

Abstract.—Northern searobins, *Prionotus carolinus*, and striped searobins, *P. evolans*, are commonly taken in bottom trawl, pound-net, and hook-and-line fisheries of the temperate, western North Atlantic. Seasonal movements, size structure, and interannual variations in population size of both species were examined with data from three fishery-independent trawl surveys. Geographic distributions of both species overlapped year-round, but on average, northern searobins were found in colder, deeper water than were striped searobins. Northern searobins were found north and east of Cape Cod during the warmest months and north-east of Hudson Canyon during the coldest months, whereas striped searobins were rarely found in these regions during these seasons. Furthermore, northern searobins moved north and near-shore earlier in spring and left these habitats earlier in autumn. Modal size of adult northern searobins was generally between 17 and 21 cm total length, about 5 cm shorter than that of adult striped searobins. Overall, northern searobins were collected more frequently and were more numerous than striped searobins. Because they were smaller and occurred in cooler waters, however, they were not dominant by weight in coastal habitats during autumn. During the past 25–30 years, the annual population size of both species has varied by an order of magnitude, fluctuating without any clear trend. Although seasonally abundant in coastal and continental shelf waters, searobins, because of their small size in relation to other species, are usually discarded and contribute little to landings from the mid-Atlantic states.

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Interspecific comparisons of searobin (*Prionotus* spp.) movements, size structure, and abundance in the temperate western North Atlantic

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Searobins (family Triglidae) are commonly taken in pound-net and bottom trawl fisheries along the United States east coast but are only occasionally sold as foodfish, lobster bait, or livestock feed (e.g. Goode, 1888; Smith, 1894a). Commercial landings of 100–200 metric tons annually were reported from the mid-Atlantic states during the 1880’s (Collins, 1892), 1930’s (Marshall, 1946), and 1950’s (McHugh, 1977). Millions of searobins are also taken incidentally by hook-and-line recreational anglers (Table 1). Researchers have long recognized the potential for increasing U.S. landings by developing a searobin fishery (Smith, 1894b; Marshall, 1946; Merriman and Warfel, 1948; Perlmutter, 1959–60), but the market potential for searobins is limited by their relatively small size and a false perception that they are poi-

sonous or difficult to handle (Johnson et al., 1987; Murray et al., 1987).

Two searobin species are common in the temperate, western North Atlantic: northern searobin, *Prionotus carolinus* (Linnaeus, 1771), and striped searobin, *P. evolans* (Linnaeus, 1766). They range from Canada to northern Florida (Bigelow and Schroeder, 1953; Gilmore, 1977; Scott and Scott, 1988; Russell et al., 1992) but are most common year-round on the continental shelf from Cape Cod to Cape Hatteras (Nichols and Breder, 1926; Hildebrand and Schroeder, 1928; Edwards et al., 1962). Life history information is provided in Marshall (1946), Wong (1968), McEachran and Davis (1970), Richards et al.

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(1979), Yuschak and Lund (1984), Yuschak (1985), Keirans et al. (1986), and McBride and Able (1994).

This study describes and compares the seasonal movements, size structure, and interannual varia-

tions in population size of northern and striped searobins in the Mid-Atlantic Bight. No previous study has synthesized searobin data over such a large geographic scale. The present and potential roles of searobins in fisheries of the temperate western North Atlantic are also discussed.

Table 1

Estimated numbers of searobins (all triglid species combined) caught by marine recreational anglers from 1979 to 1991 in the Mid-Atlantic, as well as in all subregions of the U.S. east coast combined: Gulf of Maine, Mid-Atlantic, South Atlantic, and Gulf of Mexico. Data prior to 1979 are not available.

Year	Numbers (in millions)		Source
	Mid-Atlantic	U.S. east coast	
1979	3.548	5.145	Holliday, 1984
1980	7.102	7.957	Holliday, 1984
1981	1.624	2.613	NMFS, 1985a
1982	2.795	5.074	NMFS, 1985a
1983	8.750	10.058	NMFS, 1985b
1984	6.189	6.752	NMFS, 1985b
1985	3.562	4.361	NMFS, 1986
1986	10.908	11.858	NMFS, 1987
1987	4.824	5.071	Essig et al., 1991
1988	5.182	5,899	Essig et al., 1991
1989	2.631	2.947	Essig et al., 1991
1990	4.896	5.518	Van Voorhees, et al., 1992
1991	7.254	7.799	Van Voorhees, et al., 1992
Mean (per yr)	5.328	6.235	
Total	69.265	81.052	

Materials and methods

Data were derived from three fishery-independent bottom trawl surveys (Table 2). One survey, conducted by the National Marine Fisheries Service, covered the entire Mid-Atlantic Bight (i.e. the coastal region from Cape Cod to Cape Hatteras), as well as Georges Bank and the Gulf of Maine (Fig. 1). Data from two regional surveys were also examined: one at the northern extent of the Mid-Atlantic Bight near Cape Cod, the other within a central portion of the Mid-Atlantic Bight offshore of New Jersey. In each survey a stratified, random design was used for allocating trawl tows. Strata were established by depth categories and other physiographic boundaries. Numbers of tows within each stratum were proportional to stratum area; within each stratum, tow locations were randomly assigned. Fishes were counted and weighed; measurements were reported to the nearest centimeter total length (TL). In preliminary analyses geographic and length-distribution data were plotted for all years available, but herein only data from selected cruises (1991–92) are graphed. Preliminary calculations of abundance showed that

Table 2

Sources and details of trawl data examined for this study. Data for the period 1982–91 were the focus of most analyses. Data regarding distribution and size structure for the years 1991–92 were plotted (Figs. 2–7) as representative years.

Data source	Trawl headrope (m) (mesh [mm])	Tow time (min)	Season	Month	Sampling depth (m)	Years
Throughout the Mid-Atlantic Bight NEFSC, NMFS ¹	18.3–19.8	30	Spring	Mar–May	9–366	1968–95
	(12.7)	30	Summer	Jun–Aug	9–200	1963–65, 69, 77–81
		30	Autumn	Sep–Nov	9–366	1963–95
		30	Winter	Dec–Feb	9–200	1964–6, 7, 8, 1, 9, 1–2
Offshore of Massachusetts and New Jersey MDMF ²	11.9	20	Spring	May	9–55	1978–95
	(12.7)	20	Autumn	Sep	9–55	1978–95
	NJBMF ³	24.4	20 ⁴	5–6/year	Jan–Dec	6–27
	(6.3)					

¹ Northeast Fisheries Science Center, National Marine Fisheries Service.

² Massachusetts Division of Marine Fisheries.

³ New Jersey Bureau of Marine Fisheries.

⁴ Tows in 1988 were for 30 minutes.

fish numbers and weight had similar trends (McBride, 1994); therefore only weight indices are reported here. Some descriptive statistics were also based on subsets of data (1982–91), as noted below. Statistical significance was evaluated at $P < 0.05$. The above comments pertain to all data examined, and comments below outline procedures specific to each sampling program.

NMFS sampling

Survey data from the National Marine Fisheries Service (NMFS), Northeast Fisheries Science Center (NEFSC), were examined. The survey area was divided into 76 strata from Cape Fear, North Carolina, to Cape Sable, Canada, in waters 9–366 m deep. Spring and autumn cruises sampled a total of about 350 stations during a 6–8 week period, whereas summer and winter cruises sampled about half as many stations (Table 2). The primary gear used was a no. 36 Yankee trawl. In spring, summer, and autumn cruises a roller-rigged footrope was used; however, in winter cruises a cookie sweep and ground cable designed to target flatfish were used. Latitude, longitude, and depth were recorded at the start of each tow. Bottom temperature was usually recorded by using an XBT cast or a CTD probe. See Grosslein (1969, 1976), Azarovitz (1981), and Despres-Patanjo et al. (1988) for further sampling details.

Exploratory data analyses considered all 76 strata, but interannual comparisons of abundance considered only latitudinal strata within the Mid-Atlantic Bight because both species were uncommon or absent in the Gulf of Maine and on Georges Bank and because sampling south of Cape Hatteras was not broad in coverage or consistent between years. Because the distribution of both species varied seasonally, largely as an onshore–offshore pattern, different depth strata sets were used for calculating spring and autumn abundances; the autumn strata selected were generally < 27 m and the spring strata were > 27 m deep. Because the purpose here was to compare interspecific abundances, the final selection of strata included the broadest possible latitudinal range within the Mid-Atlantic Bight where both species occurred.

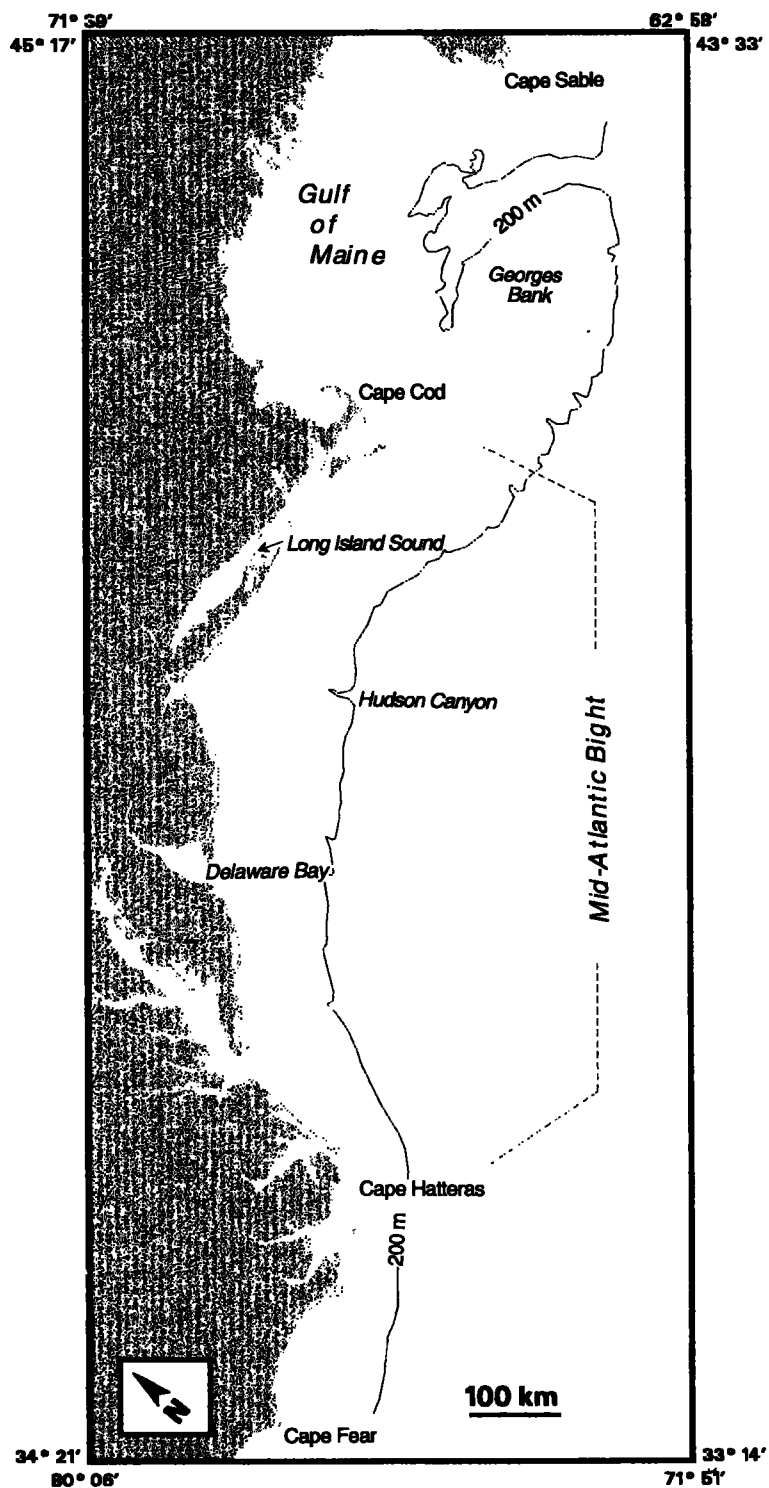


Figure 1

Study area of the U.S. east coast, with some landmarks identified in the text (additional landmarks are depicted in Fig. 3). The Mid-Atlantic Bight is defined as the coastal region between Cape Cod and Cape Hatteras. Sampling strata for the Mid-Atlantic Bight survey (NEFSC, NMFS, Table 2) extended in total from Cape Fear to Cape Sable. Sampling regions for the Massachusetts and New Jersey surveys (Mass. Div. Mar. Fisheries and New Jersey Bureau of Mar. Fisheries; Table 2) are depicted in Figures 3 and 4.

The autumn strata selected were NMFS inshore strata identification numbers 01–61, and the spring strata were NMFS offshore strata 01–12, 25, and 61–72. The summer and winter seasons were not sampled consistently enough to be included in these comparisons of abundance. Abundance of each species was estimated as a stratified mean weight per tow with the methods of Finney (1941) and Pennington (1983). These values are log-transformed ($\ln[x+1]$) means, weighted by stratum area.

Regional sampling

The Massachusetts Division of Marine Fisheries (MDMF) sampled 23 strata along the Massachusetts shoreline (<55 m). Approximately 80–90 stations were sampled in May and again in September (Table 2) with a 3/4 North Atlantic type-2 seam trawl at random locations, except where precluded by untowable bottom and extensive fixed commercial gear (Howe, 1989). Abundance indices were calculated in the same manner as those calculated for the sampling by NMFS (see above). Strata were selected to encompass an area where both species occurred in each season (MDMF strata no. 10–19 for spring; 11–12 for autumn).

The New Jersey Bureau of Marine Fisheries (NJBMF) sampled 15 strata along the New Jersey coast (<27 m). Cruises occurred every 6–10 weeks during 1988–92 (Table 2). Each cruise sampled 25–39 stations during a 1–4 week period using a 3-in-1 trawl at random locations (Byrne, 1989). Mean weight per tow ($\ln[x+1]$) was calculated without weighting for strata areas, and tows from all strata were used because both species occurred throughout the NJBMF sampling area during most of the year.

Results and discussion

Movements

Northern searobins, but not striped searobins, moved seasonally between the Mid-Atlantic Bight and the Gulf of Maine, and they used habitats on Georges

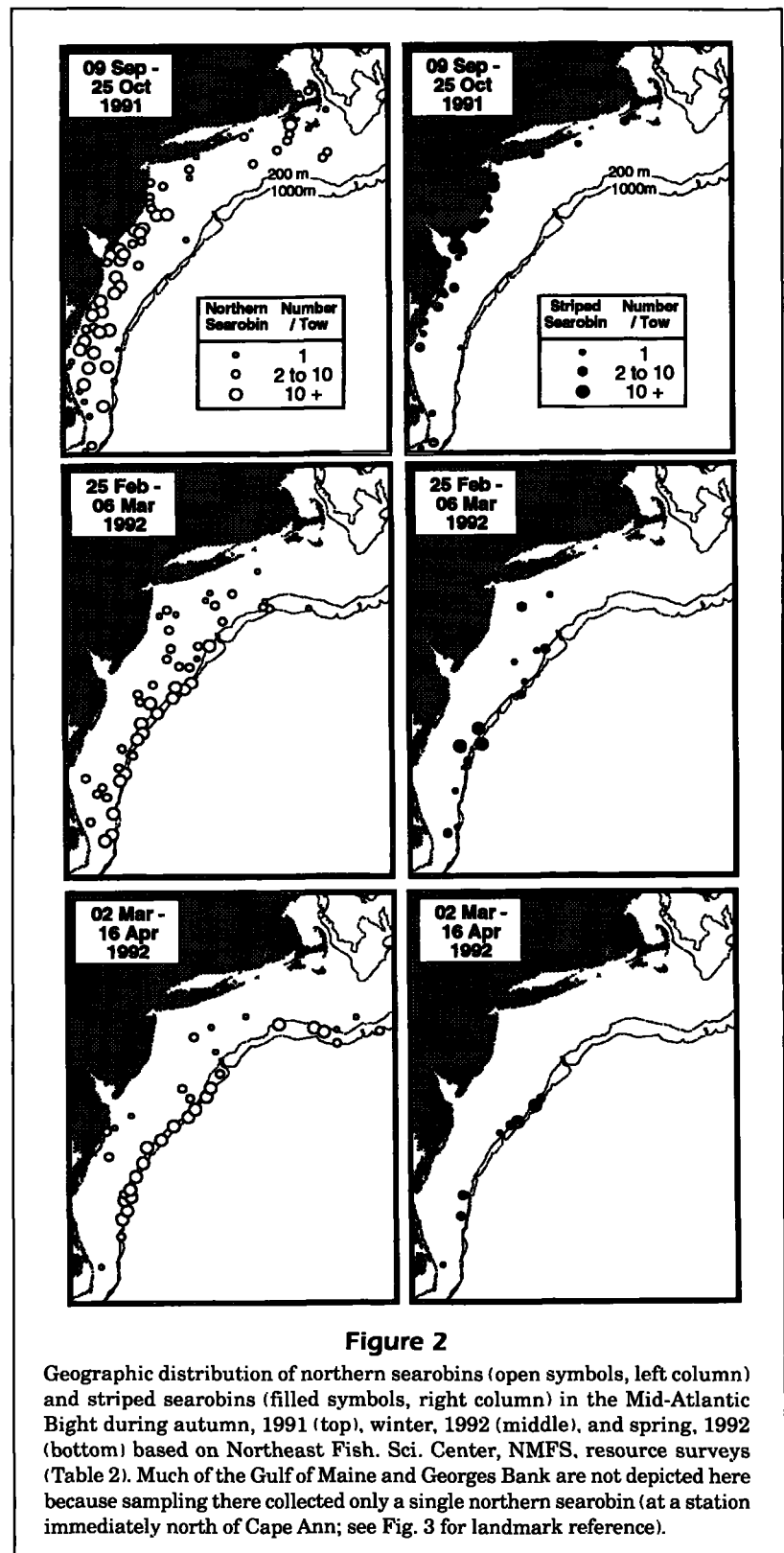
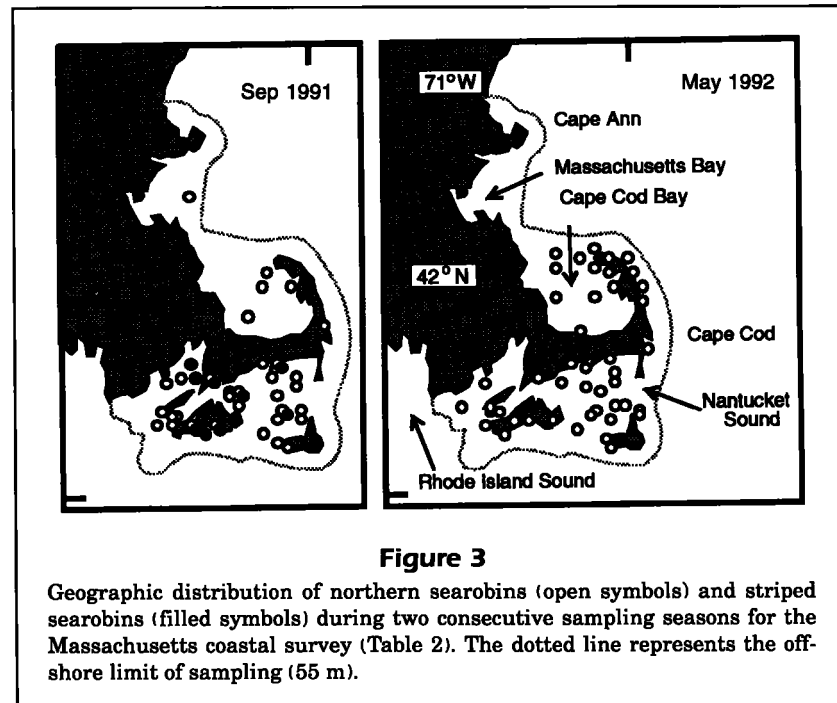


Figure 2
Geographic distribution of northern searobins (open symbols, left column) and striped searobins (filled symbols, right column) in the Mid-Atlantic Bight during autumn, 1991 (top), winter, 1992 (middle), and spring, 1992 (bottom) based on Northeast Fish. Sci. Center, NMFS, resource surveys (Table 2). Much of the Gulf of Maine and Georges Bank are not depicted here because sampling there collected only a single northern searobin (at a station immediately north of Cape Ann; see Fig. 3 for landmark reference).

Bank (Figs. 2 and 3). Striped searobins occurred rarely north or east of Cape Cod in any year, but northern searobins, although not common there, oc-



curred annually on parts of Georges Bank and in the southern portion of the Gulf of Maine during summer and autumn. In general, both species were broadly distributed within the central Mid-Atlantic Bight but moved southward during winter and spring (Figs. 2 and 4). Striped searobins moved well south and west of Hudson Canyon, which appears as an approximate northern limit for striped searobins during the overwintering season, whereas northern searobins had a broader latitudinal distribution in the Mid-Atlantic Bight while overwintering (see also McBride and Able, 1994). These data suggest that by spring large striped searobins moved either farther offshore into continental slope waters (>200 m) or migrated south of the zoogeographic boundary represented by Cape Hatteras (i.e. between the Mid-Atlantic and the South Atlantic Bight) because sizes > 25 cm TL are uncommon during spring cruises (Fig. 5). We cannot prove this hypothesis, however, because these southern and offshore regions were not well sampled during the overwintering season (see Table 2 for sampling area limits).

Both searobin species migrated seasonally in an onshore-offshore direction as well as in a north-south direction (Fig. 2). Northern searobins were, however, consistently found in significantly deeper waters than were striped searobins during both spring ($78.3 \text{ m} \pm 5.27$ vs. $60.4 \text{ m} \pm 9.30$; mean depth $\pm 95\%$ confidence limits [CL]) and autumn ($30.7 \text{ m} \pm 1.73$ vs. $20.0 \text{ m} \pm 1.44$) during 1982–91. Northern searobins were also found in significantly colder bot-

tom temperatures than were striped searobins in spring ($9.2 \pm 0.3^\circ\text{C}$ vs. $11.8 \pm 0.56^\circ\text{C}$; mean $\pm 95\%$ CL) and autumn ($17.6 \pm 0.40^\circ\text{C}$ vs. $19.6 \pm 0.40^\circ\text{C}$), although both species were collected in a wide range of temperatures (4–28°C) during 1982–91. These results support McBride and Able's (1994) postulation that temperature is the principal factor producing distinctive geographic distributions for each species. Other western North Atlantic searobins (*Prionotus* and *Bellator* species) that are distributed in subtropical and tropical waters reside within species-specific depth regions but show little tendency to migrate seasonally (Lewis and Yerger, 1976; Ross, 1977; Floyd, 1980; Hoff, 1992). South of Cape Hatteras, where temperatures fluctuate less between seasons than in the Mid-Atlantic Bight, even northern searobins show little tendency to migrate seasonally (Floyd, 1980).

Size structure

Modal size of northern searobins was consistent between seasons (17–21 cm TL), but striped searobins were both larger and more variable in size (18–28 cm TL; Fig. 5). The larger size of *P. evolans* is largely accounted for by its faster growth rate and greater maximum age (Richards et al., 1979). An earlier analysis of NMFS survey data has reported northern searobins as large as 34 cm and striped searobins as large as 41 cm (Wilk et al., 1978). The maxima observed in our study were 5–7 cm larger, but these

are most likely the result of much larger sample sizes (total for combined species was 1,314 fish measured in 1974–75 [Wilk et al., 1978] vs. 69,072 in 1982–

91[our study]). Briggs (1977) reported a single record of a striped searobin measuring 485 mm TL, which equaled the size of our largest striped searobin. Floyd (1980) reported the largest northern searobin as 26 cm TL ($n=1795$) and the largest striped searobin as 35 cm TL ($n=47$) based on trawl collections south of Cape Hatteras. These findings support Ginsburg's (1950) observation that searobin size increases with higher latitudes.

Young-of-the-year (YOY) of both species were evident in all surveys (Figs. 5–7), particularly during autumn months, when a size of 15 cm TL was used to separate YOY from older year classes (Richards et al., 1979; McBride and Able, 1994). Collections from Massachusetts waters did not indicate overwintering by YOY searobins near Cape Cod, a finding similar to that reported by Richards et al. (1979). In New Jersey nearshore waters, YOY northern searobins were evident in April, suggesting that they had migrated back inshore in this region much sooner than had been observed farther north.

Abundance

Northern searobins were more abundant than striped searobins by numbers and frequency of occurrence. A total of 66,064 northern searobins were collected in 1,125 tows, whereas only 3,008 striped searobins were collected in 366 tows out of a total of 7,369 NMFS tows during spring and autumn, 1982–91. Both species were caught together in 202 of these 7,369 tows. In Massachusetts waters, northern searobins were also more numerous than striped searobins in spring (88,565 vs. 75 fish) and autumn (10,966 vs. 374 fish) during 1982–91. And in New Jersey waters, northern searobins were more numerous than striped searobins (35,471 vs. 5,258 fish) in 700 tows during 1989–92. Northern searobin aggregate weight was not, however, always heavier in coastal waters during autumn (Figs. 8 and 9) because striped searobins weigh more on average and because striped searobins occupy inshore habitats more frequently in the warmest season. In proximity to New Jersey, northern searobins appear to migrate inshore earlier, peak in abundance earlier, and move offshore earlier than striped searobins, a behavior consistent with their postulated temperature preference.

The Mid-Atlantic Bight (NMFS) time series of stratified mean weight per tow was

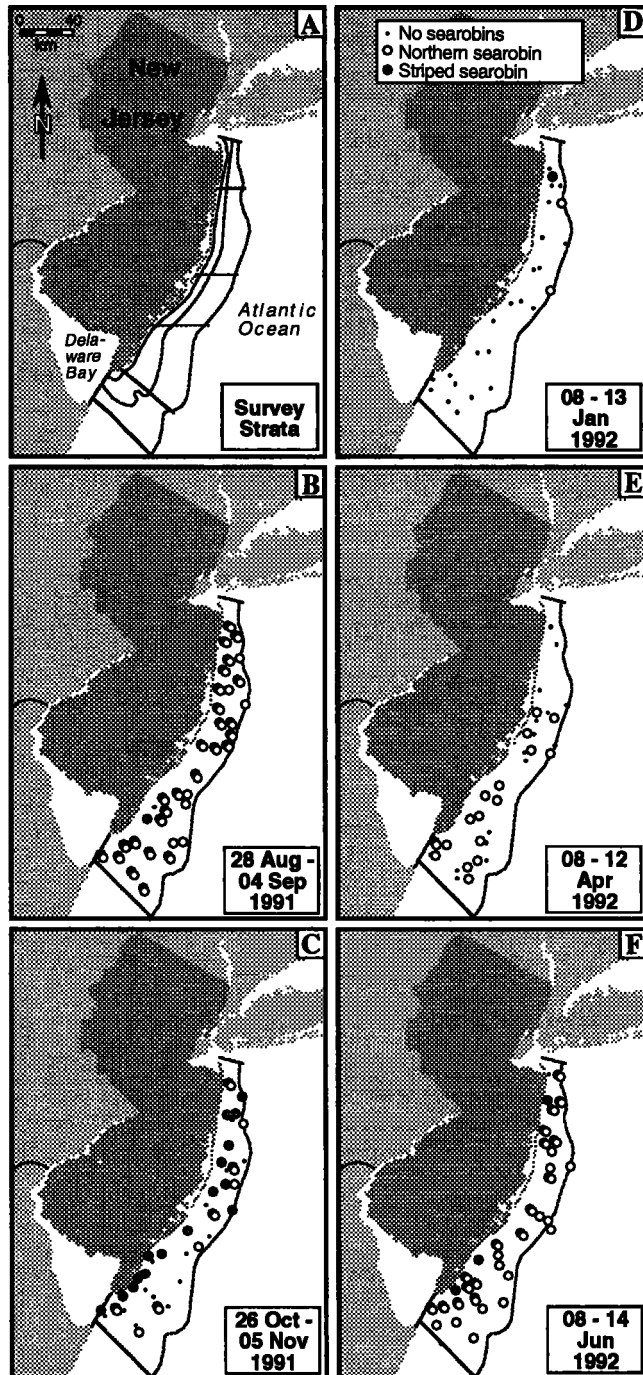


Figure 4

Seasonal distributions of northern searobins (open symbols) and striped searobins (filled symbols) during five consecutive cruises for the New Jersey coastal survey (Table 2).

highly variable (for northern searobins, CV=48 in spring and 49 in autumn; for striped searobins, CV= 68 in spring and 101 in autumn; Fig. 8) but showed no clear trend over time. There was one notable period of decline for northern searobins during spring surveys throughout the 1970's, but there was also a modest rebound in abundance during the 1980's. The low values in the early 1990's were similar to values measured in the late 1960's. The abundance of northern searobins during autumn cruises suggested no trend but was punctuated with sporadic peaks. Striped searobins also appeared to be more abundant during the 1970's than in the 1960's or 1990's, according to spring indices. The autumn time series for striped searobins declined overall, until the last year (1995), which showed a sudden increase. Abundance was compared between species to establish if each species' population size followed similar seasonal and interannual trends. Correlation analyses detected a significant relation between northern and striped searobin annual indices measured in the spring survey (Spearman rank correlation, $r_s=0.47$, $P=0.01$, $n=28$), but the correlation between species abundance in the autumn surveys was not significant ($r_s=0.006$, $P=0.97$, $n=24$). The spring and autumn indices for a given year were not significantly correlated for northern searobins ($r_s=0.14$, $P=0.51$, $n=24$) but were significantly correlated for striped searobins ($r_s=0.65$, $P=0.0006$, $n=24$). These latter results suggested that the selected spring and autumn strata measured similar trends of abundance for striped searobins but not for northern searobins.

Earlier estimates of searobin population size also noted considerable yearly variations in abundance. Clark and Brown (1977) reported a dramatic 97% decline in abundance (by weight) of searobins in the southern Mid-Atlantic region (also depicted in Grosslein [1976]) based on the same database during the period 1967–74. But they also reported a 143% increase in abundance of searobins in the southern New England region. It is difficult to compare their results with our Figure 8 because they grouped northern and striped searobins together. They also used autumn collections from offshore strata sets, but our autecological analyses revealed these strata as only marginally appropriate, at least for striped searobins that are still inshore during autumn. Their analysis of abundance reviewed years during which fairly rapid change was occurring for

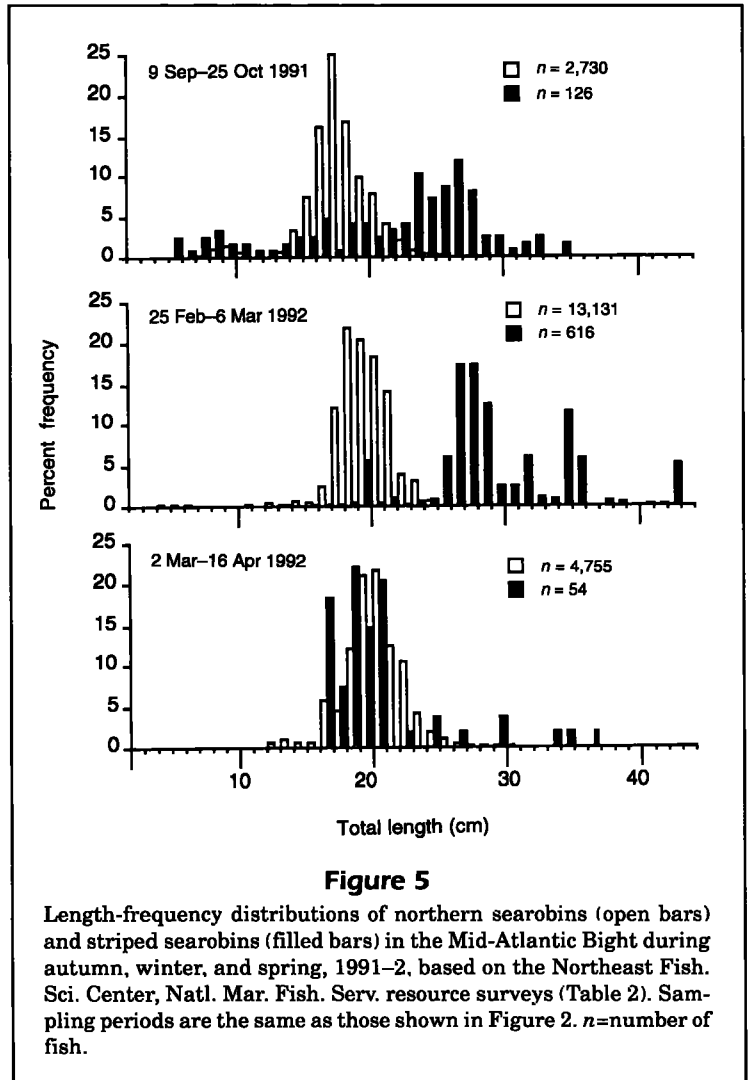
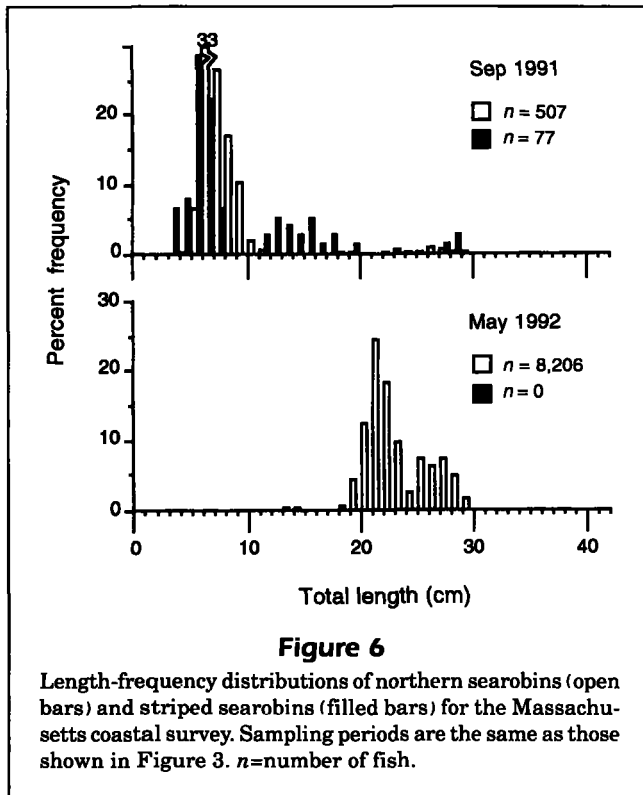


Figure 5
Length-frequency distributions of northern searobins (open bars) and striped searobins (filled bars) in the Mid-Atlantic Bight during autumn, winter, and spring, 1991–2, based on the Northeast Fish. Sci. Center, Natl. Mar. Fish. Serv. resource surveys (Table 2). Sampling periods are the same as those shown in Figure 2. n=number of fish.

both searobins and the groundfish assemblage in general, but our analyses demonstrate that searobin abundance has fluctuated up and down since the early 1970's.

Northern searobin annual abundance in the Massachusetts coastal survey has also shown large long-term variations (Fig. 8). Modest increases for northern searobin abundance in the early 1990's barely offset dramatic declines during the 1980's. In contrast, there was no trend in abundance of striped searobins during this 20-year period. These indices could be biased with respect to interannual variations in coastal temperatures because Murawski (1993) demonstrated that the latitudinal range of northern searobins varied between years with respect to sea-temperature anomalies. Thus, one might expect that searobins are more abundant in coastal Massachusetts waters during warmer years. Such does not appear to be the case, however, because

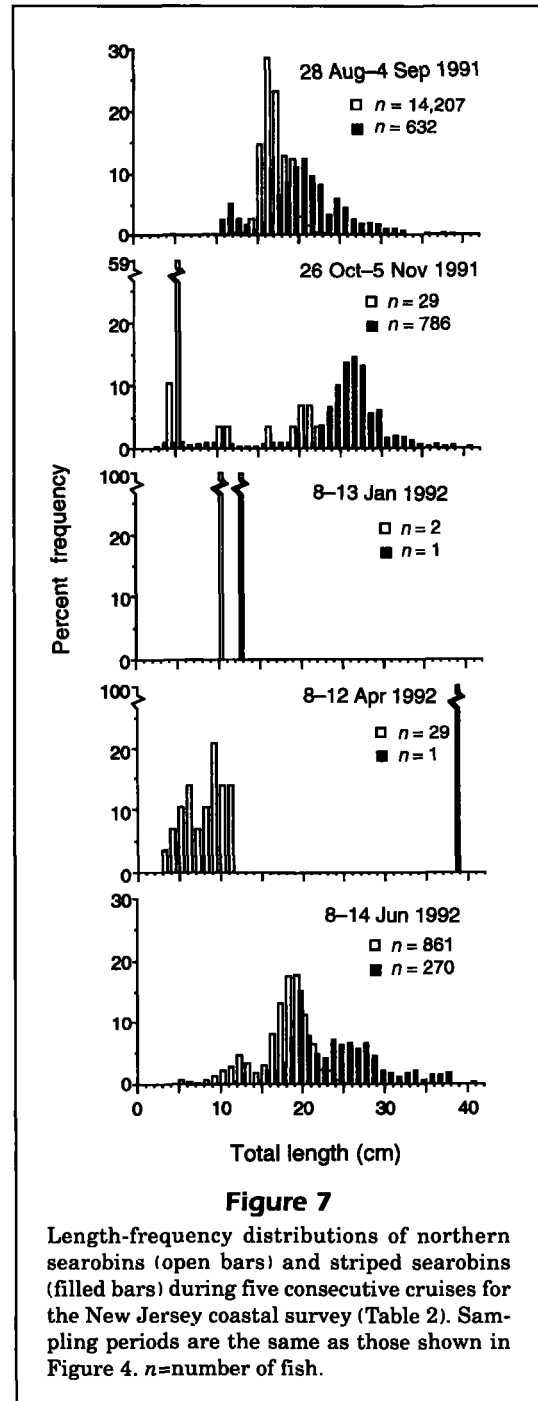


Murawski reported that after an anomalously warm period in the 1970's (when northern searobin abundance did increase) temperatures in the 1980's fluctuated without a trend (but northern searobin abundance declined dramatically; see Fig. 8).

The indices of stratified mean weight per tow between the Mid-Atlantic Bight (NMFS) and the Massachusetts (MDMF) surveys were compared to examine how robust these measures of abundance were. Correlation analyses revealed a significant relation between northern searobin abundance in spring ($r_s=0.51$, $P=0.032$, $n=18$) between the two surveys, but autumn abundances in similar years were negatively correlated between the two surveys ($r_s=-0.60$; $P=0.008$, $n=18$). There was a significant relation between these surveys for striped searobin abundance in spring ($r_s=0.51$, $P=0.029$, $n=18$) but not for autumn ($r_s=0.077$, $P=0.76$, $n=18$). These significant, positive relations between the two surveys support our use of spring but not autumn indices for examining northern and striped searobin population trends.

Implications for fishery ecology

Northern and striped searobins belong to a "warm-temperate" group (Musick et al., 1989), an assemblage that migrates onshore and north as temperatures increase, offshore and south as temperatures



decline. Our descriptive analysis supports this characterization of both species but reveals interspecific differences in the timing and extent of seasonal movements, as well as in size and abundance. Selection of sampling strata for calculating abundance indices was constrained by our goal to compare the ecology of both species. Nevertheless, indices from spring cruises in the Mid-Atlantic Bight and along the Massachusetts coast were significantly and positively

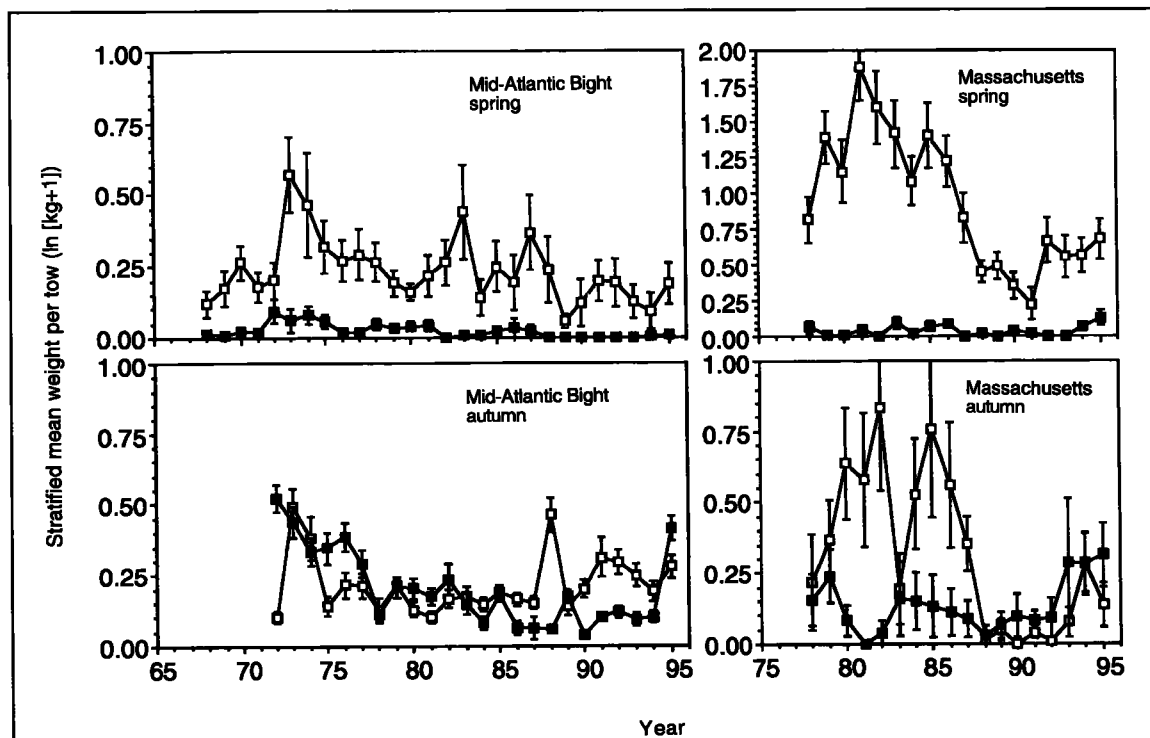


Figure 8

Annual biomass indices for northern searobins (open symbols) and striped searobins (filled symbols). Mid-Atlantic Bight indices (left) are based on sampling by Northeast Fish. Sci. Center, NMFS, resource surveys (Table 2). Massachusetts indices (right) are based on the Massachusetts (Mass. Div. Mar. Fisheries [MDMF]) coastal surveys (note the scale of the ordinate is doubled for MDMF Spring). All values are log-transformed and plotted with ± 1 standard error bar. See text for details of strata selection and statistical calculations (e.g. spring and autumn strata are different).

correlated, so that they were especially useful in evaluating population trends. On the other hand, the inshore strata selected for autumn cruises in the Mid-Atlantic Bight were adequate for sampling striped searobins but were too shallow for northern searobins because the latter occupied a mean depth of 31 m during that season.

Searobins are not important fishery species in the United States but are components of bycatch in commercial and sport fisheries; their population sizes could be affected by fishing or other factors. However, their population size varied without a specific directional trend during three decades. The long-term trend of annual biomass indices for searobins is similar to other demersal finfish such as white hake (*Urophycis*

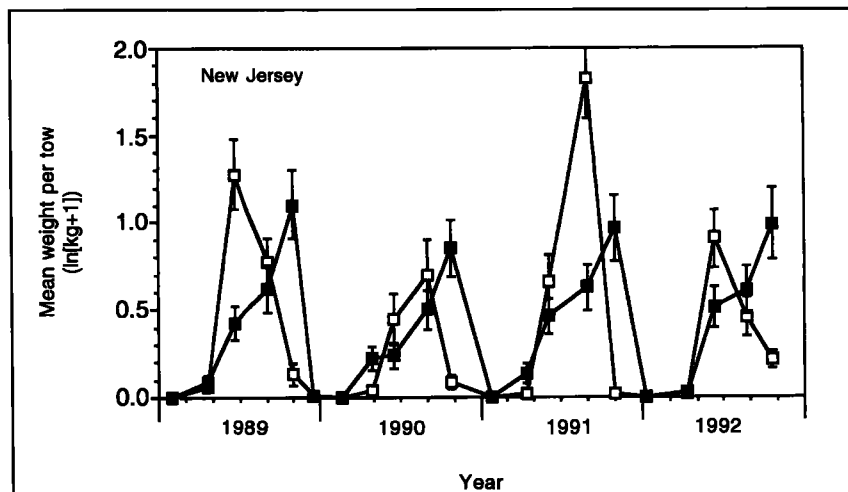


Figure 9

Seasonal abundance of northern searobins (open symbols) and striped searobins (filled symbols) based on all cruises (1989–92) for the New Jersey coastal survey (Table 2). Abundance is depicted as mean weight (± 1 standard error) of all tows per cruise. Cruises typically lasted one week, and a mean date value was used to plot each cruise.

tenuis), cusk (*Brosme brosme*), scup (*Stenotomus chrysops*), and ocean pout (*Macrozoarces americanus*) (U.S. Dep. Commerce, 1993). In contrast, population declines have been characteristic of traditional groundfish and flounder species, and aggregate biomass of principal pelagic species, skates, and spiny dogfish have increased in the western North Atlantic (U.S. Dep. Commerce, 1993).

Fishery landings, value, and catch rates for mid-Atlantic states have all declined over the past several decades (McHugh and Conover, 1986), and underused species such as searobins have limited potential to counter these trends. Our survey results, for New Jersey in particular, show that searobins are seasonally abundant in areas amenable to in-shore commercial and recreational fisheries during summer and autumn. Trawlers can also find large aggregations offshore during winter and spring. Searobins are also a large proportion of pound-net landings during summer, although this fishing method is now reduced in comparison with historical levels (McHugh and Conover, 1986). Striped searobins may be a more marketable species because they are larger on average. Efforts to expand the marketability of searobins, such as has occurred recently by selling them live in restaurants (Lynch¹), may lead to increased total landings and a more diverse fishery resource for the mid-Atlantic region.

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