

3-Surfzone and Nearshore Ichthyoplankton

Introduction

Potential impacts of beach nourishment operations on the ichthyoplankton are poorly understood. This general lack of understanding can be attributed to two factors, first, because the distribution, abundance and composition of fish early life history stages in surfzone and adjacent shallow nearshore waters are poorly known, and second, because any impacts can be easily confounded by naturally high mortality rates and larval transport processes.

Specific concerns associated with beach nourishment projects for protection of ichthyoplankton assemblages have only recently been raised. A recent review that focused on the Atlantic coast identified dominant fishes that might be influenced by beach nourishment activities in the South Atlantic Bight, i.e. south of Cape Hatteras, North Carolina (Hackney et al. 1996), but did not comment on fish larvae. Other studies have identified the fish fauna on ocean beaches of the U.S., including those from New York (Briggs 1975, Schaefer 1967), New Jersey (McDermott 1983, Wilber et al. in review), Virginia (Layman 2000), North Carolina (Tagatz and Dudley 1961), South Carolina (Cupka 1972, Anderson et al. 1977, DeLancey 1984, 1989), Florida (Peters and Nelson 1987) and the Gulf of Mexico (Reid 1956, Gunter 1958, Saloman and Naughton 1979, Modde 1980, Modde and Ross 1981, 1983, McMichael and Ross 1987, Ross et al. 1987). However, studies that have focused on larval fishes of ocean beaches of the U.S. are limited to the Gulf of Mexico (Ruple 1984, Sanvicente-Anorve et al. 1998). Emerging concerns are based on insights into the ecological role of ocean beaches as nursery areas (Ross 1983).

To enhance our understanding of ocean beach and shallow nearshore larval fish assemblages and to provide some insights into the probability of impacts of beach nourishment activities on these larvae, we examined the summer larval fish assemblages off northern New Jersey beaches from 1995 – 1999. Particular attention was paid to temporal and spatial patterns of distribution, abundance, size, stage and species composition prior to, during, and after beach nourishment.

Materials and Methods

Site Description: The study area is located on a 15 km stretch of beach on the coast of New Jersey in the Middle Atlantic Bight between the Townships of Deal and Manasquan (Fig. 3-1). The beaches in this region are typically high energy, exposed and steeply sloped. Wave heights average 0.3 to 1.2 m with a period of 5 to 9 seconds and a tidal range of approximately 1.4 m. The beach is divided at regular intervals by groin structures (Nordstrom et al. 1977). Within the study area are two inlets, one at the southernmost extent, Manasquan Inlet, and one located roughly in the center, Shark River Inlet.

Sampling Technique: Sampling occurred monthly from May to July, 1995 through 1999 with each sampling event occurring over a week-long period (Table 3-1). Sampling was conducted in two zones relative to the beach, surfzone (generally within 50 m of the MLW mark) and nearshore (along the 6-7 m depth contour). Surfzone sampling consisted of 22 sampling stations spaced fairly evenly throughout the area (Fig. 3-1). At each site a 0.5 m (505 μ mesh)

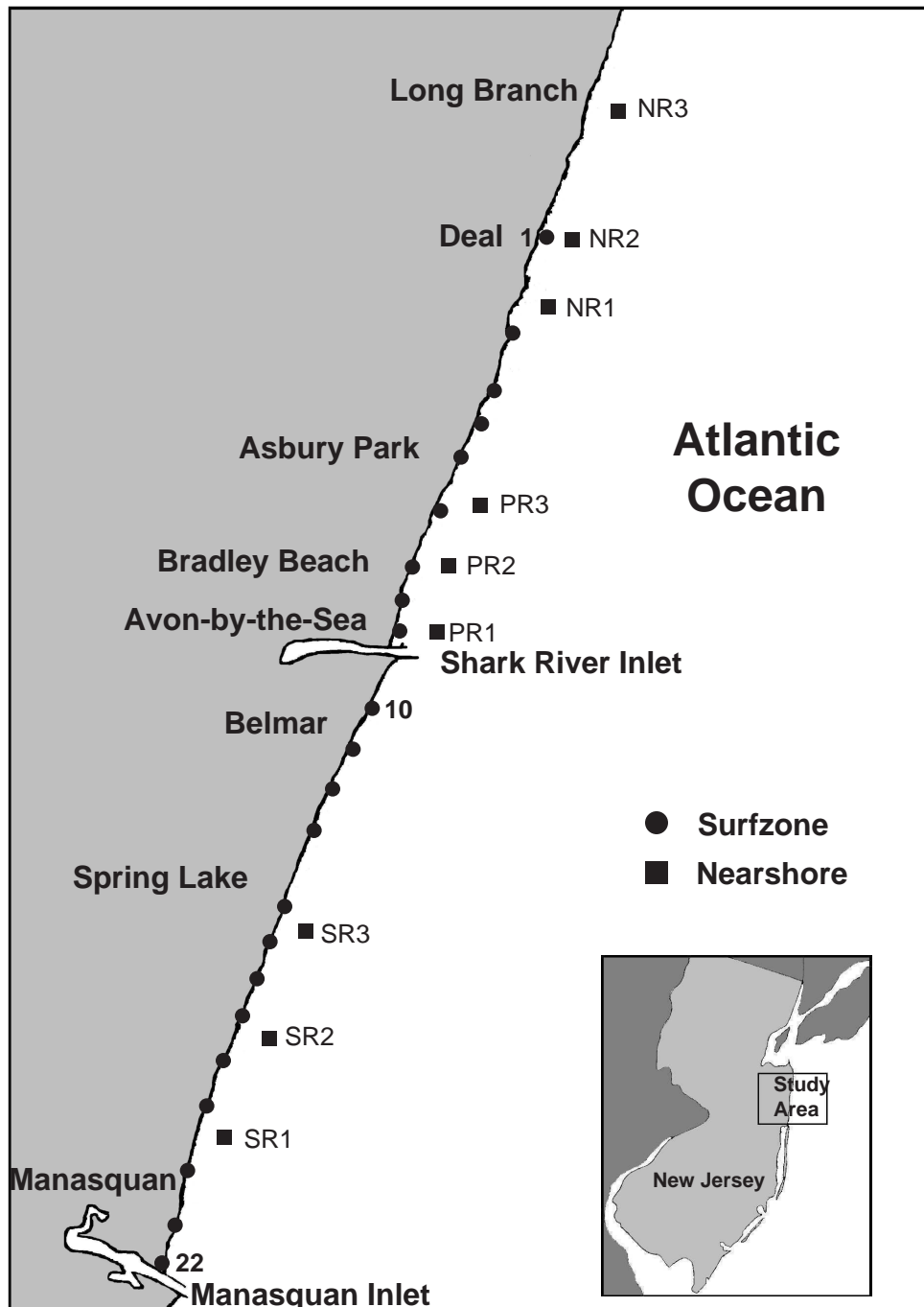


Figure 3-1. Ichthyoplankton sampling locations in northern New Jersey from 1995 to 1999. Surfzone sites are numbered from 1-22 while nearshore sites have an alpha-numeric designation.

Table 3-1. Sampling effort and number of samples processed and average density (number/100m³ ∓ SE) for Army Corps of Engineers ichthyoplankton from Monmouth County, New Jersey, beaches. Notes: 1995 nearshore - no samples; May 1997 surfzone not sampled; nearshore 1997, only year that all five replicate tows were identified. See Fig. 3-1 for sampling locations.

Year	Surfzone (22 sites)		Nearshore (9 sites)	
	Number of samples	Avg. density (SE)	Number of samples	Avg. density (SE)
1995	66	6.26 (1.72)	-	
1996	66	27.33 (6.91)	54	103.77 (15.38)
1997	44	17.39 (4.68)	270	50.34 (9.39)
1998	66	48.66 (12.98)	54	75.64 (21.09)
1999	43	35.98 (11.98)	54	70.76 (18.89)

Table 3-2. Overall abundance and average density of larvae from nearshore and surfzone ichthyoplankton collected from ocean beaches in northern New Jersey from 1995 through 1999. See Fig. 1 for sampling locations.

Species	Origin	Nearshore		Surfzone	
		Abundance	Density (SE)	Abundance	Density (SE)
<i>Anchoa sp.</i>	Estuarine/Oceanic	71304	75.25(13.37)	2110	20.89(4.10)
<i>Brevoortia tyrannus</i>	Oceanic	28393	23.74(4.37)	828	20.2(11.89)
<i>Scomber scombrus</i>	Oceanic	8726	28.84(5.96)	1140	26.51(9.62)
<i>Tautoga onitis</i>	Estuarine/Oceanic	5942	10.21(2.87)	100	2.13(0.22)
<i>Scophthalmus aquosus</i>	Estuarine/Oceanic	5507	7.90(1.51)	1183	21.51(7.43)
<i>Tautogolabrus adspersus</i>	Oceanic	4560	7.81(1.44)	41	2.28(0.71)
<i>Cynoscion regalis</i>	Estuarine/Oceanic	3623	6.82(0.91)	100	2.63(0.48)
Unidentified fish		2861	5.67(1.60)	256	5.95(1.45)
<i>Pomatomus saltatrix</i>	Oceanic	2431	9.57(2.03)	16	2.00(0.50)
<i>Lophius americanus</i>	Oceanic	1828	2.34(0.35)	195	4.06(0.99)
<i>Anchoa mitchilli</i>	Estuarine/Oceanic	1003	5.50(1.22)	32	2.46(0.63)
<i>Etropus microstomus</i>	Oceanic	701	5.06(1.25)	56	5.6(2.66)
<i>Prionotus evolans</i>	Oceanic	688	2.89(0.38)	55	2.12(0.32)
<i>Syngnathus fuscus</i>	Estuarine	600	1.30(0.20)	116	1.84(0.19)
<i>Enchelyopus cimbrius</i>	Oceanic	458	1.21(0.27)	58	3.05(0.99)
<i>Hippoglossina oblonga</i>	Oceanic	386	1.47(0.26)	29	2.07(0.40)
<i>Pseudopleuronectes americanus</i>	Estuarine	379	0.80(0.09)	24	2.67(1.30)
Atherinidae sp.	Estuarine	357	0.86(0.12)	616	5.81(1.07)
<i>Prionotus carolinus</i>	Oceanic	316	2.80(0.41)	6	1.50(0.29)
<i>Menticirrhus sp.</i>	Oceanic	205	1.63(0.32)	125	4.63(1.64)
<i>Peprilus triacanthus</i>	Oceanic	148	1.87(0.37)	364	16.55(4.89)
<i>Menticirrhus saxatilis</i>	Oceanic	125	2.91(0.48)	3	1.00(0)
<i>Hypsoblennius hentz</i>	Estuarine/Oceanic	109	5.94(3.95)	6	1.00(0)
<i>Anchoa hepsetus</i>	Oceanic	90	1.61(0.35)		
<i>Centropristis striata</i>	Oceanic	82	3.73(1.80)	23	2.09(0.44)
<i>Urophycis chuss</i>	Oceanic	82	1.41(0.39)	4	1.00(0)
<i>Sphoeroides maculatus</i>	Estuarine	74	0.70(0.14)	10	1.00(0)

Table 3-2 continued

Species	Origin	Nearshore		Surfzone	
		Abundance	Density (SE)	Abundance	Density (SE)
<i>Opisthonema oglinum</i>	Oceanic	38	0.94(0.18)		
<i>Engraulis eurystole</i>	Oceanic	32	6.64		
<i>Astroscopus guttatus</i>	Estuarine/Oceanic	31	1.85(0.71)	2	2.00
Gobiidae sp.	Estuarine	28	0.55(0.15)	4	1.00(0)
Clupeiformes sp.	Oceanic	20	5.00		
<i>Prionotus</i> sp.	Oceanic	18	0.59(0.15)	8	1.33(0.21)
<i>Urophycis regia</i>	Oceanic	18	0.58(0.30)		
<i>Ammodytes</i> sp.	Oceanic	15	0.20(0.03)	2	2.00
Scombridae sp.	Oceanic	13	1.86		
<i>Gasterosteus aculeatus</i>	Estuarine	10	0.70(0.39)		
<i>Menidia menidia</i>	Estuarine	9	0.60(0.37)	236	4.72(1.28)
<i>Ophidion</i> sp.	Oceanic	9	0.82(0.52)		
<i>Ulvaria subbifurcata</i>	Oceanic	8	0.16(0.02)	1	1.00
<i>Gobiosoma bosc</i>	Estuarine	6	0.42(0.14)		
<i>Scomberomorus maculatus</i>	Oceanic	4	0.40(0.11)	2	2.00
Sciaenidae sp.	Oceanic	3	0.47	6	3.00(1.00)
<i>Strongylura marina</i>	Estuarine	2	0.45	6	2.00(0.58)
<i>Scomberomorus</i> sp.	Oceanic	2	0.30	3	1.50(0.50)
<i>Micropogonias undulatus</i>	Oceanic	2	0.94		
<i>Myoxocephalus aeneus</i>	Estuarine/Oceanic	2	0.15(0.04)		
<i>Pollachius virens</i>	Oceanic	2	0.15(0.01)		
Stichaeidae sp.	Oceanic	2	0.32		
<i>Bairdiella chrysoura</i>	Estuarine/Oceanic	1	0.36	5	1.00(0)
<i>Fundulus heteroclitus</i>	Estuarine	1	0.11	4	1.00(0)
<i>Bothus ocellatus</i>	Oceanic	1	0.31	2	1.00(0)
<i>Conger oceanicus</i>	Oceanic	1	0.21	1	1.00
<i>Apeltes quadracus</i>	Estuarine	1	0.19	1	1.00
<i>Auxis</i> sp.	Oceanic	1	0.21		
<i>Conger</i> sp.	Oceanic	1	0.21		
<i>Gobiosoma</i> sp.	Estuarine	1	0.20		

Table 3-2 continued

Species	Origin	Nearshore		Surfzone	
		Abundance	Density (SE)	Abundance	Density (SE)
<i>Limanda ferruginea</i>	Oceanic	1	0.12		
<i>Trinectes maculatus</i>	Estuarine	1	0.28		
<i>Urophycis sp.</i>	Oceanic	1	0.22		
<i>Mugil curema</i>	Oceanic			4	2.00(0)
<i>Caranx hippos</i>	Oceanic			2	1.00(0)
<i>Morone americana</i>	Estuarine			1	1.00
<i>Membras martinica</i>	Oceanic			1	1.00
Carangidae sp.	Oceanic			1	1.00
<i>Cyprinodon variegatus</i>	Estuarine			1	1.00
Grand Totals		141263		7789	

Table 3-3. Abundance (number of total individuals collected) for nearshore (Near) and surfzone (Surf) ichthyoplankton collected from northern New Jersey beaches from 1995 through 1999. Notes: 1995 nearshore - no samples; May 1997 surfzone not sampled; nearshore 1997, only year that all five replicate tows were identified. See Fig. 3-1 for sampling locations.

Species	1995	1996		1997		1998		1999		Grand Total
	Surf	Near	Surf	Near	Surf	Near	Surf	Near	Surf	
<i>Anchoa sp.</i>	3	14720	339	54970	399	1536	1361	78	8	73414
<i>Brevoortia tyrannus</i>		5153	70	4338	35	9588	22	9314	701	29221
<i>Scomber scombrus</i>	8	5432	544	1		2879	587	414	1	9866
<i>Scophthalmus aquosus</i>	7	1332	86	532	39	3462	1039	181	12	6690
<i>Tautoga onitis</i>		736	28	3074	28	278	25	1854	19	6042
<i>Tautogolabrus adspersus</i>	1	889	1	3345	10	58	11	268	18	4601
<i>Cynoscion regalis</i>	5	333	41	2673	46	362	1	255	7	3723
Unidentified fish	2	2338	202	316	9	139	22	68	21	3117
<i>Pomatomus saltatrix</i>		760	1	1272	2		1	399	12	2447
<i>Lophius americanus</i>	1	612	131	1187	51	28	9	1	3	2023
<i>Anchoa mitchilli</i>		160		748	5	29	27	66		1035
Atherinidae sp.	244	98	188	216	79	12	23	31	82	973
<i>Etropus microstomus</i>		8		366	2	1		326	54	757
<i>Prionotus evolans</i>				590	4	38	11	60	40	743
<i>Syngnathus fuscus</i>	20	181	13	353	29	45	24	21	30	716
<i>Enchelyopus cimbrius</i>		248	49	19		117	9	74		516
<i>Peprilus triacanthus</i>		40	4	27	1		28	81	331	512
<i>Hippoglossina oblonga</i>		141	11	189	5	26	13	30		415
<i>Pseudopleuronectes americanus</i>		152	19	123		26	5	78		403
<i>Menticirrhus sp.</i>	1		11	151	1	53	6	1	106	330
<i>Prionotus carolinus</i>				274	3	1	1	41	2	322
<i>Menidia menidia</i>	108	2	53		1	7	19		55	245
<i>Menticirrhus saxatilis</i>		16		11	1		2	98		128
<i>Hypsoblennius hentz</i>								109	6	115
<i>Centropristis striata</i>					3		1	82	19	105
<i>Anchoa hepsetus</i>				50				40		90

Table 3-3 continued

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Table 3-3 continued

Species	1995	1996		1997		1998		1999		Grand Total
	Surf	Near	Surf	Near	Surf	Near	Surf	Near	Surf	
<i>Auxis sp.</i>				1						1
Carangidae sp.							1			1
<i>Conger sp.</i>				1						1
<i>Cyprinodon variegatus</i>					1					1
<i>Gobiosoma sp.</i>						1				1
<i>Limanda ferruginea</i>		1								1
<i>Membras martinica</i>					1					1
<i>Morone americana</i>					1					1
<i>Trinectes maculatus</i>						1				1
<i>Urophycis sp.</i>						1				1
Grand Total	413	33409	1804	74997	765	18751	3260	14106	1547	149052

Table 3-4. Percent composition based on origin of species for ichthyoplankton collected on northern New Jersey beaches for nearshore (Near) and surfzone (Surf). No nearshore samples for 1995.

Origin	1995	1996		1997		1998		1999	
	Surf	Near	Surf	Near	Surf	Near	Surf	Near	Surf
Estuarine	93.43	1.56	17.04	1.04	15.61	0.53	2.29	0.75	11.14
Estuarine/Oceanic	3.65	52.82	30.90	83.30	68.39	32.65	75.82	33.73	3.67
Oceanic	2.92	45.62	52.06	15.66	16.01	66.83	21.90	65.53	85.19

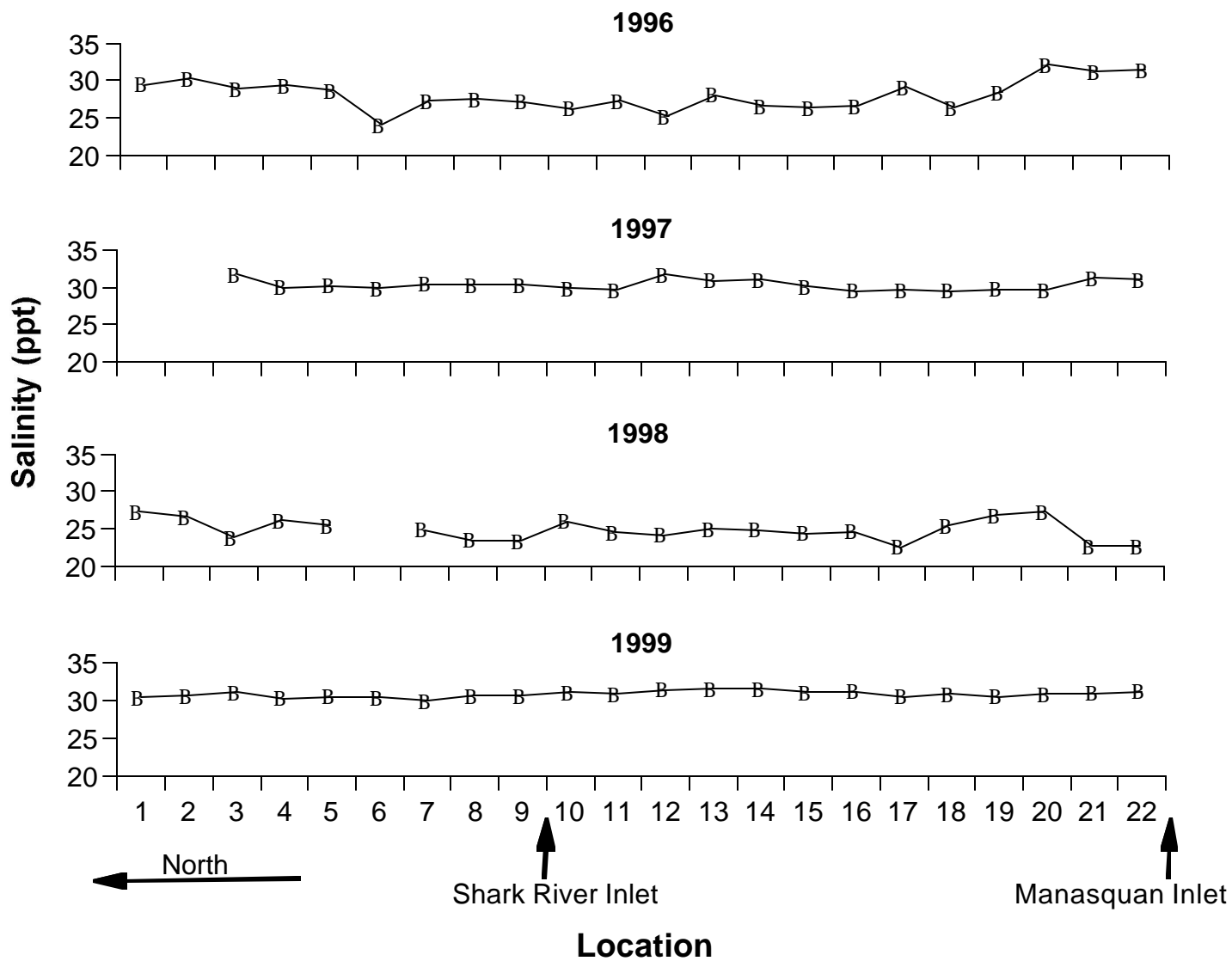


Figure 3-2. Average salinity (ppt) by study site (see Fig. 3-1) for ichthyoplankton sites in northern New Jersey.

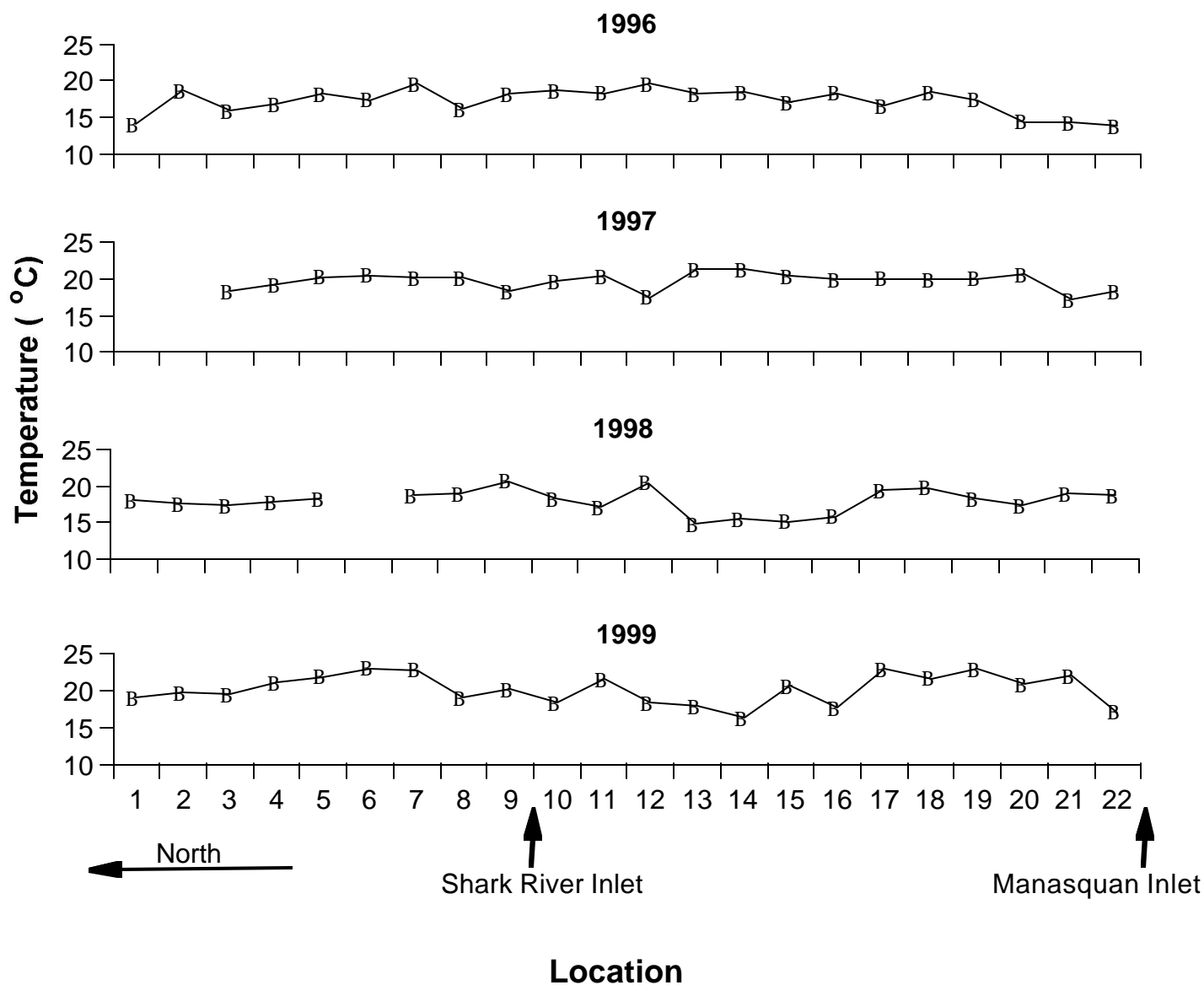


Figure 3-3. Average temperature ($^{\circ}\text{C}$) by study site (see Fig. 3-1) for ichthyoplankton sites in northern New Jersey.

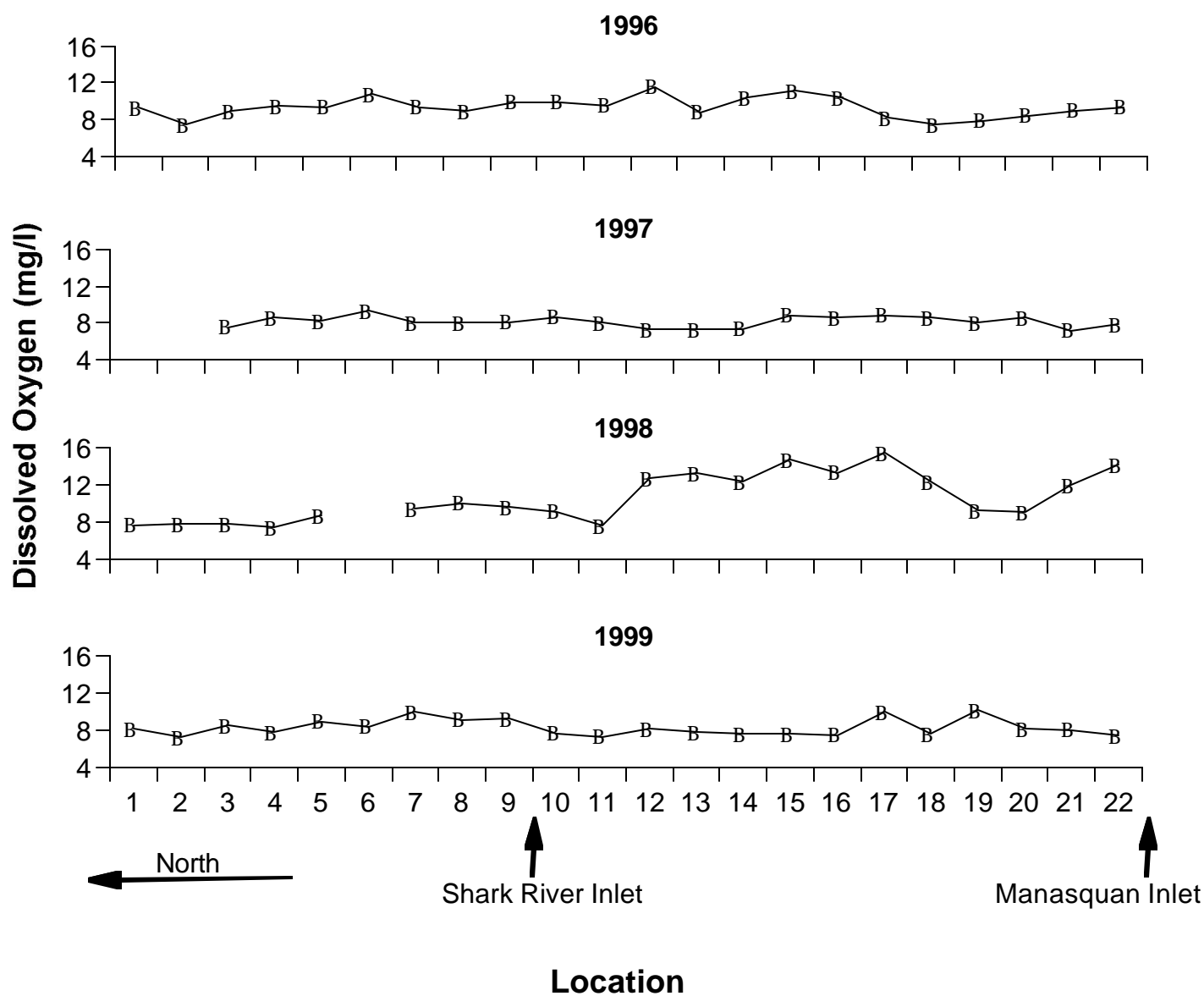


Figure 3-4. Average dissolved oxygen (mg/l) by study site (see Fig. 3-1) for ichthyoplankton sites in northern New Jersey.

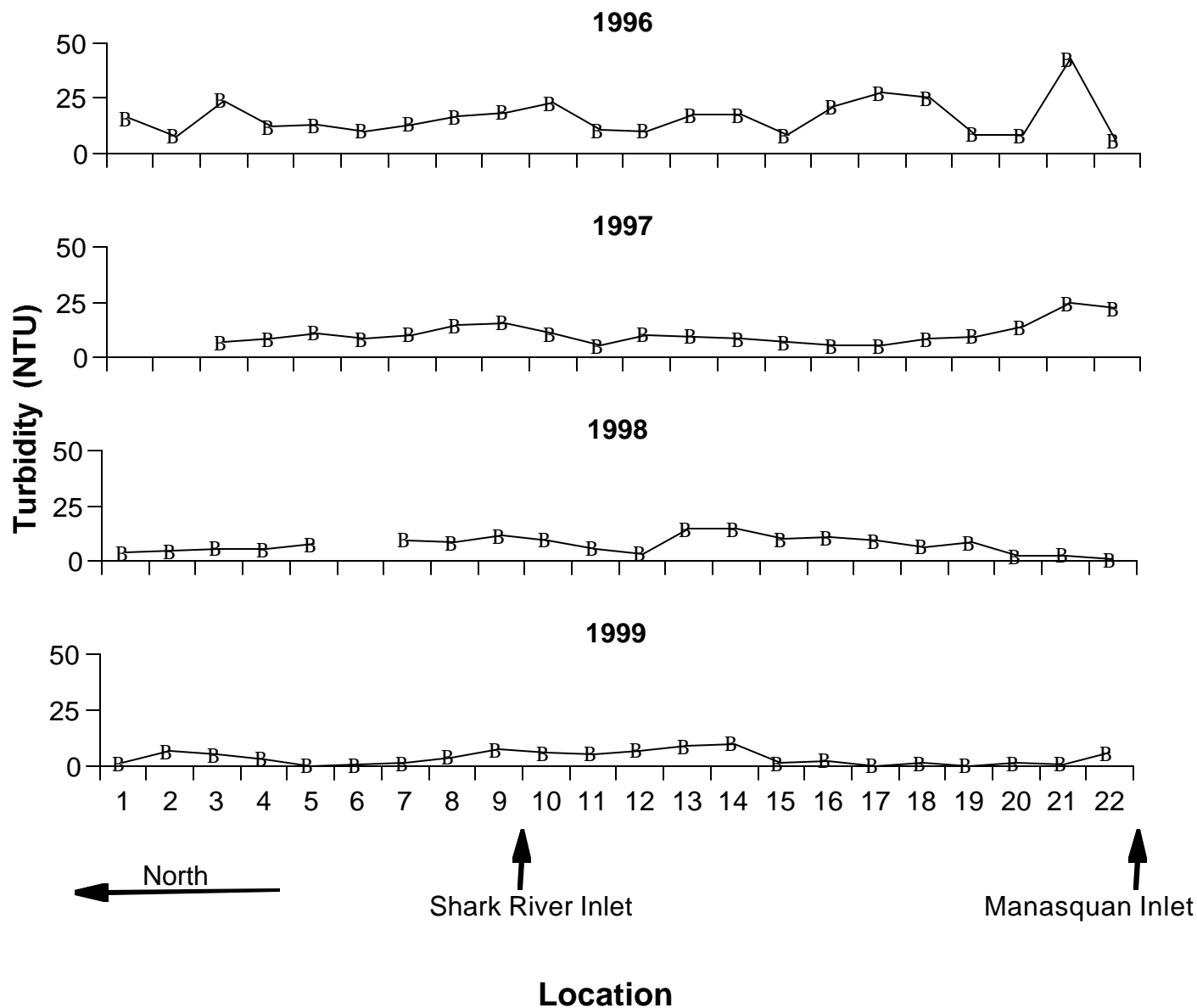


Figure 3-5. Average turbidity (NTU) by study site (see Fig. 3-1) for ichthyoplankton sites in northern New Jersey.

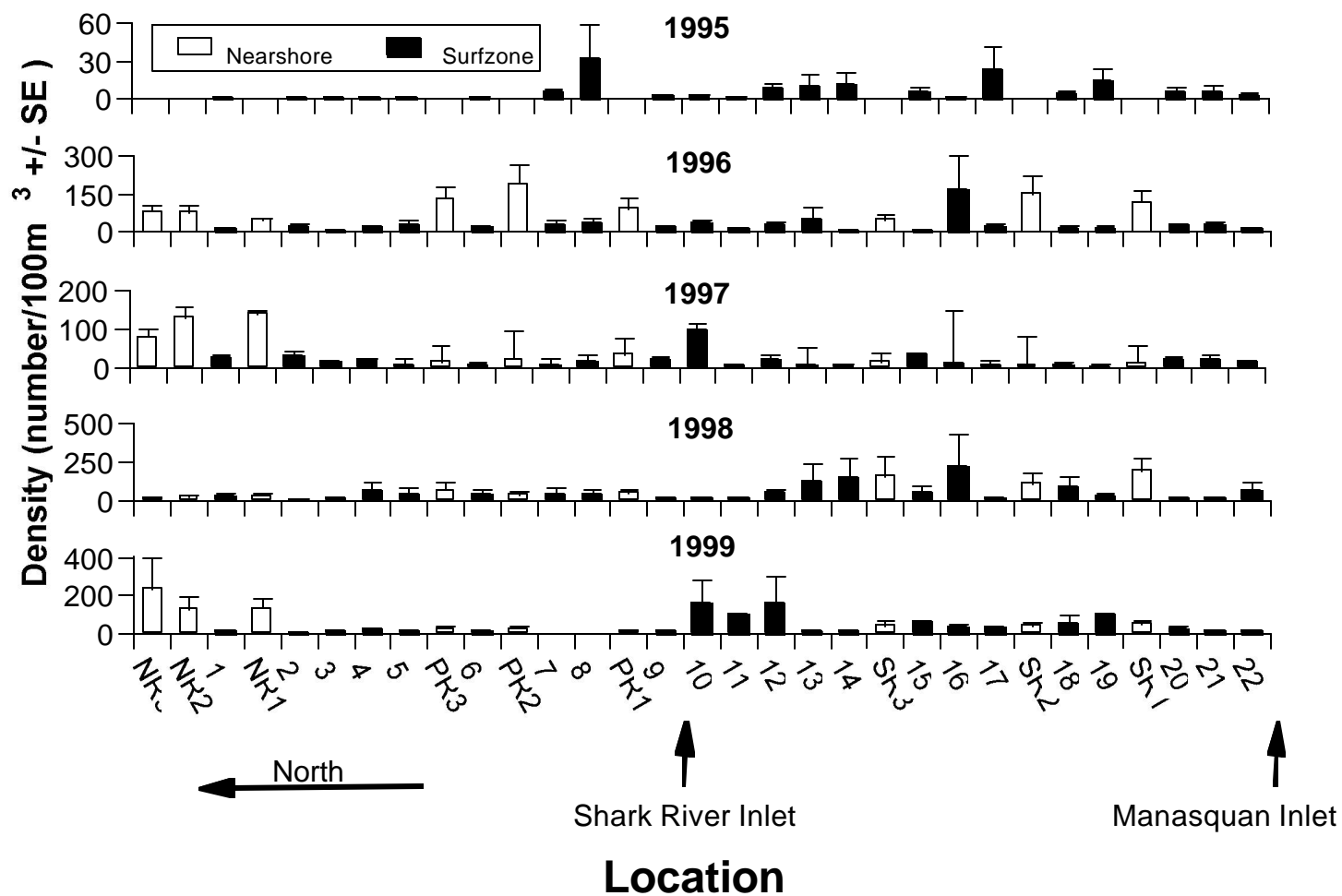


Figure 3-6. Average larval density for nearshore and surfzone ichthyoplankton collected from northern New Jersey beaches. No nearshore samples in 1995. See Fig. 3-1 for sampling locations.

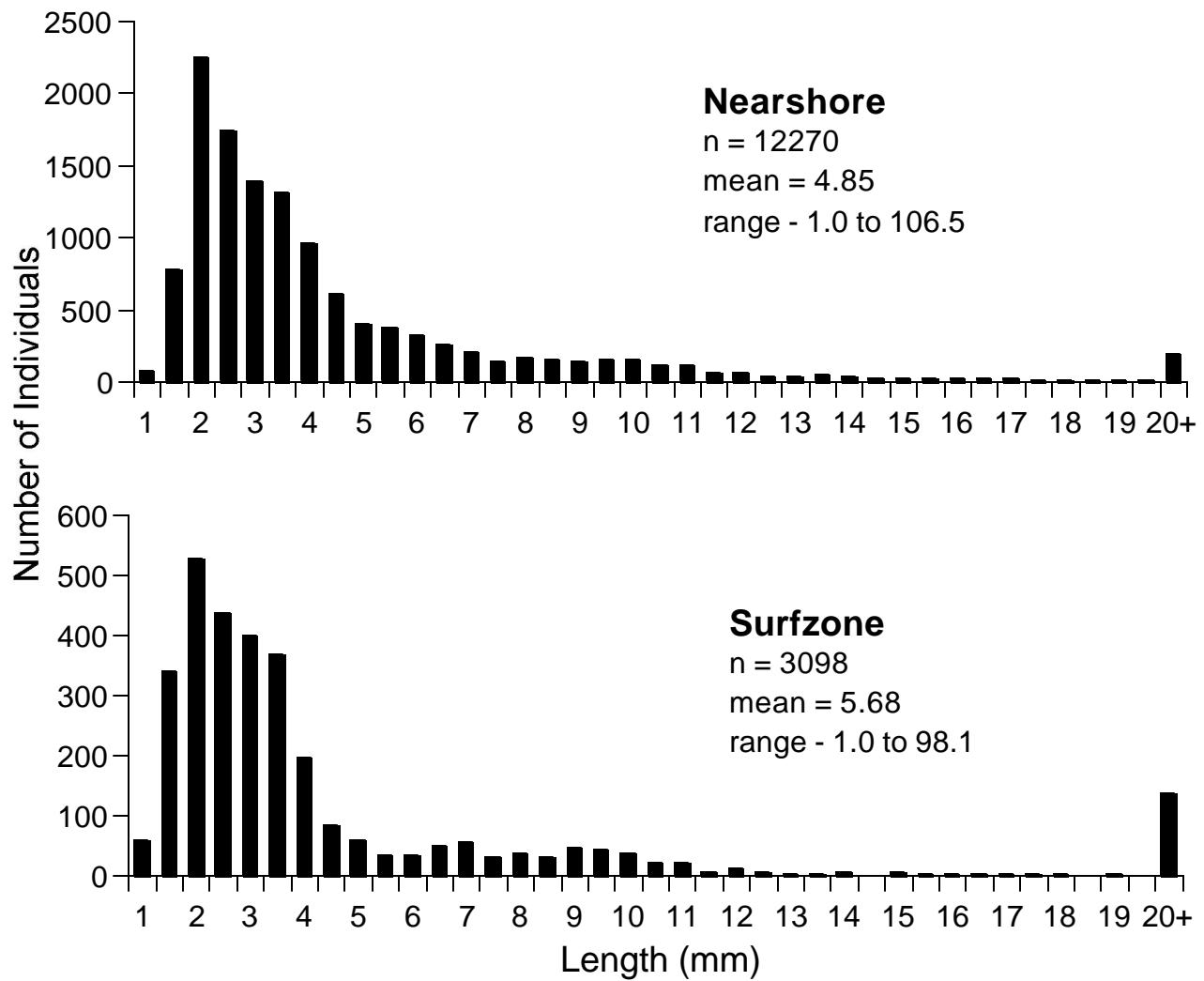


Figure 3-7. Composite lengths for (surfzone and nearshore) ichthyoplankton samples from northern New Jersey beaches for 1996 through 1999.

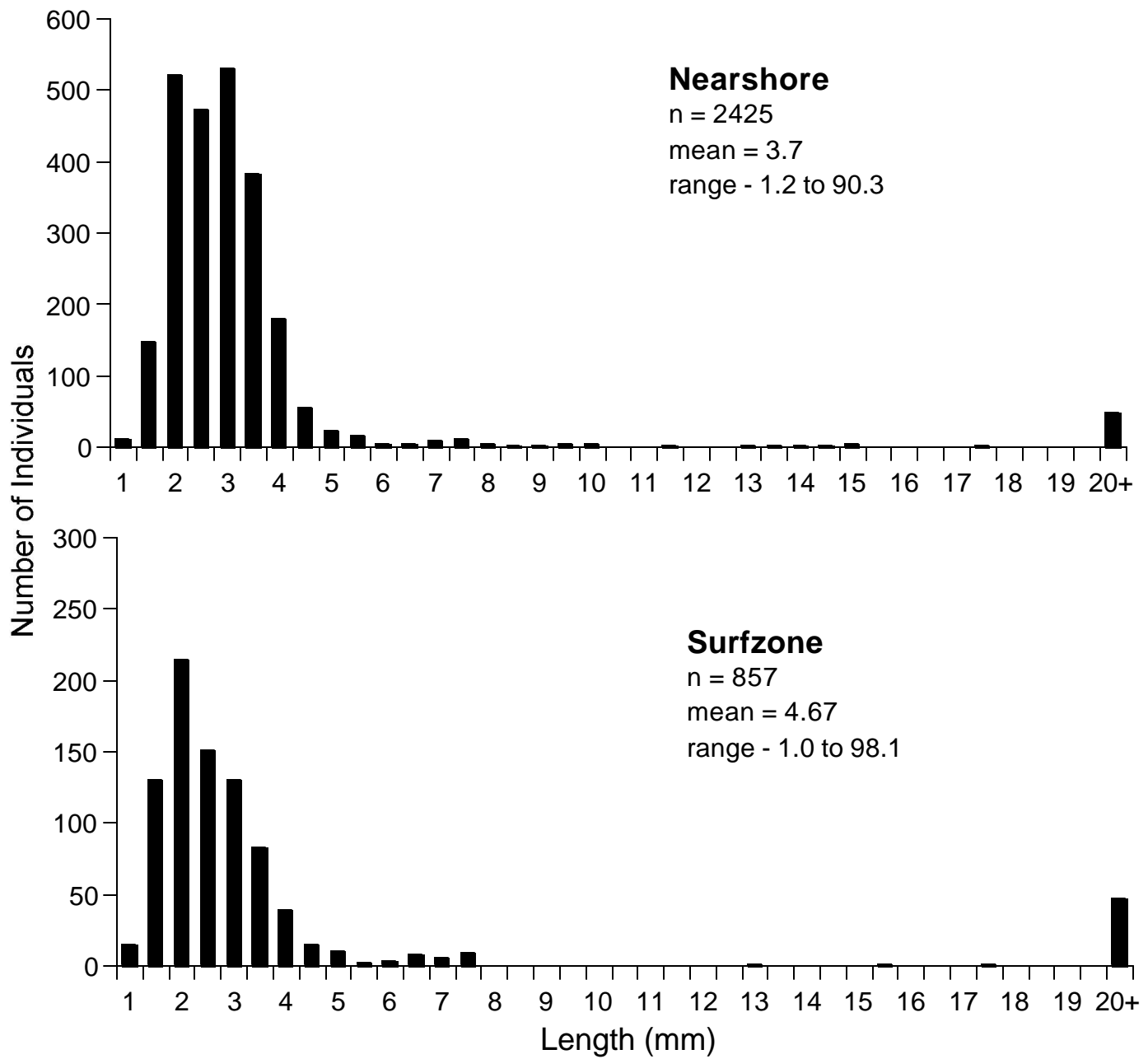


Figure 3-8. Composite lengths for (surfzone and nearshore) ichthyoplankton samples from northern New Jersey beaches for 1996.

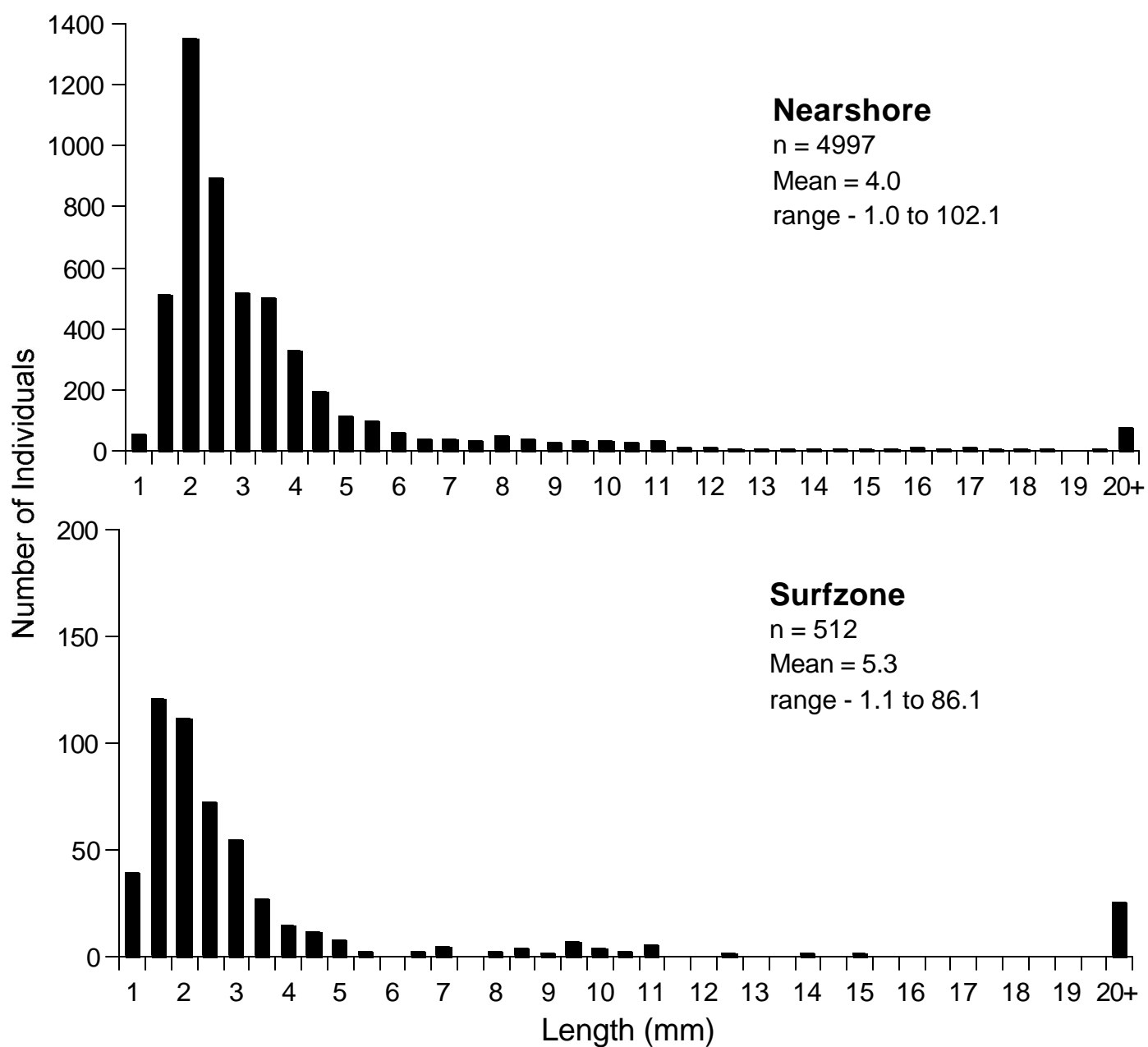


Figure 3-9. Composite lengths for (surfzone and nearshore) ichthyoplankton samples from northern New Jersey beaches for 1997.

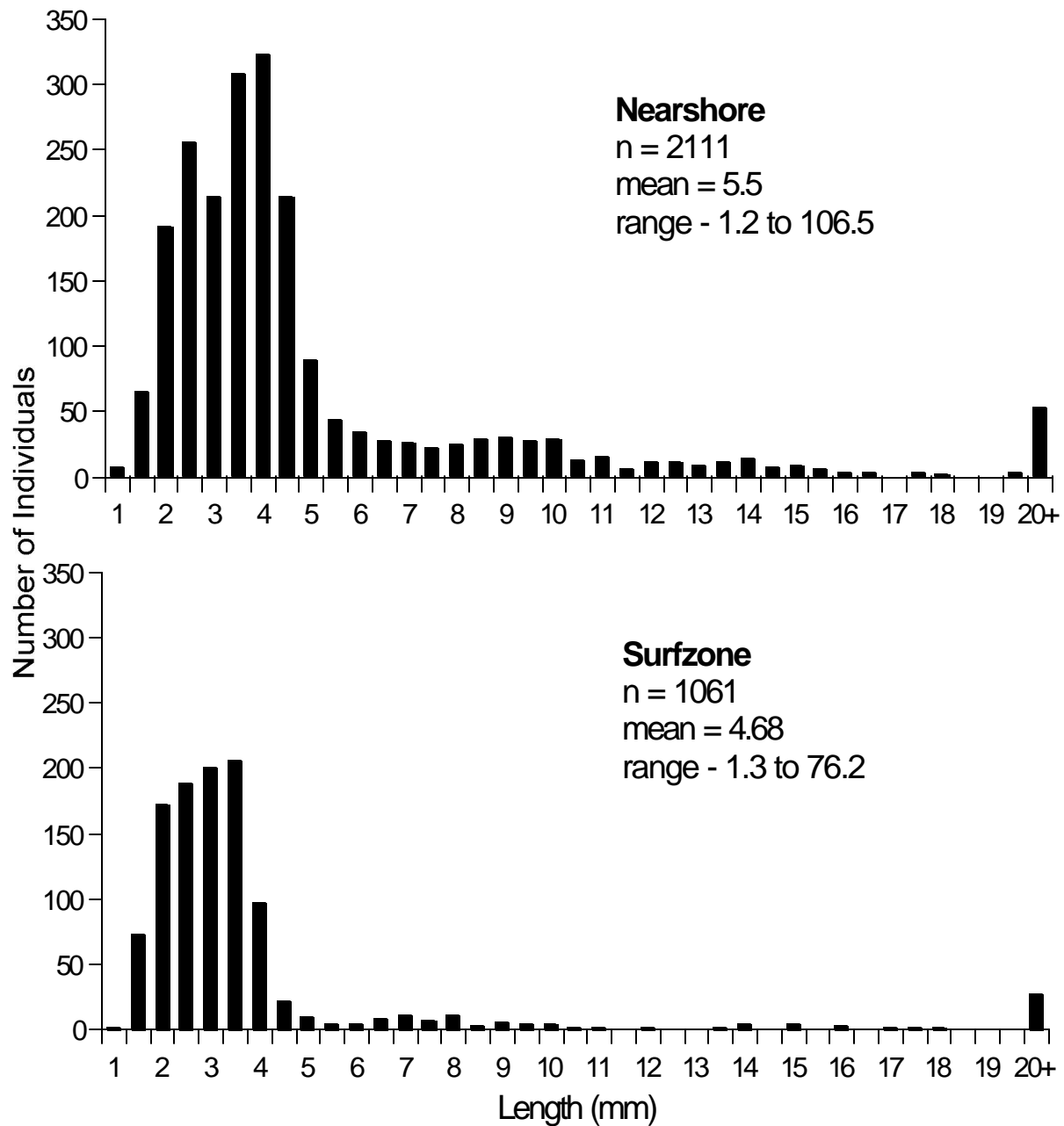


Figure 3-10. Composite lengths for (surfzone and nearshore) ichthyoplankton samples from northern New Jersey beaches for 1998.

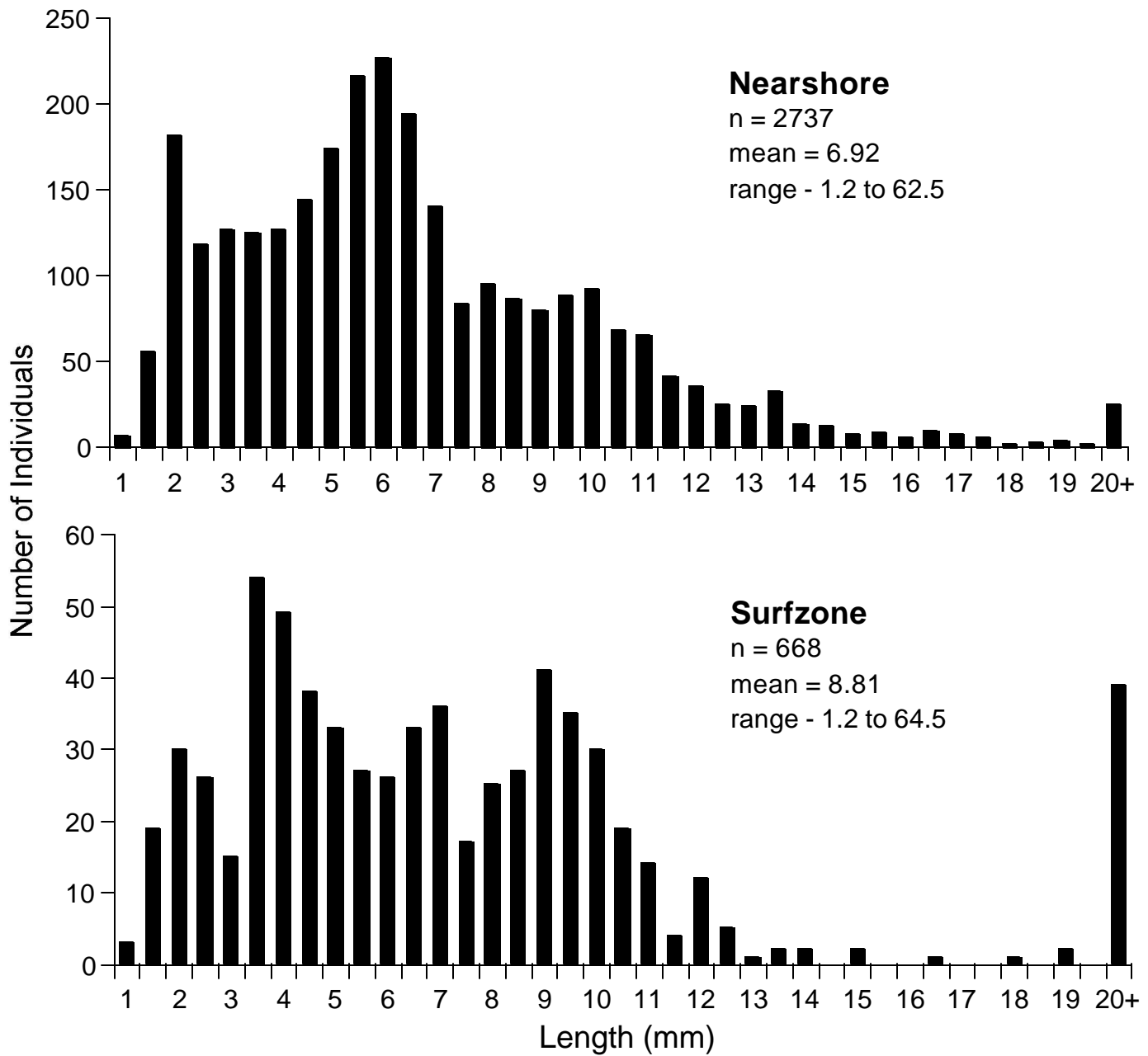


Figure 3-11. Composite lengths for (surfzone and nearshore) ichthyoplankton samples from northern New Jersey beaches for 1999.

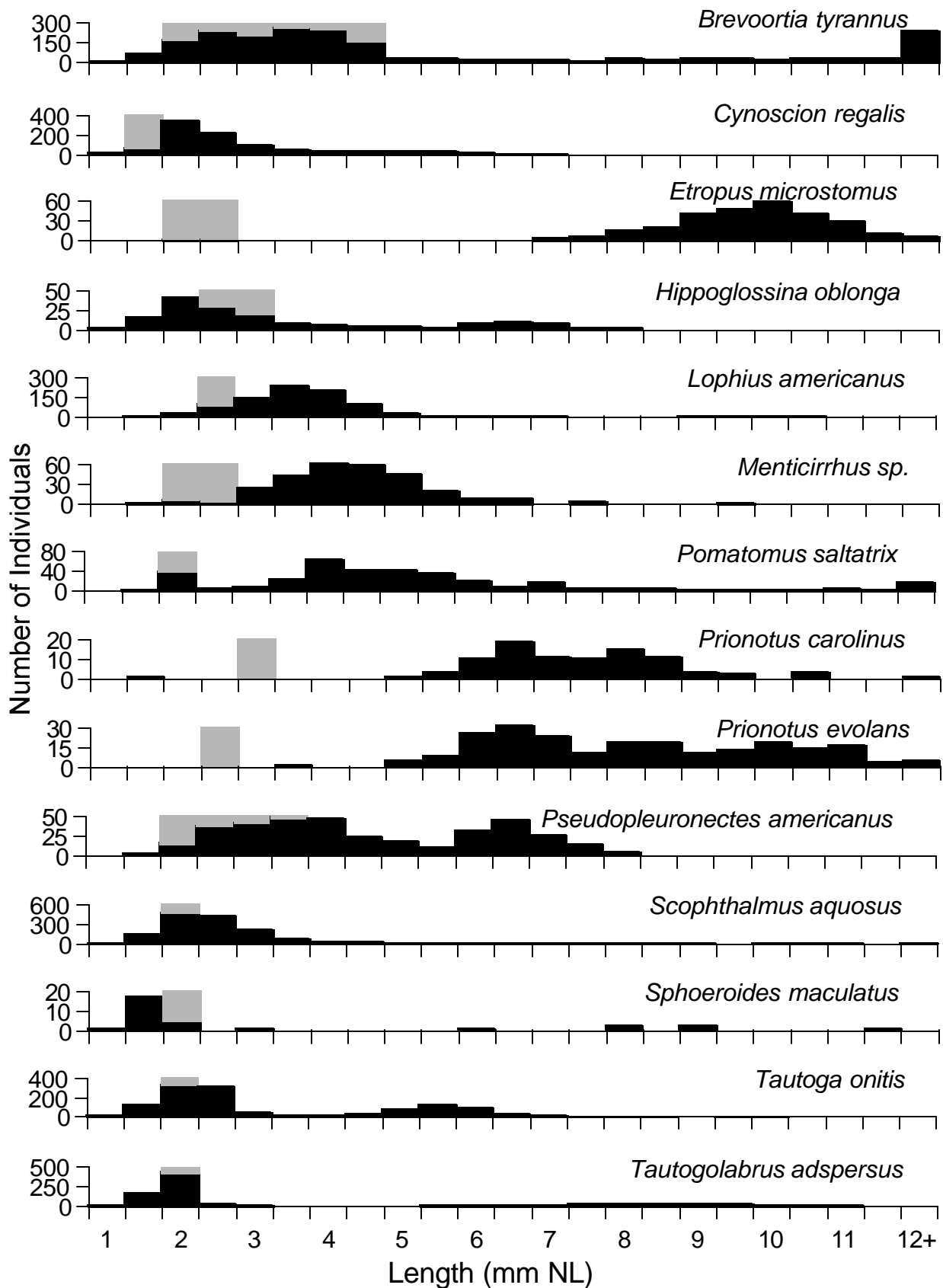


Figure 3-12. Length composition (black) relative to hatching size reported from the literature (hatched area) for selected species collected from northern New Jersey beaches from 1995 through 1999 (nearshore and surfzone combined).

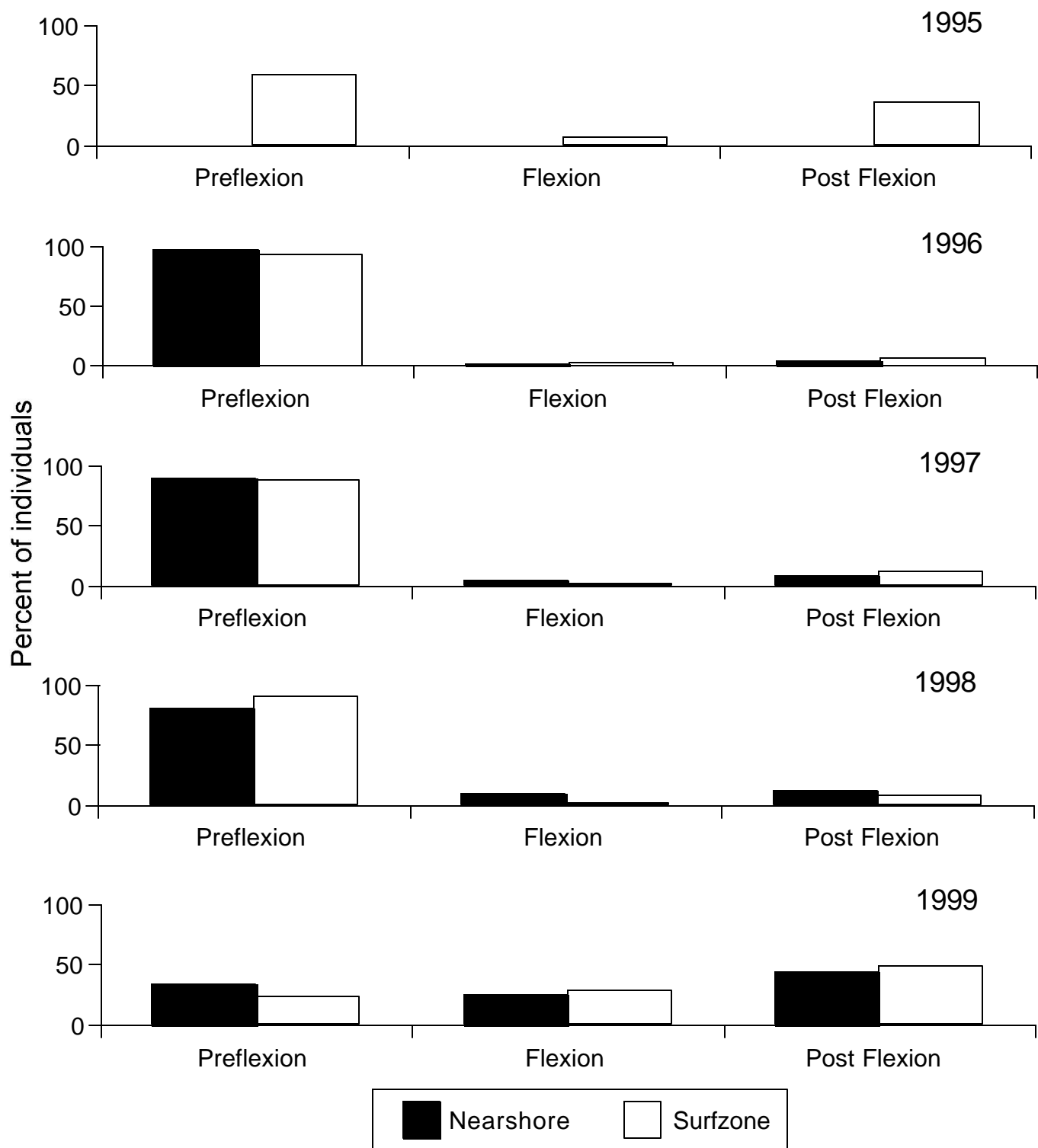


Figure 3-13. Flexion stage composition for ichthyoplankton samples from northern New Jersey beaches. Note there were no nearshore collections in 1995. See Fig. 3-1 for sampling locations.

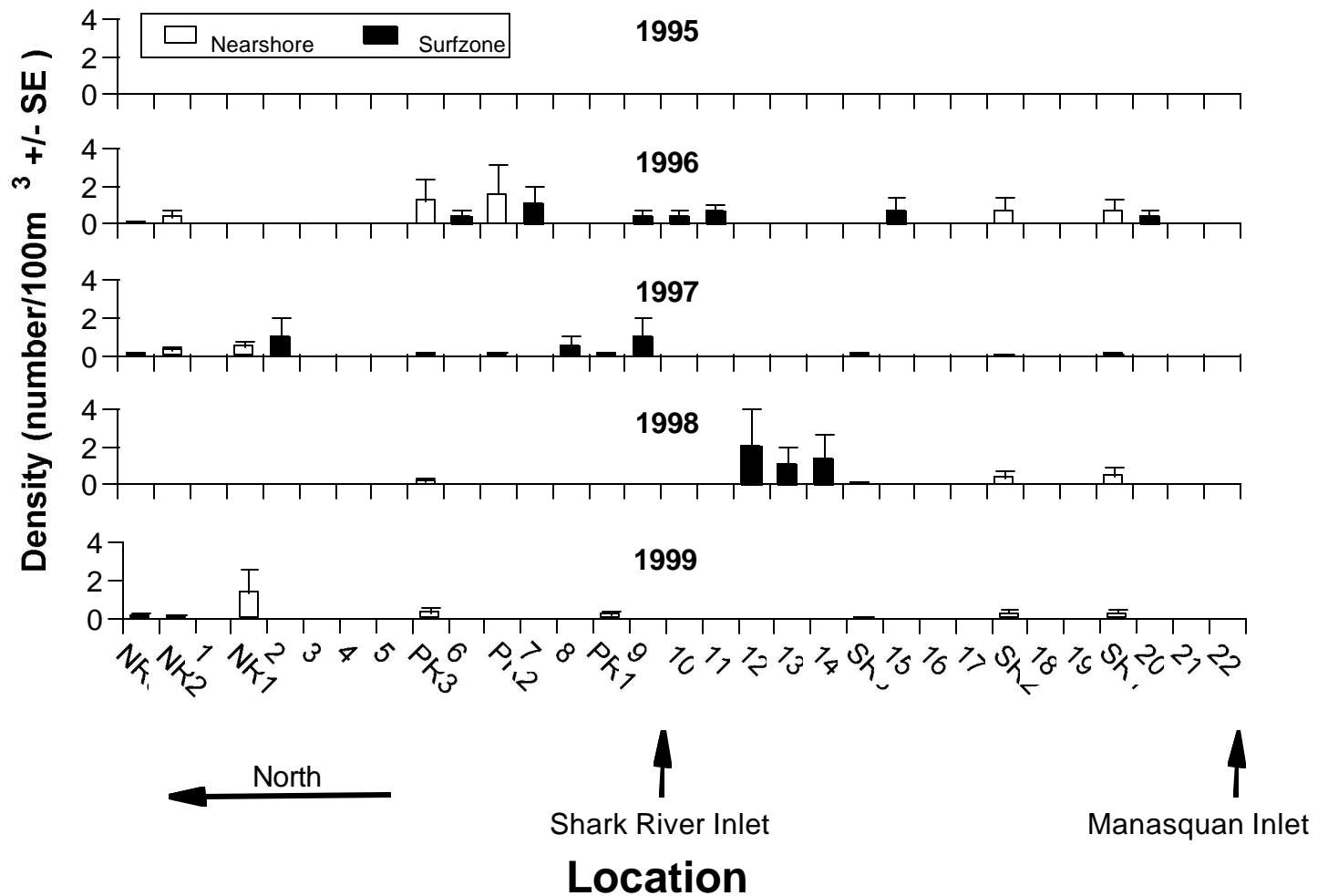


Figure 3-14. Average larval density of *Hippoglossina oblonga* for nearshore and surfzone ichthyoplankton collected from northern New Jersey beaches. No nearshore samples in 1995. See Fig. 3-1 for sampling locations.

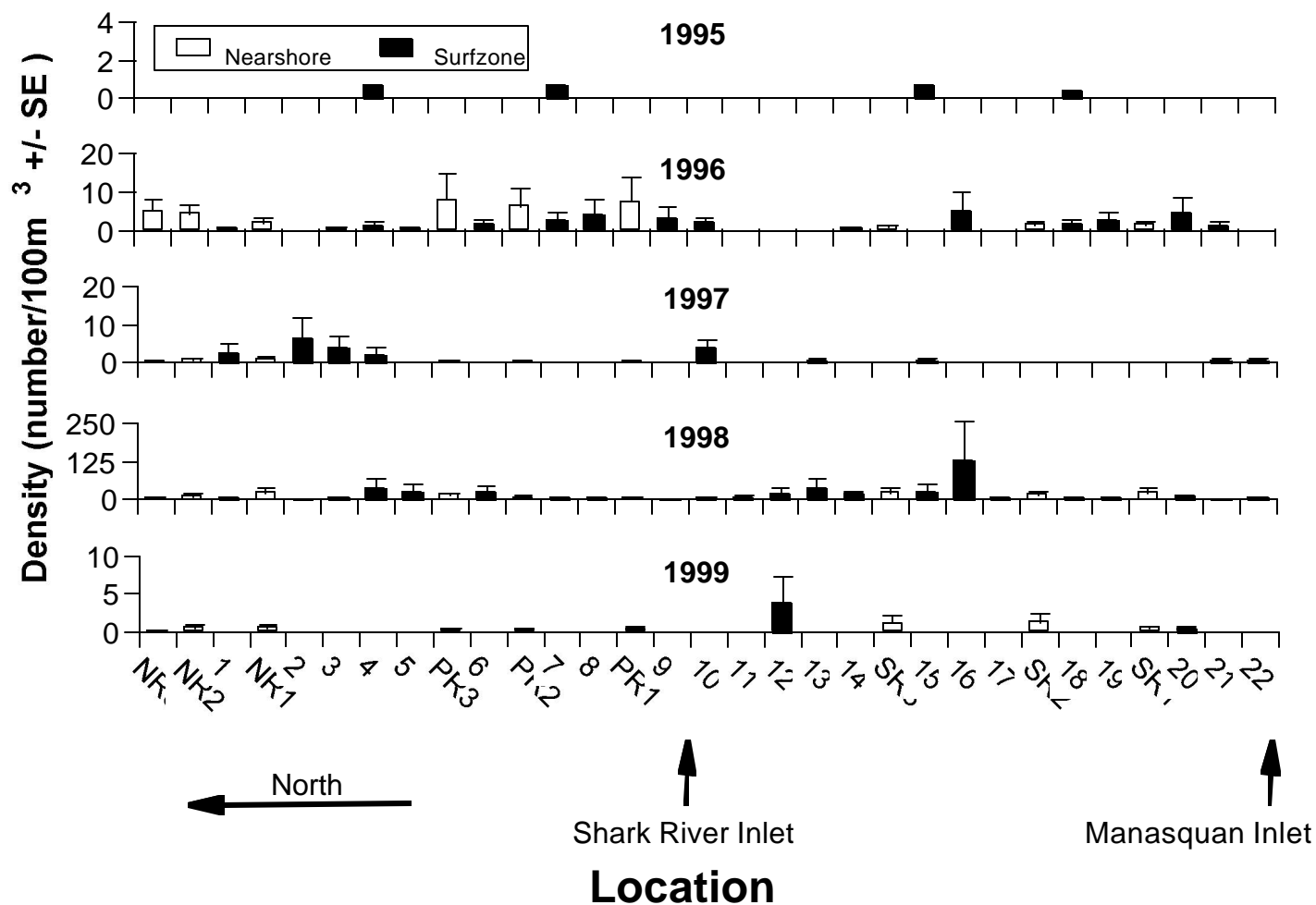


Figure 3-15. Average larval density of *Scophthalmus aquosus* for nearshore and surfzone ichthyoplankton collected from northern New Jersey beaches. No nearshore samples in 1995. See Fig. 3-1 for sampling locations.

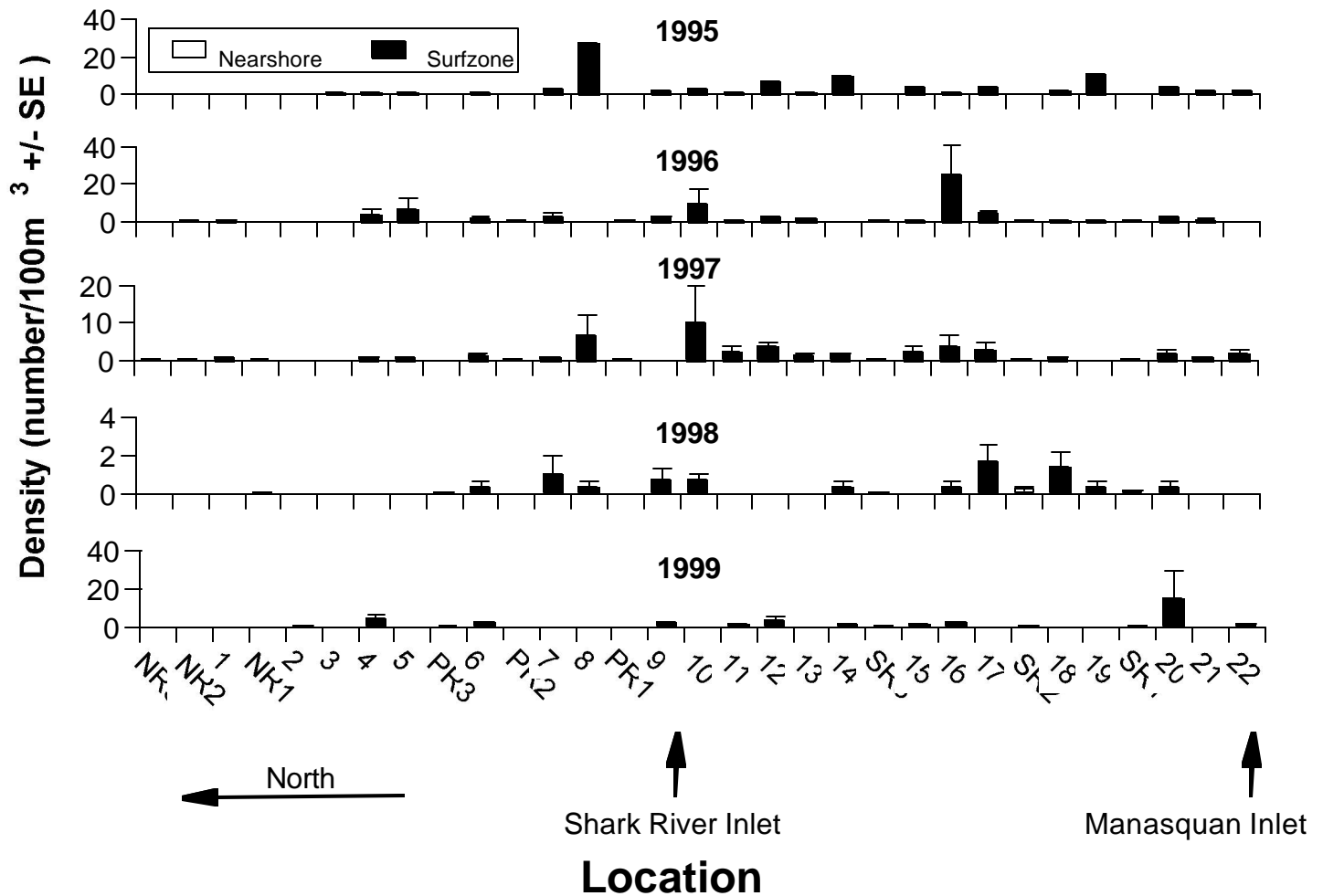


Figure 3-16. Average larval density of *Atherinidae* sp. for nearshore and surfzone ichthyoplankton collected from northern New Jersey beaches. No nearshore samples in 1995. See Fig. 3-1 for sampling locations.

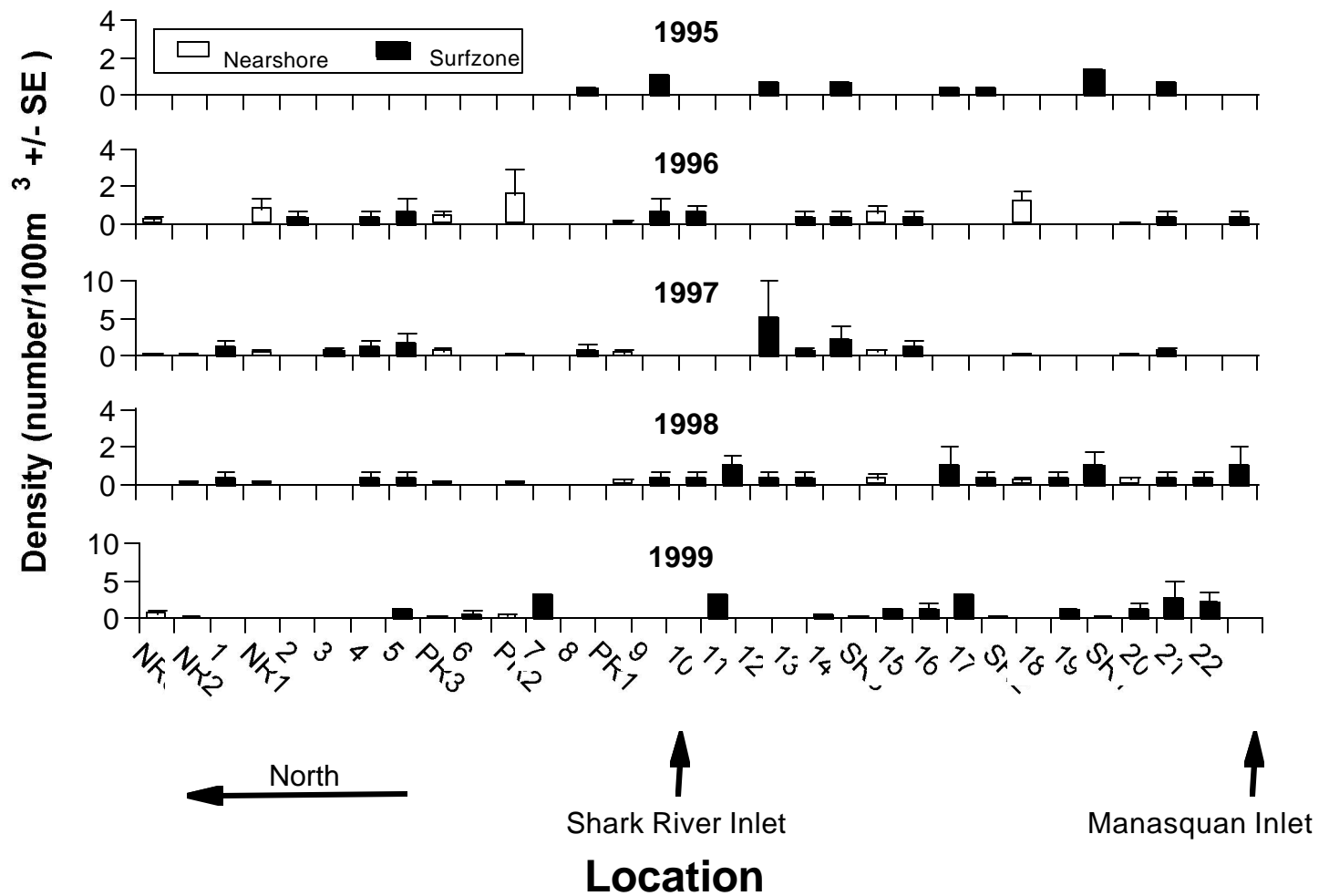
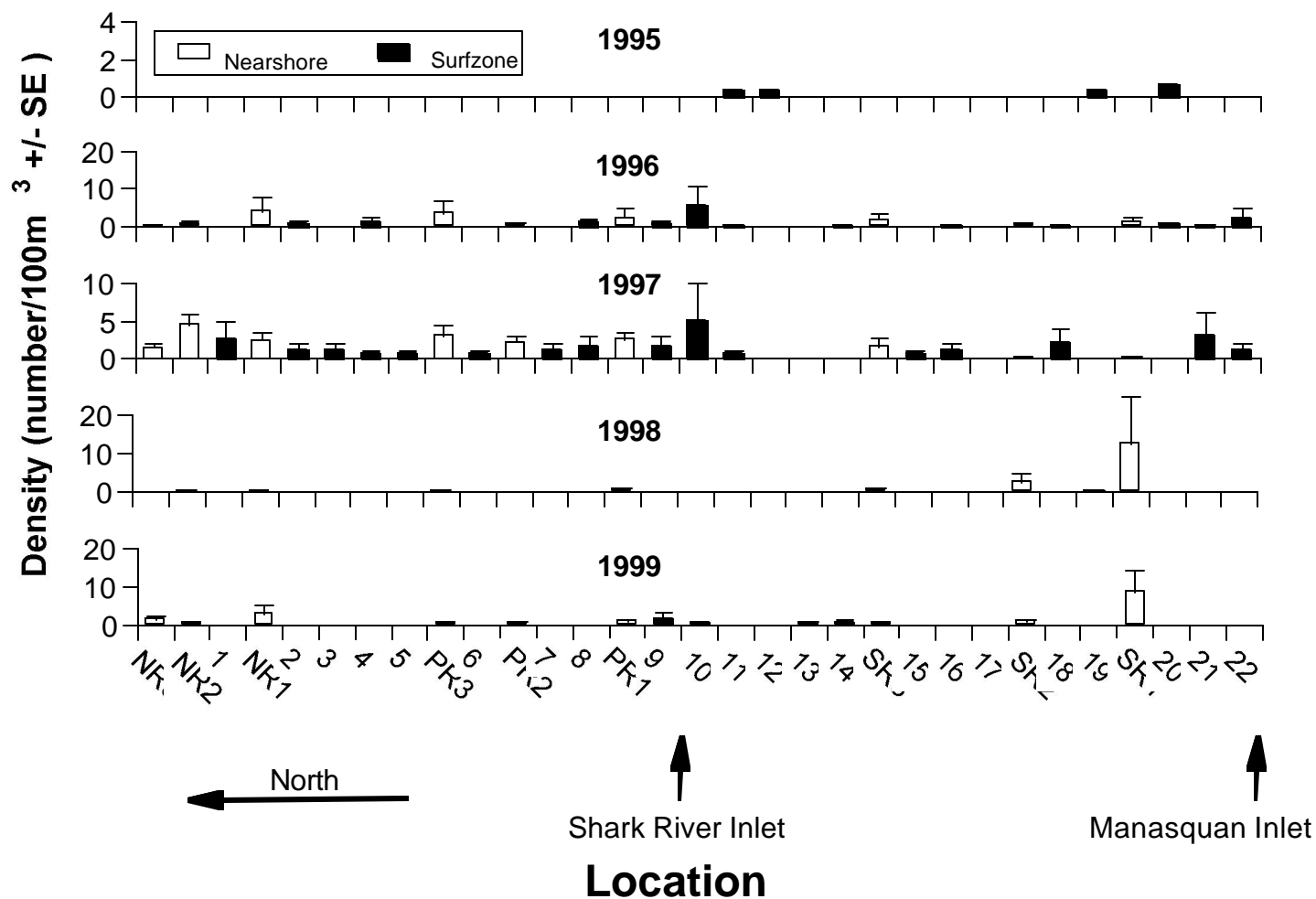


Figure 3-17. Average larval density of *Syngnathus fuscus* for nearshore and surfzone ichthyoplankton collected from northern New Jersey beaches. No nearshore samples in 1995. See Fig. 3-1 for sampling locations.



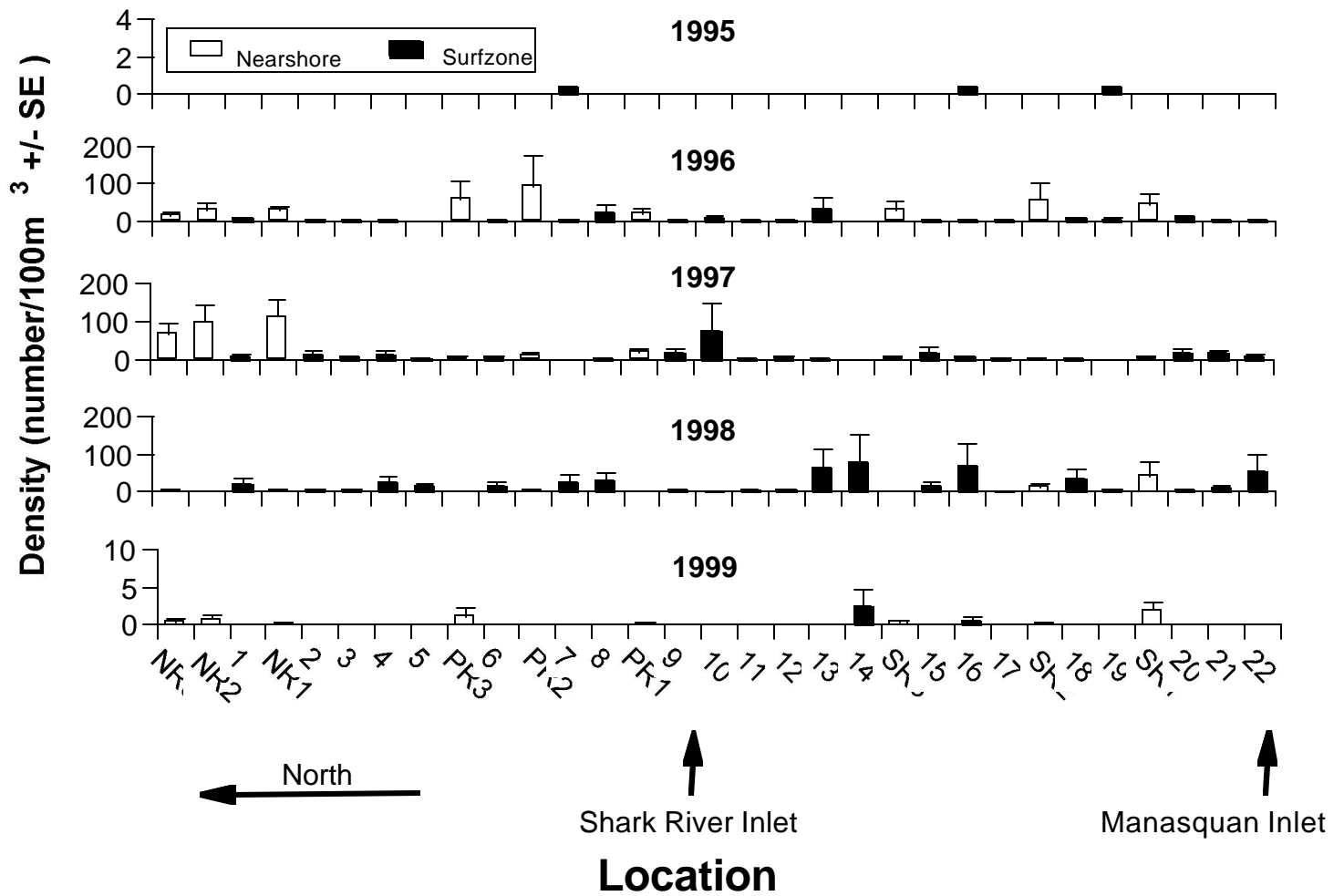


Figure 3-19. Average larval density of *Anchoa* sp. for nearshore and surfzone ichthyoplankton collected from northern New Jersey beaches. No nearshore samples in 1995. See Fig. 3-1 for sampling locations.

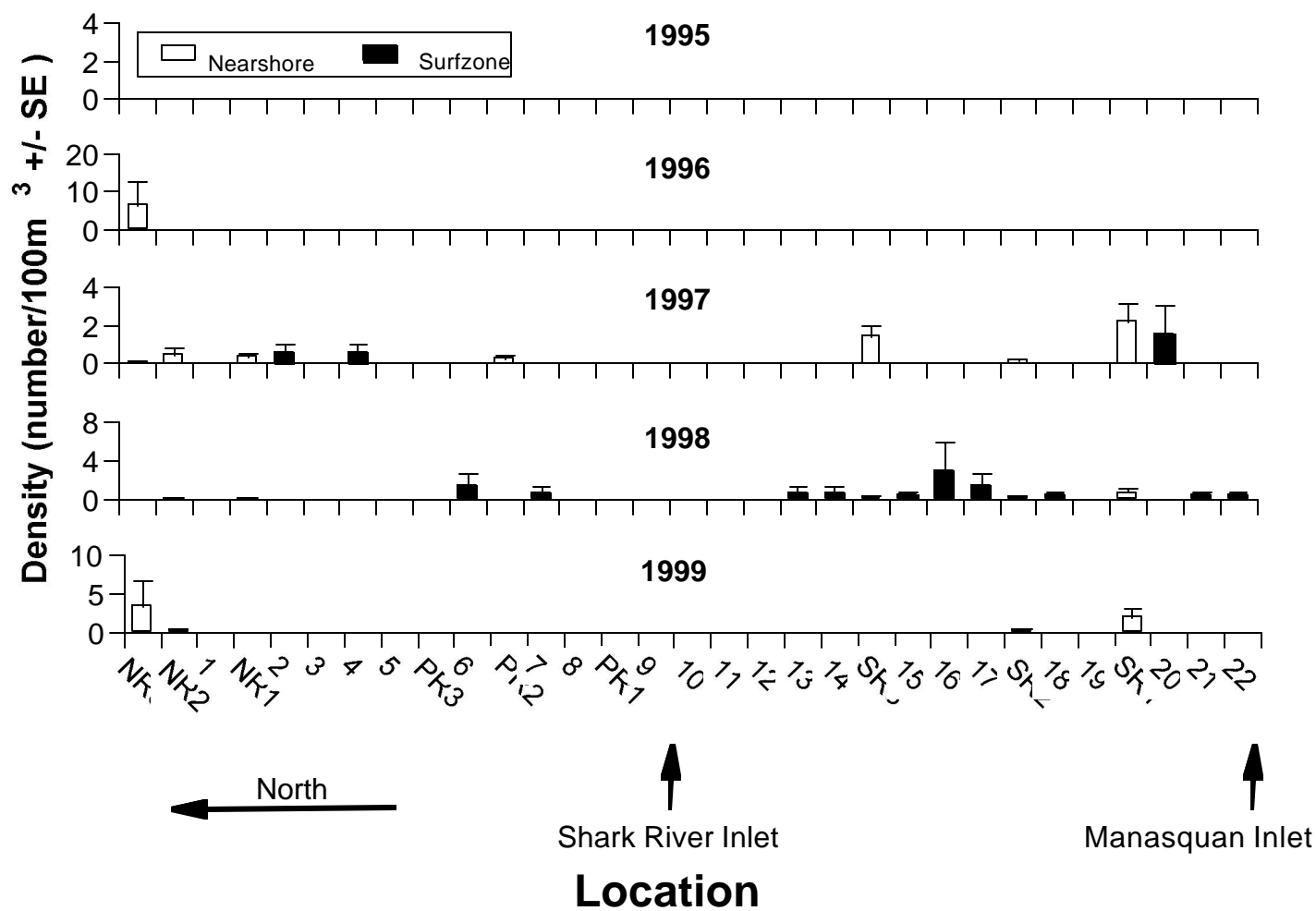


Figure 3-20. Average larval density of *Anchoa mitchilli* for nearshore and surfzone ichthyoplankton collected from northern New Jersey beaches. No nearshore samples in 1995. See Fig. 3-1 for sampling locations.

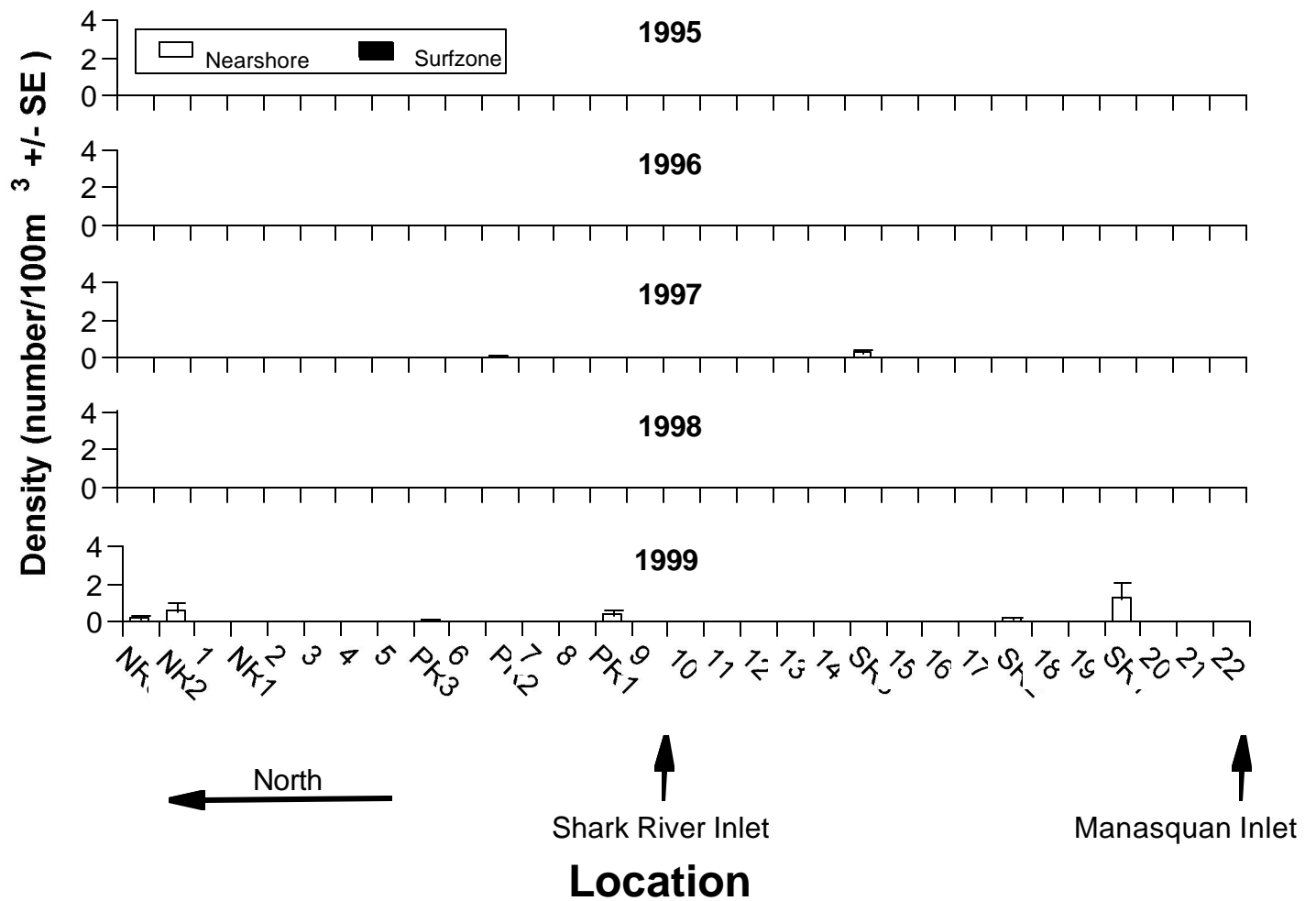


Figure 3-21. Average larval density of *Anchoa hepsetus* for nearshore and surfzone ichthyoplankton collected from northern New Jersey beaches. No nearshore samples in 1995. See Fig. 3-1 for sampling locations.

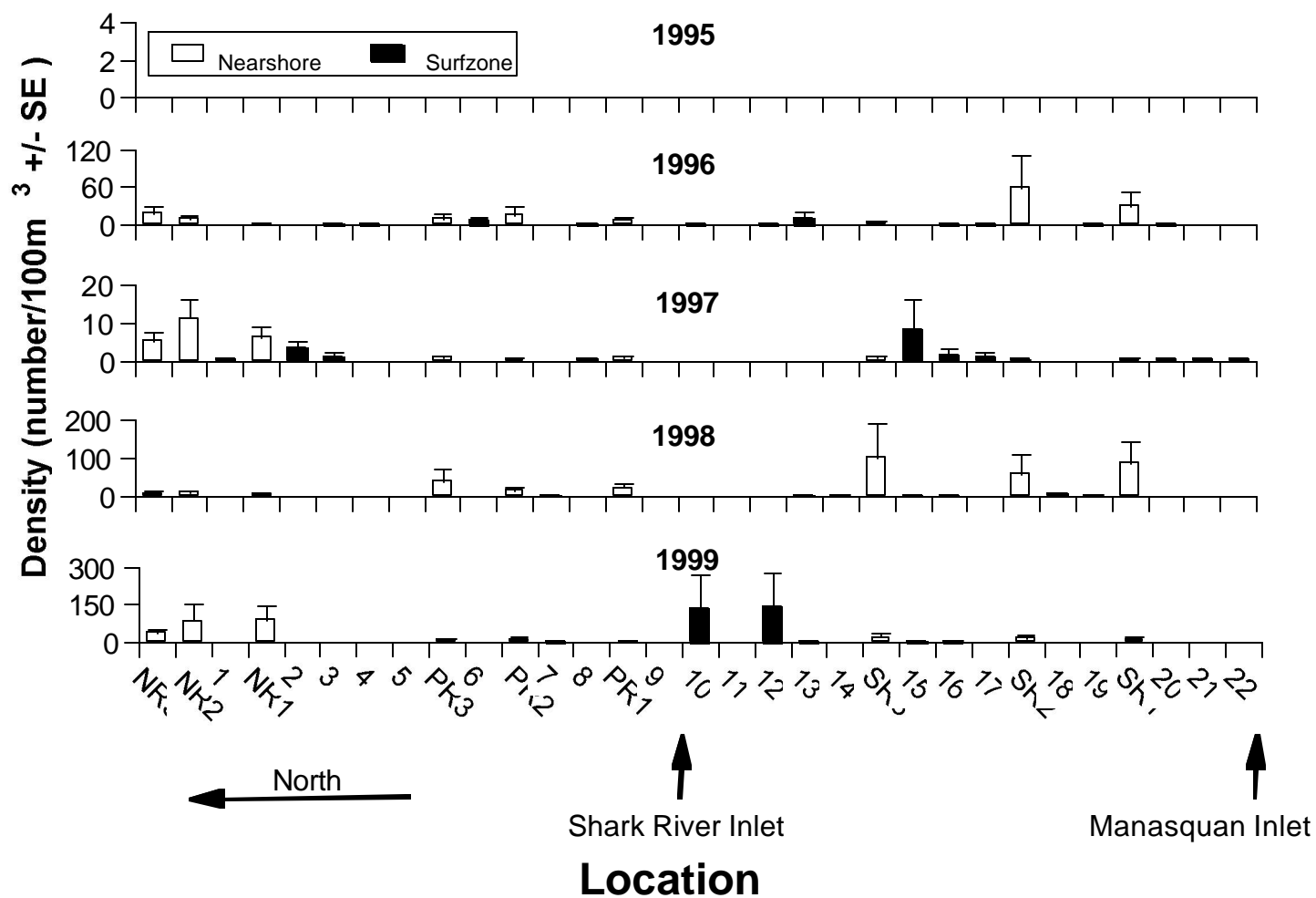


Figure 3-22. Average larval density of *Brevoortia tyrannus* for nearshore and surfzone ichthyoplankton collected from northern New Jersey beaches. No nearshore samples in 1995. See Fig. 3-1 for sampling locations.

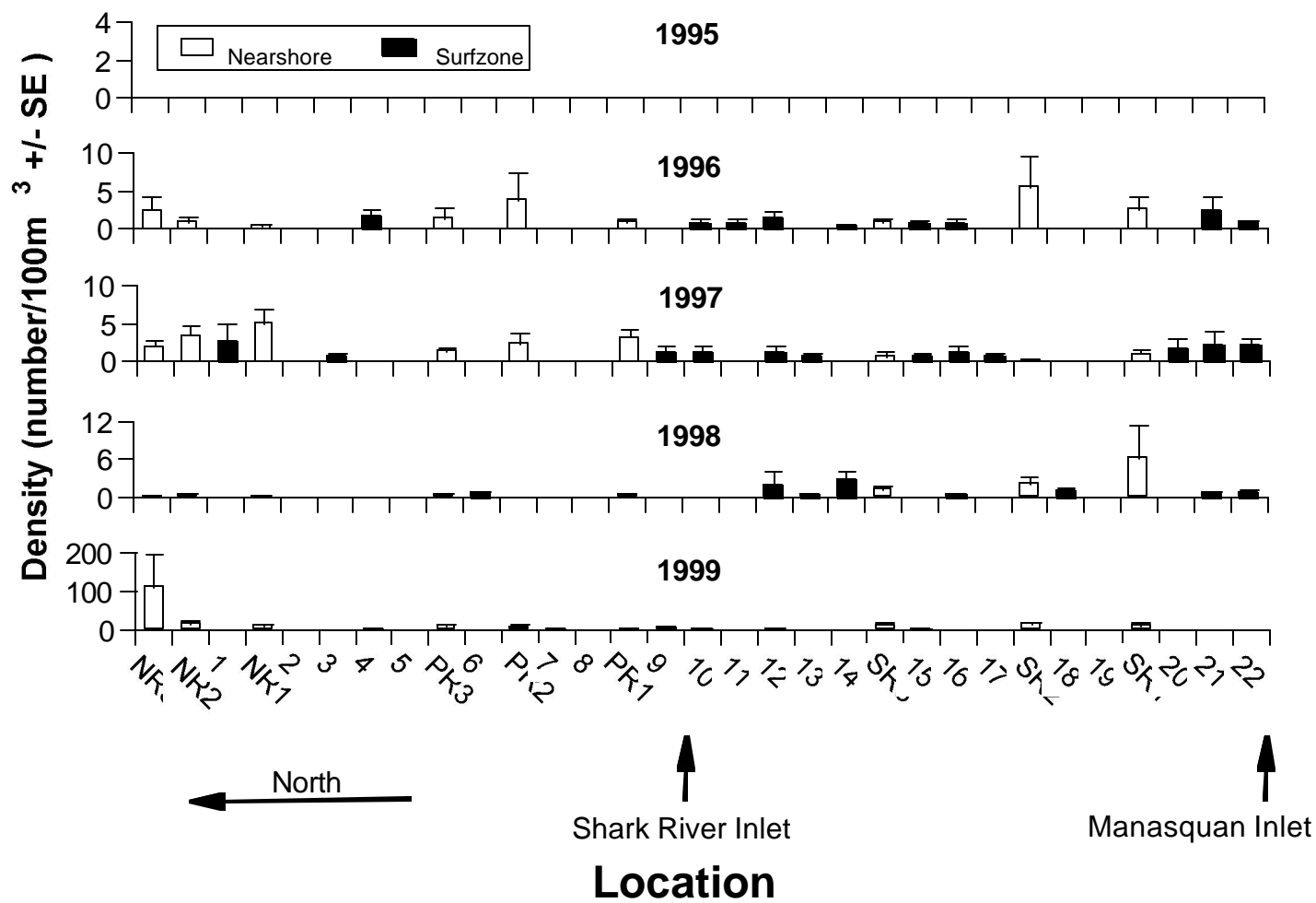
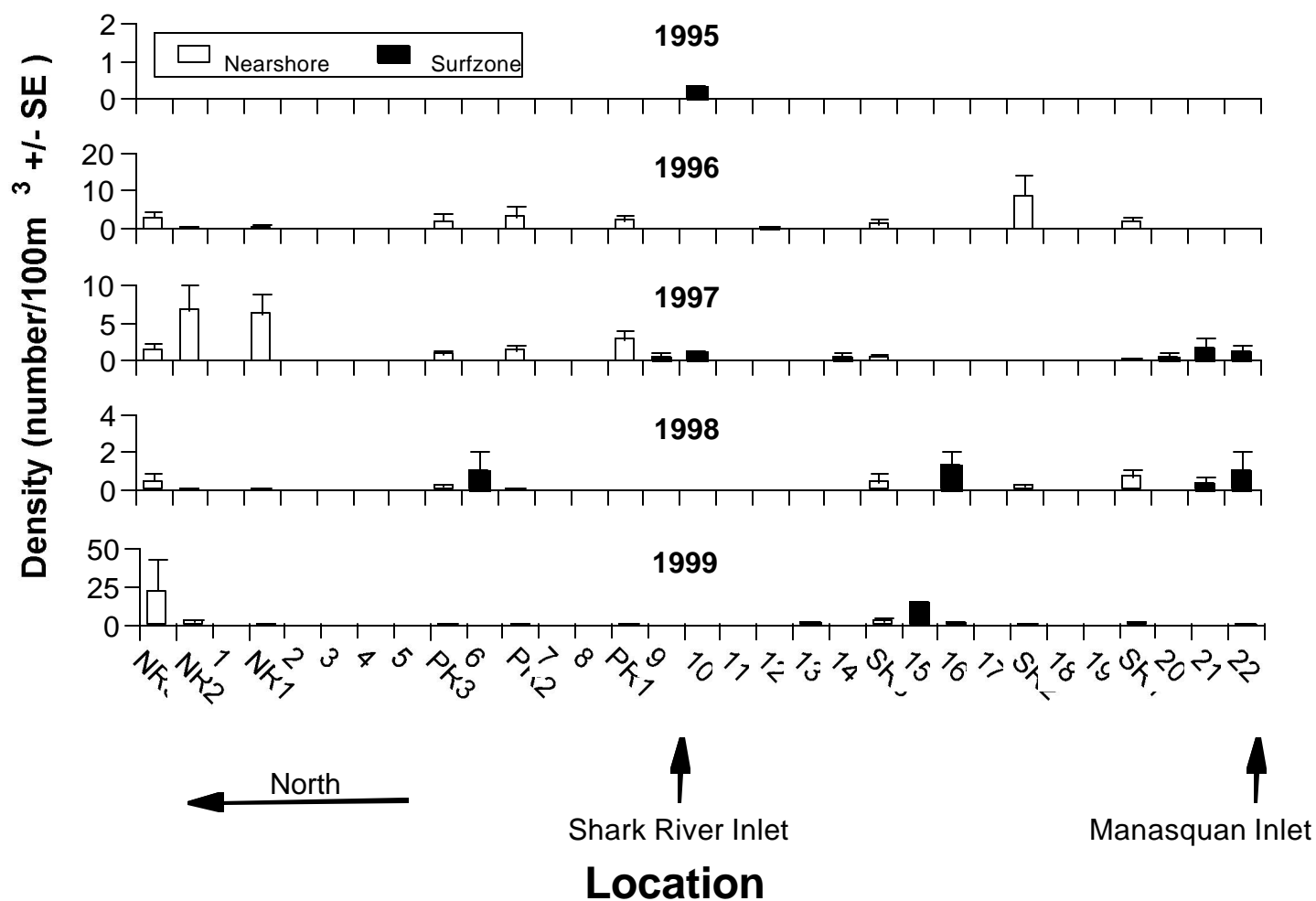


Figure 3-24. Average larval density of *Tautoga onitis* for nearshore and surfzone ichthyoplankton collected from northern New Jersey beaches. No nearshore samples in 1995. See Fig. 3-1 for sampling locations.



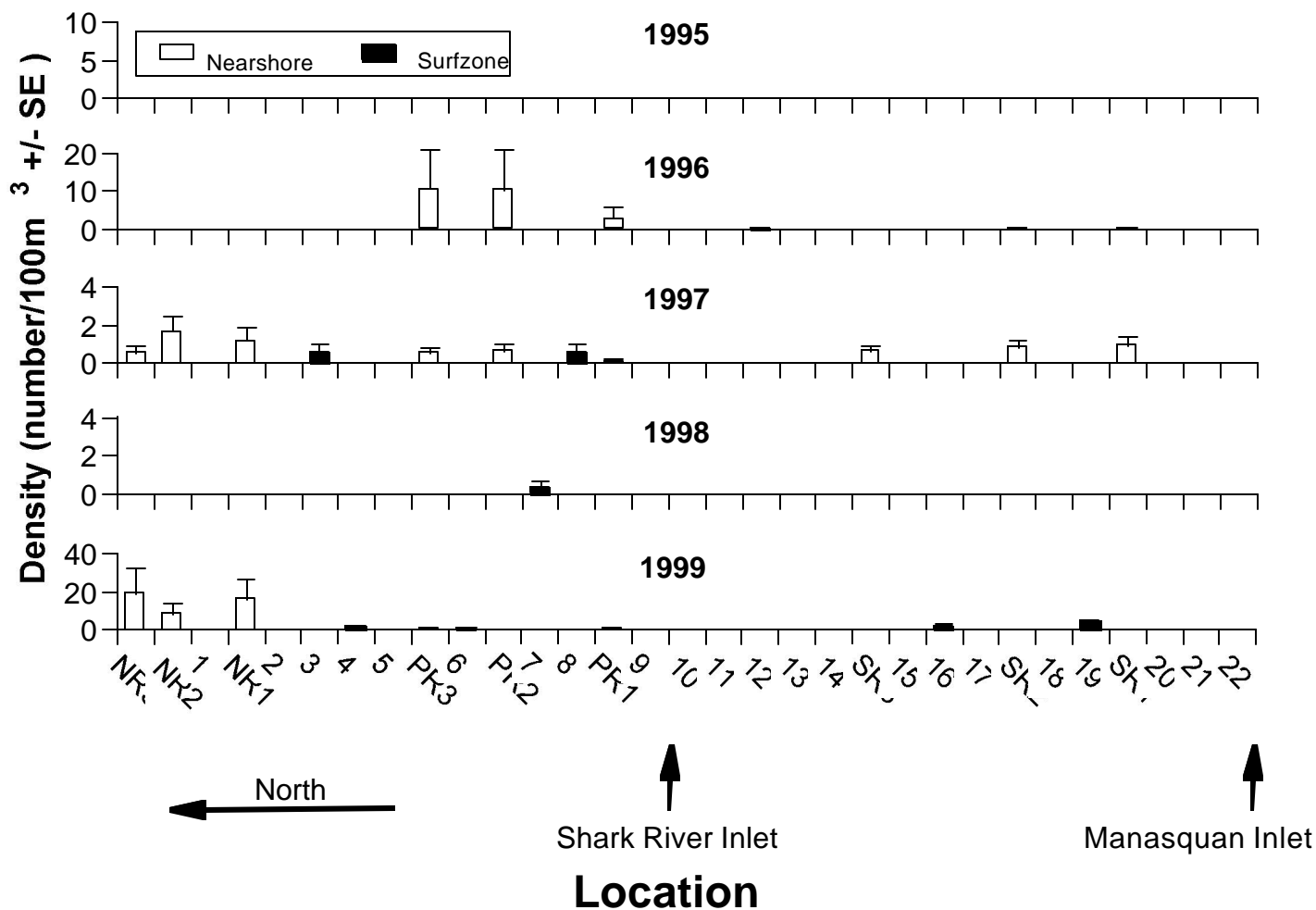


Figure 3-26. Average larval density of *Pomatomus saltatrix* for nearshore and surfzone ichthyoplankton collected from northern New Jersey beaches. No nearshore samples in 1995. See Fig. 3-1 for sampling locations.

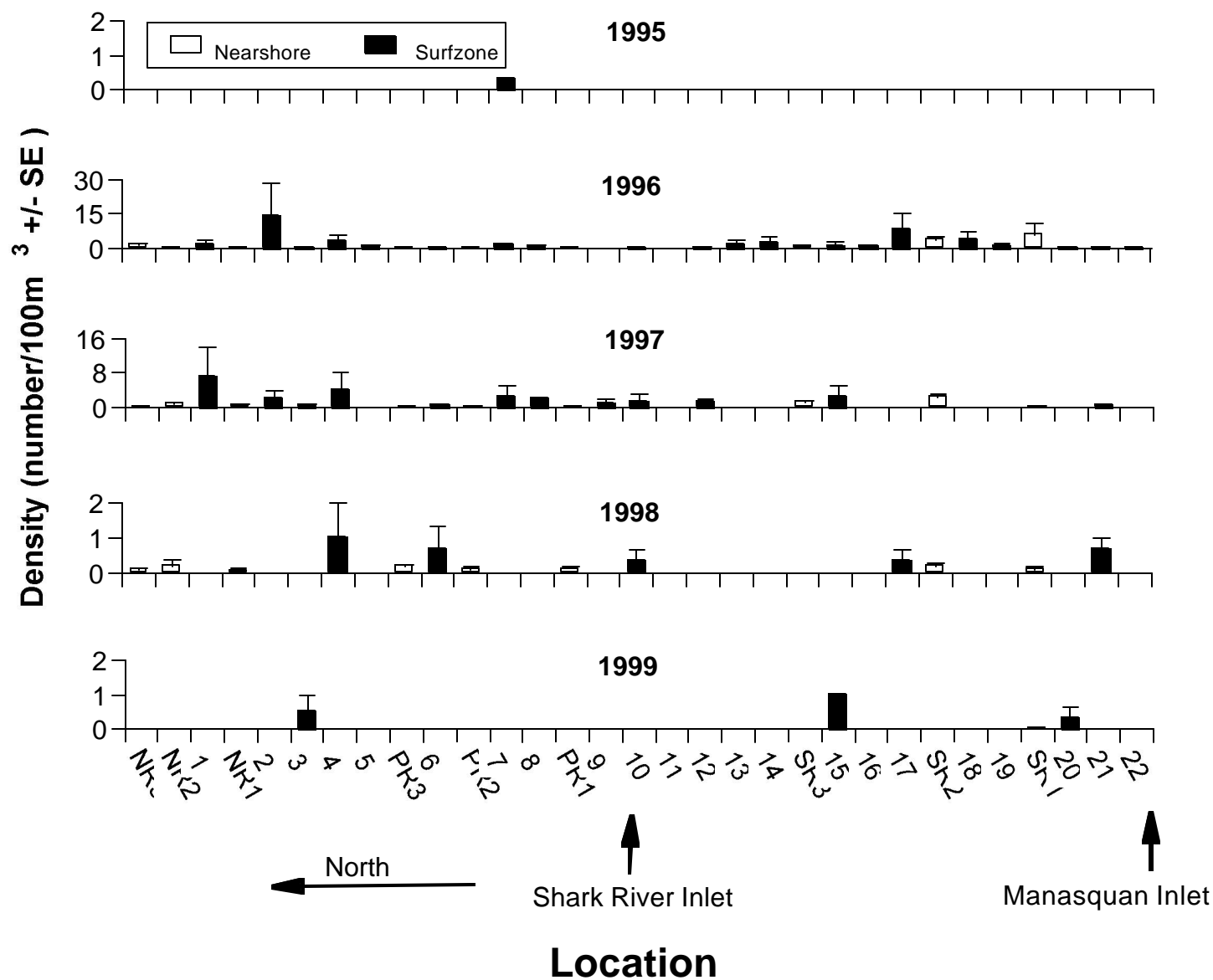


Figure 3-27. Average larval density of *Lophius americanus* for nearshore and surfzone ichthyoplankton collected from northern New Jersey beaches. No nearshore samples in 1995. See Fig. 3-1 for sampling locations.

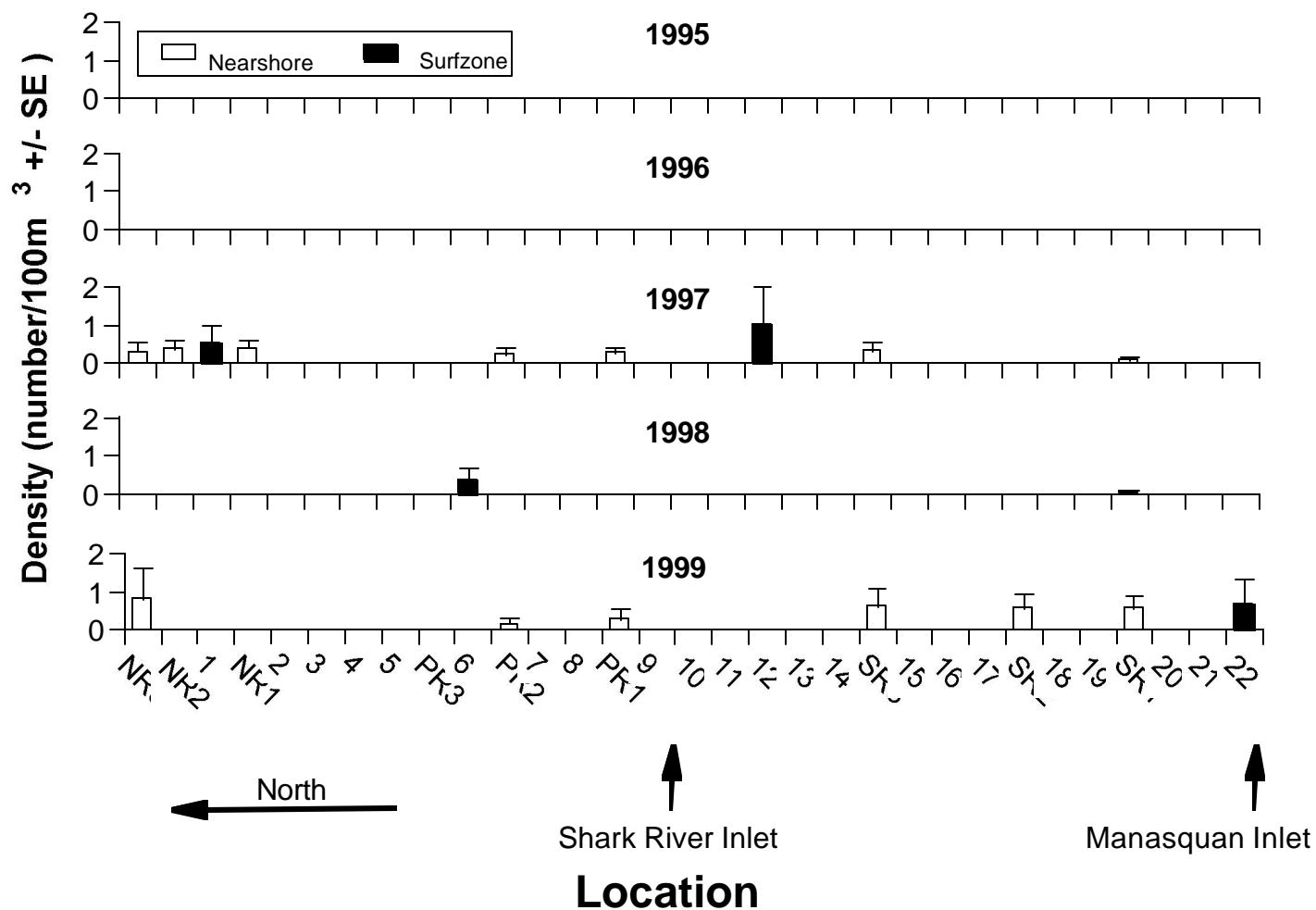


Figure 3-28. Average larval density of *Prionotus carolinus* for nearshore and surfzone ichthyoplankton collected from northern New Jersey beaches. No nearshore samples in 1995. See Fig. 3-1 for sampling locations.

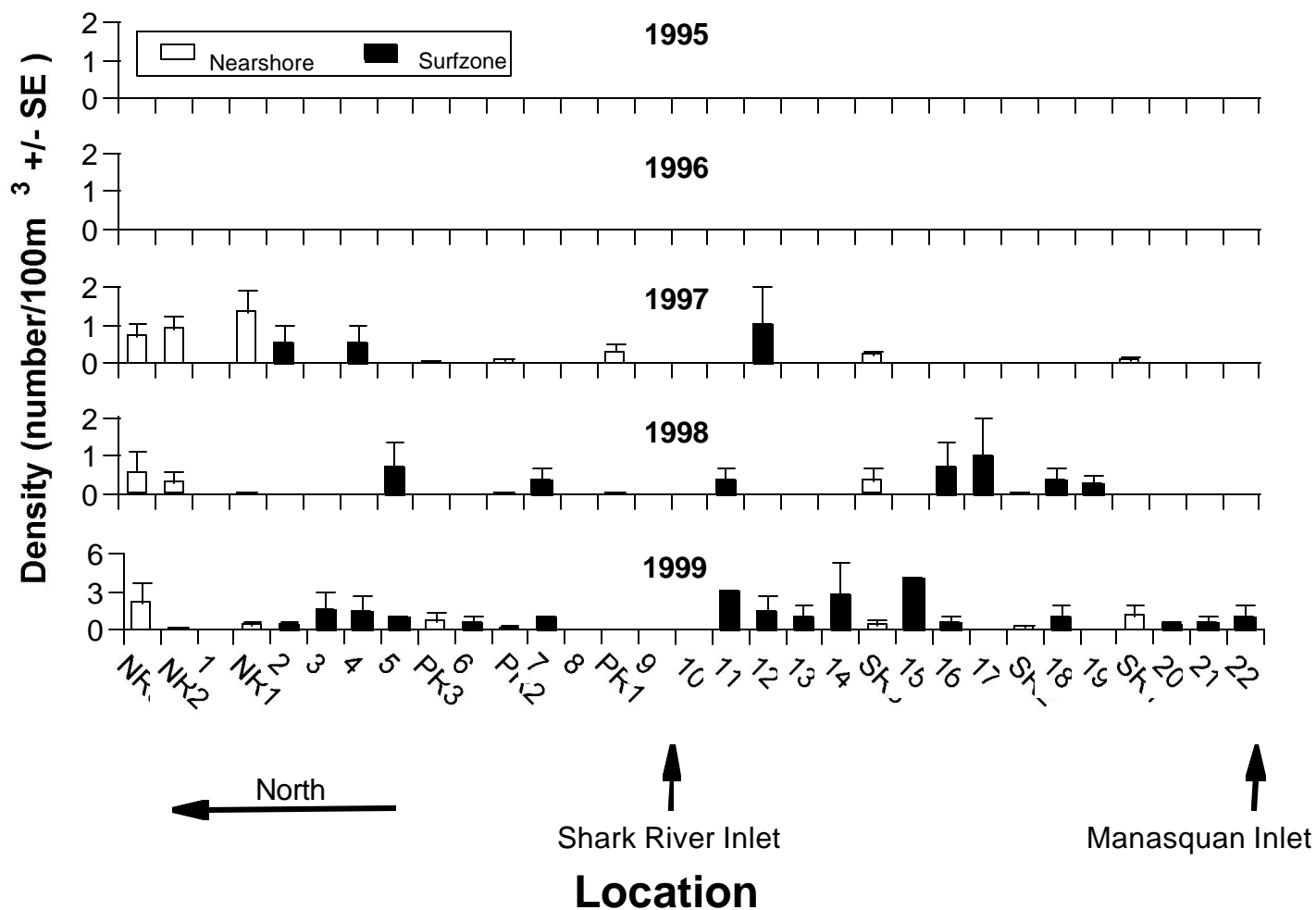


Figure 3-29. Average larval density of *Prionotus evolans* for nearshore and surfzone ichthyoplankton collected from northern New Jersey beaches. No nearshore samples in 1995. See Fig. 3-1 for sampling locations.

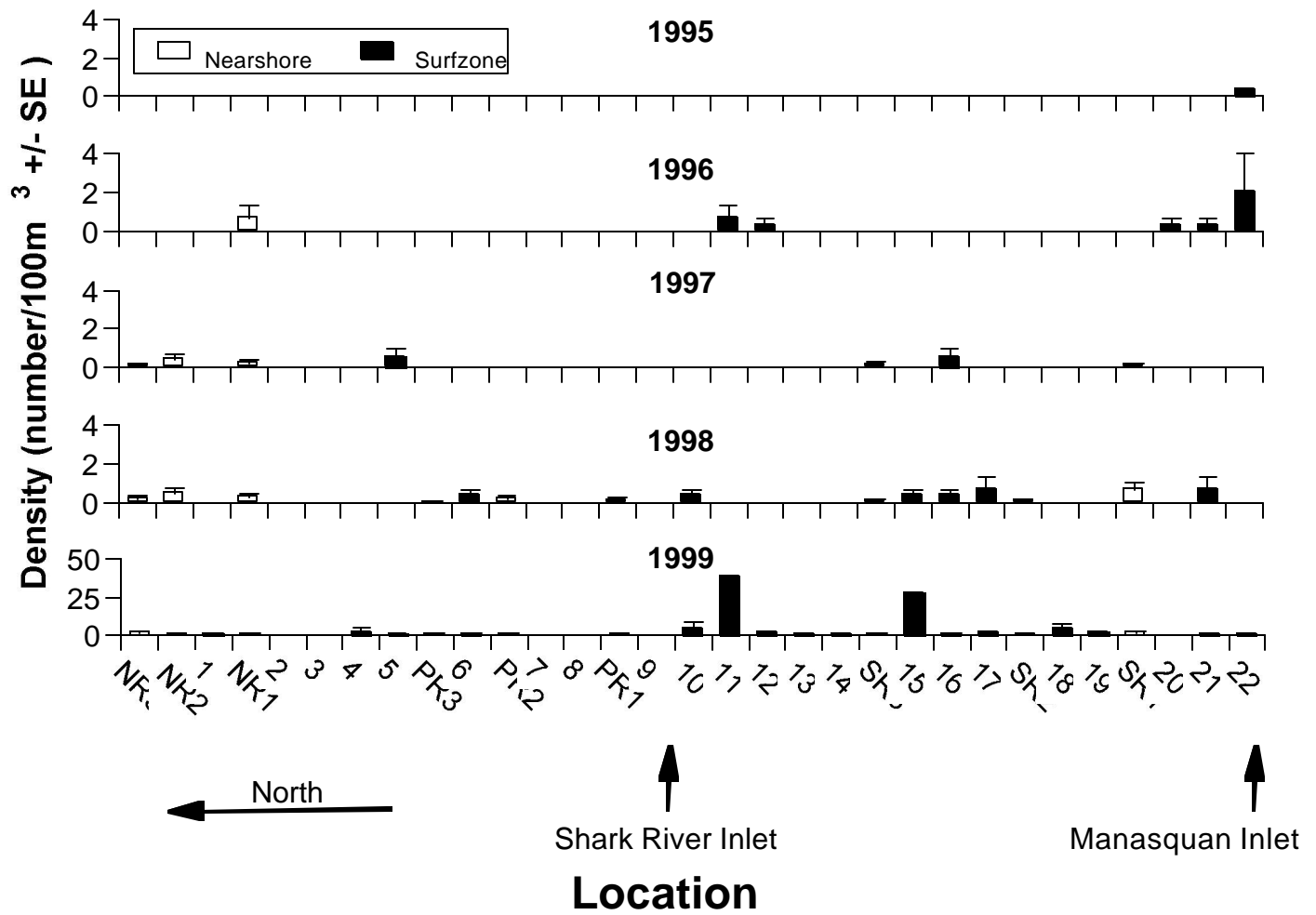


Figure 3-30. Average larval density of *Menticirrhus* sp. for nearshore and surfzone ichthyoplankton collected from northern New Jersey beaches. No nearshore samples in 1995. See Fig. 3-1 for sampling locations.

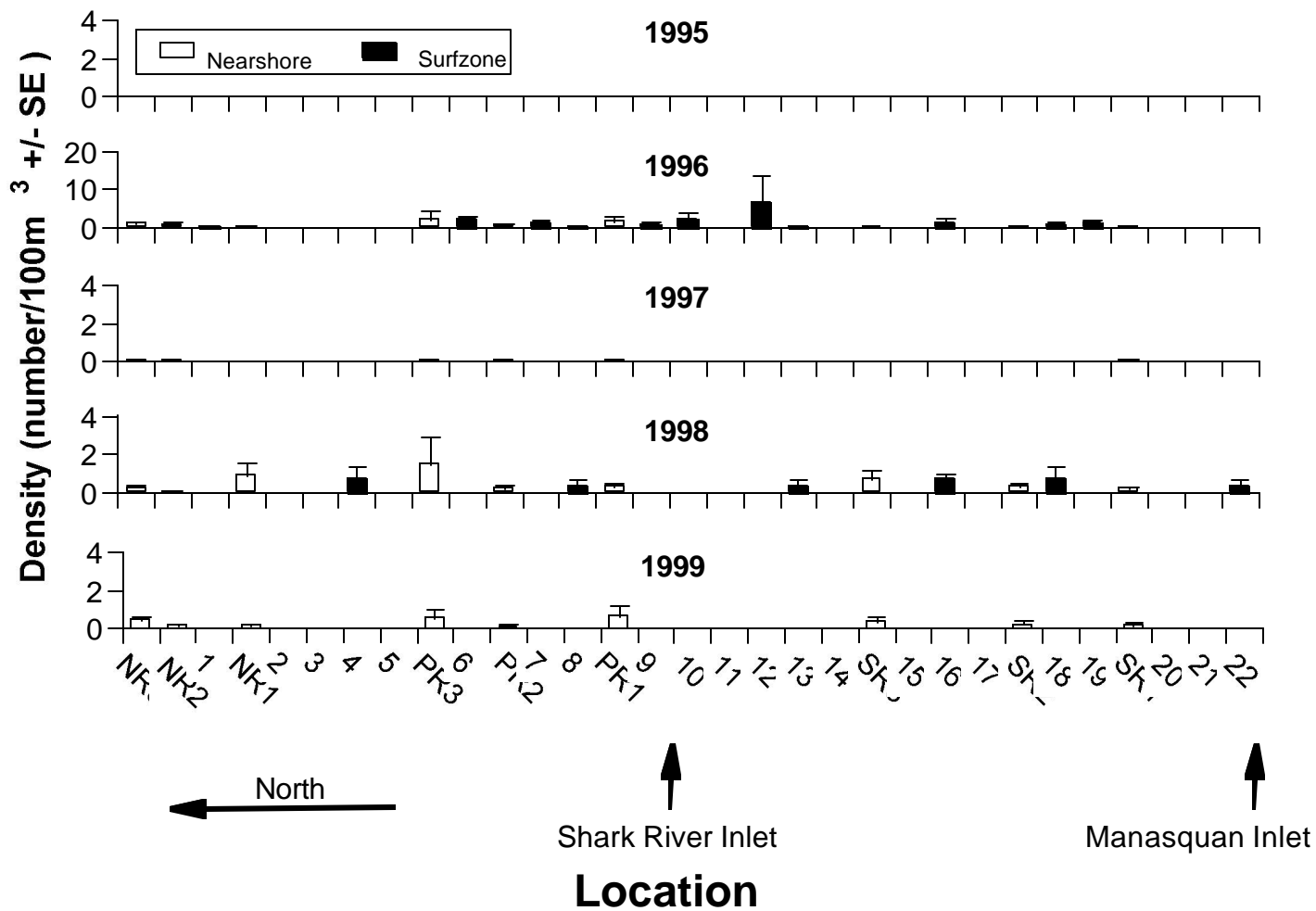


Figure 3-32. Average larval density of *Enchelyopus cimbrius* for nearshore and surfzone ichthyoplankton collected from northern New Jersey beaches. No nearshore samples in 1995. See Fig. 3-1 for sampling locations.

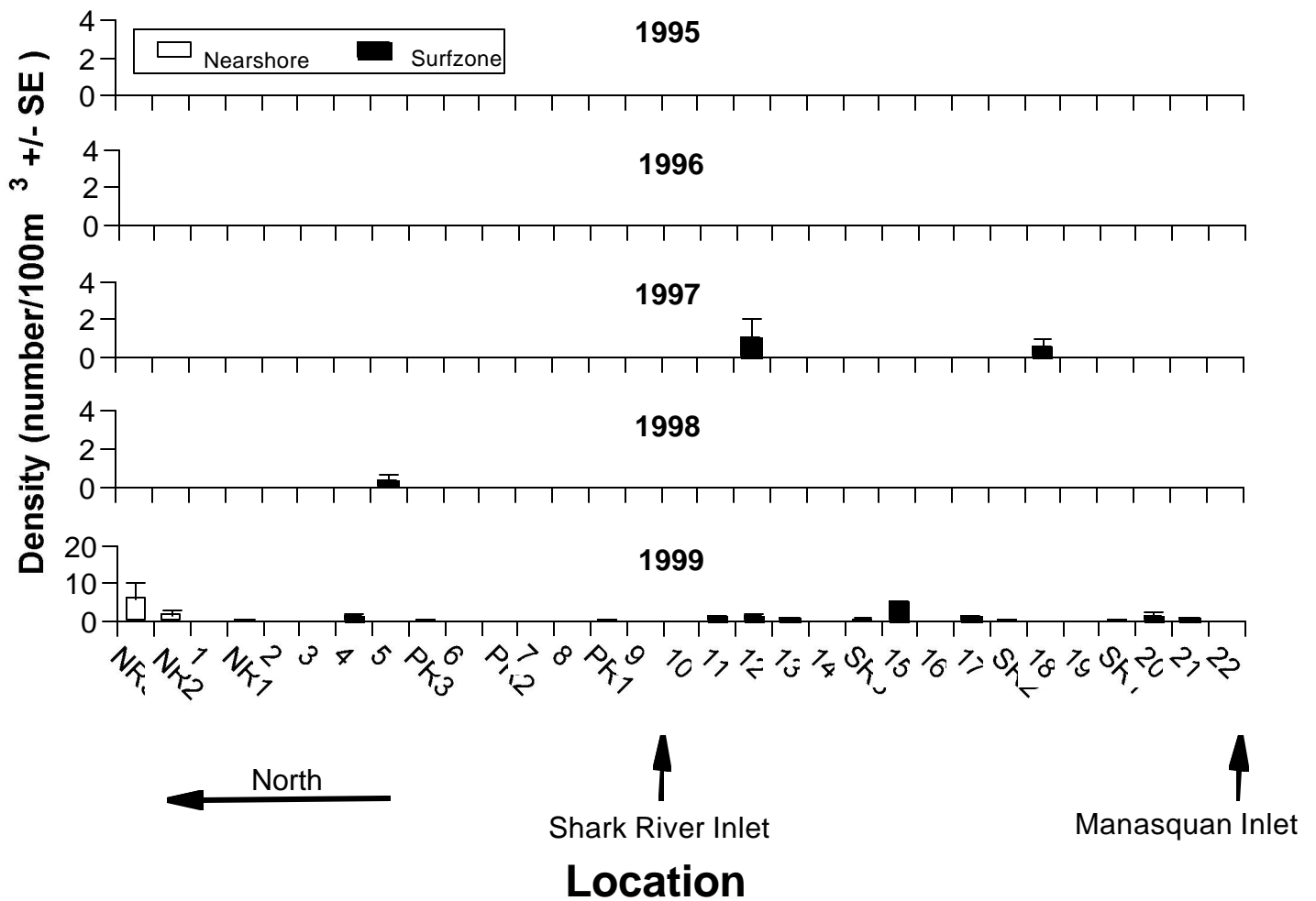


Figure 3-33. Average larval density of *Centropristis striata* for nearshore and surfzone ichthyoplankton collected from northern New Jersey beaches. No nearshore samples in 1995. See Fig. 3-1 for sampling locations.

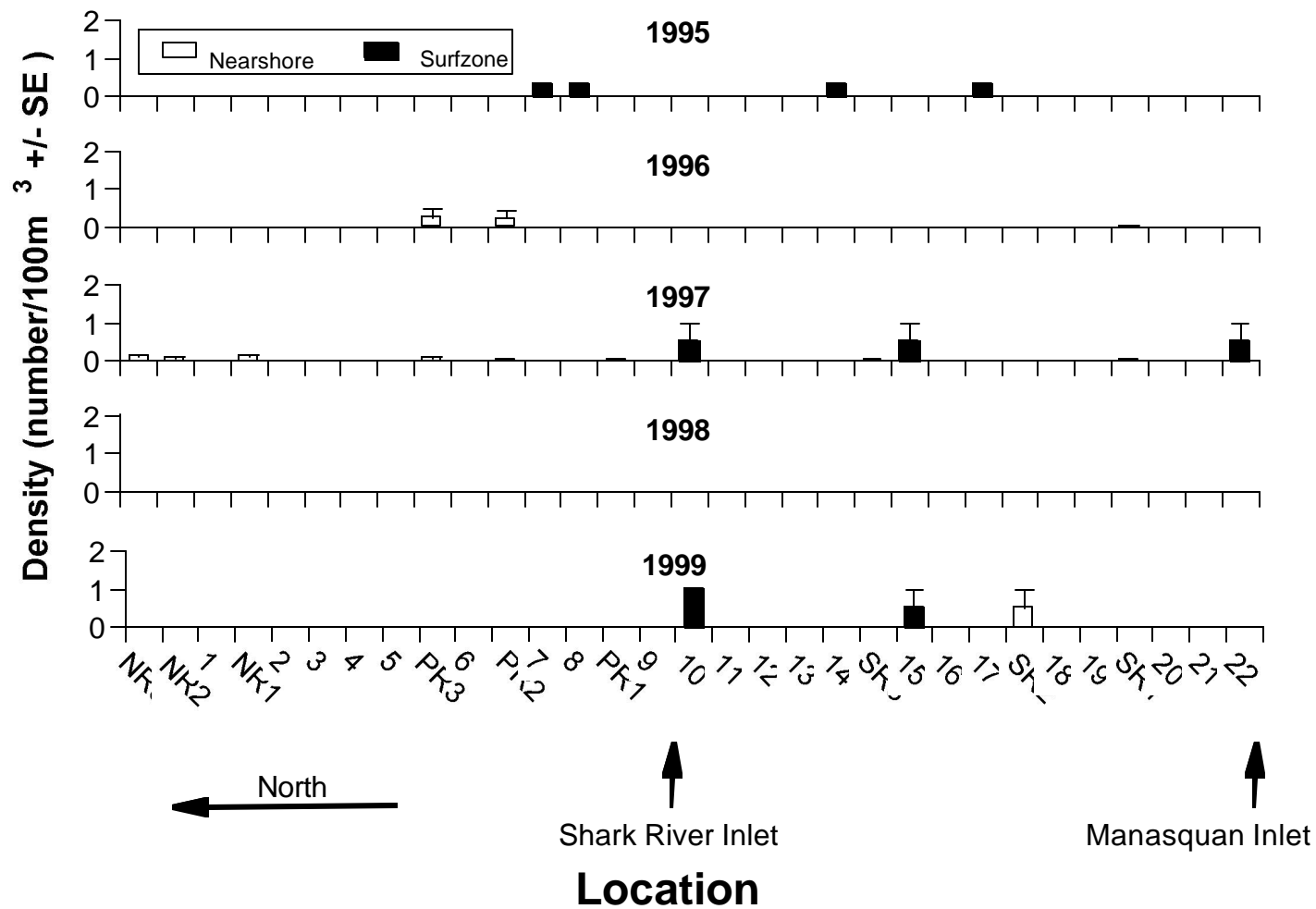


Figure 3-34. Average larval density of *Sphoeroides maculatus* for nearshore and surfzone ichthyoplankton collected from northern New Jersey beaches. No nearshore samples in 1995. See Fig. 3-1 for sampling locations.

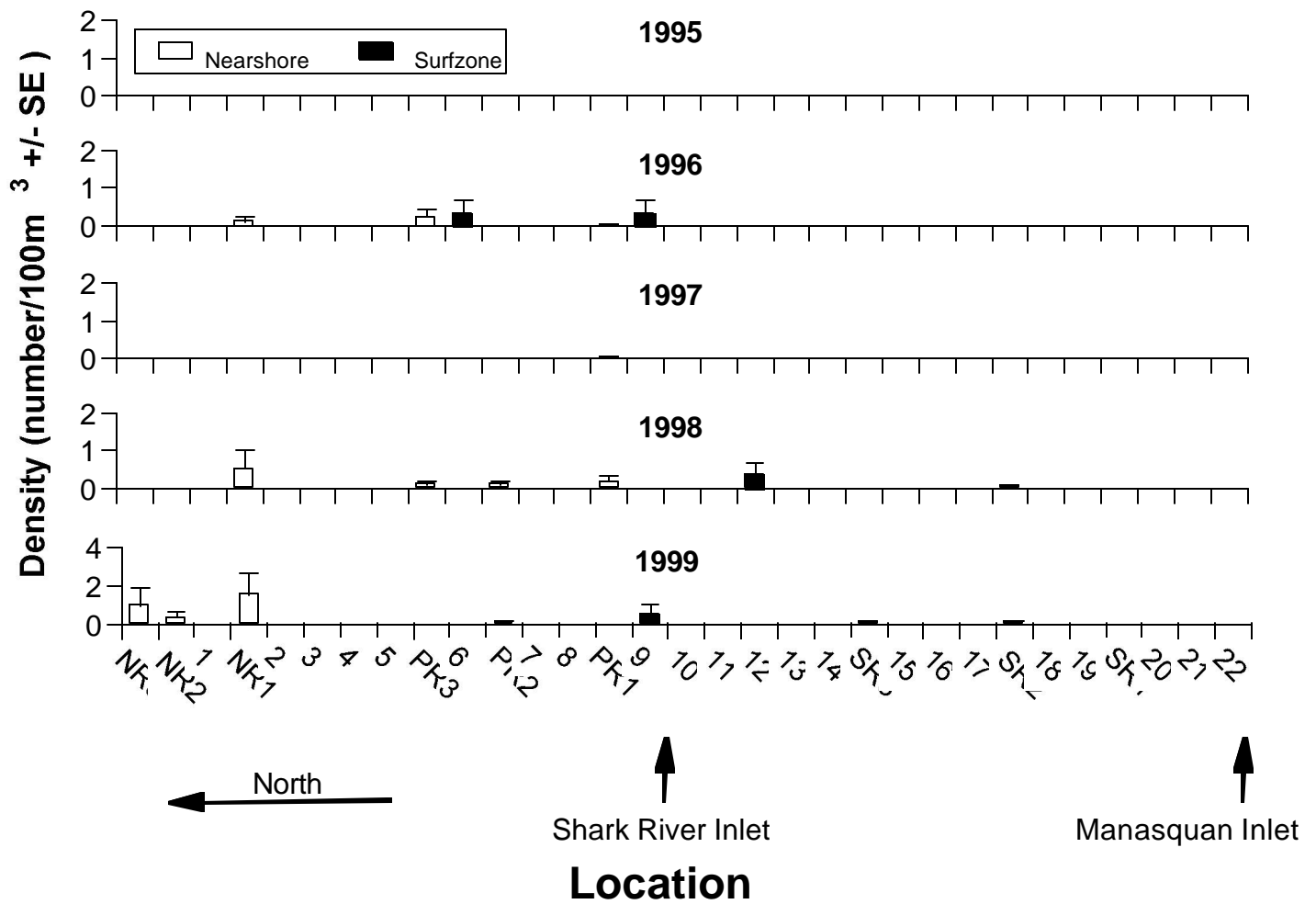


Figure 3-35. Average larval density of *Urophycis chuss* for nearshore and surfzone ichthyoplankton collected from northern New Jersey beaches. No nearshore samples in 1995. See Fig. 3-1 for sampling locations.

Estuarine Species

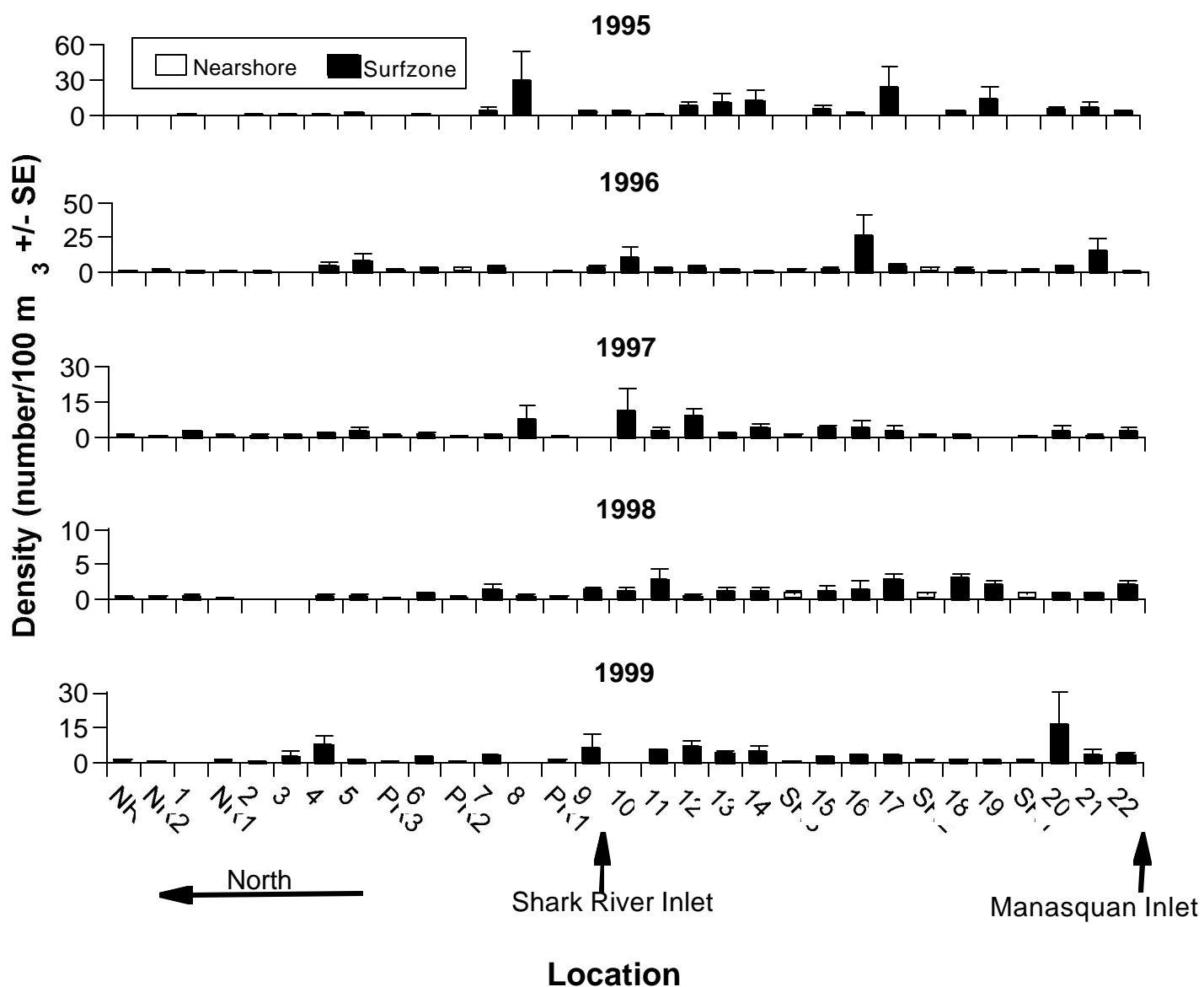


Figure 3-36. Average larval density for species of estuarine origin for nearshore and surfzone ichthyoplankton collected from northern New Jersey beaches. No nearshore samples in 1995. See Fig. 3-1 for sampling locations.

Estuarine/Ocean Species

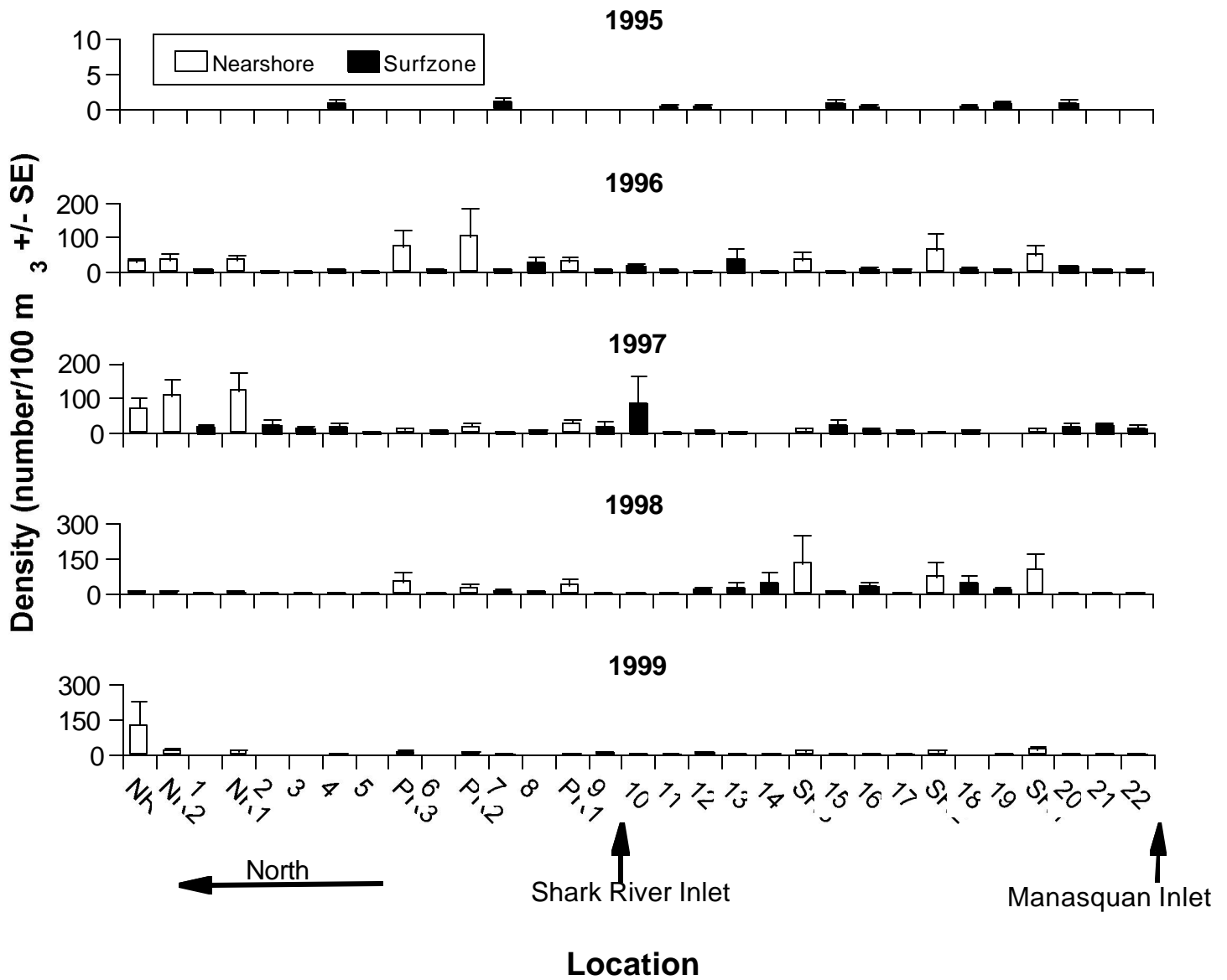
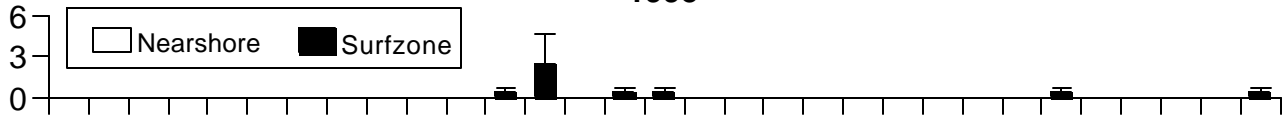


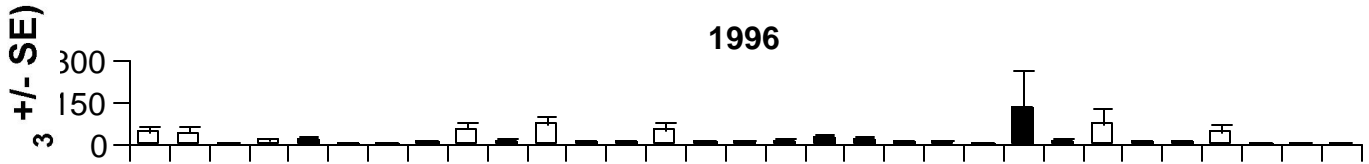
Figure 3-37. Average larval density for species of estuarine/ocean origin for nearshore and surfzone ichthyoplankton collected from northern New Jersey beaches. No nearshore samples in 1995. See Fig. 3-1 for sampling locations.

Ocean Species

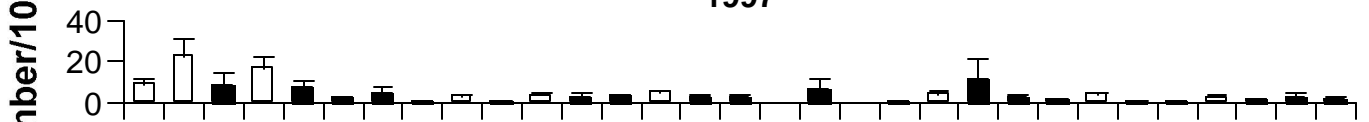
1995



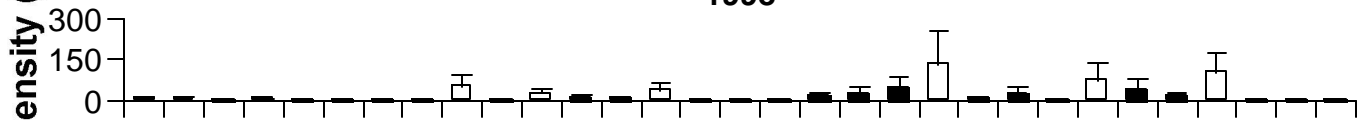
1996



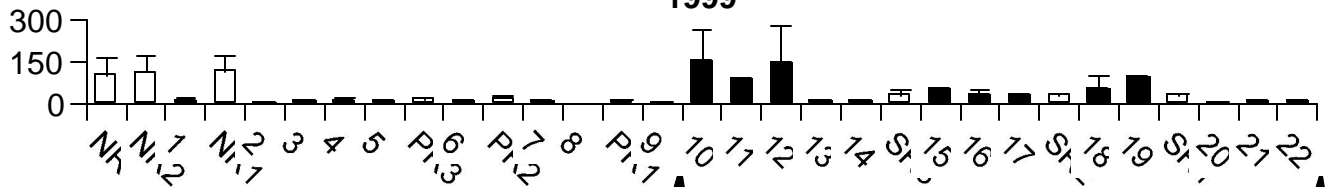
1997



1998



1999



← North

Shark River Inlet

Manasquan Inlet

Location

Figure 3-38. Average larval density for species of oceanic origin for nearshore and surfzone ichthyoplankton collected from northern New Jersey beaches. No nearshore samples in 1995. See Fig. 3-1 for sampling locations.

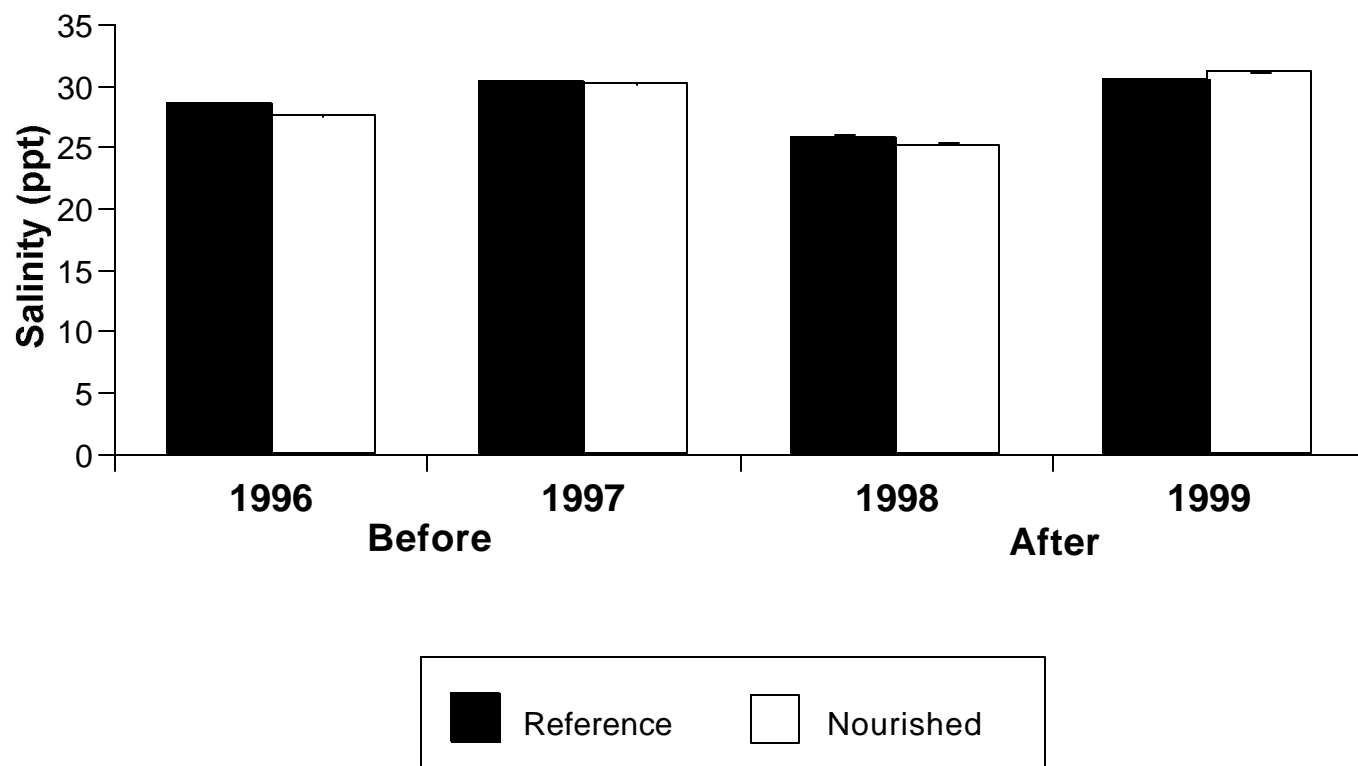


Figure 3-39. Average salinity (ppt \pm SE) for reference and nourished sites for ichthyoplankton sampling in northern New Jersey. See Fig 3-1 for sampling locations.

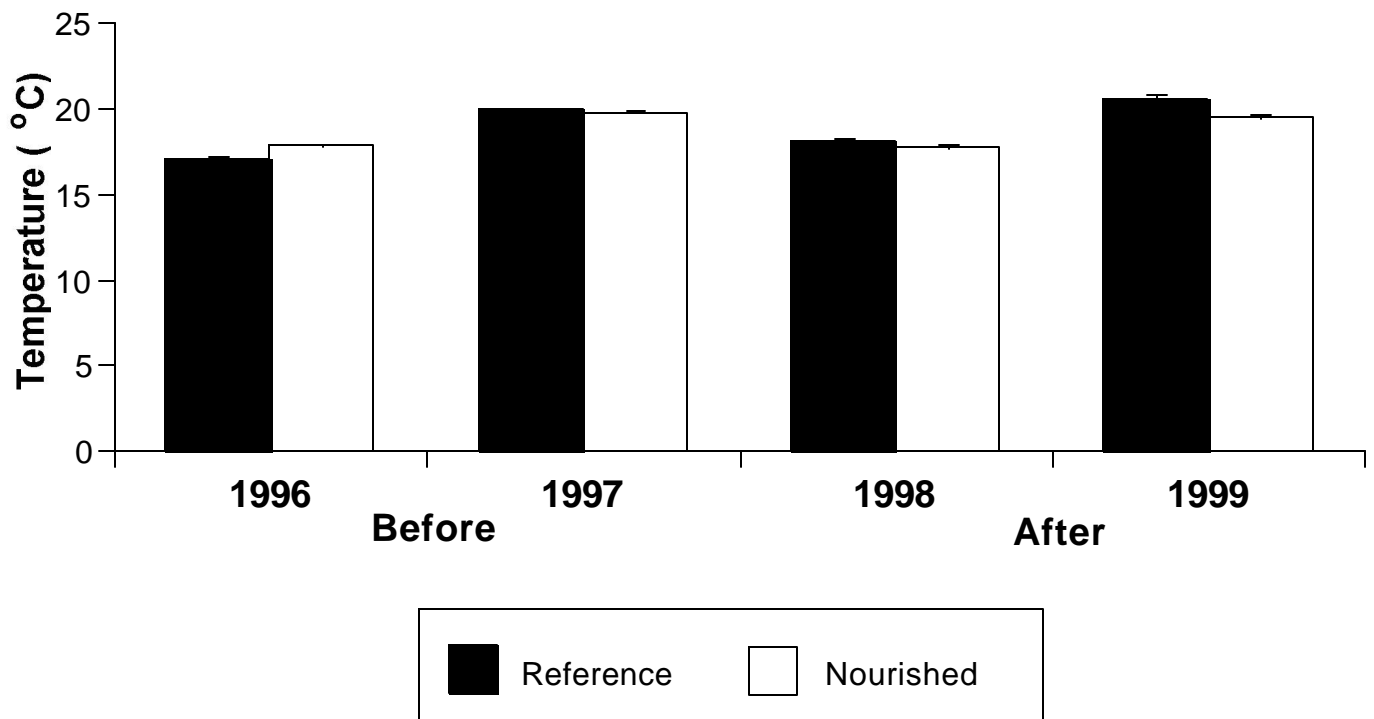


Figure 3-40. Average temperature ($^{\circ}\text{C}$ \pm SE) for reference and nourished sites for ichthyoplankton sampling in northern New Jersey. See Fig. 3-1 for sampling locations.

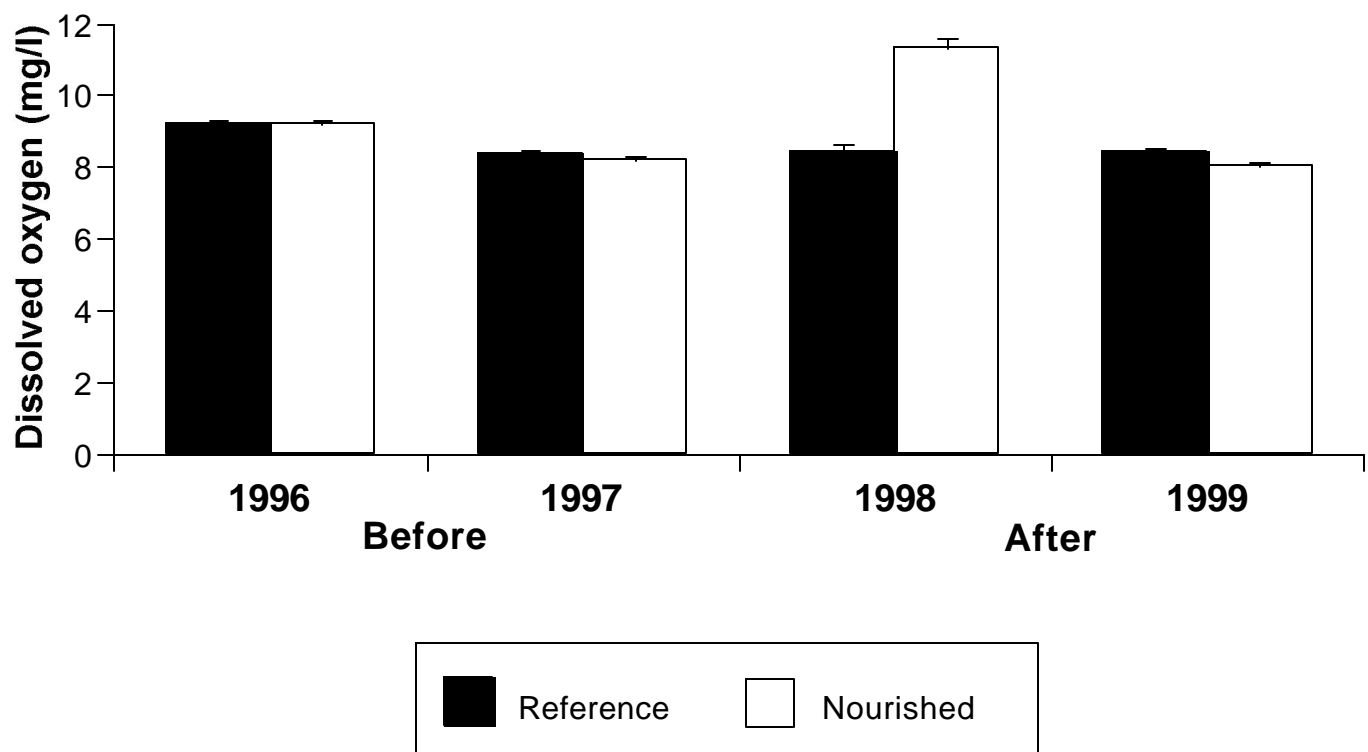


Figure 3-41. Average dissolved oxygen (mg/l \pm SE) for reference and nourished sites for ichthyoplankton sampling in northern New Jersey. See Fig. 3-1 for sampling locations.

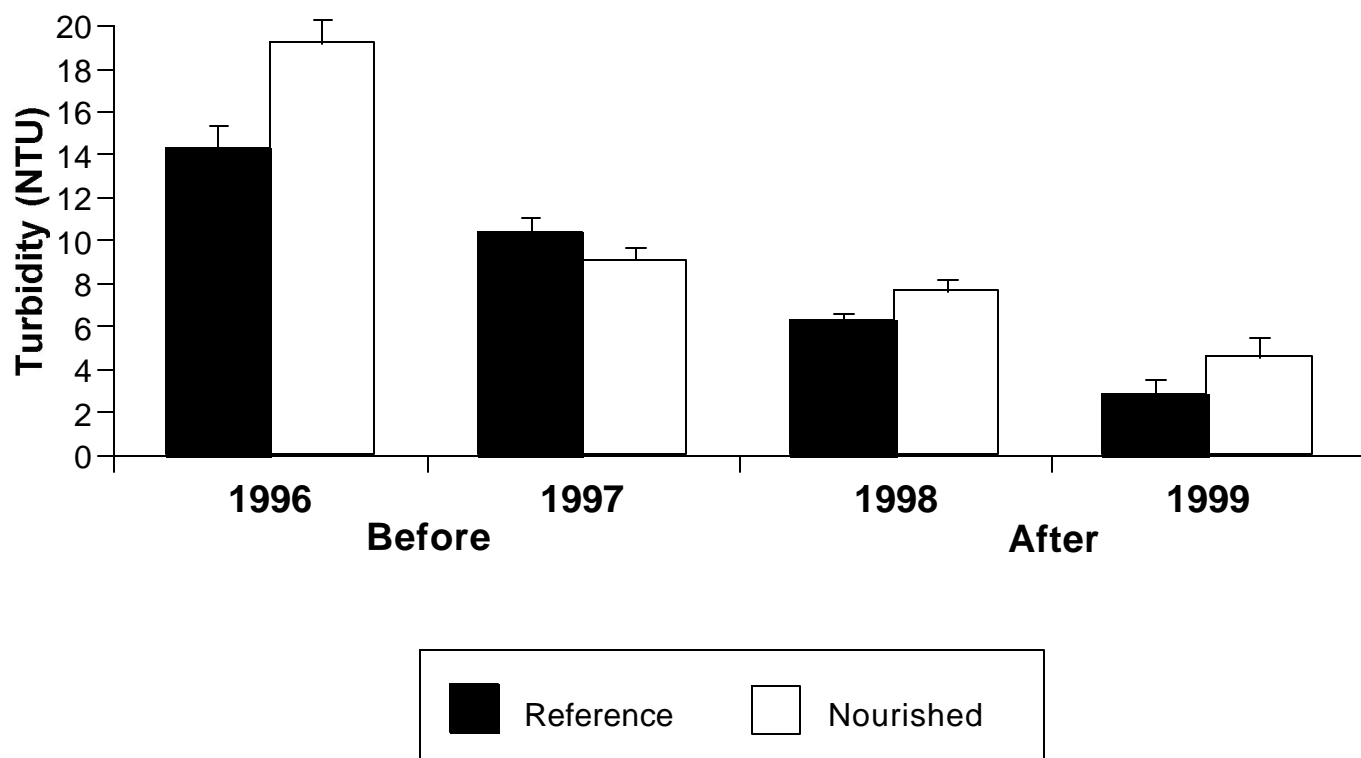


Figure 3-42. Average turbidity (NTU +/- SE) for reference and nourished sites for ichthyoplankton sampling in northern New Jersey. See Fig. 3-1 for sampling locations.

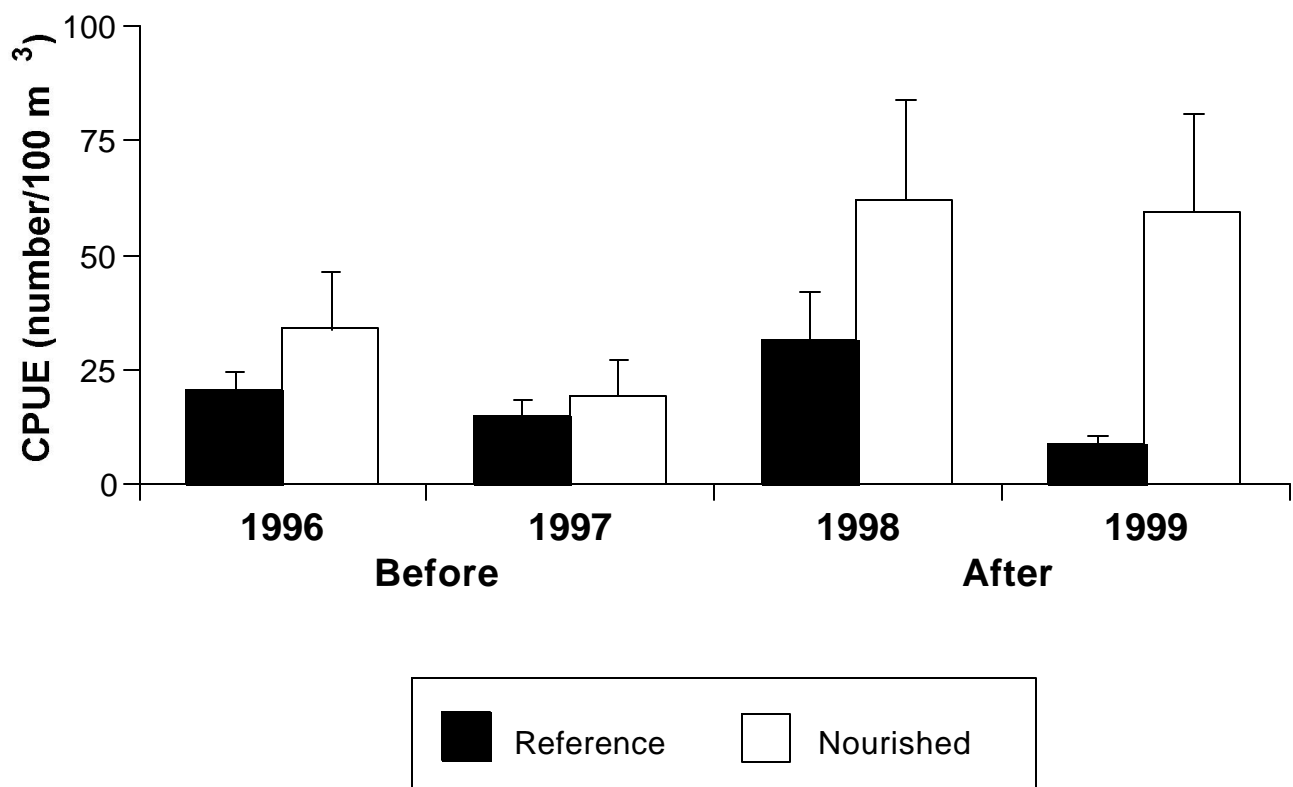


Figure 3-43. Catch per unit effort (CPUE - number/100m³ +/- SE), at reference and nourished sites for 1996 - 1999.

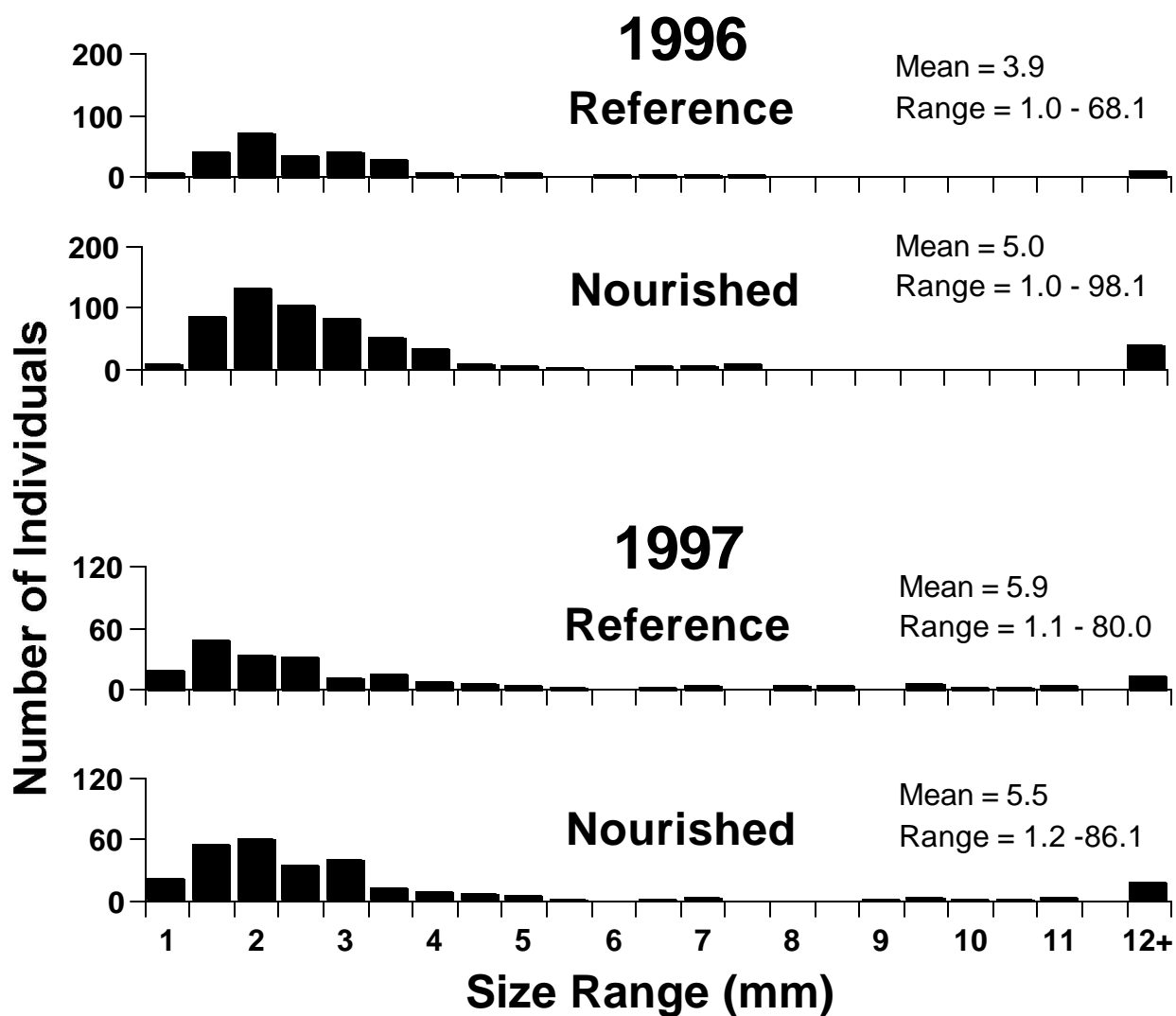


Figure 3-44. Composite lengths for surfzone ichthyoplankton samples from northern New Jersey beaches before nourishment (1996 - 1997) from reference and nourished sites.

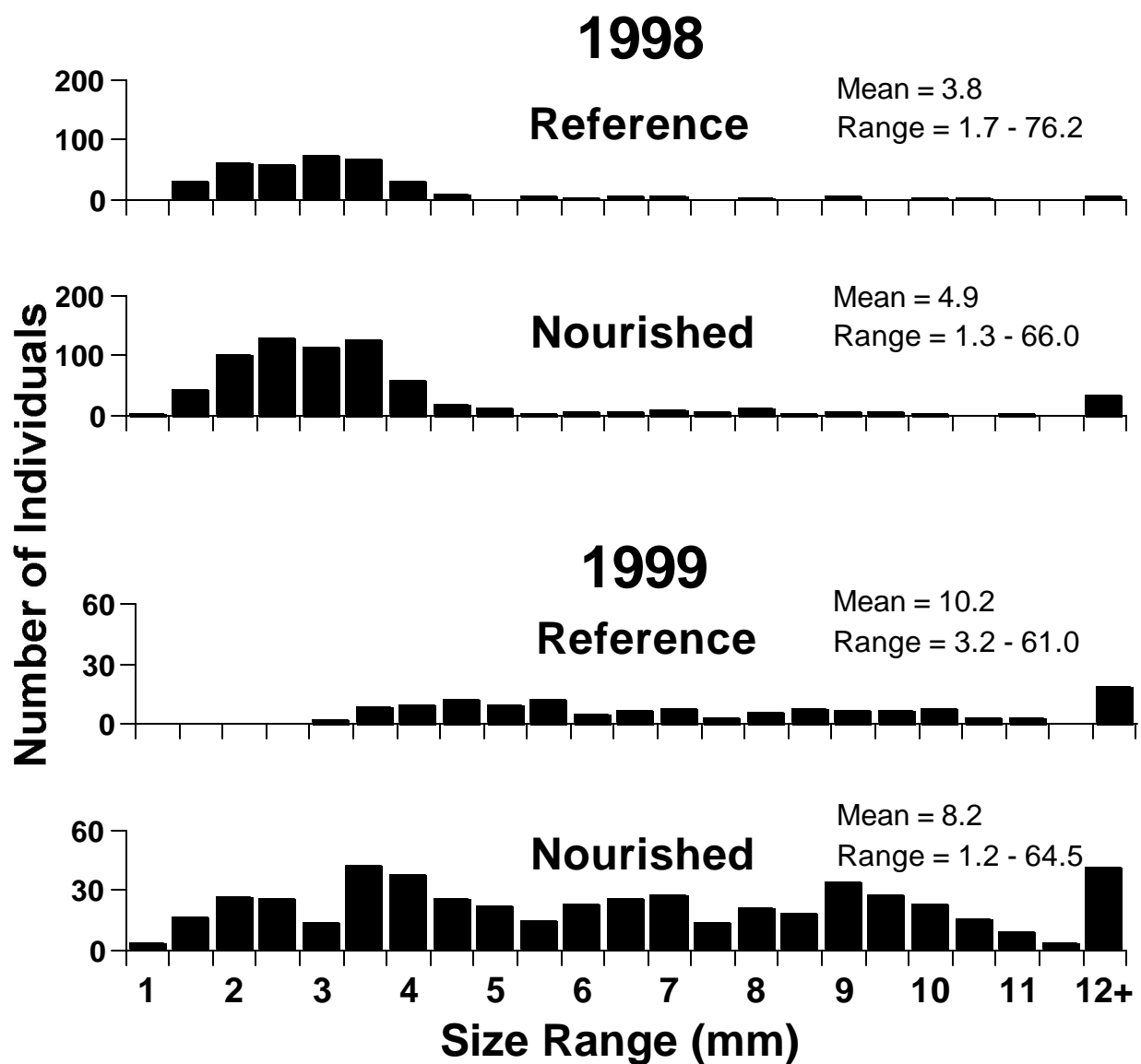


Figure 3-45. Composite lengths for surfzone ichthyoplankton samples from northern New Jersey beaches after nourishment (1998 - 1999) from reference and nourished sites.

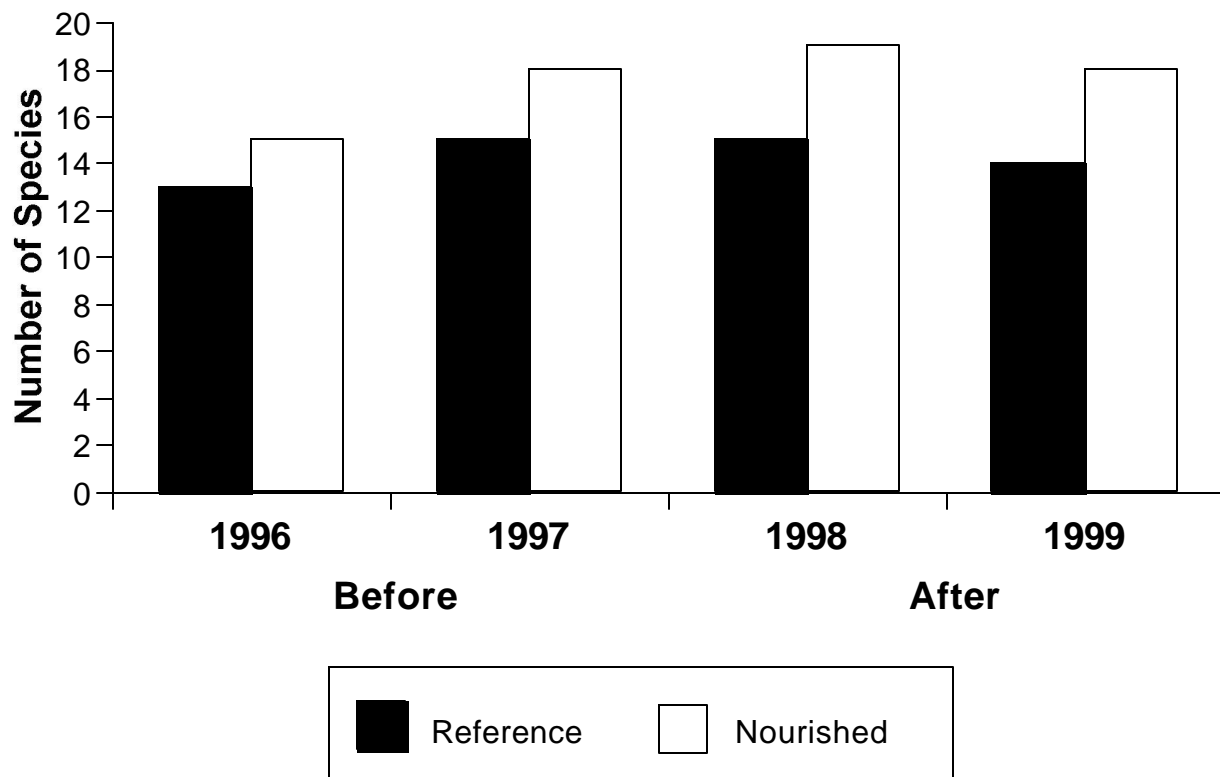


Figure 3-46. Species richness, as expressed as total number of species, at reference and nourished sites during 1996 - 1999.

plankton net with a three-point bridle was deployed 50 m from shore by a swimmer and then towed back in by a line by a team on the beach. Twenty-one daytime tows were performed in this manner to accumulate approximately 100 m³ of water sampled. The contents of all the tows were pooled and fixed with 5% formalin.

Nearshore sampling consisted of five replicate 5-minute tows performed at nine sites (Fig. 3-1) along the 6.5 m depth contour with two 1.0 m (505 μ mesh) bongo nets. Surface and bottom tows were made at each site, with bottom tows approximately 1 - 2 m off the bottom. Samples from each of the two nets were pooled and fixed with 5% formalin. A General Oceanics flow meter was attached to each net. Larval abundance is expressed as number per 100 m³.

For both nearshore and surfzone samples, contents were transferred from formalin solution and placed into 95% ethanol in the laboratory prior to removal of fishes. In instances where there was a great deal of detritus or amphipods that hindered sorting, the samples were split with a standard plankton splitter. The sorted samples were then separated by species, enumerated, and 20 individuals of each species were measured to the nearest millimeter. Individuals < 10 mm were measured with an ocular micrometer, whereas those > 10 mm were measured with a dial caliper. For those individuals that were measured, flexion stage was also recorded (Kendall et al. 1984). Standard length was recorded for postflexion individuals and notochord length was recorded for preflexion and flexion individuals.

At the beginning of sampling at each surfzone station, a HydroLab® data logger was deployed 50 m from the beach and was removed at the end of the sampling period. Data were recorded at 10-minute intervals and then averaged for each sampling site.

Results and Discussion

Larval Fish Distributions

Physio-chemical characteristics: Many of the variables measured were similar over the study area and between years during the May - July sampling period. Salinity was consistently high with an average of 28.2 ppt with a range of 20.9 - 33.4 ppt over 1996 - 1999 (Fig. 3-2). However, values averaged lower in 1998 (mean = 25.3 ppt). There was little spatial variation in salinity as well and Shark River Inlet had no apparent effect on salinities at stations in proximity to the inlet. Temperature was similarly consistent across temporal and spatial scales (Fig. 3-3). Temperatures during the summer averaged 18.0°C with a range of 9.4 - 24.4 °C, with somewhat lower values (mean = 17.4 °C, range = 9.4 - 24.4 °C) in 1996. Dissolved oxygen values were consistently high in the study area across all years with an average of 9.08 mg/l and a range of 5.32 - 15.9 mg/l. However, in 1998 oxygen levels appeared much higher (mean = 10.5 mg/l, range = 6.1 - 15.9 mg/l) at most stations south of Shark River Inlet during 1998 (Fig. 3-4). Turbidity varied between years with values averaging higher in 1996 (mean = 17.0 NTU, range = 0 - 340.0 NTU) and 1997 (mean = 10.4 NTU, range = 0 - 39.4 NTU) than in 1998 (mean = 7.2 NTU, range = 0 - 44.2 NTU) and 1999 (mean = 4.2 NTU, range = 0 - 90.2 NTU) (Fig. 3-5).

The relatively uniform physio-chemical features of the study area during the summer months may reflect the absence of a well-defined Hudson River plume, which is typically pushed offshore by westerly winds under summertime conditions (Bowman 1978, Cowen 1996).

Larval Abundance: The density of larvae in the study area varied across years over the area from Long Branch to Manasquan Inlet during 1996-1999. Larvae were more abundant in nearshore versus surfzone samples in every year (Table 3-1). The larvae were most abundant in the surfzone in 1998 and in the nearshore samples in 1996. There was no obvious correspondence between larval density in nearshore versus surfzone samples in any given year (Fig. 3-6). In addition, there was no general pattern of overall greater abundance at any one location, either for nearshore or surfzone collections. Possible exceptions were that larval density was high at some of the northernmost nearshore stations (NR3, NR2 and NR1) in 1999, 1997 and to some degree in 1996, however this was not the case in 1998 (Fig. 3-6). During two of the five years (1997 and 1999) values were among the highest at Station 10, just south of Shark River Inlet, but this was not the case in the other three years.

The summer sampling for this study was near or during the peak in larval abundance as a result of a typical mid- to late-summer peak in reproduction in the Middle Atlantic Bight (Able and Fahay 1998). The lack of consistency in larval abundance in surfzone versus nearshore samples may be due to complex circulation, both on large regional or small against the shoreline spatial scales, or species specific differences in the timing of larval occurrence and transport or retention. Some of these same characteristics may account for the lack of distinct spatial patterns in the abundance of any of the species that we examined in detail.

Size and stage composition: While the sampling nets in the nearshore and surfzone collections differed in size and mode of deployment, the size and stage of larval development appeared to be similar across years. The composite (Fig. 3-7) and annual (Fig. 3-8 to 3-11) size frequency distributions were similar with most individuals < 5 mm, but individuals up to 15 mm were fairly equally represented, and some individuals > 20 mm were also collected. For these composite samples the means were nearly identical, i.e. 5.7 mm in the surfzone and 4.8 in the nearshore collections. The annual pattern of size distribution did vary somewhat with relatively more individuals in the 5 – 15 mm range in the nearshore collections in 1998 (Fig. 3-10) and a larger proportion of larger individuals, i.e. > 5 mm in both nearshore and surfzone collections in 1999 when the mean sizes were 6.9 and 8.8 mm, respectively (Fig. 3-11). The relatively small sizes across habitats and gears are supported by the fact that, for many of the species, the average size at collection (both gears combined) approximated the size at hatching (Fig. 3-12). This was evident for *Brevoortia tyrannus*, *Cynoscion regalis*, *Lophius americanus*, *Scophthalmus aquosus*, *Sphoeroides maculatus*, and *Tautoglabrus adspersus*. The possibility that many of these species spawn in relatively shallow waters is supported by prior studies (see Able and Fahay 1998 for a review; Berrien and Sibunka 1999). Spawning by *L. americanus* in these nearshore waters has not previously been reported, but seemed evident in a number of years. For other species that were represented by two size modes, the smallest mode also represented the size at hatching, including *Hippoglossina oblonga*, *Pomatomus saltatrix*, *Pseudopleuronectes americanus* and *Tautoga onitis*. Most of these species are reported to reproduce in coastal waters (Grosslein and Azarovitz 1982). The exception is *P. americanus*, which is presumed to spawn in adjacent estuaries (Able and Fahay 1998), but some of the larvae are presumably transported out

of the estuary (Able and Fahay 1998, Chant et al. 2000). In other instances, the smallest individuals collected were larger than the size at hatching, e.g., *Etropus microstomus*, *Prionotus carolinus*, and *P. evolans*. This may be due to spawning over the continental shelf, as occurs for the *Prionotus* species (McBride and Able 1994). The overall small size of the larvae collected is reflected in the dominance of preflexion stage individuals in most years and in both gears/habitats (Fig. 3-13). A possible exception is in 1997 and more clearly in 1999 when relatively larger numbers of postflexion larvae were collected.

Species composition: Species richness, based on combined nearshore and surfzone collections, was relatively high with 51 species represented over the five years from 1995 -1999 (Table 3-2). Species richness varied between years with 28 taxa represented in 1996 and 38 in 1997 and 1999. We have excluded 1995 because there was no nearshore sampling performed that year. The number of species also varied between habitats with a larger number of species in nearshore (46) than in surfzone (38) collections.

The composite nearshore and surfzone larval collection was dominated by a diverse assemblage of fishes from 33 families (Table 3-2). Of these the sciaenids, gadids, engraulids, scombrids and bothids were the most speciose. The sciaenids had four species (*Bairdiella chrysoura*, *C. regalis*, *Menticirrhus saxatilis* and *Micropogonias undulatus*), the gadids had four species (*Enchelyopus cimbrius*, *Pollachius virens*, *Urophycis chuss* and *U. regia*), the engraulids had three species (*Anchoa hepsetus*, *A. mitchilli* and *Engraulis eurystole*), the scombrids had three species (*Auxis* sp., *Scomber scombrus* and *Scomberomorus maculatus*) and the bothids had three species (*Bothus ocellatus*, *E. microstomus* and *H. oblonga*). Several species were among the most abundant in both nearshore and surfzone collections. These included *Anchoa* sp. (most likely *A. mitchilli* given the dominance of this form over other engraulids among those identified to species), *B. tyrannus*, *S. scombrus*, *S. aquosus*, and *L. americanus*.

Some relatively abundant (>10 in total catch) species were restricted in the habitats in which they occurred (Table 3-2). Those only collected in the nearshore included *A. hepsetus*, *Opisthonema oglinum*, *E. eurystole*, *U. regia*, and *Gasterosteus aculeatus*. Species that appeared disproportionately abundant in the nearshore were *Anchoa* sp., *T. onitis* and *P. saltatrix*. There were no abundant species that were only found in the surfzone, however several were relatively more abundant there including *Menidia menidia*, *S. aquosus*, Atherinidae and *Peprilus triacanthus*. Many of these species are typical larvae from the central part of the Middle Atlantic Bight based on an 11-year data set from NMFS-MARMAP surveys (Able and Fahay 1998, Table 4.1). Also, many species from the study area overlap with the inshore larval assemblage reported from slightly deeper water in the Middle Atlantic Bight (Cowen et al. 1993).

The catches of selected species varied by year (Table 3-3). In the nearshore collections the abundance of *Anchoa* sp. was much greater in 1996 and 1997, perhaps because the smallest individuals are difficult to identify to species and small individuals were very abundant in those years. This pattern was similar for the surfzone except that 1998 collections were abundant as well. The pattern of relative abundance observed for this taxon in the nearshore collections was consistent with that for *A. mitchilli*, suggesting again that unidentified specimens may be this species. *Scomber scombrus* was very abundant in 1996 and 1998 in both nearshore and surfzone

collections, but virtually absent in 1997 and at a low level in 1999. *Tautogolabrus adspersus* was especially abundant in 1998, while another labrid, *T. onitis*, was abundant in 1997 and 1999. *Cynoscion regalis* was consistently present, but was most abundant in 1997. *Pomatomus saltatrix* was abundant in nearshore collections in every year except 1998, but seldom occurred in surfzone collections. *Lophius americanus* was most abundant in 1996 and 1997.

The sources of the larvae in the coastal ocean, i.e. nearshore and surfzone combined, seemed to vary between years (Table 3-4). In 1995, a high percent composition of species of estuarine origin, i.e. presumably spawned there (see Table 3-2), was evident, implying that surfzone collections are dominated by species of estuarine origin. This may simply reflect the absence of nearshore collections during that year. In most other years the contribution of estuarine species was relatively low. In 1997, the percent composition of estuarine/oceanic species was high in both nearshore and surfzone collections.

Spatial Distribution by Species: For the large majority of species examined, there were no consistent spatial patterns in larval abundance across years over the 15 km of the study area between Long Branch and Manasquan Inlet (Fig. 3-14 to 3-35). For example, while *H. oblonga* were most abundant at four stations (PR2, 3, 6, 7) north of Shark River Inlet in 1996, they were never abundant there again and in 1998 they were most abundant at three stations (SR12,13,14) south of Shark River Inlet (Fig. 3-14). Many species such as *S. aquosus* were distributed widely across the entire sampling area (Fig. 3-15). Some species of presumed estuarine origin were most abundant in surfzone collections including atherinid sp. (Fig. 3-16) and *Syngnathus fuscus* (Fig. 3-17). For some species such as *C. regalis* (Fig. 3-18) there were distinct periods in a single year, such as the consistent occurrence of larvae north of Shark River Inlet in 1997, but this pattern was not repeated in other years.

The spatial distribution relative to the source of the larvae did not show any clear patterns (Fig. 3-36 to 3-38). One exception is that most of the estuarine species (Table 3-2) were found almost exclusively in the surfzone samples, indicating that they preferred or were constrained by circulation patterns within the shallow waters in the study area. In addition, there appeared to be a tendency for more estuarine larvae downstream of Shark River Inlet, perhaps because that was a major source for this group (Fig. 3-36).

Larval Fish Response to Beach Nourishment:

For purposes of looking at impacts of beach nourishment we divided the study area in half with the Shark River Inlet as the mid-point. Nourishment was performed in the areas south of the inlet in 1997 after sampling was completed for that year. Nourishment was not performed in the northern areas until 1999 after all sampling activities were completed. Therefore we viewed the sites north of the inlet as the reference area and the sites south of the inlet as the nourished area. The years 1996-1997 are considered “before” and 1998-1999 are considered “after.” The data from 1995 were not considered in this analysis. Only surfzone samples were considered in this analysis because they were the most likely to be impacted by beach nourishment activities. Due to the possibility of influences from the two inlets the stations closest to them (9 and 22, see Fig. 3-1) were not included in this analysis.

Physio-chemical characteristics: As stated earlier there was very little variability in physio-chemical characteristics over the study area. This holds true as well in terms of reference versus nourished areas. There was no marked difference in salinity values between reference and nourished sites. Salinity was lower in 1998 in both the reference (25.7 ppt) and nourished sites (25.2 ppt) and was higher in 1999 in the nourished sites (31.1 ppt) and in the reference sites as well (30.5 ppt) (Fig. 3-39). Water temperature also showed no differences, averaging lower in 1996 (16.9 °C reference and 17.7 °C nourished) and were highest in 1999 (20.5°C reference and 19.4°C nourished) (Fig. 3-40). Dissolved oxygen concentration does show a peak in the nourished sites in 1998 (11.3 mg/l), but remained consistent otherwise (Fig. 3-41). Turbidity values varied over the years sampled with a consistent trend towards lower values, but did not vary between nourished and reference sites. The highest turbidity occurred in 1996 (14.2 NTU reference and 19.2 NTU nourished) and the lowest values occurred in 1999 (2.8 NTU reference and 4.6 NTU nourished) (Fig. 3-42).

Larval abundance: Average larval abundance varied over the years sampled, but did not markedly vary between reference and nourished sites from 1996-1999. The lowest catch per unit effort (CPUE) values overall occurred in 1997 (14.6 per 100 m³ reference and 19.2 per 100 m³ nourished) and the highest were in 1998 (31.5 per 100 m³ reference and 62.0 per 100 m³ nourished). There was a general pattern of values being higher in the nourished areas over all of the years sampled, but only in 1997 were the values substantially greater. (Fig.3-43). The fact that the nourished area was bounded on either side by inlets may account for this pattern of greater abundance at nourished sites because the inlets, especially Shark River Inlet, may enhance the ichthyoplankton by the addition of estuarine species because some of these tended to be more abundant “downstream” of the inlet (Fig. 3-36). Alternatively, the spatial patterns observed could be independent of nourishment activities.

Size composition: The average size of larvae collected varied slightly from year to year with regards to reference versus nourished areas, but there was no consistent pattern of size differences in a given area (Figs. 3-44 and 3-45). In 1996 and 1998 the nourished areas had a slightly greater average size of larvae, while in 1997 and 1999 the reference areas had relatively larger individuals. Overall the samples collected in 1999 contained larger larvae (reference = 10.2 mm, range = 3.2 - 61 mm; nourished = 8.2 mm, range = 1.2 - 64.5 mm) than in the previous years. The size distributions were almost always similar between reference and nourished areas. One possible exception occurred in 1999 when the smallest (< 3 mm) larvae were not present in the nourished area.

Species composition: Species richness, expressed as the total number of species collected, did not vary greatly over the years sampled in regards to reference versus nourished areas. Number of species collected only ranged from 13 to 19. Values were consistently higher in nourished areas over all years with the highest degree of diversity recorded in 1998 with 19 species collected in the nourished sites (Fig. 3-46). Again, this pattern may be due to the nourished area being bordered by the two inlets.

Conclusions

Comparisons for surfzone ichthyoplankton between reference and control beaches were limited to general areas, i.e. north (reference beaches) and south (nourished beaches) of Shark River Inlet, because of the timing of nourishment activities relative to the summer sampling season. As such, specific comparisons between individual beaches were not possible. As a result of these comparisons, there were no obvious differences between reference and nourished beaches based on an analysis of a number of parameters (physical, surfzone ichthyoplankton abundance, size and species composition). Based on the findings of earlier reviews (Ross 1983, Hackney et al. 1996), these studies represent the first time that ichthyoplankton assemblages have been analyzed to evaluate beach nourishment effects.

These results also present, for the first time, an extensive examination of surfzone ichthyoplankton on the northeast coast of the U.S. This unique contribution is largely due to the difficulty of sampling in high energy surf zones. Additionally, this study included sampling in slightly deeper, nearshore waters that had not been conducted previously in New York Bight waters. As a result, we now have an improved appreciation of the extent to which these shallow coastal waters are used for reproduction and as larval habitat. This is especially striking for some species of economic (e.g., *L. americanus*, *C. regalis*, *S. scombrus*, *T. onitis*, *P. saltatrix*, *B. tyrannus*) and ecological (*A. mitchilli*, *E. microstomus*, *Prionotus* spp.) importance.

Our studies are complemented by examination of ichthyoplankton from adjacent estuaries (Croker 1965, Witting et al. 1999, see Able and Fahay 1998 for a listing of unpublished studies) and the deeper waters of the continental shelf (Cowen et al. 1993, Cowen 1996, Berrien and Sibunka 1999). These, in combination with the analysis of juvenile fish assemblages on the same beaches as the ichthyoplankton collections (Wilber et al. in review), provide for an enhanced understanding of fishes in the summer surf zone. As a result of the above, we have new insights into the early life history of fishes in these shallow waters.

It is clear from the results of the present study that incorporating ichthyoplankton sampling into beach nourishment monitoring projects presents several technical challenges. Detection of impacts on early life history stages demands a commitment of substantial resources both in terms of labor and funding. Physical attributes of high energy ocean beaches, coupled with highly dynamic spatial and temporal distributions of larvae, have the effect of masking all but very large shifts in density and size and taxonomic composition. Although such dramatic changes were not observed in this study, it does not preclude the possibility that effects occurred on smaller temporal and spatial scales not captured by the present study design (Gray 1996). Placing observed changes, or lack thereof, into perspective for environmental assessments remains difficult (Rosenthal and Alderdice 1976, Dahlberg 1979). For example, the threshold of impact in terms of ecological relevance is likely species-dependent as influenced by spawning stock size, fecundity, and a host of other reproductive traits (Levin 1996). Even for numerically dominant species, the magnitude of effect that would be meaningful (e.g., could detrimentally affect recruitment) cannot readily be estimated. This step would be required to assess the effects of larval loss due to beach nourishment operations in a manner analogous to previous studies of power plant entrainment (e.g., Dempsey 1988).

In spite of inherent limitations in interpretation of ichthyoplankton sampling data, results of the present study can be used to guide future monitoring efforts, if indeed effects on appropriate scales are deemed important. One recommendation would be to conduct more intensive, short-term sampling on smaller spatial scales, i.e. within 1,000 m laterally from an active fill discharge. Such an approach would be consistent with recommendations made by Gray (1996). If logistically feasible, diel sampling to fully cover day/night and tidal cycles should be included. Even if effects on distribution are undetected with this level of sampling, subsamples of larvae could be examined for indications of physiological damage or stress. Assuming that the mechanism of effect is related to exposure to suspended sediments, physiological manifestations similar to those detected in other impact assessment studies could be targeted for observation. In the absence of such indications of detrimental effects, one might more confidently conclude that beach nourishment effects are of minimal consequence. If effects were substantiated, then further investigation into causal mechanisms could be pursued. In addition to hypothetical effects of exposure to suspended sediments, there are likely to be interactions in the surf zone between turbidity, turbulence and larval foraging rates. Overall effects on larvae might be positive or negative (Boehlert and Morgan 1985, MacKenzie and Miller 1994, Kiorboe and MacKenzie 1995), expressed on a species-specific basis. In either case, management decisions for beach nourishment projects could benefit from knowledge that integrates the actual scales of disturbance with measured responses by species of concern.

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