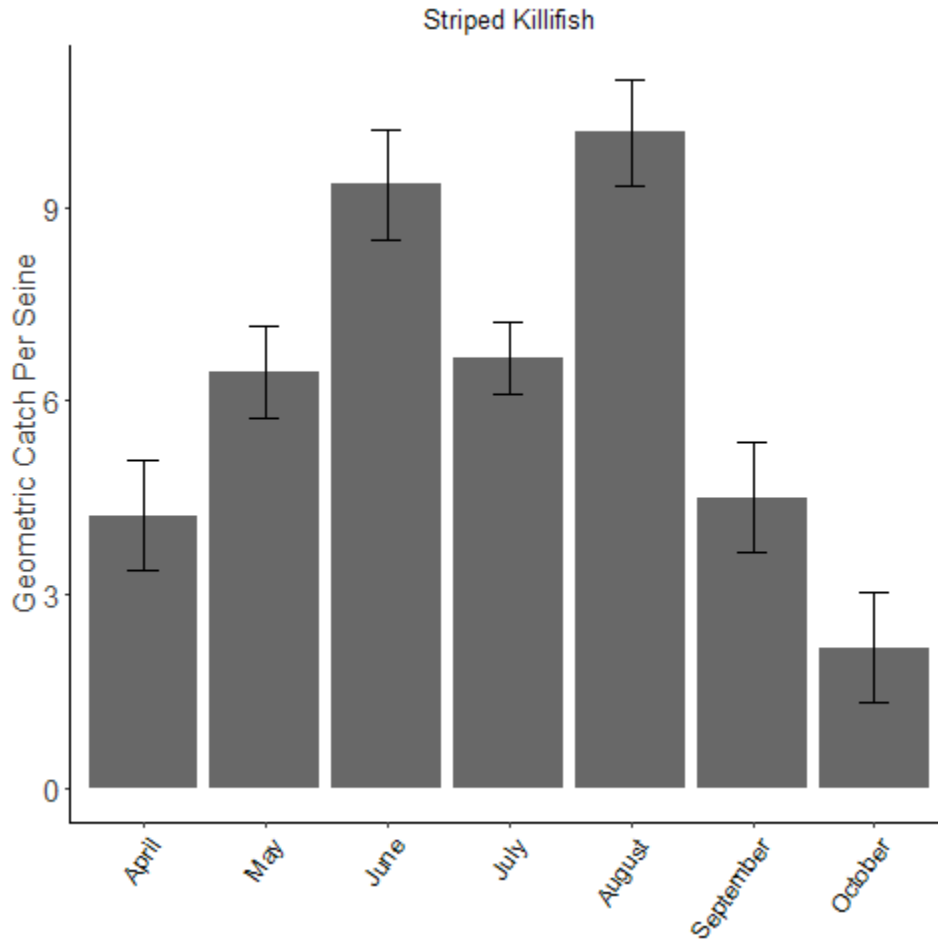**Figure 30. Geometric mean catch-per-seine during 2016 for Spot by month.**

Figure 31. Geometric mean catch-per-seine since 2011 for Spot by site.

Striped Bass

Similar to all previous survey years, the inshore areas were not heavily utilized by Striped Bass in 2016. Only 7 fish were caught, for a geometric mean of 0.01 fish per seine, less than the time series mean and median (Figure 32). Most individuals taken in the first 6 years of the survey have been juveniles measuring less than 200 mm in length. The majority of individuals were taken in September, and abundance did not differ between the bays (Figure 33-34).

Figure 32. Geometric mean catch-per-seine for Striped Bass, with the time series mean and median.

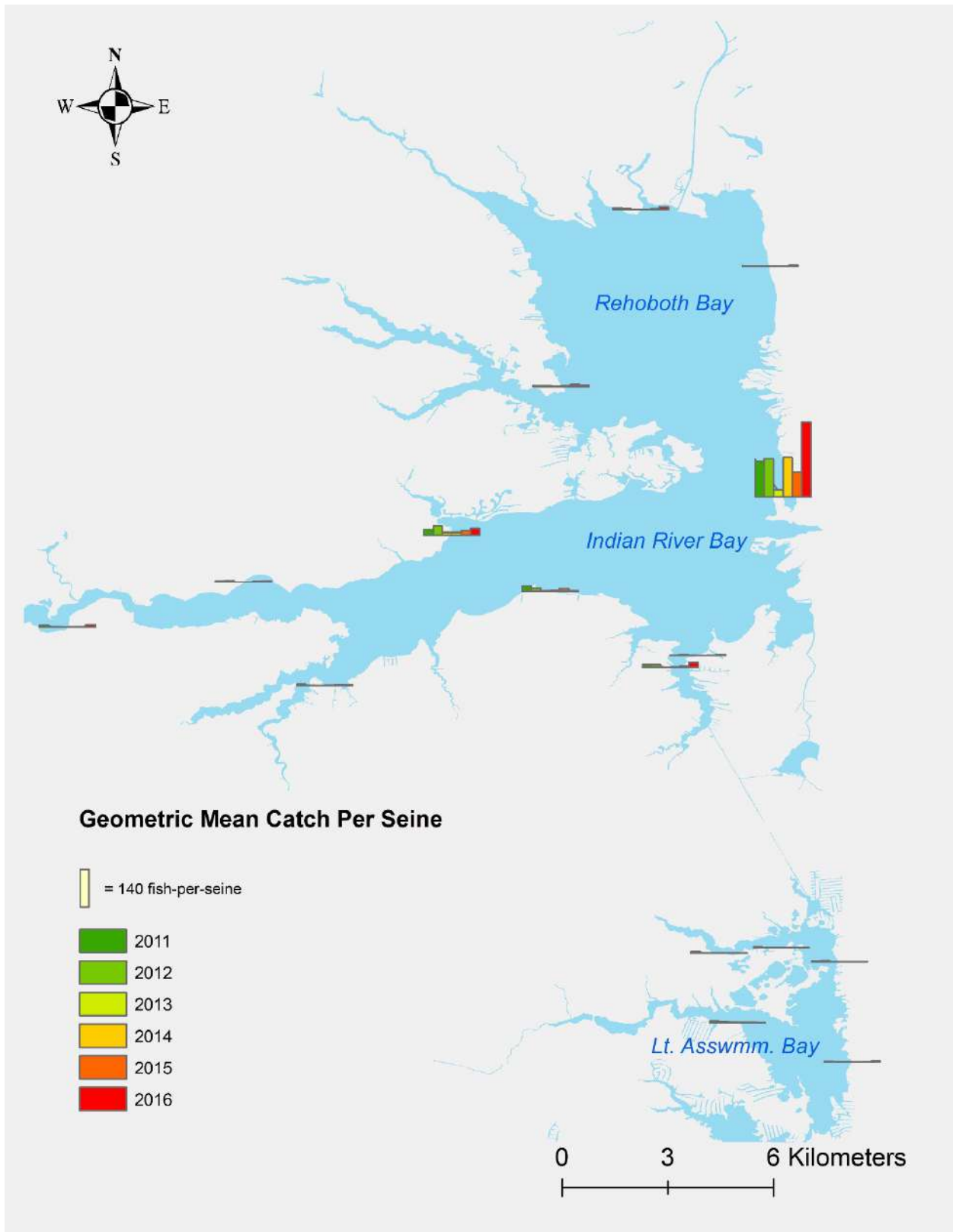**Figure 33. Geometric mean catch-per-seine during 2016 for Striped Bass by month.**

Figure 34. Geometric mean catch-per-seine since 2011 for Striped Bass by site.

Striped Killifish

10,778 Striped Killifish were caught in 2016, for a geometric mean of 5.84 fish per seine, greater than 2015 and above the time series mean and median (Figure 35). Like Atlantic Silversides and Mummichog, Striped Killifish are consistently one of the top three most abundant species every year. All size classes are present throughout the survey period. Striped Killifish are widespread and abundant every month of the survey (Figure 36), indicating the importance of inshore areas to this species. Striped Killifish were significantly more abundant in Rehoboth Bay and Indian River Bay than in Little Assawoman Bay (p < 0.001, p < 0.001). Kayak Launch (Site #1) continued to have the greatest Striped Killifish abundance (Figure 37), likely due to its sandy sediment, vegetated shoreline, and high salinity waters, all factors preferred by Striped Killifish (Harvey 1998; Able and Fahay 2010; Balouskus and Targett 2016).
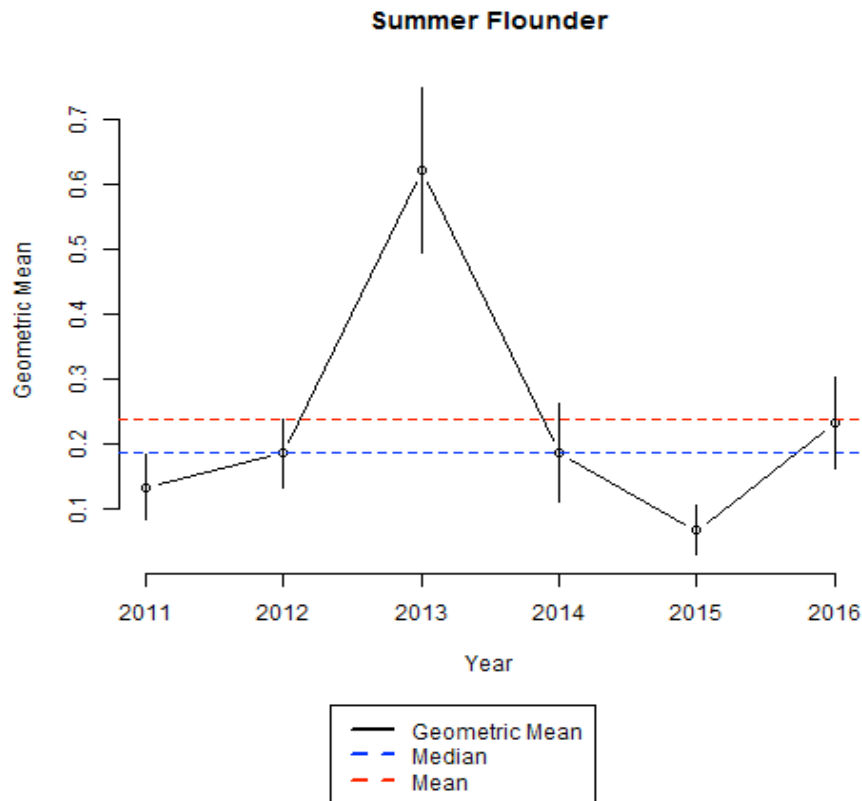

Figure 35. Geometric mean catch-per-seine for Striped Killifish, with the time series mean and median.
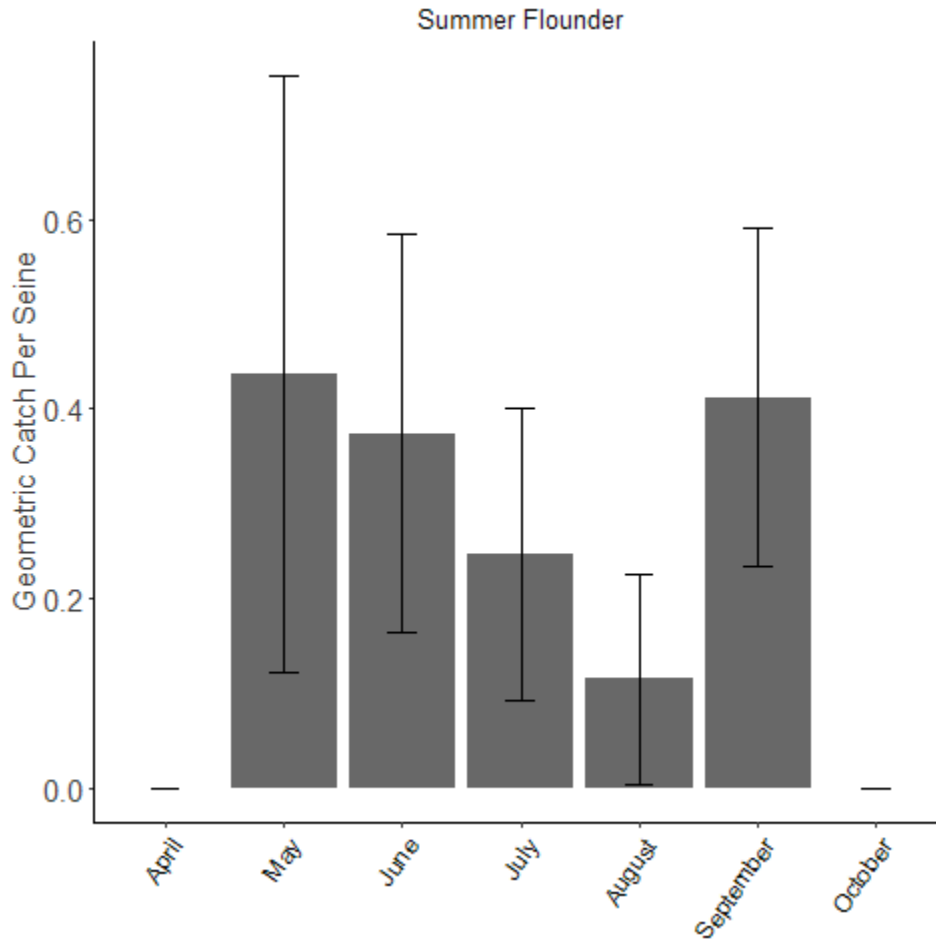
Figure 36. Geometric mean catch-per-seine during 2016 for Striped Killifish by month.

Figure 37. Geometric mean catch-per-seine since 2011 for Striped Killifish by site.

Summer Flounder

111 Summer Flounder were caught in 2016, for a geometric mean of 0.23 fish per seine, greater than 2015 and above the time series median but below the mean (Figure 38). As in previous survey years, small young-of-the-year flounder were caught primarily in early spring, with a peak in May (Figure 39), suggesting the inshore areas are used as nursery grounds by the young-of-the-year flounder, which then move into deeper waters during the summer months. We found the majority of Summer Flounder caught in 2016 measured less than 200 mm in length, the shortest length cutoff for young-of-the-year Summer Flounder used by the DNREC open water trawl survey (Greco et al. 2016), supporting the hypothesis that Summer Flounder transition to deeper waters as they grow and develop. Summer Flounder abundance was greater in Indian River Bay than in Rehoboth Bay ($p < 0.05$), and abundance continued to be greatest at the up river sites (Figure 40).
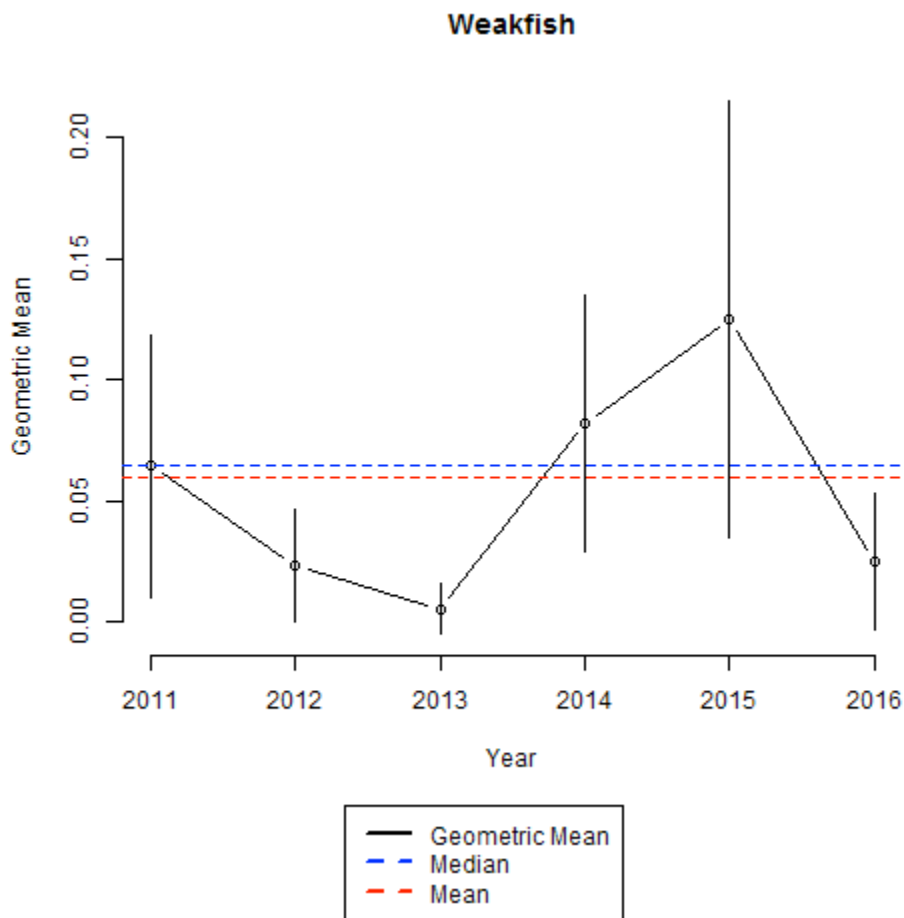

Figure 38. Geometric mean catch-per-seine for Summer Flounder, with the time series mean and median.

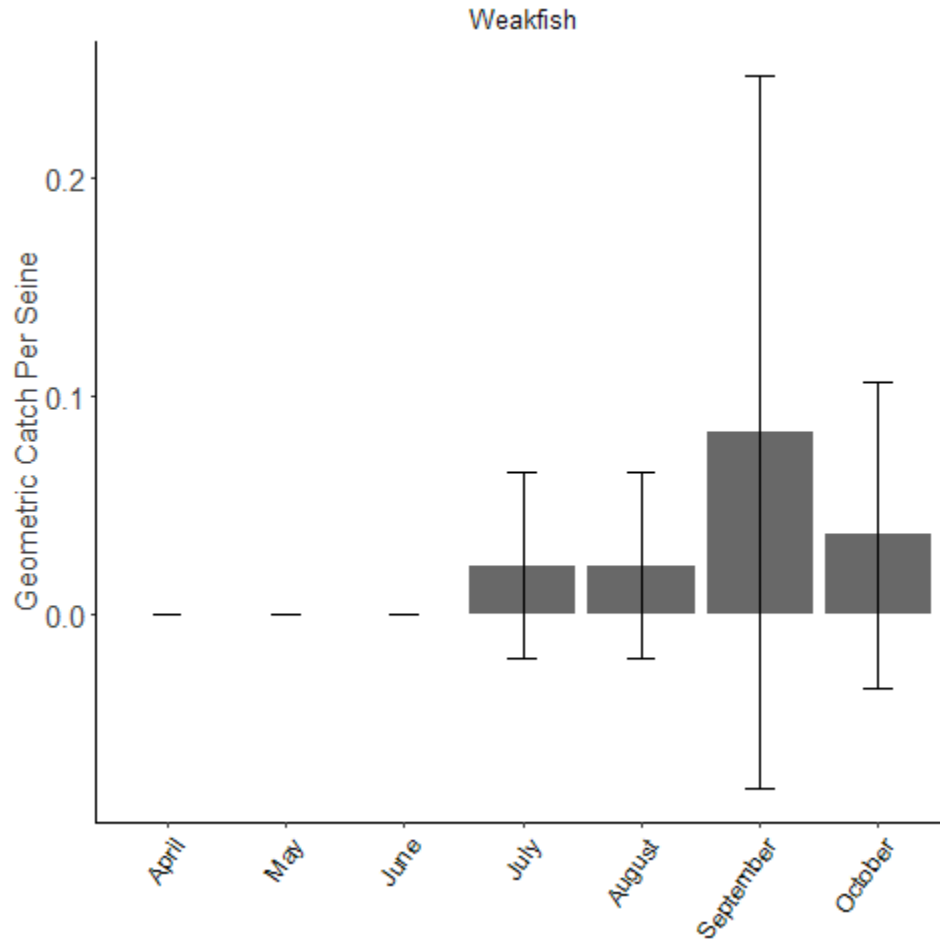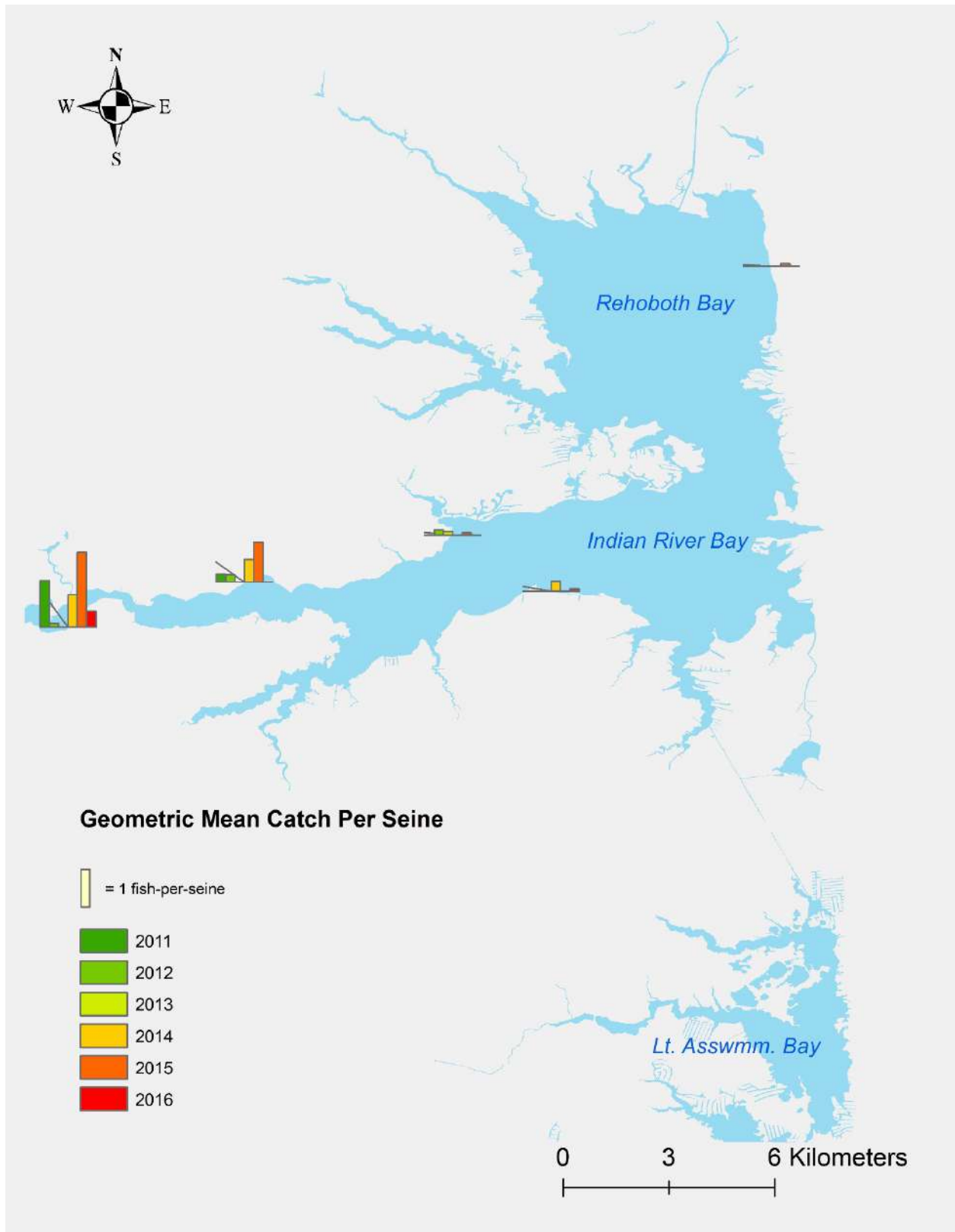**Figure 39. Geometric mean catch-per-seine during 2016 for Summer Flounder by month.**
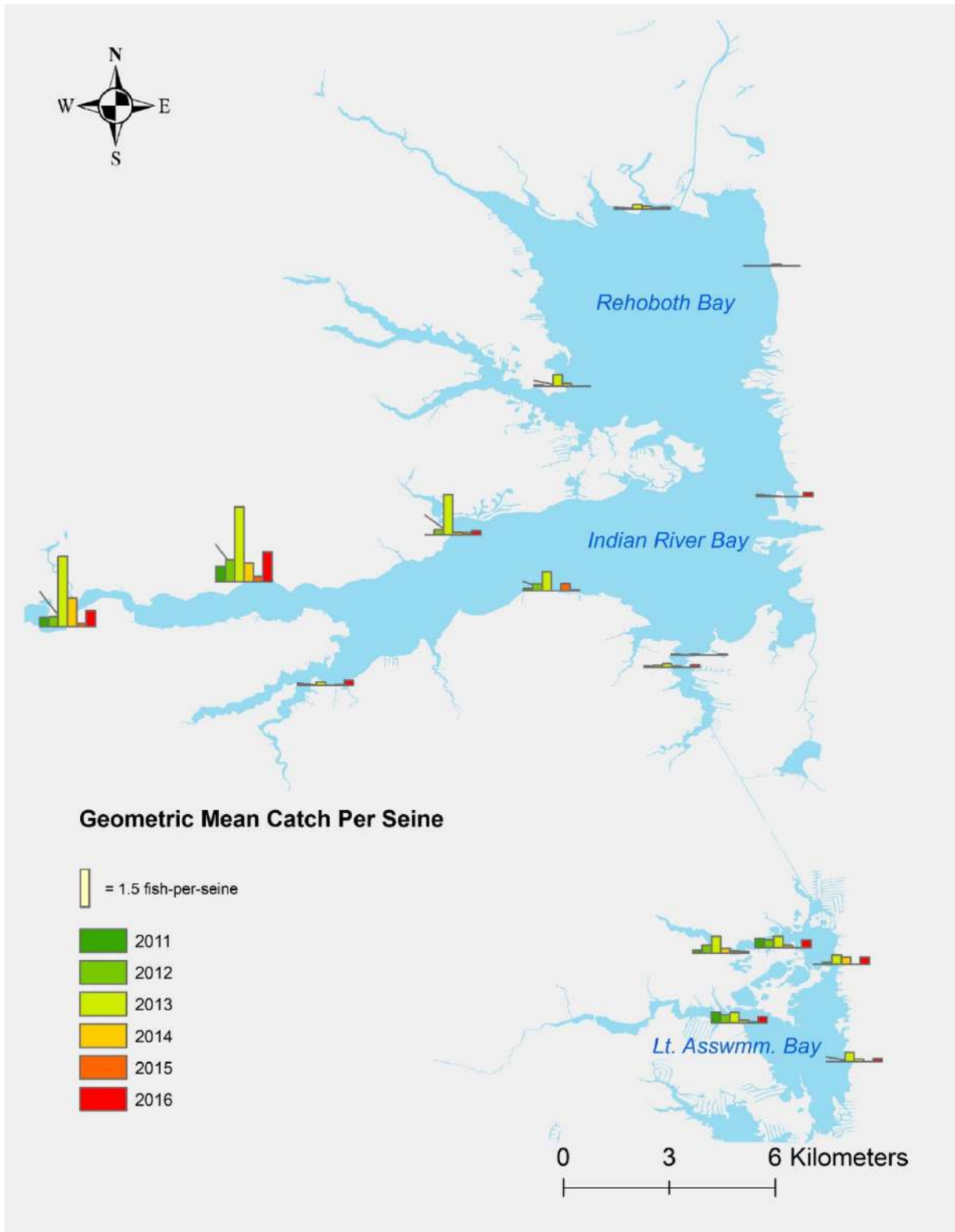
Figure 40. Geometric mean catch-per-seine since 2011 for Summer Flounder by site.

Weakfish

Only 16 Weakfish were caught in 2016, for a geometric mean of 0.02 fish per seine, far fewer than 2015 and below the times series mean and median (Figure 41). In 2015, over 400 individuals were caught in October alone, while in 2016, the peak month of occurrence was September, with 12 individuals being captured (Figure 42). Similar to previous years, the majority of Weakfish caught measured less than 75 mm in length. Weakfish abundance was not different between bays, though the furthest up river location (Sandy Beach #8) was the most productive site for Weakfish (Figure 43). Correspondingly, Weakfish were negatively correlated with salinity ($p < 0.01$; Table 4).
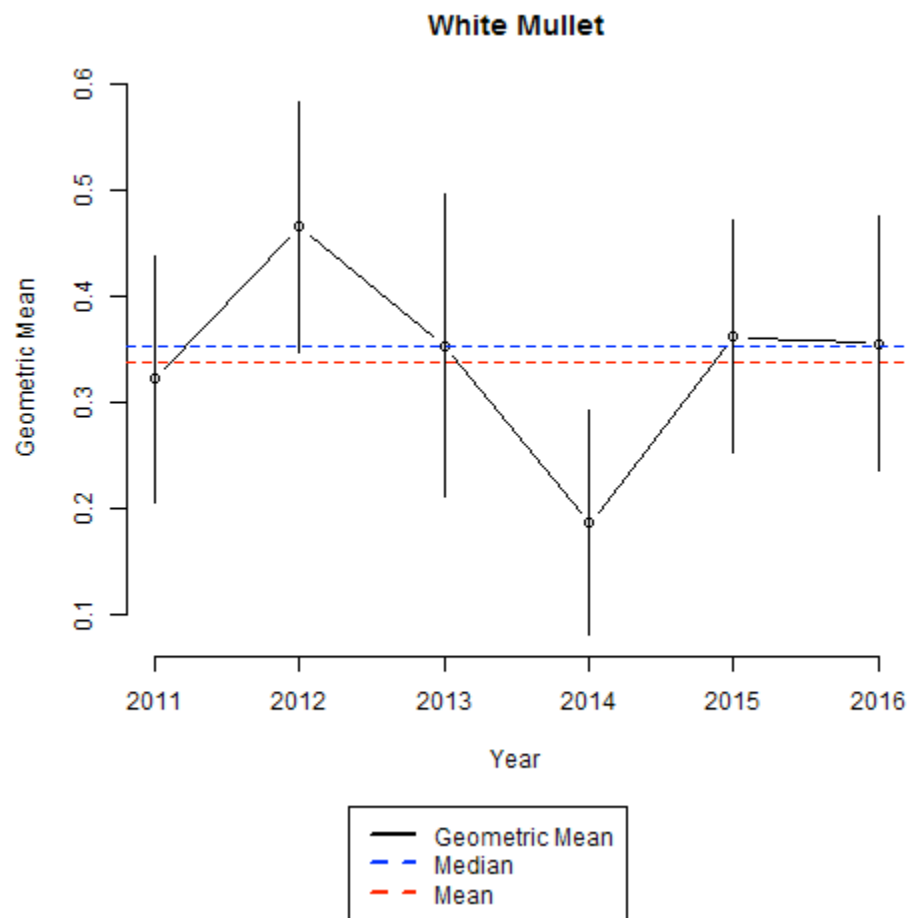

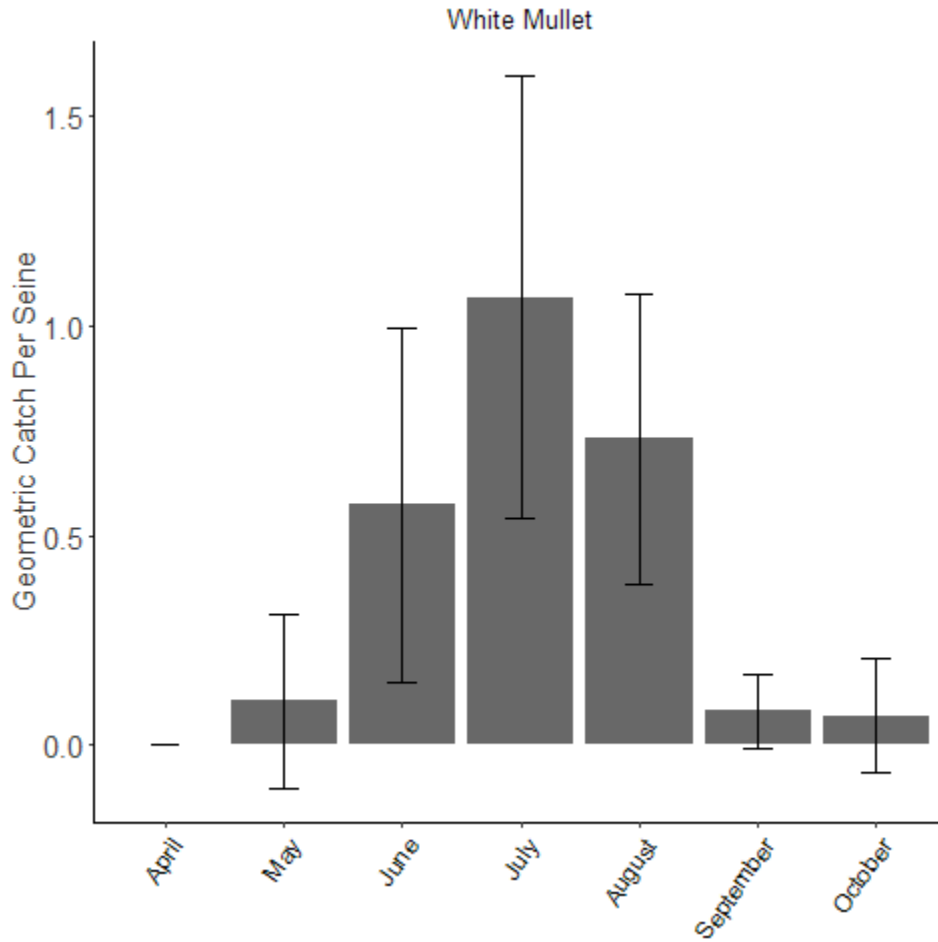Figure 41. Geometric mean catch-per-seine for Weakfish, with the time series mean and median.

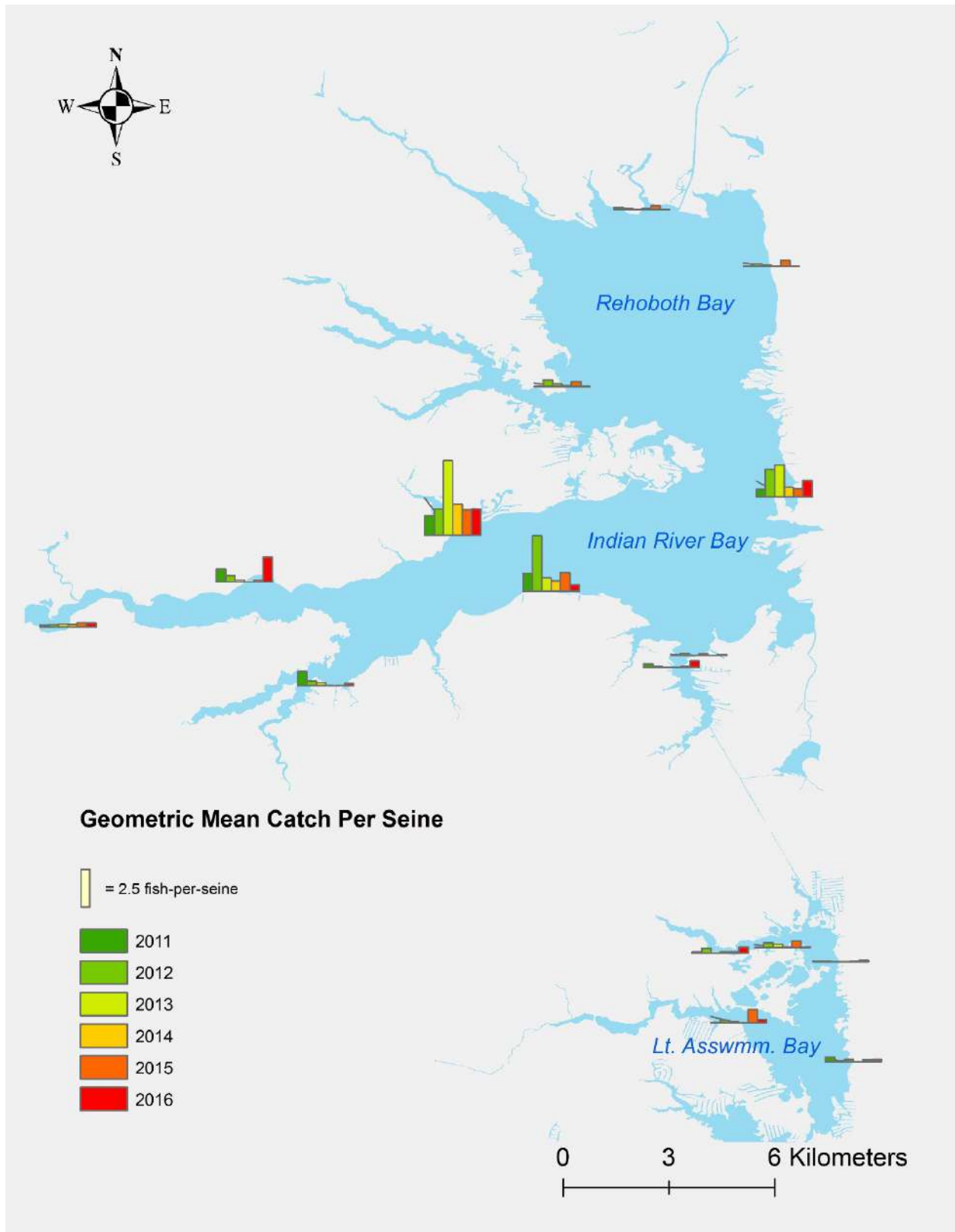**Figure 42. Geometric mean catch-per-seine during 2016 for Weakfish by month.**

Figure 43. Geometric mean catch-per-seine since 2011 for Weakfish by site.

White Mullet

A total of 479 White Mullet were caught in 2016, for a geometric mean of 0.35 fish per seine, greater than the time series mean and median (Figure 44). The majority of specimens measured less than 100 mm in length. In 2016, as in the previous 5 years, July was the peak month of occurrence (Figure 45; McGowan et al. 2017). White Mullet abundance did not differ between the bays, but the sites near the inlet saw the greatest activity (Figure 46). These sites on average have the highest salinity, and correspondingly White Mullet catch was positively correlated with salinity (p < 0.001; Table 4).
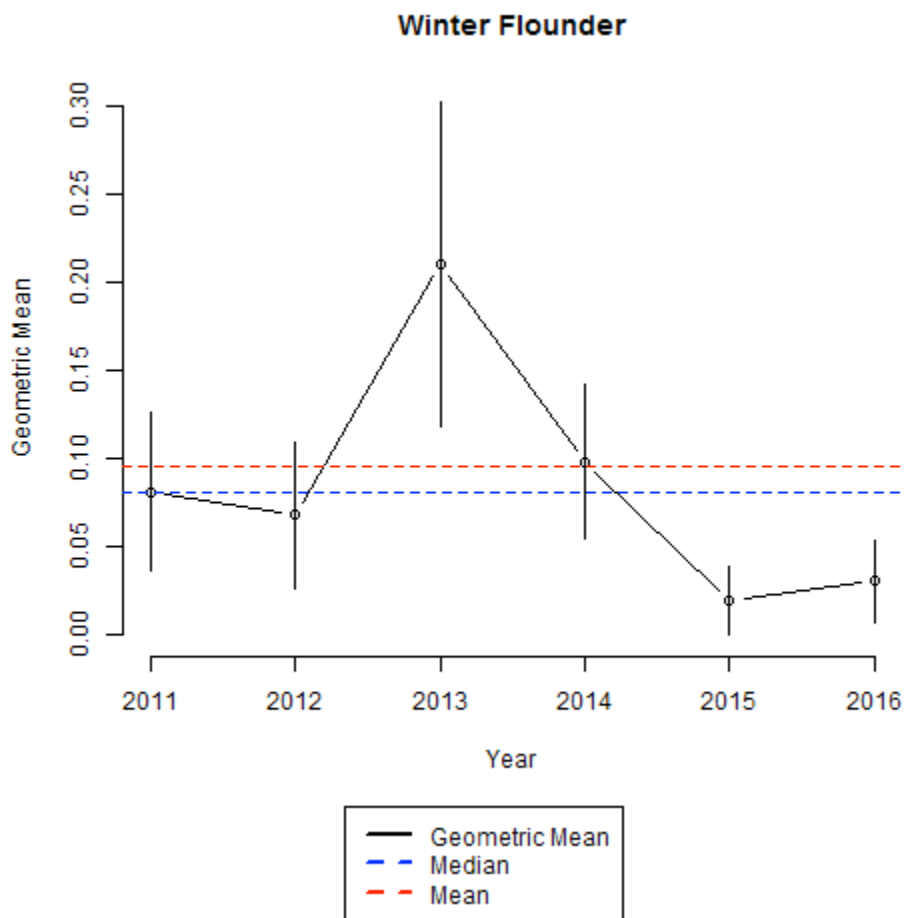

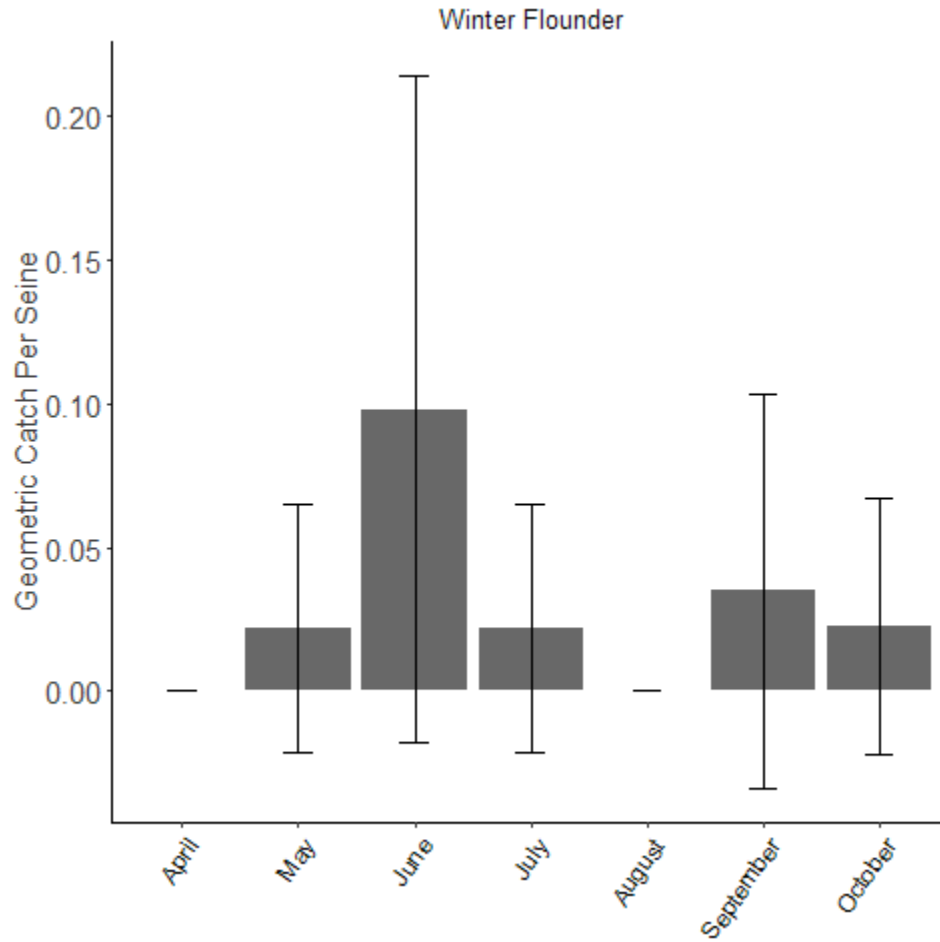Figure 44. Geometric mean catch-per-seine for White Mullet, with the time series mean and median.

Figure 45. Geometric mean catch-per-seine during 2016 for White Mullet by month.

Figure 46. Geometric mean catch-per-seine since 2011 for White Mullet by site.

Winter Flounder

Only 11 Winter Flounder were caught in 2016 for a geometric mean of 0.03 fish per seine, up slightly from 2015 but below the time series mean and median (Figure 47). With only eleven specimens collected in 2016, no conclusions can be made about the species' seasonality, but the peak month was June (Figure 48). Cumulatively, over the previous 5 years June has also been the peak month (McGowan et al. 2017). All individuals were less than 125 mm in length. Winter Flounder abundance did not differ between bays, though the sites immediately opposite the inlet were again the most productive (Figure 49).

Figure 47. Geometric mean catch-per-seine for Winter Flounder, with the time series mean and median.

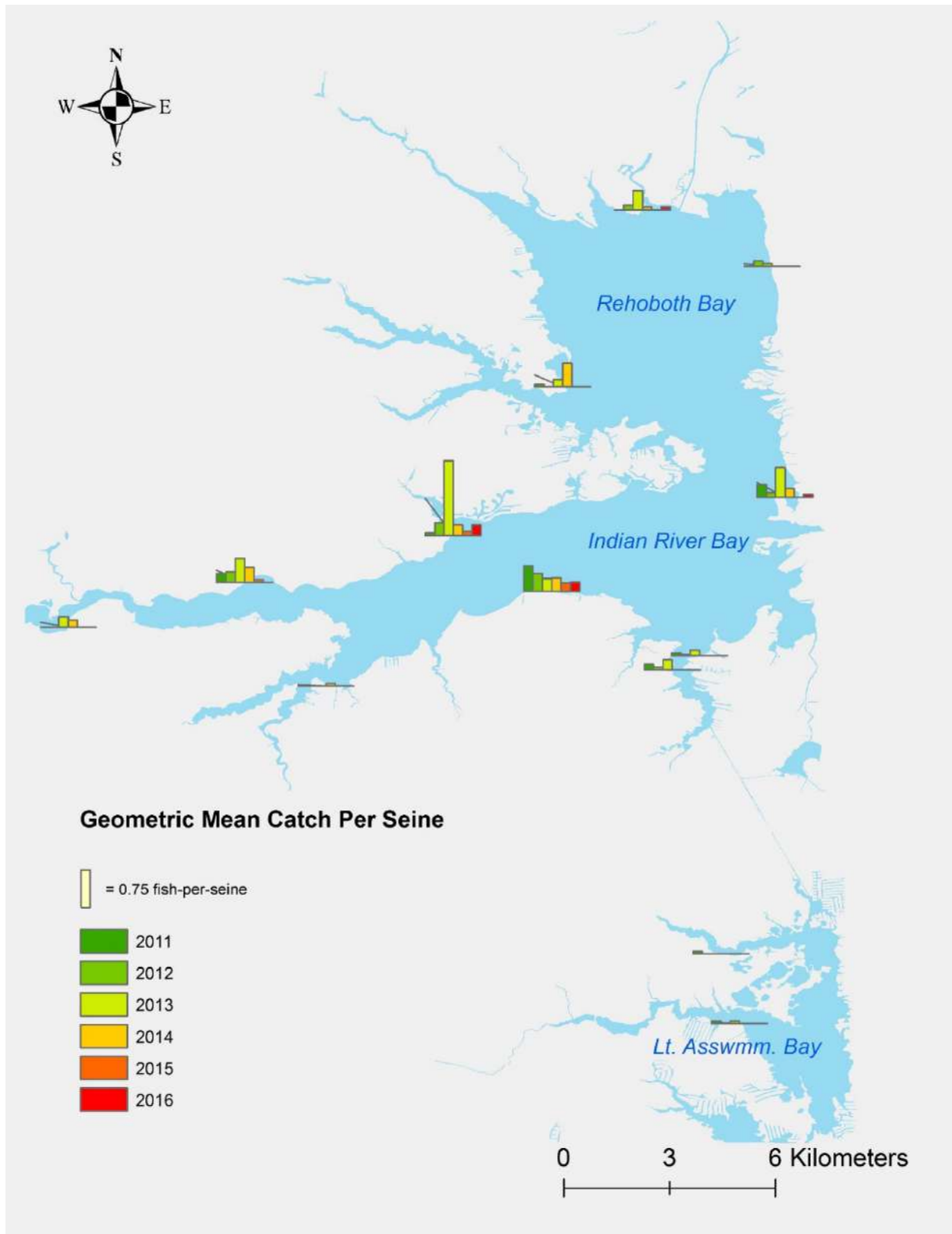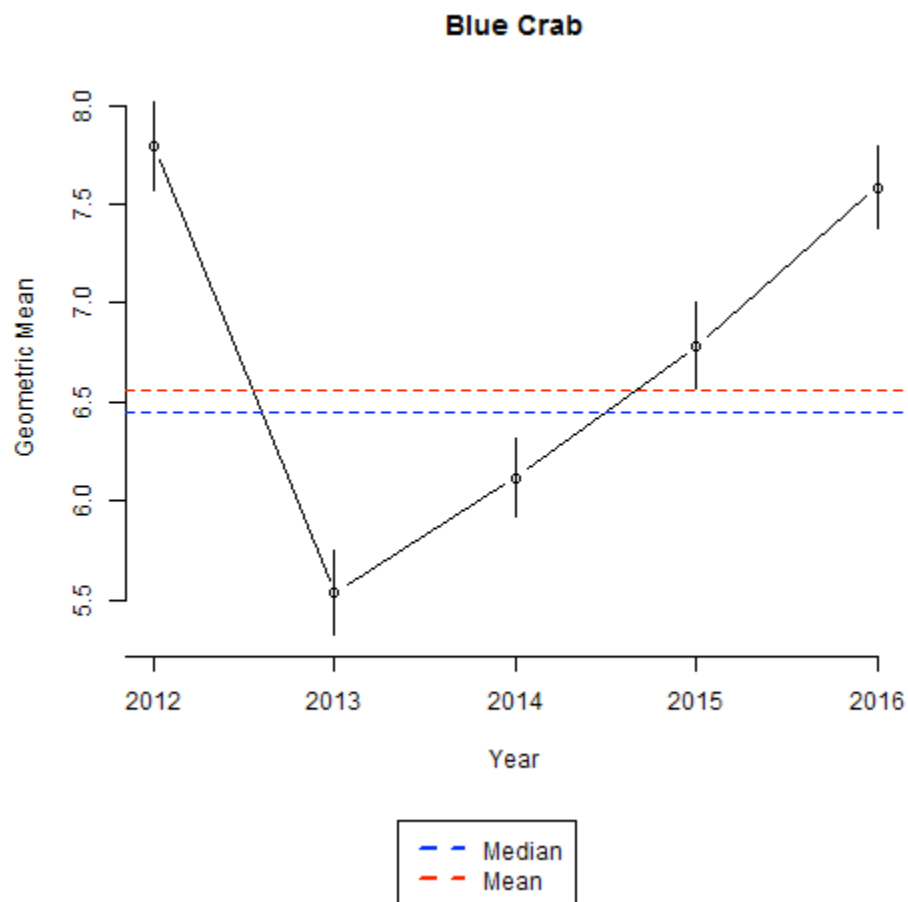**Figure 48. Geometric mean catch-per-seine during 2016 for Winter Flounder by month.**

Figure 49. Geometric mean catch-per-seine since 2011 for Winter Flounder by site.

Blue Crab

A total of 5,133 Blue Crabs were caught in 2016, for a geometric mean of 7.58 crabs per seine, up from 2015 and above the time series mean and median (Figure 50). June was the most productive month (Figure 51), a pattern also seen over the previous 5 years (McGowan et al. 2017). 3,446 small crabs, 1,541 medium crabs, and 146 large crabs were caught, with over 35 percent of crabs collected at Sandy beach (Figure 52; Site #8). Sandy beach has been a highly productive site for crabs throughout this study, likely due to its mid-salinity waters (Table 3).

Figure 50. Geometric mean catch-per-seine for Blue Crab, with the time series mean and median.
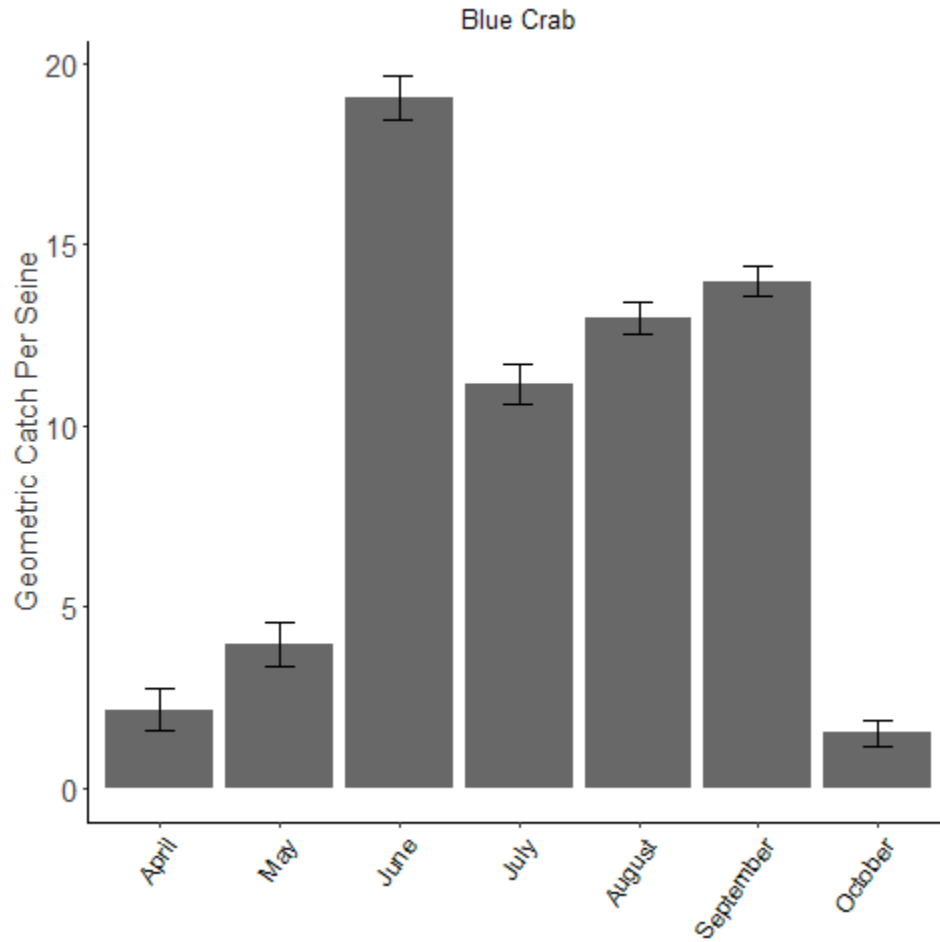
Figure 51. Geometric mean catch-per-seine during 2016 for Blue Crab by month.
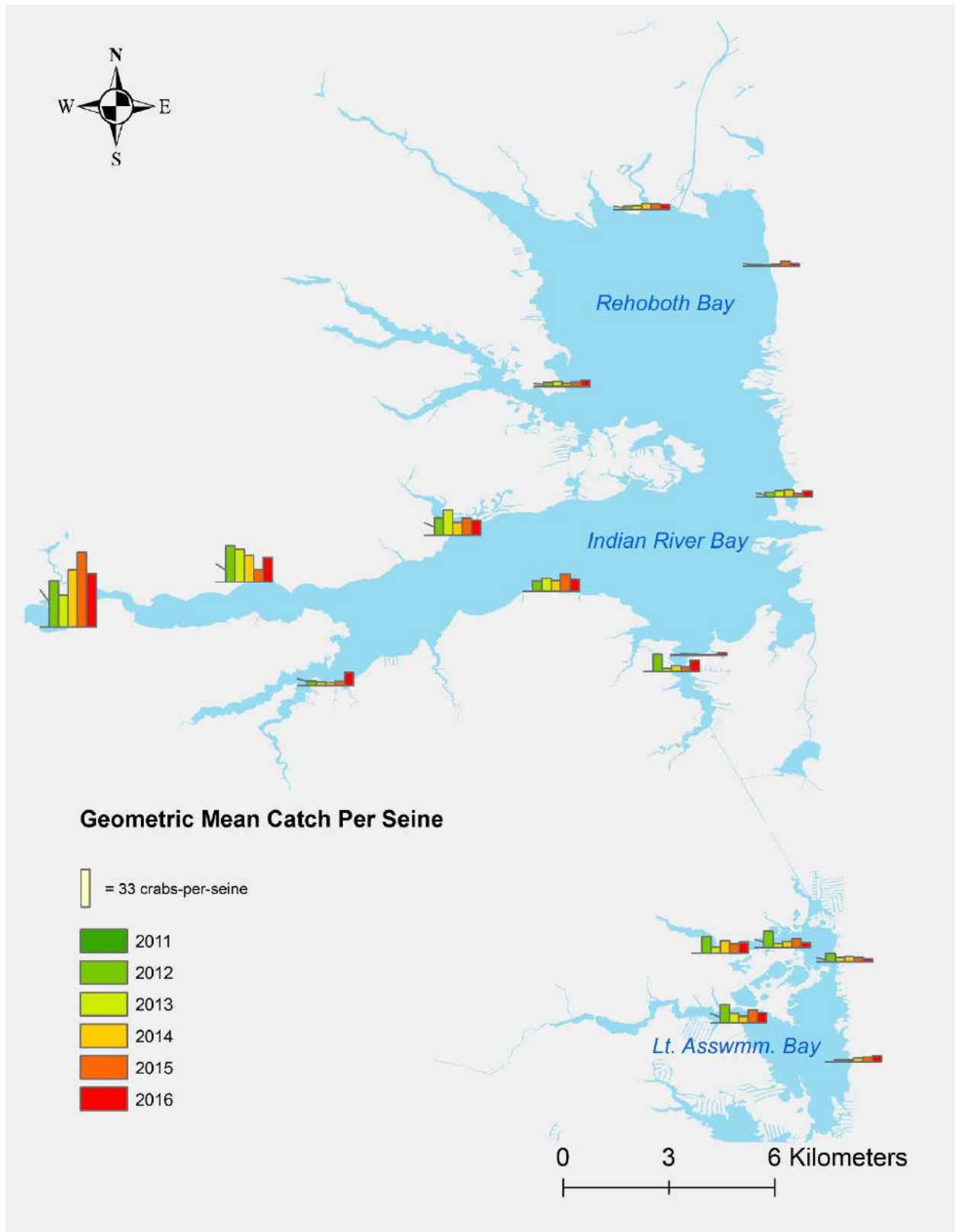
Figure 52. Geometric mean catch-per-seine since 2011 for Blue Crab by site.

CONCLUSION

The 2016 season marked the 6th completed year of the survey. 2016 was a strong year in terms of geometric mean catch-per-seine values for Atlantic Menhaden, Atlantic Silversides, Mummichog, Striped Killifish, and Blue Crabs. The 2016 season also had a relatively large arithmetic fish catch-per-seine value compared to the survey's average, and an above average species richness. Looking forward to future survey years, it has been decided that additional physical characteristics should be noted during each seine event in an effort to better capture the reasons for certain species' distributions. These parameters include the relative amount of macroalgae at the sampling site, wind speed, volume of water sampled, and the amount of rainfall in the past 24 hours. While we are able to explain why certain species are located at specific sites and not at others due to factors such as salinity and temperature, it is our hope that the addition of more explanatory variables will shed light on the spatial distribution for species which do not show correlations to already measured physical variables. Lastly, as we complete additional survey years, changes in abundances over time for target species should become clearer, and it is our hope that by measuring a suite of variables over a long period of time, we will be able to explain any trends seen, particularly for those species which do not leave the estuary and are therefore not influenced by factors occurring outside the study area.

ACKNOWLEDGEMENTS

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Appendix A. Common and scientific names of fishes and Blue Crab caught during 2016 season, with the total number of specimens caught during the 2016 season.

Common Name	Scientific Name	Number of Specimens Caught
American Eel	*Anguilla rostrate*	5
Atlantic Croaker	*Micropogonias undulatus*	64
Atlantic Menhaden	*Brevoortia tyrannus*	6,575
Atlantic Needlefish	*Strongylura marina*	4
Atlantic Silverside	*Menidia menidia*	18,287
Bay Anchovy	*Anchoa mitchilli*	2,122
Black Crappie	*Pomoxis nigromaculatus*	9
Black Drum	*Pogonias cromis*	54
Blue Crab	*Callinectes sapidus*	5,133
Bluefish	*Pomatomus saltatrix*	25
Bluegill Sunfish	*Lepomis macrochirus*	4
Bluntnose Stingray	*Dasyatis say*	1
Cownose Ray	*Rhinoptera bonasus*	2
False Silverstripe Halfbeak	*Hyporhamphus meeki*	10
Fourspine Stickleback	*Apeltes quadracus*	5
Gray Snapper	*Lutjanus griseus*	6
Hogchoker	*Trinectes maculatus*	15
Lookdown	*Selene vomer*	1
Mummichog	*Fundulus heteroclitus*	12,617
Naked Goby	*Gobiosoma bosc*	10
Northern Kingfish	*Menticirrhus saxatilis*	28
Northern Pipefish	*Sygnathus fuscus*	42
Northern Stargazer	*Astroscopus guttatus*	1
Oyster Toadfish	*Opsanus tau*	16

Permit	*Trachinotus falcatus*	3
Pinfish	*Lagodon rhomboides*	44
Rainwater Killifish	*Lucania parva*	40
Redear Sunfish	*Lepomis microlophus*	2
Sheepshead	*Archosargus probatocephalus*	2
Sheepshead Minnow	*Cyprinodon variegatus*	808
Silver Perch	*Bairdiella chrysoura*	1,533
Skilletfish	*Gobiesox strumosus*	2
Spot	*Leiostomus xanthurus*	371
Spotfin Killifish	*Fundulus luciae*	2
Spotfin Mojarra	*Eucinostomus argenteus*	190
Spotted Hake	*Urophycis regia*	1
Striped Anchovy	*Anchoa hepsetus*	48
Striped Bass	*Morone saxatilis*	7
Striped Blenny	*Meiacanthus grammistes*	2
Striped Killifish	*Fundulus majalis*	10,778
Striped Mullet	*Mugil curema*	5
Summer Flounder	*Paralichthys dentatus*	111
Threespine Stickleback	*Gasterosteus aculeatus*	4
Weakfish	*Cynoscion regalis*	16
White Mullet	*Mugil cephalus*	479
White Perch	*Morone americana*	15
Winter Flounder	*Pseudopleuronectes americanus*	11

Appendix B. Quality Control Report

SUMMARY

Data recorded during the 2016 Inshore Fish and Blue crab survey were tested according to the quality control measures outlined in the program's EPA approved QAPP. These measures included a random sampling of 10% of the data for accuracy, at least one seine per team performed under direct supervision from the Program manager, and routine calibration of equipment. In summary, no inaccuracies were found to be present in the random sampling of data sheets. All teams demonstrated proper protocol and data recording during their supervisory seine. Calibration of the YSI handheld water quality meters was deemed insufficient by the EPA and will be corrected in the following survey years. Furthermore, additional weather parameters will be taken to better document physical conditions.

ISSUES AND CORRECTIVE ACTIONS

YSI calibration was previously completed once a week by the CIB Environmental Scientist. This was deemed insufficient as the YSI meters were believed to lose their accuracy quicker than the one-week time period.

To correct this issue, the revised QAPP states that all YSI meters will be recalibrated immediately prior to each seine event.

RECOMMENDATIONS

While not in violation of the QAPP during the 2016 field season, it was brought to the Program manager's attention that additional weather and physical variables could easily be measured and recorded before each seine and would potentially help explain patterns in fish abundance. Therefore, beginning next season (2017), variables such as wave height, rainfall within the last 24 hours, wind speed, and water depth will all be taken before each seine event.