PROGRESS REPORT

State: **NEW HAMPSHIRE** **Grant:** **F-61-R-22/F19AF00061**

Grant Title: **NEW HAMPSHIRE'S MARINE FISHERIES INVESTIGATIONS**

Project III: **MULTI-SPECIES EVALUATION**

Job 3: **ESTUARINE SURVEY OF JUVENILE FINFISH**

Objective: To monitor the relative abundance of juvenile finfish utilizing New Hampshire estuaries for nursery habitat.

Period Covered: January 1, 2019 - December 31, 2019

ABSTRACT

The monitoring of finfish is necessary for the management of riverine, estuarine, and marine environments. The objective of the beach seine survey, as described in this report, is to monitor relative abundance of juvenile finfish that use New Hampshire estuaries for nursery habitat.

A total of 23 finfish species were captured during the 2019 seine survey. Atlantic Silverside *Menidia menidia*, Striped Killifish *Fundulus majalis*, Rainbow Smelt *Osmerus mordax,* Atlantic Herring *Clupea harengus,* and Fourspine Stickleback *Apeltes quadracus* accounted for 92.57% of the total catch. Since the inception of the survey in 1997, Atlantic Silverside have remained the most abundant finfish species captured. Overall relative abundance in 2019 was below the 10-year geometric mean CPUE and four of the species of special interest (Alewife *Alosa pseudoharengus*, Winter Flounder *Pseudopleuronectes americanus*, Atlantic Silverside, and Rainbow Smelt) showed a declining trend. The other two finfish species of special interest (Blueback Herring *Alosa aestivalis* and American Shad *Alosa sapidissima*) were at or above the 10-year geometric mean CPUE. Above average temperatures and salinity were recorded in 2019.

INTRODUCTION

Estuaries are highly productive ecosystems, known to provide diverse habitat utilized as nurseries and forage grounds by an array of estuarine species. Many of these estuarine species are commercially, recreationally,

and culturally significant. Monitoring spawning success and recruitment of finfish species is necessary for the effective management of riverine, estuarine, and marine environments.

Beach seining is an established sampling method for estuarine-based juvenile finfish surveys (NHFG 1981, 1982; Howell and Molnar 1993; MD DNR 1994; Young et al. 1994; NAI 1995). Juvenile finfish captured by beach seine allows for positive identification and the opportunity to collect important biological information (e.g., length, weight, and sex). With appropriate sampling procedures in place, an index of relative abundance can be calculated for each species. Evaluation of each index can provide an indication of spawning success and recruitment of important finfish species, such as Alewife *Alosa pseudoharengus*, Atlantic Herring *Clupea harengus*, Bluefish *Pomatomus saltatrix*, Striped Bass *Morone saxatilis*, and Winter Flounder *Pseudopleuronectes americanus*, which utilize estuaries on the East Coast as nursery habitat (MD DNR 1994; Young et al. 1994).

The estuarine survey of juvenile finfish was initiated in 1997. It was designed as a fixed station survey, as opposed to a stratified random survey, because strong tidal currents, rocky shorelines, and various anthropogenic shoreline structures limit the amount of suitable seining areas, particularly in the Great Bay Estuary. Many fixed sampling locations chosen for this survey were sites used by beach seine surveys conducted in New Hampshire (NH) estuaries in the past (NAI 1979; NHFG 1981, 1982; Grout and Heckman 1996). This provides the opportunity to compare data from the current program with historical survey data.

The primary objective of this beach seine survey is to monitor relative abundance of juvenile finfish that utilize NH estuaries for nursery habitat each year. As designed it is intended to be a general purpose survey, but six finfish species of special interest are: Alewife, Blueback Herring *Alosa aestivalis*, American Shad *Alosa sapidissima*, Rainbow Smelt *Osmerus mordax*, Atlantic Silverside *Menidia menidia*, and Winter Flounder.

PROCEDURES

A bag seine 30.5 m long and 1.8 m high with 6.4 mm mesh is used to sample for juvenile finfish in NH tidal waters. A single seine haul is performed each month from June through November at 15 fixed stations: four in the Hampton/Seabrook Estuary (HSE), three in Little Harbor (GBE1), three in the Piscataqua River (GBE2), and five in Little Bay/Great Bay (GBE3) (Table 3.3-1 and Figures 3.3-1 through 3.3-3).

Seine hauls are performed during daylight between 2 hours before and 2 hours after low tide. Seine hauls are set by boat 15–25 m from shoreline, ideally in water depths less than 2 m in order to prevent the foot rope of the seine from lifting off of the bottom.

All captured finfish are identified to the lowest possible taxon, measured in total length to the nearest millimeter (with a maximum of 25 individual lengths recorded per species per seine haul), and then enumerated. Water surface temperature (°C), salinity (ppt), and substrate type are recorded at each fixed station for each seine haul.

Catch distributions for many forage species or juveniles of some species can be heavily skewed due to a few large catches as a result of schooling behavior. In these instances, one or two large catches can often inflate the value of an arithmetic mean by orders of magnitude resulting in a false characterization of the true relative abundance of a species. To compensate for this potential bias, a log transformation of the catch data was used to produce a normal (as opposed to skewed) catch distribution and the resulting mean of the log-transformed data can be transformed back to produce a geometric mean (Sokal and Rohlf 1969). In recent years the geometric mean has often replaced the arithmetic mean as a measure of relative abundance for juvenile finfish because it is a more statistically robust value (Howell and Molnar 1993; MD DNR 1994; Young et al. 1994; NAI 1995).

RESULTS

A total of 15 stations were surveyed once a month from June through November, resulting in a total of 90 seine hauls. Substrate type is observed and recorded each year during sampling to identify habitat type and possible changes in substrate over time (Table 3.3-1). The majority of the stations had substrate types consisting of "mud/sand", followed by "sand", "mud/shell" or "mud", and lastly "mud/gravel".

A total of 23 finfish species were captured in 2019 (Table 3.3-2). The five most encountered finfish in 2019 were Atlantic Silverside, Striped Killifish *Fundulus majalis*, Rainbow Smelt, Atlantic Herring, and Fourspine Stickleback *Apeltes quadracus*, accounting for 92.57% of the total finfish catch.

Table 3.3-3 shows the geometric mean of species caught three or more times between 2009 and 2019; species caught less than 3 times were omitted from the table, unless caught in the 2019 survey. Overall relative abundance in 2019 was below the 10-year mean CPUE. Two of the six species of special interest, Blueback Herring and American Shad, exceeded their respective 10-year means,

while the other four, Alewife, Winter Flounder, Atlantic Silverside, and Rainbow Smelt, were below. American Shad remain a relatively rare encounter in this survey with only one individual captured in 2019 (Table 3.3-2). Four of the remaining 17 finfish species encountered in 2019 decreased, nine increased, and four were equal in abundance relative to their 10-year geometric means. Although White Perch *Morone americana* is not a species of interest in this study, the geometric mean in 2019 is three times higher than the 10-year mean (Table 3.3-3).

In comparison to all other stations, Station 33 (Figure 3.3-1) had the lowest overall geometric mean CPUE and lowest species diversity with only one species observed (Table 3.3-4). In contrast, Stations 54 and 35 had the highest abundance levels (Figure 3.3-3). Stations 30, 39, and 147 had the greatest species diversity, each with 16 different species captured. Atlantic Silverside dominated the catch composition at most stations. Striped Bass, American shad, Atlantic Moonfish *Selene setapinnis*, and Pollock *Pollachius virens* were each found at only one station, and it was the first occurrence of Atlantic Moonfish in the history of the survey (Table 3.3-4). October had the highest geometric mean CPUE value for all species combined in 2019, while July had the lowest (Table 3.3-5).

In 2019, 2,660 individual finfish were measured (Table 3.3-6). Length frequencies were weighted by catch and plotted for the species of special interest (Figure 3.3-4).

Mean surface water temperature was above average in 2019 with a mean of 17.2°C, a low of 5.8°C at Stations 29 and 33 in November, and a high of 30.8°C at Station 54 in October (Tables 3.3-7 and 3.3-8). Instrument failure prevented temperature readings in August at Stations 25 and 29. Little Harbor exhibited the coldest annual mean surface temperatures of all the areas sampled, yielding a mean temperature of 15.0°C, followed by the Hampton/Seabrook area with 15.6°C, and the Piscataqua River with 17.2°C. The Little Bay/Great Bay area exhibited the warmest annual mean surface temperatures, with a mean temperature of 19.7°C.

Historical annual mean salinity has ranged from 23.7 ppt in 2011 to 29.2 ppt in 2016. The value measured in 2019 (26.6 ppt) is near the mean for the 10-year time series (Table 3.3-7). Salinity in 2019 ranged from 7.1 ppt at Station 39 to 31.8 ppt at Station 25, both in November (Table 3.3-9). The range in recorded salinities was greatest at Station 107, ranging from 9.7 ppt to 27.1 ppt, in contrast to Station 5 which experienced a minor difference in salinity. No salinity data were measured in August 2019 at Stations 25 and 29 due to equipment failure.

DISCUSSION

The objective of this project is to annually monitor the relative abundance of juvenile finfish utilizing NH's estuaries for nursery habitat. As has been the case since the inception of the survey in 1997, only a few species account for the vast majority of those captured (Grout and Smith 1998). A total of 23 finfish species were captured during the 2019 survey season. The diversity in annual catch is reflective of the general purpose design of the survey, but Alewife, Blueback Herring, Winter Flounder, Rainbow Smelt, American Shad, and Atlantic Silverside are the primary species of interest. With the exception of American Shad, all of these species of interest have been caught in each of the last ten years of the survey (Table 3.3-3). American shad have been encountered in three out of the last four years after a 13-year absence. Five finfish species comprised 92.57% of the total finfish catch: Atlantic Silverside, Striped Killifish, Rainbow Smelt, Atlantic Herring, and Fourspine Stickleback (Table 3.3-2). Although inter-annual variation is inherent in natural systems due to fluctuations in both biotic and abiotic factors, this survey's ability to monitor trends in relative abundance for species of interest over time is informative.

Environmental conditions, both abiotic and biotic, can influence the distribution of fish, especially in an estuary where these changes can be abrupt. Overall relative abundance levels in 2019 decreased by 18.53% from 2018 (Table 3.3-3). The majority of species exhibited average or above average abundance in 2019. The relative abundance compared to the 10-year time series geometric mean was particularly high for Atlantic Herring and White Perch, which were 2.1 and 3.0 times their means, respectively. Bluefish remain sparse, having encountered none during the 2019 sampling season. It is important to understand that inter-annual variation exists with time series data. Therefore, while some species exhibit peaks one year and potential lows the next, general trends over time are the important outcomes by design of this survey.

River herring (collectively Alewife and Blueback Herring) have been declining since 2003 and are currently listed as a "Species of Concern" by the National Oceanic and Atmospheric Administration's Fisheries Service (NOAA Fisheries) and the NH Fish and Game Department (NHFG). Relative abundance of both Alewives and Blueback Herring decreased from 2018 by 70% and 50%, respectively, and Alewives are currently below the 10-year geometric mean CPUE (Table 3.3-3). Conversely, Blueback Herring were more abundant in 2019 than the 10-year geometric mean, though their general abundance has decreased in the

last few years. While no single factor has been determined for the cause of the general decline, certain factors such as habitat loss and degradation, impediments to spawning areas, fishing, and predation (e.g., Striped Bass) may all play a role in the general decline of coast-wide river herring populations (ASMFC 2012).

Rainbow Smelt is designated as a "Species of Concern" for NOAA Fisheries and NHFG. Similar to river herring, Rainbow Smelt have been declining over at least the last 15 years. Two other NHFG surveys that target Rainbow Smelt illustrate a similar decline, though their spawning and migratory patterns are poorly understood (See Project I-2 and II-1). It is believed that populations of Rainbow Smelt throughout the northwest Atlantic have declined over the past few decades due to overfishing, pollution, unfavorable changes in ocean conditions (e.g., temperature), poor water quality, physical obstructions (e.g., poorly designed culverts, dams), and degradation and loss of spawning habitat (Enterline et al. 2012). In response to the observed decline in adult Rainbow Smelt populations, the NHFG implemented a catch reduction for recreational harvest from 10 liquid quarts to 4 liquid quarts in 2015 and are currently attempting a stocking program to supplement the population. Although the population remains at low levels compared to those seen prior to 2008, Rainbow Smelt were one of the top five encountered species in 2019 and their relative abundance increased from that of 2018 to a value near the 10-year average, suggesting possible signs of recovery (Table 3.3-3).

Atlantic Silverside accounted for 75.18% of the total catch in 2019 (Table 3.3-2), and is persistently the most numerous species caught in the survey (Table 3.3-3). Furthermore, it was the most spatially diverse fish species, having been captured at all stations except one (Table 3.3-4), and was the most abundant finfish species in most months (Table 3.3-5). Atlantic Silversides are an important forage fish and documented food source for Bluefish and Striped Bass (Collette and Klein-MacPhee 2002).

Winter Flounder abundance was higher in this survey prior to 2009 before remaining fairly low through 2015, and has fluctuated in subsequent years, with general abundance for 2019 well below the 10-year average (Table 3.3-3). Winter Flounder were captured each month except June (Table 3.3-5) and encountered at 11 out of the 15 stations, suggesting the species occupies a widespread area of NH's estuaries (Tables 3.3-4 and 3.3-5). While a large portion of Winter Flounder populations are harvested in federal waters, the majority of the stock is composed of smaller localized populations that return inshore each year to spawn (ASMFC 2007). The decline in the spawning success and recruitment to the

localized populations in NH is likely the result of overfishing, pollution, habitat loss and degradation, and power plant entrainment and impingement (ASMFC 2012).

Water temperature is thought to play an important role in species abundance and movement (Roessig et al. 2004). Within NH estuaries, finfish species abundance tended to be greater in the late summer and early fall months. Geometric mean catch peaked in October, after which water temperatures decreased notably at all 15 stations (Tables 3.3-5 and 3.3-8). However, it should be noted that the two species with the highest geometric mean CPUE, Atlantic Silverside and Striped Killifish, are primarily driving this abundance level in October. In 2019, annual mean salinity was 26.6 ppt and annual mean temperature was 17.2°C. The 2019 average temperature was above the 10-year mean while the salinity was consistent with the time series mean (Table 3.3-7).

In summary, of the 23 finfish captured in the 2019 seine survey, the five most abundant species were Atlantic Silverside, Striped Killifish, Rainbow Smelt, Atlantic Herring, and Fourspine Stickleback, representing 92.57% of the total finfish catch. Overall, relative species abundance was below the 10-year mean and Atlantic Silverside continues to represent the highest relative abundance numbers annually. Two of the six species of interest exceeded average relative abundance while the other four have declined. American Shad was captured in three out of the last four years after a 13-year absence. Mean water surface temperature was above average and mean salinity was relatively consistent with the time-series mean.

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Table 3.3-1. Station number and its area code, location, coordinates, and substrate type, as well as historical seine data for each station, from a juvenile finfish seine survey conducted in New Hampshire estuaries, 2019.

Station #	Area	Station location	Latitude/longitude	Substrate	Historical data
5	GBE1	Fort Stark (Little Harbor)	43°03’28.0”N 070°42’51.7”W	sand	Grout & Heckman (1996)
7	GBE1	Wentworth (Little Harbor)	43°03’25.6”N 070°43’25.7”W	mud/sand	Grout & Heckman (1996)
9	GBE1	Odiorne Beach (Little Harbor)	43°03’07.9”N 070°43’22.9”W	sand	Grout & Heckman (1996)
30	GBE2	Schiller Plant (Piscataqua)	43°05’59.3”N 070°47’15.5”W	mud/gravel	NAI (1979)
35	GBE2	General Sullivan Bridge Cove (Piscataqua)	43°07’00.1”N 070°49’23.6”W	mud	NHFG (1981,1982)
39	GBE2	Upper Piscataqua (Power Lines)	43°10’16.2”N 070°49’43.9”W	mud/sand	None
54	GBE3	Broad Cove (Little Bay)	43°07’07.9”N 070°50’51.8”W	mud/sand	NHFG (1981)
72	GBE3	Fox Point (Little Bay)	43°07’15.0”N 070°51’33.2”W	mud/sand	NHFG (1981,1982)
93	GBE3	Herods Cove (Great Bay)	43°04’16.6”N 070°51’27.2”W	mud/sand	NHFG (1981,1982)
107	GBE3	Moody Point (Lamprey/Squamscott)	43°04’07.0”N 070°54’12.5”W	mud	NHFG (1981)
147	GBE3	Oyster River	43°07’19.3”N 070°52’23.4”W	mud/shell	None
23	HSE	Smith & Gilmore (Hampton)	42°54’03.4”N 070°49’10.0”W	mud/shell	Grout & Heckman (1996)
25	HSE	Yankee Coop (Seabrook)	42°53’33.0”N 070°49’11.1”W	mud/sand	Grout & Heckman (1996)
29	HSE	Blackwater River	42°53’42.9”N 070°49’29.8”W	sand	Grout & Heckman (1996)
33	HSE	Brown’s River	42°53’56.3”N 070°49’33.4”W	sand	Grout & Heckman (1996)

Area codes	Area names
HSE	Hampton/Seabrook Estuary
GBE1	Little Harbor
GBE2	Piscataqua River
GBE3	Little Bay/Great Bay

Table 3.3-2. Geometric mean catch per seine haul, and standard deviation values for all species captured, from a juvenile finfish seine survey conducted in New Hampshire estuaries, 2019.

Species	Scientific name	Geometric		Total catch (N)	Percentage of total catch
		Mean	SD		
Alewife	*Alosa pseudoharengus*	0.07	0.49	38	0.23
Bass, Striped	*Morone saxatilis*	0.01	0.08	1	0.01
Crab, Green	*Carcinus maenas*	1.49	2.07	503	3.09
Crab, Horseshoe	*Limulus polyphemus*	0.04	0.17	5	0.03
Cunner	*Tautogolabrus adspersus*	0.02	0.13	3	0.02
Flounder, Smooth	*Pleuronectes putnami*	0.36	1.04	96	0.59
Flounder, Winter	*Pseudopleuronectes americanus*	0.27	0.61	43	0.26
Grubby	*Myoxocephalus aenaeus*	0.20	0.51	31	0.19
Hake, Red	*Urophycis chuss*	0.10	0.29	13	0.08
Herring, Atlantic	*Clupea harengus*	0.39	1.88	467	2.87
Herring, Blueback	*Alosa aestivalis*	0.17	0.78	64	0.39
Killifish, Striped	*Fundulus majalis*	2.09	3.90	1,408	8.65
Lance, American Sand	*Ammodytes americanus*	0.05	0.29	10	0.06
Menhaden, Atlantic	*Brevoortia tyrannus*	0.09	0.37	17	0.10
Moonfish, Atlantic	*Selene setapinnis*	0.01	0.08	1	0.01
Mummichog	*Fundulus heteroclitus*	0.73	1.29	155	0.95
Perch, White	*Morone americana*	0.24	1.10	120	0.74
Pipefish, Northern	*Sygnathus fuscus*	0.09	0.33	14	0.09
Pollock	*Pollachius virens*	0.02	0.18	4	0.02
Shad, American	*Alosa sapidissima*	0.01	0.08	1	0.01
Silverside, Atlantic	*Menidia menidia*	12.94	11.64	12,233	75.18
Smelt, Rainbow	*Osmerus mordax*	0.29	1.26	744	4.57
Stickleback, Fourspine	*Apeltes quadracus*	0.53	1.44	212	1.30
Stickleback, Ninespine	*Pungitius pungitius*	0.11	0.36	17	0.10
Tomcod, Atlantic	*Microgadus tomcod*	0.23	0.82	72	0.44
	All species	42.26	6.73	16,272	100.00

Table 3.3-3. Geometric mean (*standard deviation*) catch per seine haul for all species caught in juvenile finfish seine survey conducted in New Hampshire estuaries, 2009–2019.

Species	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Mean (2009-2018)
Alewife	0.10(*0.53*)	0.08(*0.34*)	0.08(*0.44*)	0.02(*0.23*)	0.22(*1.49*)	0.05(*0.25*)	0.31(*1.09*)	0.15(*0.96*)	0.21(*0.93*)	0.23(*0.88*)	0.07(*0.49*)	0.14(*0.74*)
Anchovy, Bay	0.01(*0.08*)	0.02(*0.18*)	0.00(*0.00*)	0.00(*0.00*)	0.03(*0.15*)	0.00(*0.00*)	0.00(*0.00*)	0.03(*0.20*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.01(*0.10*)
Bass, Largemouth	0.01(*0.08*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.03(*0.34*)	0.01(*0.08*)	0.00(*0.00*)	0.01(*0.08*)	0.00(*0.00*)	0.00(*0.00*)	0.01(*0.10*)
Bass, Striped	0.01(*0.12*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.01(*0.08*)	0.00(*0.00*)	0.01(*0.08*)	0.01(*0.08*)	0.02(*0.13*)	0.01(*0.08*)	0.01(*0.08*)	0.01(*0.07*)
Bluefish	0.32(*1.08*)	0.10(*0.48*)	0.08(*0.37*)	0.35(*1.14*)	0.41(*1.22*)	0.05(*0.33*)	0.00(*0.00*)	0.02(*0.13*)	0.02(*0.15*)	0.25(*1.09*)	0.00(*0.00*)	0.15(*0.65*)
Butterflyfish, Spotfin	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.01(*0.08*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.02*)
Crab, Green	1.79(*1.80*)	1.83(*2.06*)	1.69(*1.58*)	3.28(*2.39*)	3.59(*2.97*)	2.35(*2.57*)	1.71(*1.77*)	3.79(*2.45*)	3.30(*2.24*)	1.61(*1.71*)	1.49(*2.07*)	2.39(*2.15*)
Crab, Horseshoe	0.04(*0.21*)	0.03(*0.15*)	0.05(*0.22*)	0.02(*0.11*)	0.02(*0.15*)	0.00(*0.00*)	0.02(*0.13*)	0.05(*0.22*)	0.04(*0.28*)	0.04(*0.21*)	0.04(*0.17*)	0.03(*0.18*)
Crab, Jonah	0.02(*0.11*)	0.01(*0.08*)	0.01(*0.12*)	0.00(*0.00*)	0.02(*0.11*)	0.01(*0.08*)	0.01(*0.12*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.01(*0.08*)
Crab, Rock	0.01(*0.08*)	0.01(*0.08*)	0.06(*0.31*)	0.00(*0.00*)	0.04(*0.29*)	0.01(*0.08*)	0.00(*0.00*)	0.03(*0.20*)	0.02(*0.13*)	0.05(*0.25*)	0.00(*0.00*)	0.02(*0.17*)
Cunner	0.00(*0.00*)	0.00(*0.00*)	0.02(*0.11*)	0.09(*0.36*)	0.03(*0.17*)	0.02(*0.11*)	0.00(*0.00*)	0.01(*0.08*)	0.02(*0.11*)	0.02(*0.13*)	0.02(*0.13*)	0.02(*0.14*)
Eel, American	0.01(*0.08*)	0.01(*0.08*)	0.00(*0.00*)	0.01(*0.12*)	0.00(*0.00*)	0.01(*0.08*)	0.02(*0.11*)	0.02(*0.15*)	0.01(*0.08*)	0.00(*0.00*)	0.00(*0.00*)	0.01(*0.08*)
Flounder, Smooth	0.59(*1.44*)	0.27(*0.74*)	0.87(*1.63*)	0.33(*0.79*)	0.08(*0.31*)	0.58(*1.28*)	0.38(*1.15*)	0.21(*0.68*)	0.11(*0.39*)	0.36(*1.00*)	0.36(*1.04*)	0.36(*0.94*)
Flounder, Windowpane	0.01(*0.12*)	0.01(*0.08*)	0.00(*0.00*)	0.02(*0.15*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.02(*0.11*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.01(*0.07*)
Flounder, Winter	0.35(*0.63*)	0.17(*0.53*)	0.20(*0.44*)	0.57(*0.86*)	0.38(*0.79*)	0.32(*0.66*)	0.64(*0.93*)	1.48(*1.71*)	0.90(*1.40*)	0.36(*0.73*)	0.27(*0.61*)	0.50(*0.87*)
Grubby	0.10(*0.36*)	0.04(*0.22*)	0.31(*0.72*)	0.33(*0.79*)	0.09(*0.37*)	0.19(*0.48*)	0.39(*0.76*)	0.20(*0.61*)	0.21(*0.49*)	0.18(*0.45*)	0.20(*0.51*)	0.20(*0.53*)
Gunnel, Rock	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.01(*0.12*)	0.01(*0.12*)	0.02(*0.11*)	0.00(*0.00*)	0.00(*0.06*)
Hake, Red	0.11(*0.43*)	0.02(*0.11*)	0.02(*0.13*)	0.03(*0.19*)	0.00(*0.00*)	0.04(*0.31*)	0.14(*0.48*)	0.04(*0.21*)	0.02(*0.13*)	0.04(*0.20*)	0.10(*0.29*)	0.05(*0.24*)
Hake, White	0.00(*0.00*)	0.00(*0.00*)	0.01(*0.08*)	0.00(*0.00*)	0.01(*0.08*)	0.02(*0.11*)	0.03(*0.19*)	0.08(*0.31*)	0.00(*0.00*)	0.00(*0.00*)	0.01(*0.10*)	0.08(*0.44*)
Herring, Atlantic	0.36(*1.69*)	0.33(*1.70*)	0.05(*0.33*)	0.01(*0.12*)	0.16(*0.95*)	0.17(*0.68*)	0.15(*0.82*)	0.04(*0.26*)	0.38(*1.87*)	0.36(*2.54*)	0.39(*1.88*)	0.19(*1.13*)

Table 3.3-3 (cont.)

Species	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Mean (2009-2018)
Herring, Blueback	0.20(*1.12*)	0.17(*0.79*)	0.05(*0.19*)	0.08(*0.50*)	0.04(*0.22*)	0.14(*0.64*)	0.06(*0.39*)	0.21(*1.20*)	0.30(*1.48*)	0.34(*1.29*)	0.17(*0.78*)	0.15(*0.81*)
Killifish, Striped	0.76(*2.10*)	1.65(*4.03*)	3.19(*5.08*)	1.49(*3.05*)	1.02(*2.67*)	1.39(*3.15*)	2.05(*3.77*)	2.67(*4.44*)	2.31(*4.85*)	2.55(*4.66*)	2.09(*3.90*)	1.81(*3.70*)
Lance, American Sand	0.13(*0.97*)	0.04(*0.31*)	0.20(*1.10*)	0.09(*0.43*)	0.11(*0.48*)	0.04(*0.42*)	0.08(*0.46*)	0.06(*0.35*)	0.02(*0.25*)	0.00(*0.00*)	0.05(*0.29*)	0.08(*0.52*)
Lumpfish	0.02(*0.13*)	0.01(*0.08*)	0.00(*0.00*)	0.00(*0.00*)	0.01(*0.08*)	0.00(*0.00*)	0.02(*0.11*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.01(*0.13*)	0.01(*0.06*)
Menhaden, Atlantic	0.08(*0.42*)	0.00(*0.00*)	0.02(*0.15*)	0.26(*1.90*)	0.00(*0.00*)	0.06(*0.42*)	0.03(*0.23*)	0.04(*0.28*)	0.31(*1.71*)	0.09(*0.56*)	0.09(*0.37*)	0.08(*0.66*)
Moonfish, Atlantic	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.01(*0.08*)	0.00(*0.02*)
Mummichog	0.63(*1.66*)	0.78(*2.25*)	0.66(*1.76*)	1.09(*2.47*)	0.44(*1.27*)	0.53(*1.77*)	0.86(*2.19*)	1.23(*3.01*)	0.85(*2.29*)	0.58(*1.78*)	0.73(*1.29*)	0.75(*2.01*)
Mullet, White	0.00(*0.00*)	0.02(*0.16*)	0.01(*0.08*)	0.01(*0.08*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.01(*0.08*)	0.00(*0.00*)	0.00(*0.06*)
Perch, White	0.00(*0.00*)	0.13(*0.56*)	0.02(*0.13*)	0.02(*0.15*)	0.03(*0.19*)	0.35(*1.26*)	0.01(*0.08*)	0.02(*0.15*)	0.20(*0.89*)	0.04(*0.28*)	0.24(*1.10*)	0.08(*0.44*)
Pipefish, Northern	0.07(*0.27*)	0.06(*0.30*)	0.11(*0.42*)	0.21(*0.48*)	0.22(*0.56*)	0.09(*0.34*)	0.10(*0.31*)	0.19(*0.49*)	0.08(*0.27*)	0.13(*0.46*)	0.09(*0.33*)	0.12(*3.70*)
Pollock	0.00(*0.00*)	0.01(*0.08*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.01(*0.08*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.02(*0.18*)	0.00(*0.03*)
Pumpkinseed	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.02(*0.16*)	0.01(*0.08*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.01(*0.08*)	0.00(*0.00*)	0.00(*0.06*)
Raven, Sea	0.02(*0.11*)	0.01(*0.08*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.01(*0.12*)	0.01(*0.08*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.06*)
Shad, American	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.00(*0.00*)	0.02(*0.16*)	0.01(*0.08*)	0.00(*0.00*)	0.01(*0.08*)	0.00(*0.05*)
Silverside, Atlantic	8.24(*7.39*)	27.73(*10.20*)	26.38(*12.98*)	18.67(*9.57*)	11.20(*9.42*)	24.77(*12.19*)	18.87(*11.81*)	21.78(*10.15*)	19.21(*9.23*)	21.17(*15.59*)	12.94(*11.64*)	18.77(*10.66*)
Smelt, Rainbow	0.42(*1.69*)	0.39(*4.28*)	0.49(*4.45*)	0.24(*3.31*)	0.13(*2.35*)	0.41(*4.33*)	0.56(*3.51*)	0.15(*3.60*)	0.51(*3.10*)	0.21(*4.00*)	0.29(*1.26*)	0.34(*1.42*)
Stickleback, Fourspine	0.14(*0.58*)	0.43(*1.22*)	0.85(*2.06*)	0.40(*0.94*)	0.37(*1.13*)	0.36(*1.49*)	0.28(*0.79*)	0.14(*0.52*)	0.23(*0.76*)	0.29(*0.89*)	0.53(*1.44*)	0.34(*1.03*)
Stickleback, Ninespine	0.23(*0.80*)	0.15(*0.87*)	0.78(*3.09*)	0.05(*0.25*)	0.41(*1.94*)	0.41(*1.48*)	0.05(*0.28*)	0.04(*0.21*)	0.22(*0.92*)	0.22(*0.91*)	0.11(*0.36*)	0.24(*1.10*)
Stickleback, Threespine	0.05(*0.22*)	0.06(*0.28*)	0.06(*0.29*)	0.02(*0.11*)	0.01(*0.08*)	0.05(*0.19*)	0.02(*0.13*)	0.00(*0.00*)	0.01(*0.08*)	0.03(*0.15*)	0.00(*0.00*)	0.03(*0.17*)
Tomcod, Atlantic	0.17(*0.69*)	0.07(*0.33*)	0.05(*0.25*)	0.06(*0.25*)	0.11(*0.48*)	0.30(*0.98*)	0.09(*0.39*)	0.19(*0.79*)	0.23(*0.87*)	0.29(*1.25*)	0.23(*0.82*)	0.15(*0.65*)
All species	29.22(*5.20*)	62.10(*6.32*)	80.15(*6.51*)	46.59(*6.58*)	36.34(*6.45*)	64.47(*7.00*)	53.31(*6.77*)	59.60(*6.07*)	55.20(*7.16*)	51.87(*11.40*)	42.26(*6.73*)	52.04(*6.93*)

Table 3.3-4. Geometric mean catch per seine haul, by station and species, for all months combined, from a juvenile finfish seine survey conducted in New Hampshire estuaries, 2019.

	Station #														
	Little Harbor			Hampton/Seabrook Estuary				Piscataqua River			Little Bay/Great Bay				
Species	5	7	9	23	25	29	33	30	35	39	54	72	93	107	147
Alewife	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.81	0.00	0.12	0.12	0.12	0.00
Bass, Striped	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00
Crab, Green	1.22	1.12	1.53	1.14	1.14	0.12	0.00	14.39	11.26	0.94	0.62	0.93	1.04	0.00	5.08
Crab, Horseshoe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.41	0.12	0.00
Cunner	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.12	0.00	0.00	0.12
Flounder, Smooth	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	1.57	0.35	0.41	0.35	5.20	0.92	0.12
Flounder, Winter	0.12	0.51	0.51	0.00	0.20	0.12	0.00	0.91	0.57	0.12	0.62	0.66	0.00	0.00	0.12
Grubby	0.20	0.47	0.12	0.41	0.00	0.00	0.00	0.78	0.00	0.12	0.00	0.26	0.00	0.00	1.22
Hake, Red	0.00	0.12	0.26	0.00	0.00	0.12	0.00	0.51	0.12	0.12	0.26	0.00	0.00	0.00	0.12
Herring, Atlantic	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.20	0.69	1.19	0.82	0.82	1.29	0.60	1.24
Herring, Blueback	0.12	0.20	0.00	0.12	0.00	0.00	0.00	0.72	0.00	0.62	0.20	0.53	0.00	0.31	0.00
Killifish, Striped	0.12	0.12	0.00	0.00	0.00	0.00	0.00	0.59	6.43	6.24	21.72	5.93	27.21	5.53	6.07
Lance, American Sand	0.00	0.00	0.12	0.00	0.51	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Menhaden, Atlantic	0.20	0.00	0.00	0.00	0.12	0.00	0.00	0.12	0.26	0.00	0.00	0.00	0.12	0.73	0.00
Moonfish, Atlantic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12
Mummichog	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.12	0.41	3.91	2.24	0.78	5.81	2.52	2.15
Perch, White	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	5.59	0.00
Pipefish, Northern	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.35	0.12	0.35	0.00	0.12	0.51
Pollock	0.00	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Shad, American	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00
Silverside, Atlantic	4.05	4.20	21.58	26.76	1.14	1.26	0.00	42.72	39.78	6.64	95.92	48.53	35.34	28.65	25.08
Smelt, Rainbow	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.78	2.76	0.00	0.59	0.51	0.00	0.12	1.18
Stickleback, Fourspine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.20	3.22	0.74	0.00	1.04	0.78	15.59
Stickleback, Ninespine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.26	0.35	0.12	0.26	0.00	0.89
Tomcod, Atlantic	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.12	0.12	0.00	0.78	0.67	0.00	0.41	2.71
All species	11.10	10.87	51.44	54.12	4.86	2.85	0.20	140.78	322.15	53.14	355.70	171.88	188.15	75.31	139.07

Table 3.3-5. Geometric Mean catch per seine haul, by species and month, for all stations combined, from a juvenile finfish seine survey conducted in New Hampshire estuaries, 2019.

Species	June	July	August	September	October	November
Alewife	0.27	0.00	0.05	0.00	0.00	0.15
Bass, Striped	0.00	0.00	0.00	0.00	0.00	0.05
Crab, Green	2.24	4.24	1.65	0.94	0.91	0.43
Crab, Horseshoe	0.15	0.00	0.05	0.05	0.00	0.00
Cunner	0.00	0.00	0.00	0.00	0.10	0.05
Flounder, Smooth	0.81	0.64	0.35	0.25	0.17	0.08
Flounder, Winter	0.00	0.37	0.38	0.37	0.41	0.15
Grubby	0.36	0.40	0.05	0.10	0.13	0.22
Hake, Red	0.05	0.00	0.10	0.10	0.36	0.05
Herring, Atlantic	4.77	0.13	0.08	0.00	0.05	0.00
Herring, Blueback	0.21	0.11	0.00	0.05	0.79	0.00
Killifish, Striped	0.71	0.82	3.76	4.65	4.34	0.93
Lance, American Sand	0.10	0.00	0.00	0.05	0.18	0.00
Menhaden, Atlantic	0.00	0.08	0.00	0.05	0.43	0.05
Moonfish, Atlantic	0.00	0.00	0.00	0.00	0.05	0.00
Mummichog	0.69	1.25	1.18	0.61	0.75	0.16
Perch, White	0.05	0.22	0.42	0.46	0.29	0.08
Pipefish, Northern	0.05	0.21	0.00	0.00	0.26	0.08
Pollock	0.11	0.00	0.00	0.00	0.00	0.00
Shad, American	0.05	0.00	0.00	0.00	0.00	0.00
Silverside, Atlantic	0.45	0.36	34.04	47.33	56.70	37.17
Smelt, Rainbow	0.05	0.10	0.05	0.33	1.48	0.15
Stickleback, Fourspine	0.62	0.63	0.38	0.55	0.47	0.55
Stickleback, Ninespine	0.10	0.13	0.17	0.08	0.13	0.10
Tomcod, Atlantic	0.79	0.29	0.13	0.18	0.13	0.00
All species	19.72	13.34	60.86	76.00	95.06	47.18

Table 3.3-6. Arithmetic mean, minimum, and maximum total length (cm), as well as sample size (N), for all fish species measured, from a juvenile finfish seine survey conducted in New Hampshire estuaries, 2019.

Species	Total length (cm)			
	AM	Minimum	Maximum	N
Alewife	13.43	3.60	24.30	29
Bass, Striped	81.30	81.30	81.30	1
Cunner	4.23	3.20	5.20	3
Flounder, Smooth	6.09	2.90	12.20	96
Flounder, Winter	6.65	2.40	25.60	43
Grubby	4.71	2.90	7.40	31
Hake, Red	5.90	2.70	9.00	13
Herring, Atlantic	6.63	4.60	12.20	152
Herring, Blueback	10.44	4.10	24.60	64
Killifish, Striped	5.68	3.50	8.70	155
Lance, American Sand	4.73	2.80	9.70	479
Menhaden, Atlantic	8.70	5.60	10.50	10
Moonfish, Atlantic	9.35	4.10	34.90	17
Mummichog	3.80	3.80	3.80	1
Perch, White	5.72	2.80	28.00	108
Pipefish, Northern	15.69	7.80	20.50	14
Pollock	5.58	5.20	5.80	4
Shad, American	17.60	17.60	17.60	1
Silverside, Atlantic	8.32	3.40	13.60	1,147
Smelt, Rainbow	6.46	3.30	9.00	60
Stickleback, Fourspine	4.00	3.00	5.10	150
Stickleback, Ninespine	4.21	3.00	5.00	16
Tomcod, Atlantic	7.85	4.60	14.00	66
			Total	2,660

Table 3.3-7. Mean minimum, and maximum water surface temperature and salinity, from a juvenile finfish seine survey conducted in New Hampshire estuaries, 2009 – 2019.

	Temperature (°C)			Salinity (ppt)		
Year	Mean	Min	Max	Mean	Min	Max
2009	15.9	6.9	23.8	24.1	2.3	31.5
2010	17.1	7.5	26.7	27.1	9.7	31.2
2011	17.2	5.7	28.2	23.7	1.6	30.2
2012	17.1	6.2	28.2	26.1	4.7	31.1
2013	16.2	3.5	27.9	25.1	2.3	32.1
2014	16.8	7.2	28.1	26.9	6.2	34.4
2015	16.8	10.8	26.2	27.8	9.2	31.9
2016	17.4	8.6	30.6	29.2	11.7	32.3
2017*	16.0	5.6	25.6	28.0	10.4	31.6
2018	17.5	2.4	27.6	24.6	0.2	31.4
2019*	17.2	5.8	30.8	26.6	7.1	31.8
Mean	16.8			26.3		

*Data for some samples not collected due to instrument failure

Table 3.3-8. Water surface temperature (ºC) by month and station, from a juvenile finfish seine survey conducted in New Hampshire estuaries, 2019.

	Station #															
	Little Harbor			Hampton/Seabrook Estuary				Piscataqua River			Little Bay/Great Bay					Monthly
Month	5	7	9	23	25	29	33	30	35	39	54	72	93	107	147	mean
June	14.2	16.2	17.1	17.1	18.5	19.0	18.8	16.2	17.0	22.0	19.0	16.2	17.9	19.2	17.5	17.7
July	15.2	17.3	17.8	19.3	20.3	20.6	20.8	18.7	18.9	25.6	21.7	22.7	25.7	27.6	25.7	21.2
August	16.0	18.0	18.8	17.6	*	*	20.2	19.2	19.8	23.8	22.3	21.8	24.4	24.0	24.7	20.6
September	14.6	16.4	16.3	20.0	16.1	16.1	16.1	17.8	18.2	15.5	19.9	20.0	21.0	22.3	22.8	18.2
October	14.2	13.8	13.8	14.0	14.6	15.1	15.0	14.2	14.4	16.2	30.8	15.8	17.3	17.7	16.7	16.2
November	10.4	10.5	10.1	6.5	6.0	5.8	5.8	11.2	11.0	10.0	11.4	11.6	10.3	12.1	10.7	9.6
Site mean	14.1	15.4	15.7	15.8	15.1	15.3	16.1	16.2	16.6	18.9	20.9	18.0	19.4	20.5	19.7	
Area mean	15.0			15.6				17.2			19.7					

*Data not collected due to instrument failure

Table 3.3-9. Salinity (ppt) by month and station, from a juvenile finfish seine survey conducted in New Hampshire estuaries, 2019.

	Station #															
	Little Harbor			Hampton/Seabrook Estuary				Piscataqua River			Little Bay/Great Bay					Monthly
Month	5	7	9	23	25	29	33	30	35	39	54	72	93	107	147	mean
June	29.2	28.4	27.5	27.1	28.6	27.9	28.3	26.8	25.3	10.5	24.2	24.2	21.6	15.1	20.4	24.3
July	28.6	29.7	29.9	29.9	30.0	29.9	29.8	28.4	27.2	14.8	26.0	26.5	24.3	16.0	24.7	26.4
August	30.4	30.5	30.2	30.5	*	*	29.9	29.6	29.2	15.0	28.2	28.9	26.5	21.1	25.7	27.4
September	30.8	30.5	30.8	25.8	31.1	31.2	31.2	29.8	28.6	21.5	28.2	28.3	26.7	17.8	26.3	27.9
October	31.1	27.2	31.2	30.6	31.0	30.9	30.9	31.0	30.4	24.6	15.3	30.7	29.9	27.1	29.9	28.8
November	30.2	29.5	27.9	31.1	31.8	31.0	30.9	27.3	25.5	7.1	24.2	24.2	21.6	9.7	21.6	24.9
Site mean	30.1	29.3	29.6	29.2	30.5	30.2	30.2	28.8	27.7	15.6	24.4	27.1	25.1	17.8	24.8	
Area mean	29.6			30.0				24.0			23.8					

*Data not collected due to instrument failure

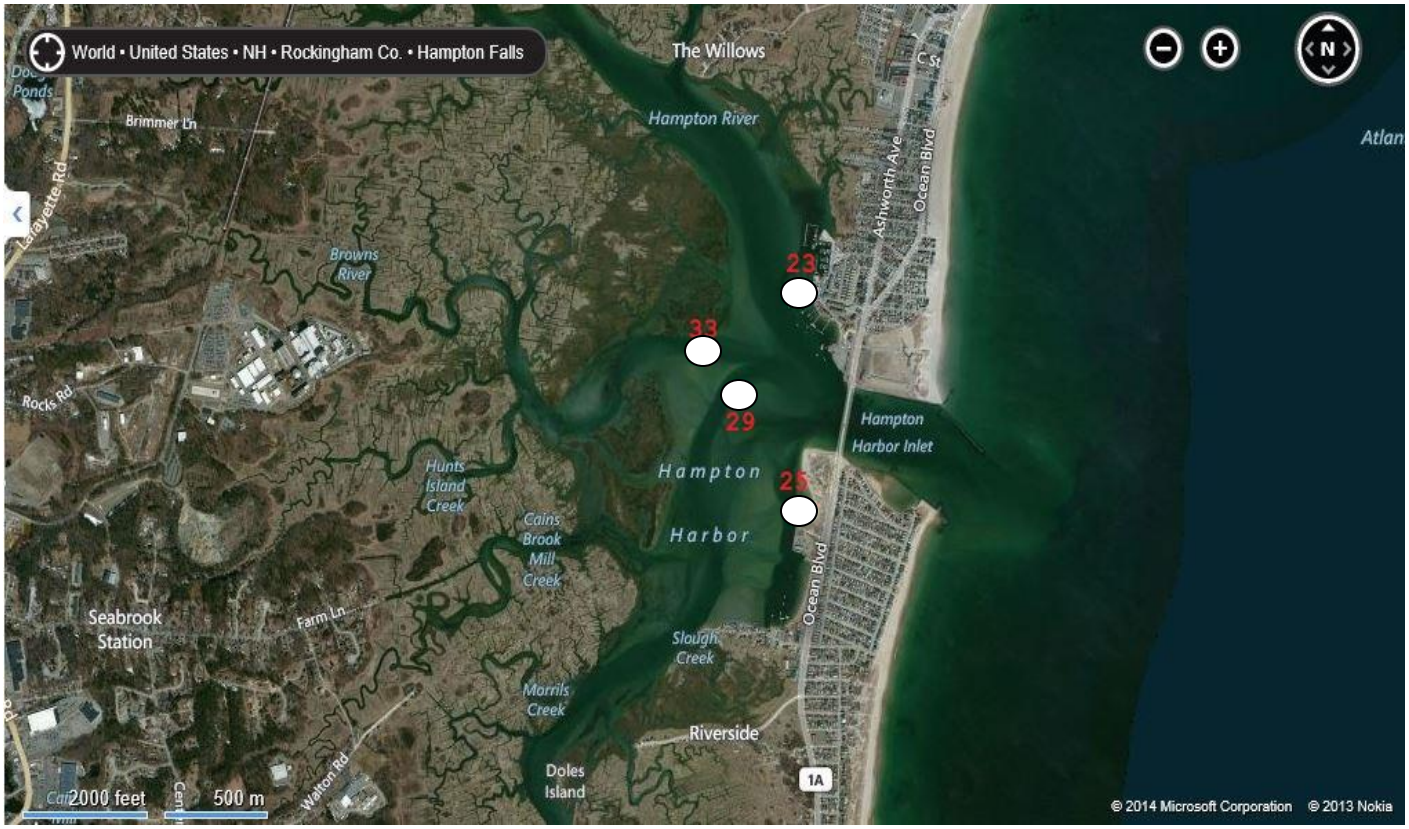

Figure 3.3-1. Sampling stations in Hampton/Seabrook Estuary, from a juvenile finfish seine survey conducted in New Hampshire estuaries, 2019.

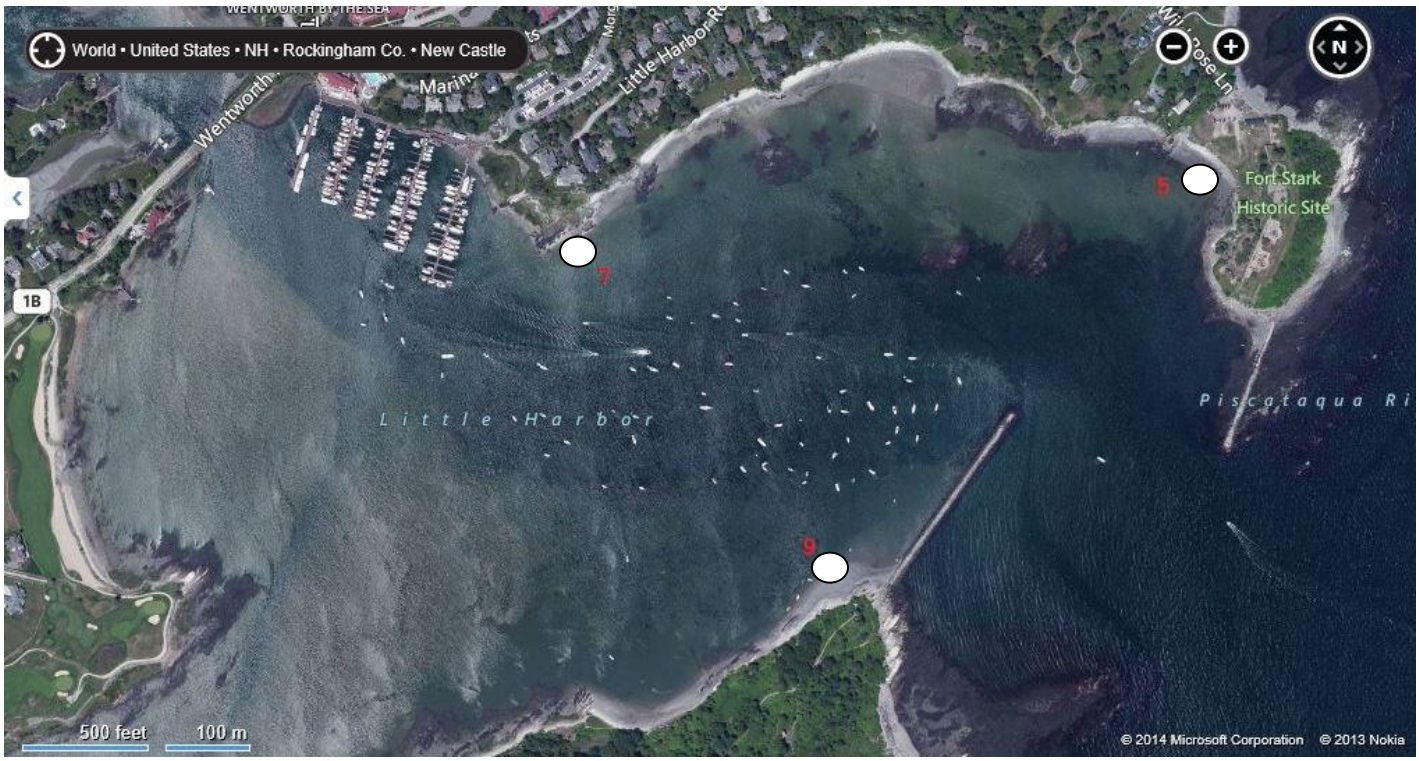

Figure 3.3-2. Sampling stations in Little Harbor, from a juvenile finfish seine survey conducted in New Hampshire estuaries, 2019.

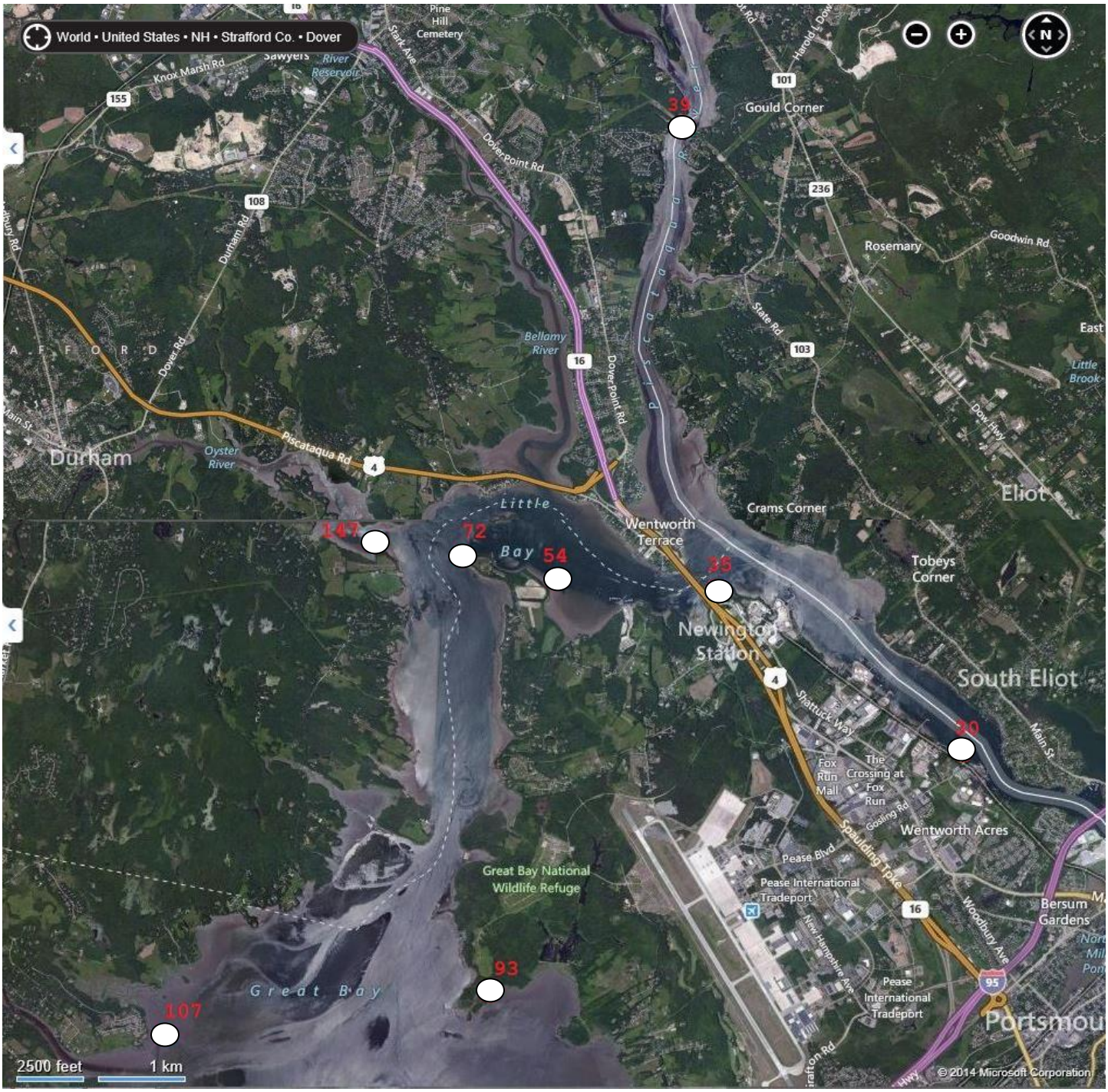

Figure 3.3-3. Sampling stations in the Piscataqua River and Little Bay/Great Bay area from a juvenile finfish seine survey conducted in New Hampshire estuaries, 2019.

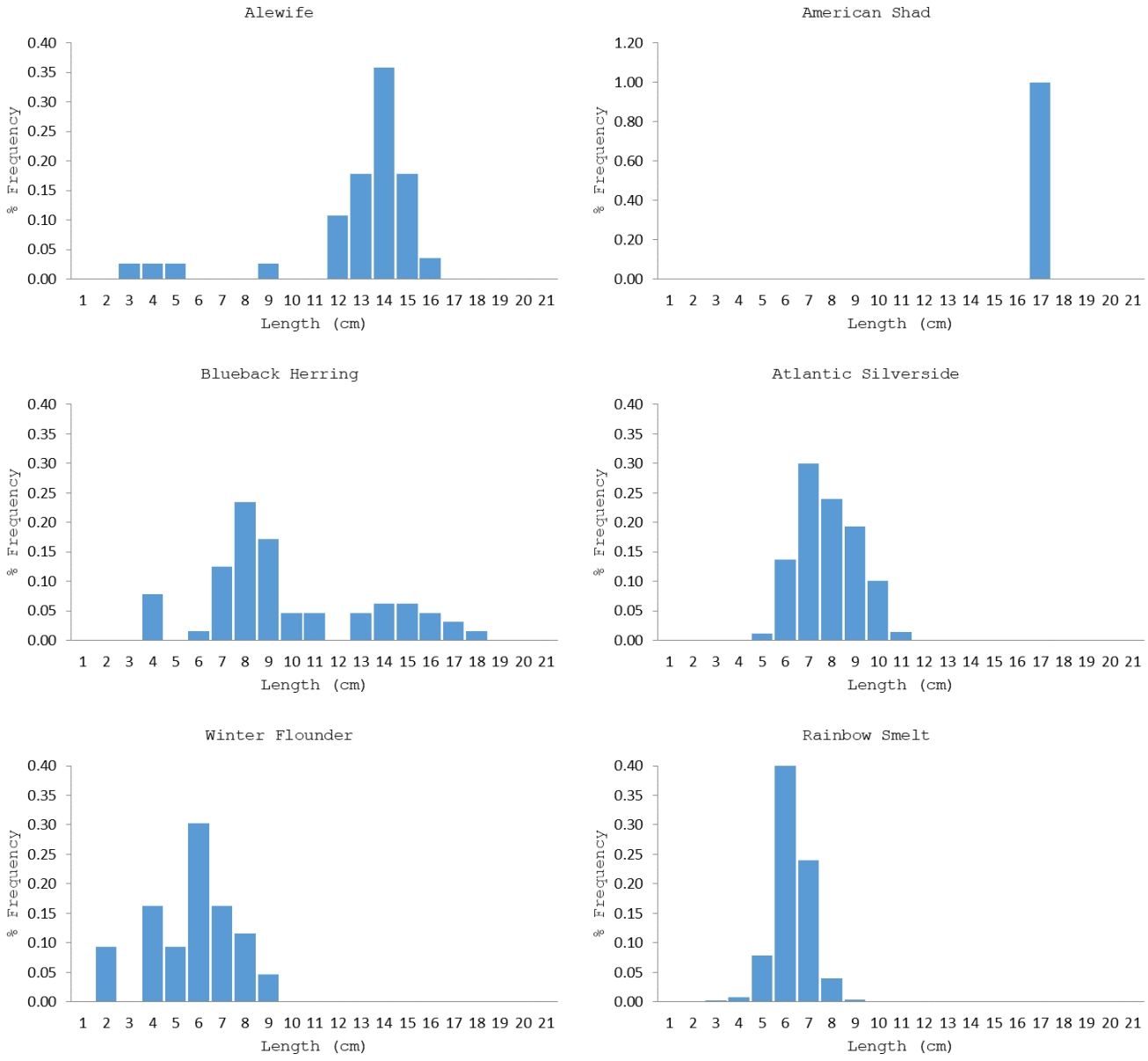

Figure 3.3-4. Weighted length frequencies of six finfish species of special interest captured from a juvenile finfish seine survey conducted in New Hampshire estuaries, 2019.