Plankton studies in Buzzards Bay, Massachusetts, USA. V. Ichthyoplankton, 1987 to 1993

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ABSTRACT: Monthly sampling for ichthyoplankton was conducted at 8 stations in Buzzards Bay, Massachusetts, from October 1987 to September 1993 using a 48 cm diameter plankton net with 0.102 mm mesh. From October 1992 to September 1993, an additional 75 cm diameter net with 0.202 mm mesh was also towed to compare mesh selectivity. Stations included two with heavy anthropogenic impact, the urbanized inner harbor of New Bedford, Massachusetts, and over New Bedford's offshore sewage outfall, as well as other nearshore shallow and offshore deep stations in comparatively pristine areas of the bay. Fish larvae from 32 genera were identified. Fish eggs were counted but not identified. There was a pronounced summer peak in larval abundance dominated by cunner *Tautogolabrus adspersus*, anchovy *Anchoa* sp. and tautog *Tautoga onitis*. A smaller winter/ early spring peak was dominated by sand lance *Ammodytes* sp. This pattern was evident for all 6 years of the study. The assemblage of fish larvae found in Buzzards Bay differed from that in Cape Cod Bay, lending support to the concept of Cape Cod as a faunal boundary. The 2 differently sized nets used during the last year of the study did not catch significantly different numbers of fish larvae per m^3, but length frequency distributions of 4 abundant species of larvae revealed that the smaller mesh net caught significantly smaller *Anchoa* sp. The larger mesh net collected significantly more species of fish larvae. A comparison of annual mean catches of 4 species did not reveal significant changes in abundance over 6 yr.

KEY WORDS: Ichthyoplankton · Composition · Abundance · Buzzards Bay

INTRODUCTION

Many marine fishes, including those that are not resident species, spawn in or near productive coastal bays and estuaries (Wheatland 1956, Richards 1959, Pearcy & Richards 1962, Powles et al. 1984). Hydrographic conditions that retain planktonic eggs and larvae within bays and estuaries (Doyle et al. 1993), together with enhanced densities of food, may allow developing larvae to grow rapidly into strong swimmers, thus helping them to avoid predators and resist being dispersed by currents (Bourne & Govoni 1988, Olney & Boehlert 1988).

Ichthyoplankton species composition and abundance data can help elucidate local patterns of distribution and spawning for non-resident as well as local species, and determine an area's importance as a nursery ground. Ichthyoplankton data can also help clarify broad-scale trends of fish distribution and spawning ranges; such an area of interest is located around Cape Cod, which has long been considered a faunal boundary (Ekman 1953, Anraku 1964, Scherer 1984, Azarovitz & Grosslein 1987). The narrow peninsula of Cape Cod divides Cape Cod Bay, which is influenced by cold Gulf of Maine water, from Buzzards Bay, which is influenced by warmer Mid-Atlantic Bight water (Collings et al. 1981). The 11 km long Cape Cod Canal connects Buzzards Bay and Cape Cod Bay (Fig. 1).

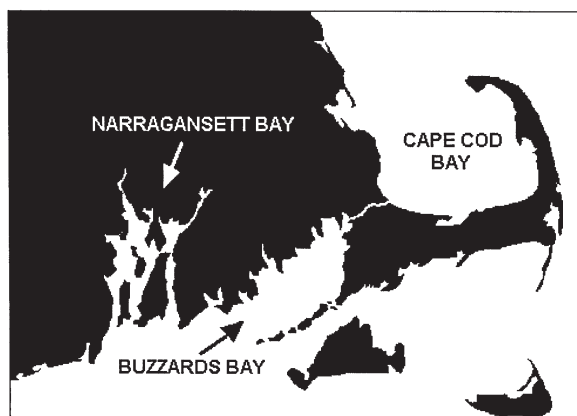*Corresponding author. E-mail: jturner@umassd.edu

Fig. 1. Location of Buzzards Bay in relation to Narragansett Bay and Cape Cod Bay

Thus, Buzzards Bay is a mixture of 2 very different water masses, particularly at its northern end. The proximity and connectedness of the 2 bays prompts a comparison of ichthyoplankton assemblages.

Buzzards Bay is a large embayment (45 km long and an average of 13 km wide), and because of an average depth of only 11 m, the bay remains well mixed by wind and tide throughout the year, and undergoes large annual fluctuations in temperature (Turner & Borkman 1993). Semidiurnal tidal flow floods northeast into and ebbs southwest out of the bay through its entrance at the south end, and through the channels in the Elizabeth Islands along the southern boundary of the bay.

Buzzards Bay can be characterized as 'partially urbanized' (Turner & Borkman 1993) with numerous point sources of pollution, such as municipal wastewater treatment facilities. Buzzards Bay has been classified by NOAA/EPA (1989) as highly susceptible to concentrating pollutants due to large overall volume relative to comparatively low volume of freshwater inflow that would flush the estuary. These same characteristics would facilitate retention of ichthyoplankton within the bay.

The primary objective of this study was to determine annual patterns and interannual variability of ichthyoplankton distributions in Buzzards Bay, and to relate these patterns to those reported for adjacent estuarine areas to the north and south, in order to clarify the biogeographical position of Buzzards Bay along a distributional gradient of fish species. Several ichthyoplankton surveys have been conducted in adjacent southern New England coastal waters, including Cape Cod Bay (Scherer 1984), Narragansett Bay (Herman 1963, Bourne & Govoni 1988, Keller et al. 1999), Block Island Sound (Merriman & Sclar 1952) and Long Island Sound (Wheatland 1956, Monteleone et al. 1987). A secon-

dary objective was to compare ichthyoplankton in anthropogenically impacted versus more pristine areas of the bay. Although there have been several ichthyoplankton surveys in the Buzzards Bay region, presented in reports of management agencies or unpublished theses (Lebida 1969, Stolgitis 1970, Crestin 1973, Govoni 1973, Collings et al. 1981, Lux & Wheeler 1992), these were for only part of the year, or for portions of the bay or its tributaries. There has never been a multi-year qualitative and quantitative ichthyoplankton survey in the open waters of Buzzards Bay.

MATERIALS AND METHODS

Samples were collected over a span of 6 yr, from October 1987 to September 1993. There were a total of 17 cruises in the first year (October 1987 and June through October 1988 sampled biweekly, the rest of the year sampled monthly) and 16 in the second year (June through August 1989 sampled biweekly, the rest of the year sampled monthly). A monthly sampling schedule followed for the remaining 4 yr of the study. A total of 484 samples from 81 cruises were analyzed. Each cruise sampled at 8 stations around the bay (Fig. 2). Five stations were situated on the periphery of the bay, including the southern entrance to the Cape Cod Canal (Stn 2) and the New Bedford sewage outfall site (Stn 7), and 3 stations in the open water areas of the bay (Stns 4, 5 and 6). All stations were between 5 and 15 m deep, the mid-bay stations being the deepest.
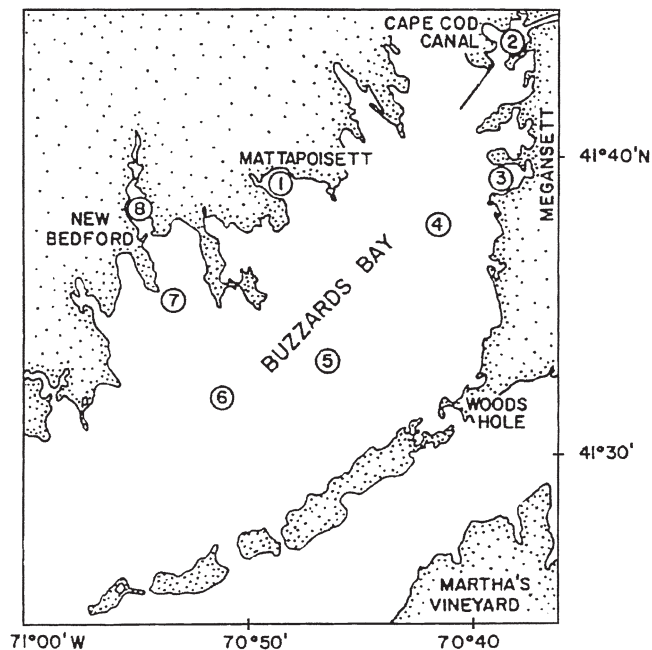

Fig. 2. Sampling stations in Buzzards Bay

Stations were located using Loran coordinates. Cruises were always completed in a single day. All samples were taken during daylight hours, and stations were sampled upon arrival, irrespective of tidal state.

The sampling protocol used for the first 5 yr of this study was originally designed for zooplankton. Such a protocol has been proven effective for collecting fish larvae (Olney 1983), even though zooplankton tow times are shorter, and net meshes and diameters are generally smaller than those typically used in ichthyoplankton surveys. A double oblique net tow (down and up) was made at each station, from the surface to approximately 1 m above the bottom (judged by wire out and wire angle) with a 48 cm diameter 0.102 mm mesh zooplankton net equipped with a flowmeter and closed cod end jar. When sampling with a 0.102 mm mesh net in phytoplankton rich estuarine waters, net clogging can occur during periods of blooms of chain-forming diatoms. Care was taken to ensure that flowmeters were still turning upon retrieval of the nets, indicating no clogging. When clogging occurred,

samples were discarded and tows were repeated for shorter time intervals, until tows without clogging were obtained. Samples were preserved within minutes in 5% formaldehyde, and after at least 3 wk curing time, samples were transferred to 70% ethanol solutions. Upon arrival at each station, surface, mid-depth and bottom water temperatures were recorded using an electronic temperature probe. Salinities were measured with a refractometer from surface, mid-depth and bottom Niskin bottle samples.

Two plankton nets were towed consecutively at each station for the final year of sampling: the aforementioned 0.102 mm mesh net and a 0.202 mm mesh net with a 75 cm mouth diameter. Double oblique tows were made with each net, one immediately after the other, and the same preservation procedure was followed for both tows. Tows made with the 0.202 mm mesh net averaged about 50 s and filtered an average of 10.4 m^3 of water (n = 96). Tows made with the 0.102 mm mesh net averaged 52 s and filtered an average of 5.3 m^3 of water (n = 388).

Table 1. Average lengths are based on fish collected during the entire 6 yr sampling period; the total number of larvae collected was 7871

| Species	Common name	Total no.	Average length in mm (range)
Tautogolabrus adspersus	Cunner	2942	2.9 (1.0–11.5)
Anchoa sp.	Anchovy	2228	2.8 (1.4–15.4)
Tautoga onitis	Tautog	922	3.1 (1.0–8.5)
Ammodytes sp.	Sand lance	706	7.5 (3.6–25.0)
Stenotomus chrysops	Scup	404	2.7 (1.3–7.6)
Peprilus triacanthus	Butterfish	93	2.5 (1.5–8.5)
Etropus microstomus	Smallmouth flounder	91	3.2 (1.2–10.9)
Pleuronectes americanus	Winter flounder	84	3.5 (2.2–7.2)
Centropristis striata	Black sea bass	51	2.3 (1.2–4.5)
Gobiosoma sp.	Goby	46	2.8 (2.1–5.0)
Myoxocephalus sp.	Sculpin	45	7.5 (5.0–15.0)
Prionotus sp.	Sea robin	38	2.7 (1.6–9.0)
Enchelyopus cimbrius	Fourbeard rockling	36	3.5 (2.0–8.0)
Paralichthys oblongus	Fourspot flounder	25	3.2 (2.0–5.6)
Scophthalmus aquosus	Windowpane	22	3.0 (1.8–7.6)
Trinectes maculatus	Hogchoker	17	2.1 (1.7–3.7)
Syngnathus fuscus	Northern pipefish	16	21.0 (9.0–25.0)
Scomber scombrus	Atlantic mackerel	15	4.1 (1.3–10.0)
Pholis gunnellus	Rock gunnel	12	13.1 (10.5–19.0)
Brevoortia tyrannus	Atlantic menhaden	9	4.0 (2.2–7.5)
Menidia menidia	Atlantic silverside	6	6.6 (4.4–9.0)
Cryptacanthodes maculatus	Wrymouth	5	28.6 (25.0–33.0)
Liparis atlanticus	Sea snail	4	3.4 (2.9–4.1)
Urophysis sp.	Hake	4	2.3 (1.8–3.0)
Ulvaria subbifurcata	Radiated shanny	3	6.6 (5.4–8.0)
Ophidion marginatum	Margined cusk eel	3	4.9 (3.0–8.5)
Urophysis chuss	Red hake	2	7.3 (6.8–7.7)
Merluccius bilinearis	Silver hake	2	2.9 (2.8–2.9)
Clupea harengus	Atlantic herring	2	17.25 (12.5–22.0)
Paralichthys dentatus	Summer flounder	1	6.0
Glyptocephalus cynoglossus	Witch flounder	1	5.3
Cynoscion regalis	Weakfish	1	1.8
Unidentifiable		35	
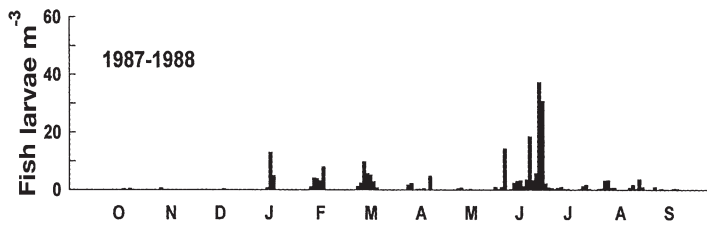
Fig. 3. Densities of fish larvae (n m^{-3}) collected at each station in 1987 to 1988. Unlabelled histograms represent densities at (in order) Stns 1 to 8. Sampling was conducted twice during the months of October 1987, and June, July, August and September 1988. In the figure there are 2 groups of histograms for these months, one for the first sampling cruise of the month, and another for the second

Fish eggs and larvae were sorted from the samples using a dissecting microscope, and fish larvae were identified to the lowest possible taxon and measured to the nearest 0.1 mm total length with an ocular micrometer. Preserved lengths were transformed using Theilacker's (1980) equation to better approximate live lengths. Fish eggs were counted (total = 17 520) but not identified. For the first and last years of the study (October 1987 through September 1988, and October 1992 through September 1993), ichthyoplankton samples from all 8 stations were sorted. For the middle 4 yr (October 1988 through September 1992) only samples from the open water stations (Stns 4, 5 and 6) were analyzed.

To test whether the 0.75 m diameter net with the 0.202 mm mesh was a more efficient sampler of fish larvae than the 0.5 m diameter net with the 0.102 mm mesh, numbers of fish larvae (expressed as larvae per m^3 of water filtered) caught by both nets were compared using a Wilcoxon matched-pairs test. To investigate whether the nets were sampling the same sizes of fish, a nonparametric Kolmogorov-Smirnov 2-sample test was performed on untransformed length frequency data for the 4 most abundant species caught by both nets.

A *t*-test was also performed on log(*x* + 1) transformed data. The Kolmogorov-Smirnov test detects differences in the distributions of the 2 samples of fish lengths, while the *t*-test tests for differences in the means.

Fig. 4. Densities of fish larvae (n m^{-3}) collected at Stns 4, 5 and 6 during the middle years of the study, 1988–1989, 1989–1990, 1990–1991 and 1991–1992. Sampling was conducted twice during the months of October 1987, and June, July, August and September 1988. In the figure there are 2 groups of histograms for these months, one for the first sampling cruise of the month, and another for the second

RESULTS

Twenty-six species of fish larvae were identified (Table 1), and additional taxa were identified only to genus due to uncertain taxonomy (*Ammodytes*; Nizinski et al. 1990) or difficulty in separating species due to small size of specimens (*Anchoa*, *Gobiosoma*, *Prionotus*, *Myoxocephalus*).

The labrid fishes *Tautogolabrus adspersus* (cunner) and *Tautoga onitis* (tautog) comprised nearly half of the total collection of 7871 larvae, with 38 and 11% respectively (Table 1). The forage fishes *Anchoa* sp. (anchovies) and *Ammodytes* sp. (sand lance) represented a total of 38% of the catch, with 9% sand lance and 29% anchovy. The fifth most abundant larvae were *Stenotomus chrysops* (scup), consisting of 5% of the total. *Peprilus triacanthus* (butterfish), *Etropus microstomus* (smallmouth flounder), and *Pleuronectes americanus* (winter flounder) made up 1% each. The remaining 23 species and generic groups comprised a combined total of only 5% of the catch. Individuals of several species were found <10 times, and 4 species were represented by a single specimen only. This pattern of dominance by a few species is a common one (Chenoweth
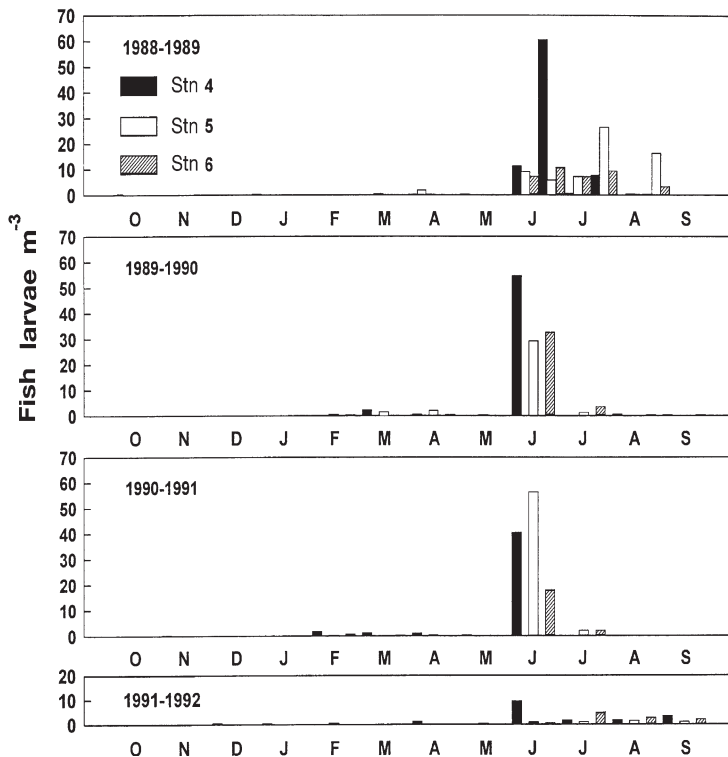
1973, Olney 1983, Bourne & Govoni 1988, Monteleone 1992).

Fish larvae were collected during every month of the year (Table 2), in a repeated annual pattern (Figs 3, 4 & 5). Samples collected during the months of October, November and December contained very few larvae. In January, an increase in spawning activity was evidenced by catches of *Ammodytes* sp., *Myoxocephalus* sp. and *Pleuronectes americanus* larvae, which continued through April. Since these species hatch from demersal eggs, the eggs collected at this time (usually less than 2 m^{-3}) may have been stirred up from the bottom.

Peak abundance of fish eggs (Figs 6 & 7) and larvae occurred during June, July and August of every year. During these months, *Anchoa* sp. and *Tautogolabrus adspersus* were the most abundant larvae in the samples. *Anchoa* sp. and *Tautoga onitis* had extended spawning periods starting in June, peaking in July and

Fig. 5. Densities of fish larvae (n m^{-3}) collected at each station in 1992 to 1993 with the 0.102 mm mesh net (upper) and the 0.202 mm mesh net (lower). Unlabelled histograms represent densities at (in order) Stns 1 to 8

Table 2. Species of larval fish collected in Buzzards Bay from October 1987 through October 1993. Months during which a species was collected are indicated by x

Species	J	F	M	A	M	J	J	A	S	O	N	D
Ammodytes sp.	x	x	x	x	x							x
Myoxocephalus sp.	x	x	x	x	x							
Pholis gunnellus	x	x	x									
Pleuronectes americanus					x	x	x					
Enchelyopus cimbrius					x	x	x	x		x	x	
Cryptacanthodes maculatus					x							
Glyptocephalus cynoglossus					x							
Centropristis striata						x	x	x	x			
Liparis atlanticus						x						
Ulvaria subbifurcata						x						
Tautogolabrus adspersus						x	x	x				
Anchoa sp.						x	x	x	x			
Tautoga onitis					x	x	x	x				
Stenotomus chrysops						x	x	x				
Peprilus triacanthus						x	x	x				
Etropus microstomus						x	x	x	x	x		
Gobiosoma sp.						x	x	x	x			
Prionotus sp.						x	x	x	x			
Paralichthys oblongus						x	x	x				
Scophthalmus aquosus						x	x		x	x		
Trinectes maculatus						x	x	x				
Sygnathus fuscus						x	x	x	x			
Scomber scombrus						x	x					
Brevoortia tyrannus						x					x	
Menidia menidia						x	x					
Urophysis sp.						x			x	x		
Ophidion marginatum						x	x	x				
Cynoscion regalis						x						
Merluccius bilinearis									x			
Clupea harengus											x	x
Paralichthys dentatus											x	

Fig. 6. Densities of fish eggs (n m^{-3}) collected at each station in 1987 to 1988. Unlabelled histograms represent densities at (in order) Stns 1 to 8. Sampling was conducted twice during the months of October 1987, and June, July, August and September 1988. In the figure there are 2 groups of histograms for these months, one for the first sampling cruise of the month, and another for the second
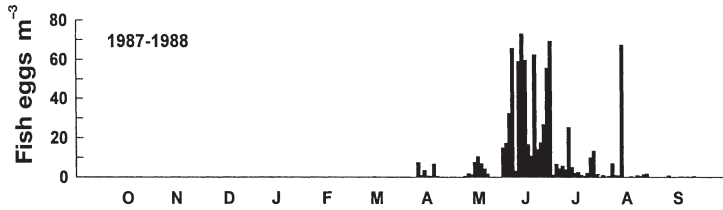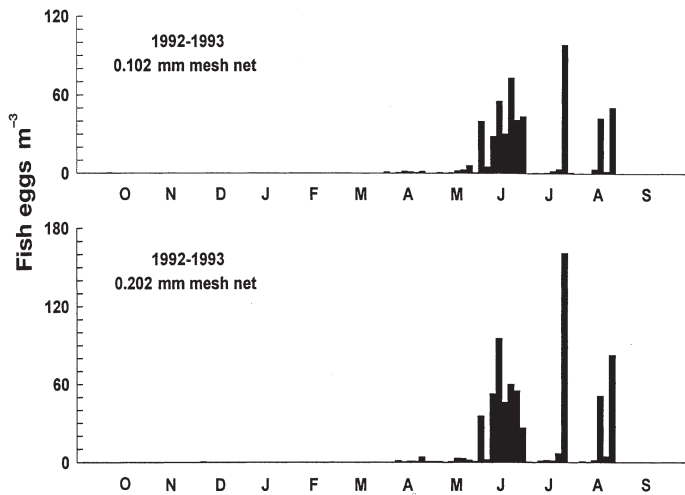

Fig. 7. Densities of fish eggs (n m^{-3}) collected at each station in 1992 to 1993 with the 0.102 mm mesh net (upper) and the 0.202 mm mesh net (lower). Unlabelled histograms represent densities at (in order) Stns 1 to 8

highest densities of fish larvae were found at Stn 7, over the outfall from the New Bedford wastewater treatment facility. Borkman & Turner (1993) and Pierce & Turner (1994a,b) also found the highest abundances of phytoplankton, tintinnids and dinoflagellates at this station compared to the others in Buzzards Bay. With the constant input of nutrients, the sewage outfall station provided an abundant source of food for both the larval fish and spawning adults, and perhaps a refuge from visual predators, since the water was quite turbid. The stations at the edges of the bay (Stns 1, 3, 7 and 8) contributed the most larvae to the late winter/early spring pulse. During the middle 4 yr of the study when only the open water stations were analyzed, the pattern of 2 annual larval peaks was not as pronounced. This was expected, since many estuarine species spawn in the winter (de Lafontaine 1990), and since our stations at the periphery of the bay were closer to marshes and rivers, larvae originating further up the estuary would be collected there. Stn 2 (the entrance to the Cape Cod Canal) was similar to these more estuarine stations in that it had a late winter/early spring pulse of eggs and lacked the large summer peak. The larval fish assemblage collected at Stn 2 in the Cape Cod Canal was also unique (Table 3). As the tide ebbs, Cape Cod Bay water floods into the canal and brings with it the distinctly different assemblage of plankton found north of Cape Cod. Since Stn 2 was a hybrid of Cape Cod Bay water and Buzzards Bay water, it had an intermediate ichthyoplankton assemblage which lacked the distinctive large summer peaks of the more southern *Anchoa* sp. and *Tautoga onitis*.

Comparisons of sampling by the 2 types of nets produced interesting results. There was no significant dif-

early August, and continuing until September. *T. adspersus*, although more abundant than *T. onitis*, apparently had a shorter spawning period since no cunner larvae were collected after August in any year. Other larvae found consistently in June, July and August included those of *Stenotomus chrysops*, *Etropus microstomus*, *Peprilus triacanthus* and *Centropristis striata* (black sea bass). Most of the summer spawners, such as *T. adspersus*, *T. onitis* and *Anchoa* sp. have pelagic rather than demersal eggs. This was reflected in the increased numbers of fish eggs collected in June and July.

For the years during which samples from all 8 stations were analyzed, areal trends were apparent. The largest numbers and
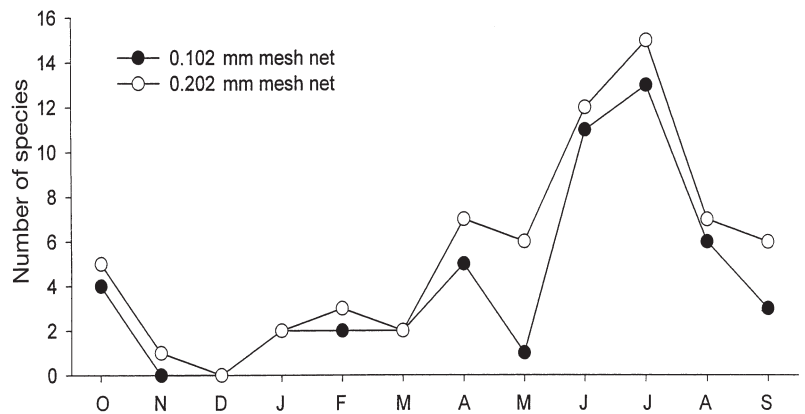

Fig. 8. Number of species of fish larvae collected per month over the 1992 to 1993 sampling year, from both the 0.102 and 0.202 mm mesh nets

ference in total numbers of larvae m⁻³ caught by the 2 nets (p = 0.839124, n = 67 pairs). Further, length frequency distributions of the most abundant taxa revealed that for *Ammodytes* sp., *Tautogolabrus adspersus* and *Tautoga onitis* the results of the Kolmogorov-Smirnov test were not significant (p = 0.1772, n = 362; p = 0.2385, n = 1056; and p = 0.5053, n = 307 respectively), indicating that the nets were not catching different sizes of larvae. For *Anchoa* sp., however, the Kolmogorov-Smirnov results were significantly different (p = 0.0001, n = 1256), indicating the nets sampled 2 different size distributions of anchovy larvae. The results of the *t*-test show a significant difference in mean sizes of *Anchoa* sp. (p = 0.0001, mean 0.102 mm = 3.55, mean 0.202 mm = 3.97) and in *Ammodytes* sp. (p = 0.0252, mean 0.102 mm = 9.57, mean 0.202 mm = 10.50) for the 2 nets. In both cases, the larger mesh net was catching the larger larvae. *T. onitis* and *T. adspersus* were not found to have significantly different mean lengths (p = 0.7609, mean 0.102 mm = 3.53, mean 0.202 mm = 3.60; p = 0.1219, mean 0.102 mm = 3.22, mean 0.202 mm = 3.36 respectively). There was also a significantly higher number of species taken per station with the larger (0.202 mm mesh) net (Fig. 8) over the full year when all 8 stations were sampled with both nets (Wilcoxon 2-sample test, p = 0.0059, n = 16).

DISCUSSION

The species assemblage of fish larvae collected in Buzzards Bay was qualitatively different from that reported for Cape Cod Bay, despite the physical connection provided by the Cape Cod Canal. Scherer's (1984) study of the ichthyoplankton of Cape Cod Bay from 1974 to 1976 found *Ammodytes* sp. to be the most abundant fish larva in Cape Cod Bay, followed by *Enchelyopus cimbrius*, *Scomber scombrus*, *Urophycis* sp. and *Tautogolabrus adspersus* (Table 3). In contrast, the present study found Buzzards Bay to be dominated by *T. adspersus*, with *Ammodytes* sp. ranked fourth and *E. cimbrius*, *S. scombrus* and *Urophycis* sp. represented in very few collections. *Anchoa* sp. and *Tautoga onitis*, the second and third most abundant species in Buzzards Bay, were ranked 29th and 22nd, respectively, in Scherer's study. *Stenotomus chrysops* (scup), *Centropristis striata* (black sea bass) and *Etropus microstomus* (smallmouth flounder), all of which made consistent albeit modest contributions to the Buzzards Bay larvae, were considered by Scherer to be 'stragglers from the south' when found above Cape Cod.

Narragansett Bay, Rhode Island (Fig. 1), sampled extensively in 1972 to 1973 (Bourne & Govoni 1988) and again in 1989 to 1990 (Keller et al. 1999), has a larval fish assemblage similar to Buzzards Bay. In both

Table 3. Species of fish larvae listed in descending order of abundance for Cape Cod Bay from 1974 to 1976 (Scherer 1984), Stn 2 at the southern end of the Cape Cod Canal from 1987 to 1988, and 1992 to 1993 (present study), all stations in Buzzards Bay from 1987 to 1993 (present study), Buzzards Bay from 1976 to 1979 (Collings et al. 1981) and Narragansett Bay from 1989 to 1990 (Keller et al. 1999). Numbers in parentheses are the maximum densities (larvae m⁻³) collected during the study

Cape Cod Bay 1974 to 1976

Ammodytes sp. (2.6)
Enchelyopus cimbrius
Scomber scombrus
Urophycis sp.
Tautogolabrus adspersus (0.9)
Ulvaria subbifurcata
Merluccius biliniaris
Clupea harengus
Glyptocephalus cynoglossus

Buzzards Bay 1976 to 1979

Tautogolabrus adspersus (49.2)
Ammodytes sp. (12.5)
Anchoa sp. (7.0)
Tautoga onitis (11.1)
Stenotomus chrysops
Brevoortia tyrannus
Scomber scombrus
Myoxocephalus sp.
Syngnathus fuscus

Buzzards Bay 1987 to 1993

Tautogolabrus adspersus (53.4)
Anchoa sp. (38.0)
Tautoga onitis (14.1)
Ammodytes sp. (14.4)
Stenotomus chrysops
Peprilus triacanthus
Etropus microstomus
Pleuronectes americanus
Centropristis striata

Cape Cod Canal Stn 2 1987 to 1988, 1992 to 1993

Ammodytes sp. (6.7)
Pleuronectes americanus
Tautogolabrus adspersus (1.1)
Enchelyopus cimbrius
Anchoa sp. (0.3)
Myoxocephalus sp.
Tautoga onitis (0.4)
Pholis gunellus
Scomber scombrus

Narragansett Bay 1989 to 1990

Anchoa sp. (26.5)
Tautoga onitis (2.7)
Tautogolabrus adspersus (3.6)
Pleuronectes americanus
Gobiosoma ginsbergi
Brevoortia tyrannus
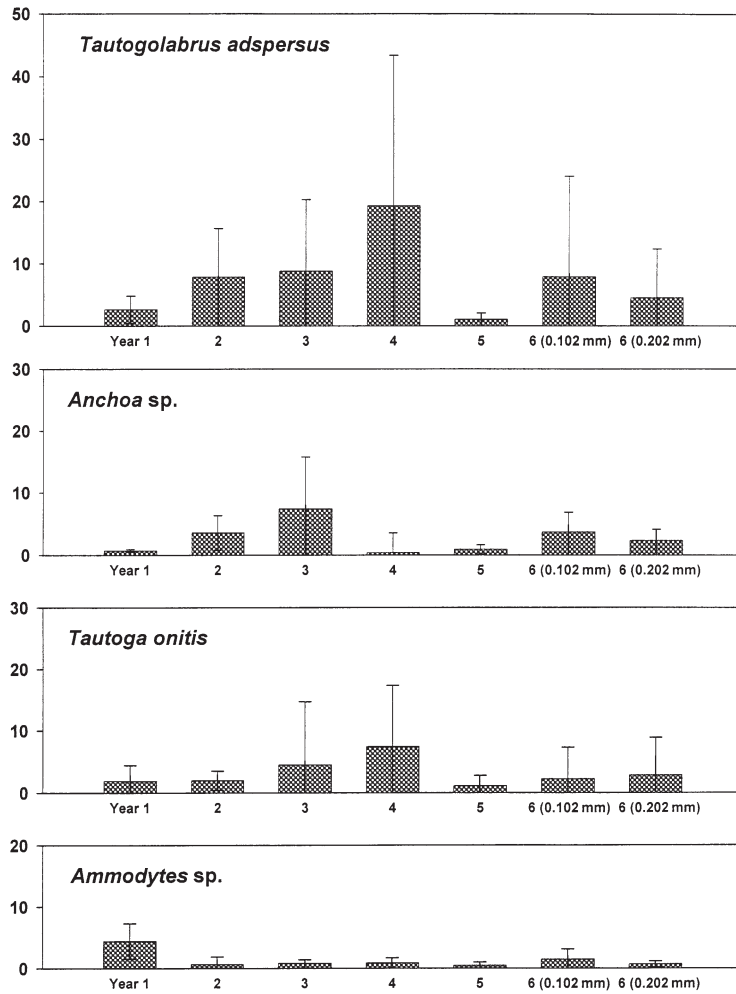*Scophthalmus aquosus*
Peprilus triacanthus
Paralichthys oblongus

Fig. 9. Mean annual densities of fish larvae (n m⁻³) for the 4 most abundant species (*Tautogolabrus adspersus*, *Anchoa* sp., *Tautoga onitis*, *Ammodytes* sp.) taken at mid-bay Stns 4, 5 and 6 during the 6 yr of the study from all 0.102 mm mesh net samples where they occurred. Year 6 shows data from the 0.102 and 0.202 mm mesh nets. Histograms are means and vertical error bars are 95% confidence limits. Year 1 is 1987 to 1988, Year 2 is 1988 to 1989, Year 3 is 1989 to 1990, Year 4 is 1990 to 1991, Year 5 is 1991 to 1992, Year 6 is 1992 to 1993

ranked second (1976 to 1979, Collings et al. 1981) and fourth (1987 to 1993, present study) in abundance. In Narragansett Bay, *Ammodytes* sp. ranked 6th in 1972 to 1973 (Bourne & Govoni 1988) and 12th or more during the Keller et al. (1999) study. *Ammodytes* sp. are known to undergo large population fluctuations, with a decrease in numbers hypothesized to be a result of an increase in the populations of herring and mackerel (Sherman et al. 1981). Since *Ammodytes americanus* is known to inhabit coastal bays and estuaries from Delaware to Labrador (Nizinski et al. 1990), localized populations may fluctuate independently.

Average annual densities (the mean density of larvae from all the samples in which they occurred) were calculated for the 4 most abundant species collected during the 6 yr of this study at Stns 4, 5 and 6, and 95% confidence intervals were assigned (Fig. 9). Overlapping confidence intervals for *Tautoga onitis*, *Tautogolabrus adspersus* and *Anchoa* sp. suggest that there were no significant changes in abundance over the 6 yr. For *Ammodytes* sp., the confidence interval for Year 1 shows no overlap with Years 3 and 5, suggesting a more variable annual spawning cycle, which may also be evidenced by seemingly low catches of these larvae in Narragansett Bay in 1989 to 1990. Collings et al. (1981) sampled ichthyoplankton in upper Buzzards Bay, the Cape Cod Canal and Cape Cod Bay from 1976 to 1979, beginning a decade before the present study. Comparison of species lists generated by the 2 studies suggests that there have been no major shifts in species composition, and recorded maximum densities of larvae were generally similar (Table 3). The number of species found at any one station varied from year to year. Usually this variation was caused by a few specimens of uncommon species.

Results of ichthyoplankton studies are highly dependent upon sampling protocols. Gear evasion and clogging can occur with small mesh nets, making samples seem sparse or skewing the length distributions of the captured larvae (Gartz et al. 1999). Conversely, nets with larger mesh may extrude smaller or thinner larvae, possibly undersampling or biasing the average length of some species (Colton et al. 1980, Hettler & Chester 1990). The deployment of 2 different nets, one immediately after the other, allowed for catch comparison and assessment of any differential avoidance or extrusion.

Narragansett Bay studies *Anchoa* sp. was the numerically dominant species, with *Tautogolabrus adpersus* and *Tautoga onitis* among the top 5 most abundant species. *Pleuronectes americanus*, however, appears to be less abundant in Buzzards Bay than in Narragansett Bay. This may be due to our processing of mid-bay samples only during the middle 4 yr of the Buzzards Bay study. Another notable difference between Buzzards Bay and Narragansett Bay (more so in the 1989 to 1990 study of Keller et al. 1999) was the small number of *Ammodytes* sp. larvae collected in Narragansett Bay. In Cape Cod Bay, *Ammodytes* sp. were the most numerous larvae (Scherer 1984), and in Buzzards Bay

Collection of significantly smaller sizes of anchovy larvae in the 0.102 mm mesh net suggests that small larvae might have been extruded through the 0.202 mm mesh net. Anchovies were the likeliest candidates for extrusion since they were the smallest of all the larvae collected, hatching at only 1.8 to 2.7 mm total length, as well as being long and thin. Even though cunner and tautog larvae hatch at only 2.0 to 2.2 mm (Fahay 1983), since they are stouter bodied, they would be less likely to be forced through a mesh size of 0.202 mm. *Ammodytes* sp., the fourth taxon tested, is a cold water spawner and hatches at about 4 mm. Although *Ammodytes* sp. larvae also have a long narrow shape, their larger mean size (10.5 mm) may not have allowed them to pass through 0.202 mm mesh, yet may have aided them in evading the smaller mouthed net, especially if its ichthyoplankton sampling efficiency was reduced due to drag due to collection of abundant zooplankton (Tranter & Smith 1968, Colton et al. 1980). Although the nets used in this study were made of mesh small enough to theoretically eliminate extrusion, the 0.202 mm mesh net may have allowed some of the smallest anchovy larvae to pass through. This is supported by the fact that our peak density of *Anchoa* sp. larvae was 38 m^{-3} with the 0.102 mm mesh, compared to peak anchovy larvae densities of only 7.0 m^{-3} with a 0.505 mm mesh in the study of Collings et al. (1981) in Buzzards Bay, 15.6 m^{-3} in the study of Monteleone (1992) in Great South Bay, New York, and 26.5 m^{-3} found by Keller et al. (1999) in Narragansett Bay, Rhode Island. There may be a tradeoff in switching to a smaller mesh net to avoid extrusion of small larvae, because the more water filtered through a coarser mesh net, the greater the chance of capturing larvae present in low numbers. This was demonstrated by the higher number of species taken per station with the larger (0.202 mm mesh) net (Fig. 8) over the full year when all 8 stations were sampled with both nets.

In summary, Buzzards Bay appears to have a larval fish assemblage different from adjacent areas of Narragansett Bay and Cape Cod Bay. This hybrid assemblage supports the notion that Buzzards Bay is in a boundary area, and that Cape Cod is a biogeographic boundary. A recurrent annual pattern of spawning was apparent, with large summer peaks of species from pelagic eggs, and smaller winter peaks of species from demersal eggs. No adverse anthropogenic effects on distributions of fish larvae were apparent, and in fact, fish larvae were most abundant at the most polluted station over the New Bedford subsurface sewage outfall. While protocols and nets used in this study were designed primarily to sample zooplankton, they also appear to capture broad-scale patterns of ichthyoplankton. The 2 types of nets used in this study did not catch significantly different numbers of fish larvae m^{-3}, but did collect significantly different sizes and diversity of larvae, in that the 0.102 mm mesh net caught significantly smaller *Anchoa* sp. larvae, whereas the larger diameter 0.202 mm mesh net collected significantly more species of larvae.

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