



CHAPTER 10.

Nekton

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Nekton

Introduction

Nekton generally refers to free-swimming organisms including invertebrates, fish, and marine turtles and mammals. In estuaries, however, this term typically refers to fishes and decapod crustaceans. Nekton is a critical functional component of estuarine ecosystems. Some estuarine nekton species are commercially and recreationally important, while others provide food for birds, mammals, and larger fish (Friedland et al., 1988; Sekiguchi, 1995; Smith, 1997). Some species of nekton can physically transfer organic materials between intertidal and subtidal estuarine habitats (Cicchetti, 1998), and as a guild, nekton can be used as an indicator of estuarine condition (Deegan et al., 1997). In some situations, nekton can exert substantial top-down control over estuarine system processes (Silliman and Bertness, 2002). Nekton is also a charismatic group of species that the public can easily relate to; it therefore can provide an important link between estuarine science and education or policy.

Narragansett Bay provides refuge, spawning, and foraging habitats for a diverse assemblage of nekton. Due to its location in southern New England, Narragansett Bay supports species from northern, boreal areas as well as species from subtropical and tropical climates over an annual cycle. These species include permanent and seasonal residents, seasonal and occasional visitors, anadromous and catadromous species, and accidentals and strays. Narragansett Bay provides support functions for all life history stages of nekton, including planktonic, larval, juvenile, and adult stages. When present in Narragansett Bay, these nekton have available to them a wide variety of habitats that include open water, unvegetated bottoms, intertidal beaches, salt and brackish marshes, SAVs, tidal freshwater creeks, rocky reefs, and human-modified shorelines.

Many species of nekton in Narragansett Bay support commercial or recreational fisheries (DeAlteris et al., 2000) and thus have been the focus of numerous research and monitoring programs. Based on data from several ongoing nekton monitoring programs, a great deal is known about the long-term trends in species abundance and biomass as well as distribution patterns over time. Aside from this, surprisingly little research has actually been done that specifically examines the ecology and functional role of most fish species in Narragansett Bay. For example, Keller et al. (1996) indicates that we still do not fully understand why the abundance of some

species varies considerably over time independent of fishing pressure.

The goal of this chapter is to provide an ecological overview of nekton from two major zones of the Bay (open water and shore) and another overview focusing on ichthyoplankton. Open water nekton include those species that typically are found in the deepwater areas of the Bay, either in pelagic or demersal habitats, and those that are typically captured with a trawl. Shore-zone or intertidal nekton include those species that are found in shallow water habitats of the Bay that include salt marshes, eelgrass beds, coves, embayments and unvegetated shallows.

Open-water Nekton

One of the first studies that focused on fishes in the open waters of Narragansett Bay was conducted over 30 years ago by Oviatt and Nixon (1973). These authors used a trawl to sample from nine regular and 13 occasional stations in Narragansett Bay for one year. Forty-four species were documented in Narragansett Bay. Although typical of temperate estuaries, a small number of species dominated the catch (in this study, the 10 most abundant species made up 91 percent of the catch). This study also demonstrated that:

- The composition of the fish community in Narragansett Bay is comparable to those in Block Island and Long Island sounds.
- Fish abundance and biomass per unit area are comparable to other New England coastal and offshore areas, although standing crop was much less than in kelp forests, coral reefs, and salt marshes.
- Winter flounder (*Pseudopleuronectes americanus*) was easily the most abundant species, making up 36 percent of the catch.
- Spatial patterns in fish distribution were not apparent except that diversity was highest near the mouth of the Bay.
- The demersal fish in Narragansett Bay may be important in regulating the diversity and abundance of the benthos.

Oviatt and Nixon's work was limited in that it only documented the fish of Narragansett Bay at one point in time. For example, although winter flounder dominated in 1971–72, this and other

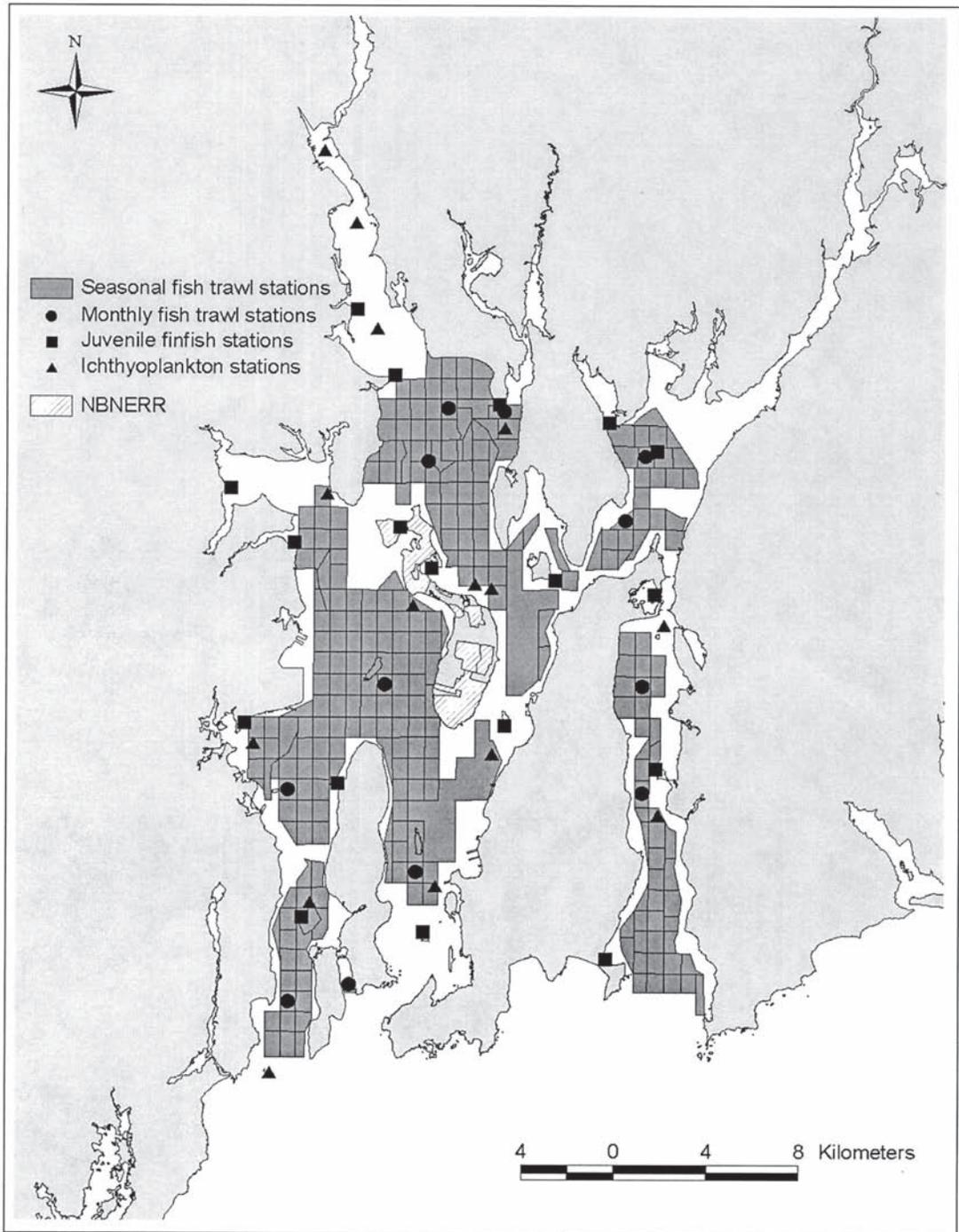


Figure 10.1. Locations of sampling stations that are part of the seasonal and monthly fish trawl survey, the juvenile finfish survey, and the Keller et al. ichthyoplankton survey that are discussed in this chapter.



demersal species have declined dramatically in subsequent decades (Oviatt et al., 2003). In recognition of the need for detailed fisheries data over time, two long-term monitoring programs were initiated in the open waters of Narragansett Bay. These programs are the RIDEM sportfish trawl survey throughout Narragansett Bay and in Rhode Island and Block Island sounds (e.g., Lynch, 2000), and the GSO fish trawl survey (Jeffries and Johnson, 1974; Jeffries and Terceiro, 1985; Jeffries et al., 1989). The GSO trawl survey is the longer running of the two, dating back to 1959; however, this survey is spatially limited since samples are only collected from two stations in the West Passage of Narragansett Bay. In contrast, the RIDEM trawl survey began 20 years later in 1979, but it samples throughout the entire Bay (Fig. 10.1) and thus provides a more comprehensive dataset in terms of combining temporal and spatial coverage. The RIDEM program has two components: a monthly survey at 12 fixed stations in the Bay that began in 1990, and a seasonal survey in spring and fall at approximately 50 stations (selected randomly from approximately 265 stations located throughout the Bay) that began in 1979.



From 1979 through 2003, 107 species (mostly fish, a few crustaceans, and one bivalve species) have been collected from the combined efforts of the RIDEM monthly and seasonal fish trawls. However, the mean number of species in any given year is much less, averaging 57 species per year from the monthly program and 45 species per year from the seasonal program (Fig 10.2). This illustrates the value of the two programs—more species are observed annually with the monthly effort, which provides a more comprehensive overall view of fish community composition and structure, while the seasonal program provides more information on the Bay-wide distribution of common species because more stations are sampled. Based on abundance from the seasonal data, five species make up greater than 90 percent of the community found in Narragansett Bay since 1979. In decreasing abundance, these species include bay anchovy (*Anchoa mitchilli*, 51 percent of total abundance), scup (*Stenotomus chrysops*, 19 percent), longfin squid (*Loligo pealei*, 8 percent), menhaden (*Brevoortia tyrannus*, 6 percent), and butterfish (*Peprilus triacanthus*, 5 percent) (Appendix 10.1). Using the same data, but considering biomass, 13 species make up over 90 percent of the total nekton biomass. In decreasing order, these species are scup (19 percent),

winter flounder (18 percent), American lobster (9 percent), skates (Rajidae, 9 percent), windowpane flounder (*Scophthalmus aquosus*, 6 percent), longfin squid (6 percent), tautog (*Tautoga onitis*, 6 percent), butterfish (5 percent), summer flounder (*Paralichthys dentatus*, 4 percent), bay anchovy (3 percent), weakfish (*Cynoscion regalis*, 2 percent), Atlantic herring (*Clupea harengus*, 2 percent), and bluefish (*Pomotomus saltatrix*, 2 percent). Based on biomass, the nekton species that dominate Narragansett Bay are primarily demersal species such as flounders, lobster, and skates. However, based on abundance, the opposite is true where the dominant species are mostly small, schooling, pelagic species.

The data from the RIDEM trawl programs are particularly useful for observing trends in fish over time and at a Bay-wide scale.

There is no clear trend in the annual number of species in Narragansett Bay (Fig. 10.2), nor is there a trend in total fish biomass over time (Fig. 10.3). In contrast, total abundance is tending to increase over time, mostly due to increases in small pelagic schooling fish such as Atlantic menhaden and bay anchovy. In fact, these data have documented a shift in species abundance patterns in Narragansett Bay. The Bay is undergoing a shift from a community

dominated by demersal species to a system dominated by pelagic species that may be due to climate and bottom-trawl fishing (Oviatt et al., 2003). Further, data from the seasonal trawl survey illustrate that this trend is occurring on a Bay-wide scale. For example, using GIS, it is clear that the abundance of the commercially important winter flounder has been in steady decline since at least the beginning of the survey, and this decline is evident throughout Narragansett Bay (Fig. 10.4). Similar patterns have been observed for other demersal species, including those that are not exposed to fishing pressure (e.g., hogchoker, *Trinectes maculatus*) (Lynch, personal communication).

In contrast to the abundance of long-term monitoring data, surprisingly little research on open-water nekton in Narragansett Bay has been conducted, especially recently. However, there are some notable recent examples. Durbin and Durbin (1998) used a bioenergetic model to examine the effects of menhaden predation on phytoplankton in Narragansett Bay. DeAlteris et al. (2000) used monitoring and landing data to summarize the status and trends of many of Narragansett Bay's commercial fisheries. Lapolla (2001a, 2001b) examined a number of population characteristics of the bay anchovy in

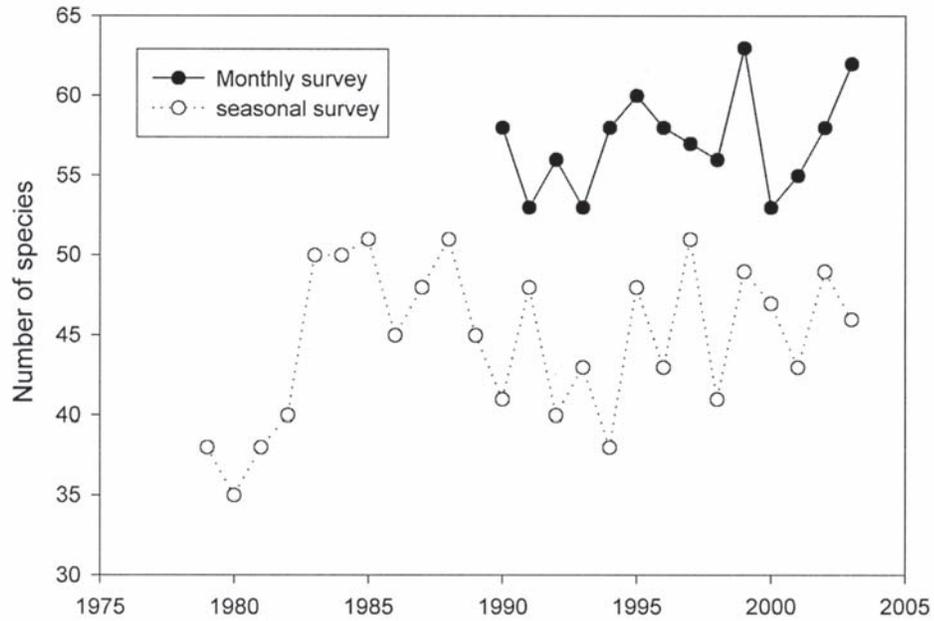


Figure 10.2. The average annual number of species of nekton in Narragansett Bay as determined from the RIDEM seasonal and monthly fish trawl program. Nearly all the species are fishes; relatively few are invertebrates.

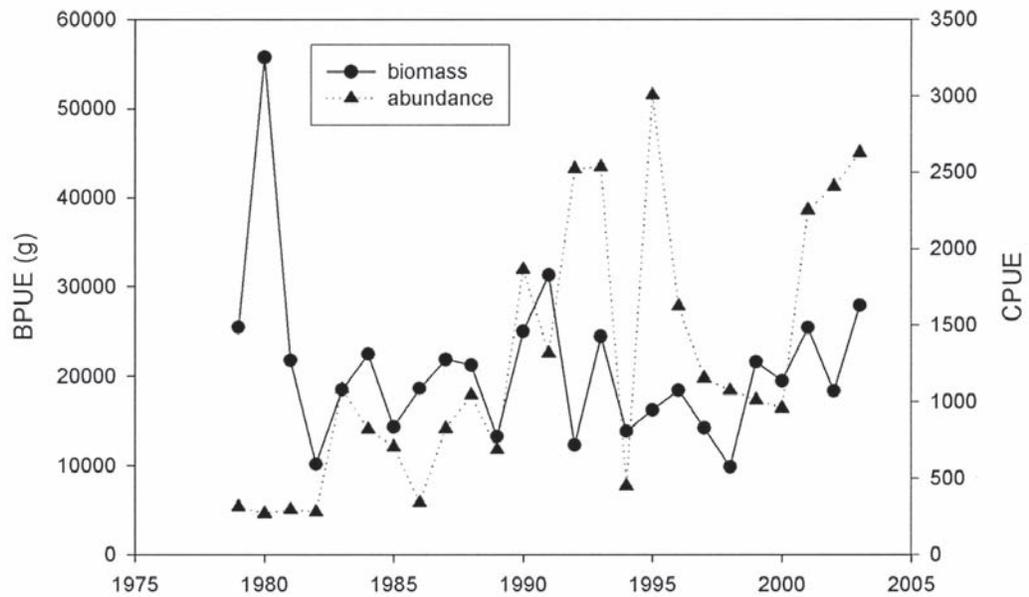


Figure 10.3. Mean catch (abundance) (number of individuals captured per trawl; CPUE) and mean biomass (biomass in grams per trawl; BPUE) between 1979 and 2003 from the RIDEM seasonal fish trawl.

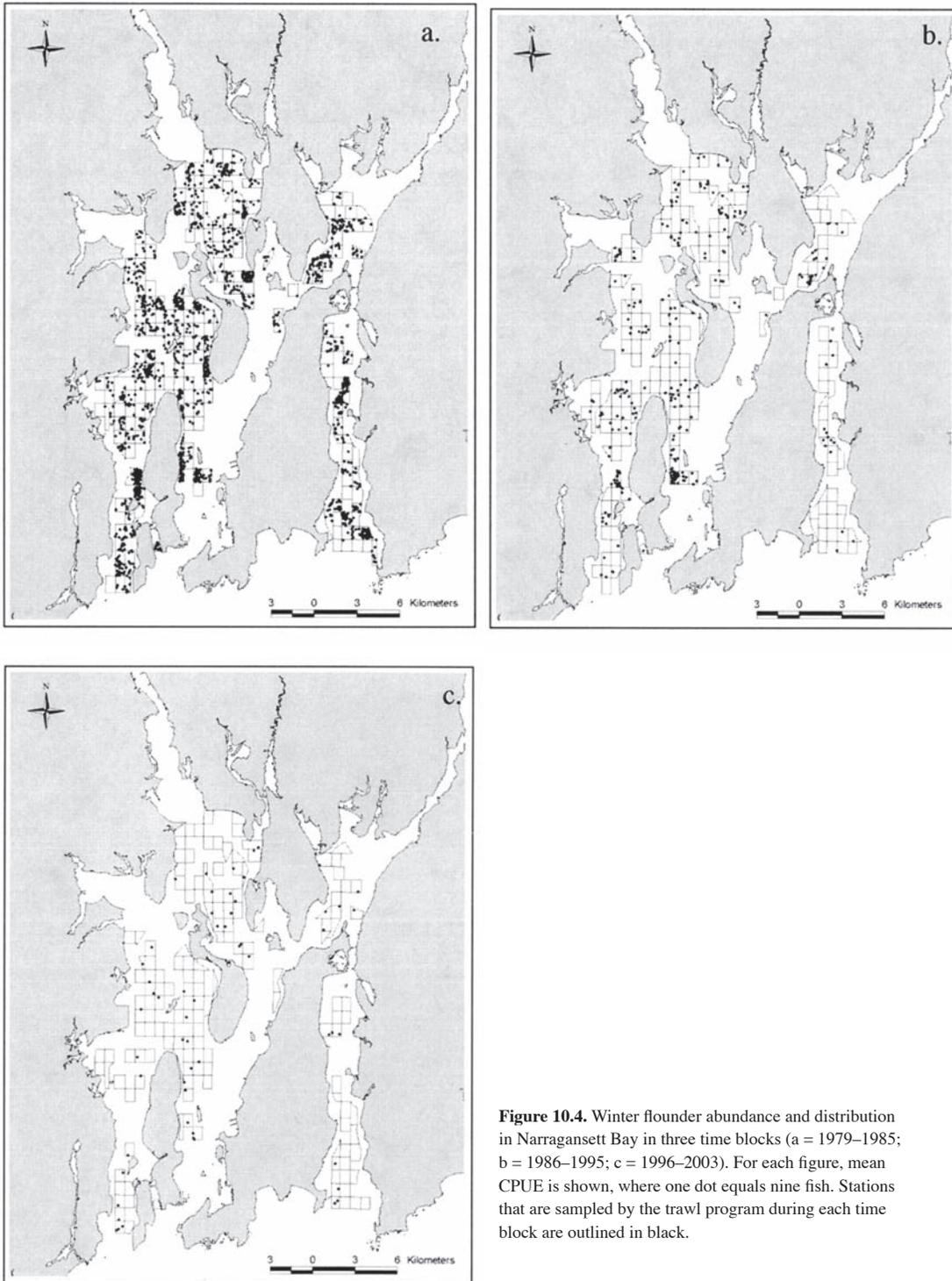


Figure 10.4. Winter flounder abundance and distribution in Narragansett Bay in three time blocks (a = 1979–1985; b = 1986–1995; c = 1996–2003). For each figure, mean CPUE is shown, where one dot equals nine fish. Stations that are sampled by the trawl program during each time block are outlined in black.



Figure 10.5. Researchers conducting the RIDEM juvenile finfish seine survey. Photo by J. Christopher Powell, RIDEM.

Narragansett Bay, including population structure, growth, mortality, and spawning season. Meng et al. (2001) found that winter flounder growth rates in Narragansett Bay were lower in the upper Bay, suggesting that anthropogenically lowered dissolved oxygen levels had a negative impact on this species. More recently, Oviatt et al. (2003) used historic and current data to demonstrate the dramatic effects humans have had on the fishes of Narragansett Bay through fishing pressures, and Castro and Angell (2000), Castro et al. (2005), and Cobb and Castro (2006) have examined aspects of the emergence, spread, and severity of lobster shell disease in the Bay.

Shore-zone and Intertidal Nekton

Shallow estuarine waters provide critical nursery habitats for juvenile estuarine fish and permanent habitats for some abundant forage species. These types of habitats are often at risk, however, due to their proximity to the land and thus the activities of humans. Nekton in shallow, shore-zone habitats are monitored monthly from June through October by RIDEM with a juvenile finfish seining survey at 20 nearshore stations in Narragansett Bay (Fig. 10.5). Since the inception of this program in 1990, 78 species (or undifferentiated species within the same family, e.g., gobidae, bothidae) have been collected from nearshore and shore-zone habitats as part of this monitoring program. Based on abundance, the most common species include Atlantic menhaden (62 percent of total abundance), silversides (*Menidia* spp., 8 percent), river herring species (6 percent), bluefish (*Pomotomus saltatrix*, 4 percent), winter flounder (3 percent), striped killifish (*Fundulus majalis*, 3 percent), sea herring species (3 percent), and bay anchovy (2 percent) (Appendix

10.2). Meng and Powell (1999) used these data to explore relationships between fish communities and habitats. This study found that separate analyses of fish communities and their habitats correlated well. In addition, it was found that total abundance, species richness, and the number of winter flounder were highest at an upper Bay station. This is contrary to the findings of Oviatt and Nixon (1973); however, the two studies used different gears to sample different age classes of fish, and the two studies were conducted over 25 years apart. Dorf and Powell (1997) used these same seining data to document the distribution and habitat preferences of juvenile tautog, a recreationally important species, in Narragansett Bay. More recently, DeLong et al. (2001) used data from this survey in a model to examine the effects of density and environmental conditions on the growth of juvenile winter flounder.

Nekton has also been sampled extensively from salt marsh habitats around Narragansett Bay and the south shore of Rhode Island (Fig. 10.6). As with salt marshes elsewhere, marshes in Rhode Island clearly support highly abundant and produc-





tive nekton communities (Raposa, 2002; Meng et al., 2004). Quantitative data collected from three salt marshes around Rhode Island show that these marshes are consistently dominated by very few species (i.e., species diversity is low). These species include the common mummichog (*Fundulus heteroclitus*), striped killifish, sheephead minnow (*Cyprinodon variegatus*), Atlantic and inland silversides (*Menidia menidia* and *Menidia beryllina*, respectively), and grass shrimp (*Palaemonetes* spp.) (Appendix 10.3). Less abundant, though ecologically important, species that also use Narragansett Bay salt marshes include juvenile winter flounder, sticklebacks (e.g., three-spined *Gasterosteus aculeatus*, fourspine *Apeltes quadracus*, and nine-spined *Pungitius pungitius*), American eel (*Anguilla rostrata*), and blue crab (*Callinectes sapidus*). The data in Appendix 10.3 further indicate that while general patterns of species composition are similar among marshes, large differences in density exist (e.g., *Palaemonetes pugio*). Halpin (1997) also noted substantial differences in mummichog use among different Narragansett Bay salt marshes. The factors that contribute to differences in nekton composition and abundance among salt marshes in Narragansett Bay are largely unknown and need to be identified and examined, especially in light of ongoing and future marsh restoration efforts.

Marsh nekton species can move among and utilize multiple marsh habitats (e.g., creeks, pools, vegetated marsh surface) depending on life history stage and tide stage. Roman et al. (2003) showed that more species were found in subtidal creeks and pools when compared to intertidal marsh habitats in the Sachuest Point salt marsh in Middletown, R.I. Data from Raposa (2002) in the Galilee, R.I., salt marsh indicate that nekton tend to be more abundant in subtidal, rather than intertidal, marsh creeks. In nearby Cape Cod, Mass., Raposa (2003) showed that mummichogs moved into soft-substrate pools in fall where they burrowed into the sediments to overwinter. A given marsh is a dynamic place with multiple habitats interacting to support nekton. Threats to some of these habitats in Rhode Island marshes include the invasion of high marsh by the common reed, *Phragmites australis*, the loss of marsh pools due to historic ditching, and tidal restrictions that limit nekton access to marsh surface habitats, which are used for foraging, nursery, and refuge.

The restoration of tide-restricted salt marshes around Narragansett Bay is clearly returning natural and abundant nekton communities to marshes that supported a dysfunctional and depleted community. Studies indicate that removing tide-restricting structures results in improved nekton function, and that the more severe the restriction, the more negatively

affected the nekton community is, and the more positive the response is after restoration (Raposa, 2002; Raposa, unpublished data; Raposa and Roman, 2003; Roman et al., 2003). A consortium of agencies, including the R.I. Coastal Resources Management Council, the Narragansett Bay Estuary Program, and Save The Bay, among others, has identified salt marshes around Narragansett Bay that are in need of restoration, and some of these efforts are under way. If previous results hold true, these restoration efforts should continue to return nekton communities to more natural conditions representative of unrestricted salt marshes. In addition to removing tidal restrictions, efforts should seek to restore pool habitats that were lost from ditching. Salt marsh pools can support dense nekton assemblages (Raposa and Roman, 2001), and if the pools are shallow enough, this nekton provides attractive forage for wading birds.

Ichthyoplankton

Ichthyoplankton (eggs and larvae) are early life-history stages of nekton that are useful for understanding adult spawning patterns and temporal fluctuations in the abundance of juvenile and adult nekton. Ichthyoplankton are particularly abundant in estuaries in part due to the use of these areas as spawning and nursery grounds by nekton species. In recognition of this, and to help fill a critical data gap, multiple surveys and ichthyoplankton monitoring programs were initiated in Narragansett Bay. The first survey occurred in 1957–1958 and included sampling in the lower East Passage of Narragansett Bay and in Mount Hope Bay (Herman, 1963). Another survey occurred in 1972–1973 and included 160 total stations divided among 10 sectors in Narragansett Bay (Bourne and Govoni, 1988; hereafter referred to as the MRI (Marine Research Inc.) survey). Almost 20 years later, similar methods were used by Keller et al. (1999; hereafter referred to as the Keller survey) to collect newer data from 1989–1990 and to explore changes in ichthyoplankton composition and abundance over time. The most recent effort is a partnership between URI and RIDEM to collect annual data beginning in 2002 to observe ichthyoplankton trends over an even longer time period (Klein-MacPhee et al., 2002). The combined data from these programs provide a baseline for examining trends in composition, relative abundance, distribution, and seasonal abundance of ichthyoplankton in Narragansett Bay.



Ichthyoplankton on the whole display a clear seasonal pattern in abundance, with a distinct peak in eggs in June and in larvae slightly later in July. This pattern was observed in both the MRI and Keller surveys. The total number of ichthyoplankton species was also similar between the two surveys (43 in the MRI survey; 41 in the Keller survey), but differences in the abundance of dominant species were apparent. In 1972–73 the most abundant species included cunner (*Tautoglabrus adspersus*), tautog, bay anchovy, Atlantic menhaden, scup, and weakfish; in 1989–90 the dominant species included bay anchovy, tautog, and cunner, but menhaden, scup, and weakfish were not abundant. Egg and larval (all species combined) densities were considerably lower in 1989–90 compared to the MRI survey. Abundance of some species declined substantially in the highly impacted upper Bay, Providence River, and Greenwich Bay areas. In fact, Keller et al. (1999) indicate that there was a general shift in ichthyoplankton distribution down-Bay away from these impacted areas. It was not clear whether this was due to reduced adult spawning in the upper Bay regions, or to higher mortality of ichthyoplankton while in these areas. In either case, upper Bay regions that were known as important historic spawning and nursery areas for some important nekton species now seem to have lost some of that value, perhaps due to impacts from human activities.

Summary

In addition to the impacts to ichthyoplankton outlined above, the abundance, distribution, growth, and survival of juvenile and adult nekton in Narragansett Bay are also affected by human activities. Commercial fishing has depleted many fish populations over at least a century (Oviatt et al., 2003), and fishing pressures continue to exert considerable influence. Substantial areas of important nursery habitats such as eelgrass and salt marshes have been extensively degraded or lost. Eutrophication and the resultant increase in the frequency and duration of hypoxia forces fish to either move out of the affected areas or suffer negative impacts. Meng et al. (2001) demonstrated that winter flounder growth and survival decreased in upper Bay areas where water quality and dissolved oxygen conditions are poor. In the summer of 2003, a large fish kill (over 1 million Atlantic menhaden) occurred in Greenwich Bay when excessive nutrients and physical processes combined to create an extensive anoxic event (RIDEM, 2003). However, despite all of these pressures, Narragansett Bay and its habitats continue to support an abundant and diverse nekton assemblage, albeit one whose composition appears to be shifting over time.



Figure 10.6. Using a throw trap to quantitatively sample nekton from salt marsh habitats. Photo from NBNERR photo library.





Appendix 10.1. Abundance and Biomass of Nekton Species

Abundance and biomass of nekton species collected during the RIDEM seasonal trawl survey. For each species, mean abundance (catch per unit effort, CPUE) and mean biomass (biomass per unit effort, BPUE) are provided as averages between 1979 and 2003. Averages for spring, fall, and all data combined are provided.

Species	Common name	CPUE			Species	Common name	BPUE		
		Spring	Fall	Total			Spring	Fall	Total
<i>Anchoa mitchilli</i>	Bay anchovy	11.65	1213.08	600.42	<i>Stenotomus chrysops</i>	Scup	920.29	7024.48	3911.69
<i>Stenotomus chrysops</i>	Scup	7.41	439.56	219.19	<i>Pseudopleuronectes americanus</i>	Winter flounder	5609.57	1812.89	3748.98
<i>Loligo pealei</i>	Longfin squid	4.17	178.85	89.77	<i>Homarus americanus</i>	American lobster	1641.79	2041.53	1837.69
<i>Brevoortia tyrannus</i>	Atlantic menhaden	0.05	144.19	70.68	Rajidae	Skates	2613.60	1006.83	1826.19
<i>Pepilus triacanthus</i>	Butterfish	2.56	129.18	64.62	<i>Scophthalmus aquosus</i>	Windowpane	1526.77	1047.50	1291.90
<i>Pseudopleuronectes americanus</i>	Winter flounder	40.21	20.97	30.79	<i>Loligo pealei</i>	Longfin squid	324.67	2172.53	1230.23
<i>Clupea harengus</i>	Atlantic herring	44.38	5.19	25.18	<i>Tautoga onitis</i>	Tautog	1465.55	965.02	1220.26
<i>Cynoscion regalis</i>	Weakfish	0.00	39.53	19.38	<i>Pepilus triacanthus</i>	Butterfish	148.57	1788.75	952.35
<i>Pomatomus saltatrix</i>	Bluefish	0.00	17.63	8.64	<i>Paralichthys dentatus</i>	Summer flounder	84.12	1634.31	843.80
<i>Menidia menidia</i>	Atlantic silverside	3.40	13.19	8.20	<i>Anchoa mitchilli</i>	Bay anchovy	16.13	1195.97	594.32
<i>Scophthalmus aquosus</i>	Windowpane	8.09	8.08	8.08	<i>Cynoscion regalis</i>	Weakfish	8.36	880.81	435.91
<i>Homarus americanus</i>	American lobster	5.89	8.72	7.28	<i>Clupea harengus</i>	Atlantic herring	673.32	40.93	363.41
<i>Alosa pseudoharengus</i>	Alewife	3.11	8.65	5.83	<i>Pomatomus saltatrix</i>	Bluefish	5.57	707.27	349.45
<i>Selene setapinnis</i>	Atlantic moonfish	0.00	9.13	4.47	<i>Mustelus canis</i>	Smooth dogfish	21.10	628.16	318.60
Rajidae	Skates	5.19	1.86	3.56	<i>Prionotus evolans</i>	Striped searobin	41.13	510.10	270.95
<i>Alosa aestivalis</i>	Blueback herring	4.37	0.88	2.66	<i>Brevoortia tyrannus</i>	Atlantic menhaden	1.80	360.91	177.79
<i>Urophycis chuss</i>	Red Hake	2.69	1.45	2.08	<i>Limulus polyphemus</i>	Horseshoe crab	44.60	282.14	161.01
<i>Trinectes maculatus</i>	Hogchoker	0.21	2.87	1.51	<i>Urophycis chuss</i>	Red Hake	165.80	123.26	144.95
<i>Tautoga onitis</i>	Tautog	0.91	1.26	1.08	<i>Trinectes maculatus</i>	Hogchoker	17.27	255.90	134.21
<i>Paralichthys dentatus</i>	Summer flounder	0.08	2.05	1.05	<i>Macrozoarces americanus</i>	Ocean pout	221.01	0.00	112.71
<i>Paralichthys oblongus</i>	Fourspot flounder	0.40	1.59	0.99	<i>Prionotus carolinus</i>	Northern searobin	146.76	74.03	111.12
<i>Urophycis regia</i>	Spotted Hake	1.05	0.64	0.85	<i>Alosa pseudoharengus</i>	Alewife	110.58	110.91	110.74
<i>Merluccius bilinearis</i>	Silver hake	0.74	0.66	0.70	<i>Alosa aestivalis</i>	Blueback herring	106.59	17.87	63.11
<i>Centropristis striata</i>	Black sea bass	0.04	1.33	0.67	<i>Hemirhamphus americanus</i>	Sea raven	119.18	1.31	61.42
<i>Prionotus carolinus</i>	Northern searobin	0.41	0.66	0.53	<i>Paralichthys oblongus</i>	Fourspot flounder	80.74	32.43	57.07
<i>Prionotus evolans</i>	Striped searobin	0.12	0.94	0.52	<i>Opsanus tau</i>	Oyster toadfish	6.85	104.49	54.70
<i>Tautoglabrus adspersus</i>	Cunner	0.51	0.45	0.48	<i>Urophycis regia</i>	Spotted Hake	17.30	78.69	47.38
<i>Syngnathus fuscus</i>	Northern pipefish	0.12	0.67	0.39	<i>Morone saxatilis</i>	Striped bass	13.95	62.97	37.97
<i>Mustelus canis</i>	Smooth dogfish	0.01	0.58	0.29	<i>Centropristis striata</i>	Black sea bass	13.87	56.15	34.59
<i>Macrozoarces americanus</i>	Ocean pout	0.42	0.00	0.22	<i>Merluccius bilinearis</i>	Silver hake	29.11	22.66	25.95
<i>Opsanus tau</i>	Oyster toadfish	0.03	0.39	0.20	<i>Tautoglabrus adspersus</i>	Cunner	32.97	15.88	24.60
<i>Menticirrhus saxatilis</i>	Northern kingfish	0.00	0.38	0.19	<i>Selene setapinnis</i>	Atlantic moonfish	0.00	49.00	24.01
<i>Alosa sapidissima</i>	American shad	0.25	0.04	0.15	<i>Menidia menidia</i>	Atlantic silverside	18.86	22.12	20.46
<i>Ammodytes americanus</i>	American sand lance	0.27	0.00	0.14	<i>Menticirrhus saxatilis</i>	Northern kingfish	0.00	36.77	18.02
<i>Trachurus lathami</i>	Rough scad	0.00	0.20	0.10	<i>Squalus acanthias</i>	Spiny dogfish shark	13.93	2.83	8.49
<i>Gadus morhua</i>	Atlantic Cod	0.19	0.00	0.10	<i>Alosa sapidissima</i>	American shad	9.06	5.90	7.51
<i>Osmerus mordax</i>	Rainbow smelt	0.14	0.06	0.10	<i>Myoxocephalus octodecemspinos</i>	Longhorn sculpin	13.34	0.45	7.02
<i>Hemirhamphus americanus</i>	Sea raven	0.18	0.00	0.09	<i>Aequipecten irradians</i>	Sea scallop	1.04	10.26	5.56

Appendix 10.1 Continued



<i>Citharichthys arctifrons</i>	Gulfstream flounder	0.07	0.10	0.08	<i>Leiostomus xanthurus</i>	Spot	1.64	6.15	3.85
<i>Limulus polyphemus</i>	Horseshoe crab	0.03	0.14	0.08	<i>Trachurus lathami</i>	Rough scad	0.04	7.61	3.75
<i>Myoxocephalus aeneus</i>	Grubby	0.14	0.01	0.08	<i>Microgadus tomcod</i>	Atlantic tomcod	5.90	1.36	3.67
<i>Selene vomer</i>	Lookdown	0.09	0.06	0.07	<i>Urophycis tenuis</i>	White hake	6.21	0.23	3.28
<i>Sphyræna borealis</i>	Northern sennet	0.00	0.14	0.07	<i>Pollachius virens</i>	Pollock	6.11	0.00	3.12
Gobiidae	Gobies	0.01	0.13	0.07	<i>Anguilla rostrata</i>	American eel	4.85	0.58	2.75
<i>Pholis gunnellus</i>	Rock gunnel	0.04	0.09	0.07	<i>Myoxocephalus aeneus</i>	Grubby	4.53	0.29	2.45
<i>Microgadus tomcod</i>	Atlantic tomcod	0.09	0.04	0.06	<i>Priacanthus arenatus</i>	Bigeye	0.00	4.55	2.23
<i>Myoxocephalus octodecemspinos</i>	Longhorn sculpin	0.09	0.01	0.05	<i>Enchelyopus cimbrius</i>	Fourbeard rockling	1.40	2.95	2.16
<i>Aequipecten irradians</i>	Sea scallop	0.00	0.10	0.05	<i>Scomber scombrus</i>	Atlantic mackeral	0.44	3.54	1.96
<i>Priacanthus arenatus</i>	Bigeye	0.00	0.09	0.04	<i>Osmerus mordax</i>	Rainbow smelt	3.43	0.30	1.89
<i>Urophycis tenuis</i>	White Hake	0.07	0.02	0.04	<i>Syngnathus fuscus</i>	Northern pipefish	0.67	2.50	1.57
<i>Enchelyopus cimbrius</i>	Fourbeard rockling	0.02	0.06	0.04	<i>Lophius americanus</i>	Goosefish	2.68	0.40	1.56
<i>Anchoa hepsetus</i>	Striped anchovy	0.00	0.07	0.03	Gobiidae	Gobies	0.07	2.78	1.40
<i>Brosme brosme</i>	Cusk	0.06	0.00	0.03	<i>Synodus foetens</i>	Inshore lizardfish	0.00	2.76	1.35
<i>Morone saxatilis</i>	Striped bass	0.03	0.03	0.03	<i>Spherooides maculatus</i>	Northern puffer	0.00	2.48	1.22
<i>Scomber scombrus</i>	Atlantic mackeral	0.00	0.06	0.03	<i>Citharichthys arctifrons</i>	Gulfstream flounder	0.68	1.33	1.00
<i>Orthopristis chrysoptera</i>	Pigfish	0.00	0.04	0.02	<i>Ammodytes americanus</i>	American sand lance	1.62	0.00	0.83
<i>Spherooides maculatus</i>	Northern puffer	0.00	0.04	0.02	<i>Sphyræna borealis</i>	Northern sennet	0.00	1.57	0.77
<i>Mullus auratus</i>	Red goatfish	0.00	0.04	0.02	<i>Caranx hippos</i>	Crevalle jack	0.00	1.48	0.72
<i>Synodus foetens</i>	Inshore lizardfish	0.03	0.04	0.02	<i>Caranx crysos</i>	Blue runner	0.00	1.45	0.71
<i>Leiostomus xanthurus</i>	Spot	0.01	0.03	0.02	<i>Brosme brosme</i>	Cusk	1.25	0.00	0.64
<i>Gaidropsarus ensis</i>	Threebeard rockling	0.01	0.03	0.02	<i>Gaidropsarus ensis</i>	Threebeard rockling	0.29	0.97	0.62
<i>Caranx crysos</i>	Blue runner	0.00	0.02	0.01	<i>Gadus morhua</i>	Atlantic Cod	0.95	0.05	0.51
<i>Anguilla rostrata</i>	American eel	0.01	0.01	0.01	<i>Etrumeus teres</i>	Roung herring	0.00	1.01	0.50
<i>Caranx hippos</i>	Crevalle jack	0.00	0.02	0.01	<i>Cryptacanthodes maculatus</i>	Wrymouth	0.87	0.00	0.44
<i>Conger oceanicus</i>	Conger eel	0.00	0.01	0.01	<i>Mullus auratus</i>	Red goatfish	0.00	0.76	0.37
<i>Selar crumenophthalmus</i>	Bigeye scad	0.00	0.01	0.01	<i>Conger oceanicus</i>	Conger eel	0.00	0.75	0.37
<i>Synodus synodus</i>	Red lizardfish	0.00	0.01	0.01	<i>Pholis gunnellus</i>	Rock gunnel	0.41	0.16	0.29
<i>Lophius americanus</i>	Goosefish	0.01	0.00	0.01	<i>Selar crumenophthalmus</i>	Bigeye scad	0.00	0.56	0.27
<i>Pollachius virens</i>	Pollock	0.01	0.00	0.01	<i>Synodus synodus</i>	Red lizardfish	0.00	0.53	0.26
<i>Pristigenys alta</i>	Short bigeye	0.00	0.01	0.01	<i>Scomberomorus maculatus</i>	Spanish mackeral	0.00	0.51	0.25
<i>Melanogrammus aeglefinus</i>	Haddock	0.01	0.00	0.00	<i>Selene vomer</i>	Lookdown	0.21	0.27	0.24
<i>Monacanthus hispidus</i>	Planehead filefish	0.00	0.01	0.00	<i>Cyclopterus lumpus</i>	Lumpfish	0.45	0.00	0.23
<i>Fistularia tabacaria</i>	Bluespotted cornetfish	0.00	0.01	0.00	<i>Peristedion miniatum</i>	Armored searobin	0.37	0.00	0.19
<i>Upeneus parvus</i>	Dwarf goatfish	0.00	0.01	0.00	<i>Anchoa hepsetus</i>	Striped anchovy	0.00	0.30	0.15
<i>Cyclopterus lumpus</i>	Lumpfish	0.01	0.00	0.00	<i>Myoxocephalus scorpius</i>	Shorthorn sculpin	0.28	0.00	0.14
<i>Myoxocephalus scorpius</i>	Shorthorn sculpin	0.01	0.00	0.00	<i>Monacanthus hispidus</i>	Planehead filefish	0.00	0.28	0.14
<i>Lepophidium profundorum</i>	Fawn eelpout	0.01	0.00	0.00	<i>Pristigenys alta</i>	Short bigeye	0.00	0.28	0.13
<i>Squalus acanthias</i>	Spiny dogfish shark	0.00	0.00	0.00	<i>Morone americana</i>	White perch	0.24	0.00	0.12
<i>Cryptacanthodes maculatus</i>	Wrymouth	0.01	0.00	0.00	<i>Orthopristis chrysoptera</i>	Pigfish	0.00	0.24	0.12
<i>Lutjanus campechanus</i>	Red snapper	0.00	0.00	0.00	<i>Aluterus schoepfi</i>	Orange filefish	0.00	0.17	0.09
<i>Petromyzon marinus</i>	Sea lamprey	0.00	0.00	0.00	<i>Fistularia tabacaria</i>	Bluespotted cornetfish	0.00	0.17	0.08
<i>Scomberomorus</i>	Spanish	0.00	0.00	0.00	<i>Petromyzon marinus</i>	Sea lamprey	0.11	0.00	0.06



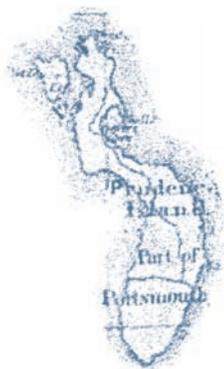
Appendix 10.1. Continued

<i>maculatus</i>	mackerel								
<i>Peristedion miniatum</i>	Armored searobin	0.00	0.00	0.00	<i>Pleuronectes ferrugineus</i>	Yellowtail flounder	0.10	0.00	0.05
<i>Decapterus macarellus</i>	Mackerel scad	0.00	0.00	0.00	<i>Lepophidium profundorum</i>	Fawn eelpout	0.08	0.00	0.04
<i>Aluterus schoepfi</i>	Orange filefish	0.00	0.00	0.00	<i>Upeneus parvus</i>	Dwarf goatfish	0.00	0.09	0.04
<i>Ulvaria subbifurcata</i>	Radiated shanny	0.00	0.00	0.00	<i>Decapterus macarellus</i>	Mackerel scad	0.00	0.08	0.04
<i>Etopus microstomus</i>	Smallmouth flounder	0.00	0.00	0.00	<i>Lutjanus campechanus</i>	Red snapper	0.00	0.07	0.04
<i>Gasterosteus aculeatus</i>	Stickleback threespine	0.00	0.00	0.00	<i>Decapterus punctatus</i>	Round scad	0.00	0.02	0.01
<i>Apeltes quadracus</i>	Fourspine stickleback	0.00	0.00	0.00	<i>Apeltes quadracus</i>	Fourspine stickleback	0.02	0.00	0.01
<i>Decapterus punctatus</i>	Round scad	0.00	0.00	0.00	<i>Epinephelus niveatus</i>	Snowy grouper	0.00	0.02	0.01
<i>Etrumeus teres</i>	Roung herring	0.00	0.00	0.00	<i>Melanogrammus aeglefinus</i>	Haddock	0.02	0.00	0.01
<i>Cyprinodon variegatus</i>	Sheepshead minnow	0.00	0.00	0.00	<i>Cyprinodon variegatus</i>	Sheepshead minnow	0.01	0.00	0.00
<i>Epinephelus niveatus</i>	Snowy grouper	0.00	0.00	0.00	<i>Gasterosteus aculeatus</i>	Stickleback threespine	0.01	0.00	0.00
<i>Morone Americana</i>	White perch	0.00	0.00	0.00	<i>Etopus microstomus</i>	Smallmouth flounder	0.00	0.00	0.00
<i>Pleuronectes ferrugineus</i>	Yellowtail flounder	0.00	0.00	0.00	<i>Ulvaria subbifurcata</i>	Radiated shanny	0.00	0.00	0.00
Total		150.17	2256.47	1182.36	Total		16331.13	25235.62	20694.83

Appendix 10.2. Species Composition and Abundance of Fishes

Species composition and abundance of fishes collected between 1990 and 2003 during the RIDEM juvenile finfish seining survey. For each species, the average number per seine (across all 20 stations and all years) is shown for each month of the survey and for the entire survey (across all months).

Species	Common Name	Jun	Jul	Aug	Sep	Oct	Average
<i>Brevortia tyrannus</i>	Atlantic menhaden	1.69	4.35	1060.21	74.32	310.31	293.31
<i>Menidia</i> spp.	Silverside	18.12	44.17	49.85	47.77	31.05	38.44
River herring spp.	River herring	27.29	81.24	9.94	17.75	1.11	27.48
<i>Pomotomus saltatrix</i>	Bluefish	0.68	16.39	40.17	25.81	0.32	16.85
<i>Pseudopleuronectes americanus</i>	Winter flounder	25.81	29.01	14.92	5.39	4.68	15.67
<i>Fundulus majalis</i>	Striped killifish	6.71	12.67	23.60	19.91	14.55	15.59
Sea herring spp.	Sea herring	62.90	1.05	0.27	4.91	0.04	13.25
<i>Anchoa mitchilli</i>	Bay anchovy	34.51	7.94	0.16	4.01	14.84	11.84
<i>Fundulus heteroclitus</i>	Mummichog	7.38	12.02	13.47	9.53	7.85	10.09
<i>Tautoga onitis</i>	Blackfish	1.65	8.13	14.97	8.04	2.24	7.10
<i>Menticirrhus saxatilis</i>	Northern kingfish	0.03	3.30	11.33	3.18	0.09	3.61
<i>Tautoglabrus adspersus</i>	Cunner	0.47	3.18	5.71	4.69	1.33	3.13
<i>Stenotomus chrysops</i>	Scup	0.01	1.43	10.25	0.80	< 0.01	2.54
<i>Ammodytes</i> spp.	Sandlance	7.26	0.27	0.36	0.06	0.70	1.67
<i>Cynoscion regalis</i>	Weakfish	< 0.01	3.18	3.69	0.02	< 0.01	1.40
<i>Microgadus tomcod</i>	Tomcod	3.87	1.28	0.35	0.37	0.13	1.16
Gasterosteidae	Stickleback	1.38	1.59	0.86	0.39	1.43	1.13
<i>Syngnathus fuscus</i>	Northern pipefish	1.78	1.35	1.27	0.58	0.56	1.10
<i>Myoxocephalus aeneus</i>	Grubby sculpin	0.78	0.77	0.97	1.92	0.65	1.02
<i>Cyprinodon variegatus</i>	Sheepshead minnow	0.03	0.43	0.31	1.79	1.29	0.78
<i>Prionotus</i> spp.	Searobin	0.08	1.91	1.46	0.06	< 0.01	0.71
Mugilidae	Mullet	0.03	0.47	0.83	0.49	0.07	0.38
<i>Morone saxatilis</i>	Striped bass	0.32	0.24	0.35	0.24	0.15	0.26
<i>Caranx hippos</i>	Crevalle jack	< 0.01	0.03	0.94	0.21	< 0.01	0.24
Cyprinodontidae	Killifish spp.	0.28	0.58	0.18	0.08	0.08	0.24
<i>Trachinotus falcatus</i>	Permit	< 0.01	0.02	0.57	0.35	0.12	0.22



Appendix 10.2. Continued

<i>Sphoeroides maculatus</i>	Northern puffer	< 0.01	0.44	0.50	0.08	< 0.01	0.21
<i>Anguilla rostrata</i>	American eel	0.24	0.23	0.43	0.08	0.01	0.20
<i>Pollachius virens</i>	Pollock	1.01	< 0.01	< 0.01	< 0.01	< 0.01	0.19
<i>Scomber scombrus</i>	Atlantic mackerel	0.04	0.75	< 0.01	< 0.01	0.02	0.16
<i>Scophthalmus aquosus</i>	Windowpane flounder	0.20	0.28	0.10	0.11	0.08	0.15
<i>Merluccius bilinearis</i>	Silver hake	0.78	0.01	< 0.01	< 0.01	< 0.01	0.15
Gobiidae	Goby	0.25	0.25	0.12	0.04	0.07	0.14
<i>Centropristis striata</i>	Black sea bass	< 0.01	< 0.01	0.46	0.20	< 0.01	0.13
<i>Caranx bartholomaei</i>	Yellow jack	< 0.01	< 0.01	0.02	0.56	< 0.01	0.11
<i>Osmerus mordax</i>	Smelt	0.31	0.06	0.01	0.01	< 0.01	0.08
<i>Opsanus tau</i>	Toadfish	0.04	0.09	0.14	0.03	0.02	0.06
<i>Pepilius triacanthus</i>	Butterfish	< 0.01	0.22	0.06	0.01	< 0.01	0.06
<i>Caranx</i> spp.	Jack spp.	< 0.01	0.02	0.07	0.20	< 0.01	0.06
Synodontidae	Lizardfish	< 0.01	0.02	0.07	0.16	0.01	0.05
<i>Lucania parva</i>	Rainwater killifish	0.02	0.06	0.06	< 0.01	0.07	0.04
<i>Urophycis regia</i>	Spotted hake	0.16	0.01	< 0.01	< 0.01	0.02	0.04
<i>Etropus microsomus</i>	Smallmouth flounder	0.02	< 0.01	< 0.01	0.05	0.05	0.02
Bothidae	Lefteye flounder	0.01	< 0.01	0.01	0.03	0.06	0.02
<i>Alosa sapidissima</i>	American shad	< 0.01	0.09	< 0.01	< 0.01	0.01	0.02
<i>Leiostomus xanthurus</i>	Spot	0.02	0.02	0.03	< 0.01	0.03	0.02
<i>Paralichthys dentatus</i>	Fluke	0.02	0.04	0.01	0.01	0.01	0.02
<i>Urophycis chuss</i>	Red hake	0.08	0.02	< 0.01	< 0.01	< 0.01	0.02
<i>Fundulus diaphanus</i>	Banded killifish	0.09	< 0.01	< 0.01	< 0.01	< 0.01	0.02
<i>Caranx crysos</i>	Blue runner	< 0.01	0.01	0.07	< 0.01	< 0.01	0.02
<i>Strongylura marina</i>	Needlefish	< 0.01	< 0.01	< 0.01	0.07	< 0.01	0.02
<i>Pholis gunnellus</i>	Rock gunnel	< 0.01	0.01	0.01	0.01	0.01	0.01
<i>Fistularia tabacaria</i>	Bluespotted coronetfish	< 0.01	< 0.01	0.02	0.01	0.01	0.01
<i>Lutjanus griseus</i>	Gray snapper	< 0.01	0.01	0.02	0.01	< 0.01	0.01
<i>Hippocampus erectus</i>	Seahorse	< 0.01	0.01	0.01	0.02	0.01	0.01
Clupeidae	Herring	0.02	0.02	< 0.01	< 0.01	< 0.01	0.01
<i>Sphyaena borealis</i>	Northern sennet	< 0.01	< 0.01	0.03	< 0.01	< 0.01	0.01
<i>Enchelyopus cimbrius</i>	Fourbeard rockling	0.03	< 0.01	< 0.01	< 0.01	< 0.01	0.01
<i>Gadus morhua</i>	Cod, Atlantic	0.02	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
<i>Citharichthys arctifrons</i>	Gulfstseam flounder	0.01	< 0.01	< 0.01	< 0.01	0.01	< 0.01
<i>Raja erinacea</i>	Little shad	< 0.01	< 0.01	< 0.01	0.01	0.01	< 0.01
<i>Decapterus macarellus</i>	Scad	0.01	< 0.01	< 0.01	0.01	< 0.01	< 0.01
Mullidae	Goatfish	< 0.01	0.01	< 0.01	< 0.01	< 0.01	< 0.01
<i>Selene vomer</i>	Lookdown	< 0.01	< 0.01	< 0.01	0.01	< 0.01	< 0.01
Balistidae	Filefish	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
<i>Eucinostomus argenteus</i>	Spotfin mojarra	< 0.01	< 0.01	< 0.01	< 0.01	0.01	< 0.01
Ostraciidae	Boxfish	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
<i>Paralichthys oblongus</i>	Fourspotted flounder	< 0.01	< 0.01	0.01	< 0.01	< 0.01	< 0.01
<i>Dactylopterus voltans</i>	Gumard	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
<i>Engraulis eurystole</i>	Silver anchovy	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
<i>Chaetodon</i> spp.	Butterflyfish	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
<i>Trinectes maculatus</i>	Hogchoker	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
<i>Chilomycterus</i> spp.	Burrfish	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
<i>Dorosoma cepedianum</i>	Gizzard shad	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
<i>Lophius americanus</i>	Monkfish	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
<i>Morone Americana</i>	White perch	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
<i>Naucrates doctor</i>	Pilotfish	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
<i>Scomber japonicus</i>	Chub mackerel	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01



Appendix 10.3. Nekton Density in Salt Marshes

Nekton density in the Sachuest Point, Coggeshall, and Galilee salt marshes in Rhode Island. All data were collected with the same methods (with a 1 m² throw trap when the marsh surface was drained), in similar habitats (e.g., creeks and pools), and are thus comparable. Galilee data are from restricted, restoring, and unrestricted marsh areas from June through September 1997–1999. Sachuest Point data are from restricted, restoring, and unrestricted marsh areas from June through October 1997–1999. Coggeshall is an unrestricted marsh and these data are from July and September 2000, 2003, and 2004.

Species	Common name	Galilee	Sachuest Point	Coggeshall	Average
<i>Palaeomonetes pugio</i>	Daggerblade grass shrimp	15.30	4.29	136.60	52.06
<i>Fundulus heteroclitus</i>	Mummichog	12.70	12.46	18.05	14.40
<i>Pagurus</i> spp.	Hermit crab	0.01	0.00	8.36	2.79
<i>Cyprinodon variegatus</i>	Sheepshead minnow	4.30	1.52	0.89	2.24
<i>Fundulus majalis</i>	Striped killifish	3.14	0.23	1.29	1.55
<i>Menidia menidia</i>	Atlantic silverside	3.54	0.18	0.22	1.31
<i>Crangon septemspinosa</i>	Sand shrimp	0.15	0.01	2.18	0.78
<i>Menidia beryllina</i>	Inland silverside	0.31	0.34	0.45	0.37
<i>Carcinus maenas</i>	Green crab	0.27	0.07	0.42	0.25
<i>Lucania parva</i>	Rainwater killifish	0.12	0.01	0.23	0.12
<i>Anguilla rostrata</i>	American eel	0.02	0.12	0.19	0.11
<i>Callinectes sapidus</i>	Blue crab	0.22	0.06	0.01	0.10
<i>Mugil curema</i>	White mullet	0.05	0.20	0.01	0.08
<i>Panopeus herbstii</i>	Black-fingered mud crab	0.00	0.00	0.19	0.06
<i>Brevoortia tyrannus</i>	Atlantic menhaden	0.08	0.02	0.03	0.04
<i>Apeltes quadracus</i>	Fourspine stickleback	0.01	0.00	0.10	0.04
<i>Centropristis striata</i>	Black sea bass	0.00	0.08	0.00	0.03
<i>Gobiosoma ginsburgi</i>	Seaboard goby	0.00	0.07	0.00	0.02
<i>Pseudopleuronectes americanus</i>	Winter flounder	0.01	0.00	0.07	0.02
<i>Ovalipes ocellatus</i>	Lady crab	0.00	0.00	0.05	0.02
<i>Pungitius pungitius</i>	Ninespine stickleback	0.02	0.01	0.01	0.01
<i>Syngnathus fuscus</i>	Northern pipefish	0.00	0.00	0.02	0.01
<i>Notropis</i> sp.	Shiner	0.00	0.01	0.00	< 0.01
<i>Tautoga onitis</i>	Tautog	0.00	0.00	0.01	< 0.01
<i>Limulus polyphemus</i>	Atlantic horseshoe crab	0.01	0.00	0.00	< 0.01
<i>Alosa aestivalis</i>	Blueback herring	0.00	< 0.01	0.00	< 0.01

Literature Cited

- Bourne, D.W. and J.J. Govoni. 1988. Distribution of fish eggs and larvae and patterns of water circulation in Narragansett Bay 1972–1973. *American Fisheries Society Symposium* **3**:132–148.
- Castro, K.M. and T.E. Angell. 2000. Prevalence and progression of shell disease in American lobster, *Homarus americanus*, from Rhode Island waters and the offshore canyons. *Journal of Shellfish Research* **19**:691–700.
- Castro, K.M., T.E. Angell, and B. Somers. 2005. Lobster shell disease in Southern New England: Monitoring and research. In: Lobster Shell Disease Workshop Forum Series 05-1. Pp. 165–172. Edited by Tlusty, M.F., H.O. Halvorson, R. Smolowitz, and U. Sharma. New England Aquarium, Boston, Mass.
- Cicchetti, G. 1998. Habitat use, secondary production, and trophic export by salt marsh nekton in shallow water. Ph.D. Dissertation, The College of William and Mary, Williamsburg, Va. 276pp.
- Cobb, J.S. and K.M. Castro. 2006. *Shell Disease in Lobsters: A Synthesis*. Edited by Somers, B. and M.L. Schwartz. Rhode Island Sea Grant, Narragansett, R.I. 16pp.
- DeAlteris, J.T., M. Gibson, and L.G. Skrobe. 2000. Fisheries of Rhode Island. White paper for the Narragansett Bay Summit 2000. 48pp.
- Deegan, L.A., J.T. Finn, S.G. Ayvasian, C.A. Ryder-Kieffer, and J. Buonaccorse. 1997. Development and validation of an estuarine biotic integrity index. *Estuaries* **20**:601–617.
- DeLong, A.K., J.S. Collie, C.J. Meise, and J.C. Powell. 2001. Estimating growth and mortality of juvenile winter flounder, *Pseudopleuronectes americanus*, with a length-based model. *Canadian Journal of Fisheries and Aquatic Science* **58**:2233–2246.
- Dorf, B.A. and J.C. Powell. 1997. Distribution, abundance, and habitat characteristics of juvenile tautog (*Tautoga onitis*, Family Labridae) in Narragansett Bay, Rhode Island, 1988–1992. *Estuaries* **20**:589–600.
- Durbin, A.G. and E.G. Durbin. 1998. Effects of menhaden predation on plankton populations in Narragansett Bay, Rhode Island. *Estuaries* **21**:449–465.
- Friedland, K.D., G.C. Garman, A.J. Bejda, and A.L. Studholme. 1988. Interannual variation in diet and condition in juvenile bluefish during estuarine residency. *Transactions of the American Fisheries Society* **117**:474–479.



- Halpin, P.M. 1997. Habitat use patterns of the mummichog, *Fundulus heteroclitus*, in New England. 1. Intramarsh variation. *Estuaries* **20**:618–625.
- Herman, S.S. 1963. Planktonic fish eggs and larvae of Narragansett Bay. *Limnology and Oceanography* **8**:103–109.
- Jefferies, H.P. and W.C. Johnson. 1974. Seasonal distributions of bottom fishes in the Narragansett Bay area: Seven-year variations in the abundance of winter flounder (*Pseudopleuronectes americanus*). *Journal of the Fisheries Research Board of Canada* **31**:1057–1066.
- Jefferies, H.P. and M. Terceiro. 1985. Cycle of changing abundances in the fishes of the Narragansett Bay area. *Marine Ecology Progress Series* **25**:239–244.
- Jefferies, P., A. Keller, and S. Hale. 1989. Predicting winter flounder, *Pseudopleuronectes americanus*, catches by time series analysis. *Canadian Journal of Fisheries and Aquatic Sciences* **46**:650–659.
- Keller, A.A., M.E.Q. Pilson, and R. Johnston. 1996. *Estuarine Profile of Narragansett Bay, Rhode Island*. 244pp.
- Keller, A.A., G. Klein-MacPhee, and J. St. Onge Burns. 1999. Abundance and distribution of ichthyoplankton in Narragansett Bay, Rhode Island, 1989–1990. *Estuaries* **22**:149–163.
- Klein-MacPhee, G., A. Keller, and D. Erkan. 2002. Monitoring ichthyoplankton abundance in Narragansett Bay and Rhode Island territorial waters. Annual report to the R.I. Department of Environmental Management, Providence, R.I. 32pp.
- Lapolla, A.E. 2001a. Bay anchovy *Anchoa mitchilli* in Narragansett Bay, Rhode Island. I. Population structure, growth and mortality. *Marine Ecology Progress Series* **217**:93–102.
- Lapolla, A.E. 2001b. Bay anchovy *Anchoa mitchilli* in Narragansett Bay, Rhode Island. II. Spawning season, hatch-date distribution and young of the year growth. *Marine Ecology Progress Series* **217**:103–109.
- Lynch, T. 2000. Assessment of recreationally important finfish stocks in Rhode Island waters. Coastal fishery resource assessment trawl survey. R.I. Department of Environmental Management Division of Fish and Wildlife, Government Center, Wakefield, R.I.
- Meng, L. and J.C. Powell. 1999. Linking juvenile fish and their habitats: An example from Narragansett Bay, Rhode Island. *Estuaries* **22**:905–916.
- Meng, L., J.C. Powell, and B. Taplin. 2001. Using winter flounder growth rates to assess habitat quality across an anthropogenic gradient in Narragansett Bay, Rhode Island. *Estuaries* **24**:576–584.
- Meng, L., G. Cicchetti, and M. Chintala. 2004. Nekton habitat quality at shallow water sites in two Rhode Island coastal systems. *Estuaries* **27**:740–751.
- Oviatt, C.A. and S.W. Nixon. 1973. The demersal fish of Narragansett Bay: An analysis of community structure, distribution and abundance. *Estuarine and Coastal Marine Science* **1**:361–378.
- Oviatt, C., S. Olsen, M. Andrews, J. Collie, T. Lynch, and K. Raposa. 2003. A century of fishing and fish fluctuations in Narragansett Bay. *Reviews in Fisheries Science* **11**:221–242.
- Raposa, K.B. 2002. Early responses of fishes and crustaceans to restoration of a tidally restricted New England salt marsh. *Restoration Ecology* **10**:665–676.
- Raposa, K. 2003. Overwintering habitat selection by the mummichog, *Fundulus heteroclitus*, in a Cape Cod (USA) salt marsh. *Wetlands Ecology and Management* **11**:175–182.
- Raposa, K.B. and C.T. Roman. 2001. Seasonal habitat-use patterns of nekton in a tide-restricted and unrestricted New England salt marsh. *Wetlands* **21**:451–461.
- Raposa, K.B. and C.T. Roman. 2003. Using gradients in tidal restriction to evaluate nekton community responses to salt marsh restoration. *Estuaries* **26**:98–105.
- R.I. Department of Environmental Management. 2003. The Greenwich Bay fish kill—August 2003: Causes, impacts and responses. 34pp.
- Roman, C.T., K.B. Raposa, S.C. Adamowicz, M.J. James-Pirri, and J.G. Catena. 2003. Quantifying vegetation and nekton response to tidal restoration of a New England salt marsh. *Restoration Ecology* **10**:450–460.
- Sekiguchi, K. 1995. Occurrence, behavior and feeding habits of harbor porpoises (*Phocoena phocoena*) at Pajaro Dunes, Monterey Bay, California. *Aquatic Mammals* **21**:91–103.
- Silliman, B.R. and M.D. Bertness. 2002. A trophic cascade regulates salt marsh primary production. *Proceedings of the National Academy of Science* **99**:10500–10505.
- Smith, J.P. 1997. Nesting season food habits of four species of herons and egrets at Lake Okeechobee, Florida. *Colonial Waterbirds* **20**:198–220.