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Interannual Variation In The Recruitment Pattern And Abundance Of Age-0 Summer Flounder, Paralichthys-Dentatus, In Virginia Estuaries

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Abstract.—Capture of transforming larval and newly settled juvenile (age-0) summer flounder, *Paralichthys dentatus*, over four years (1986–1989) in the seaside salt marshes of Virginia's Eastern Shore and in the lower Chesapeake Bay verifies Virginia waters as a nursery area. Gear specific for juvenile flatfish was used and sampling was conducted in a broad range of habitats in all months. This study demonstrates a fluctuation in the timing of the appearance and magnitude of abundance of age-0 summer flounder in Virginia waters over a four-year sampling period. Age-0 summer flounder (11–27 mm TL) began entering the area in October 1986 and were present throughout the winter of 1987. The 1988 and 1989 year classes did not appear until April at larger sizes (22–83 mm TL). Highest catch per unit of effort (CPUE) occurred between April and August and abundance declined in the fall. Data indicated that year-class strength declined from 1986 to 1988 and increased slightly in 1989. To monitor year-class strength of age-0 summer flounder, we recommend sampling Virginia estuaries in April, May, and June when both abundance of flounder is high and small-mesh-lined trawl gear is most efficient.

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Summer flounder, *Paralichthys dentatus* (Pleuronectiformes: Bothidae), is an important commercial and recreational species along the eastern coast of the United States. It ranges from Nova Scotia (Scott and Scott, 1988) to Florida (Gutherz, 1967) and its center of abundance occurs in the Middle Atlantic Bight (Scarlett, 1981). Though it is known that commercial landings of *P. dentatus* in the Middle Atlantic Bight fluctuate widely (Wilk et al., 1980), fluctuations in abundance of age-0 summer flounder have not been investigated. Because of the economic importance of summer flounder in Virginia, our first objective was to design a sampling plan based on the early life history of summer flounder to assess the relative yearly abundance of age-0 summer flounder in Virginia waters. This index will provide the fishing industry and fishery managers with knowledge of fluctuations before those fluctuations affect the fishery. A part of designing an effective sampling plan was evaluation of appropriate gear. Therefore, the second objective was to examine the effectiveness of sampling gear.

Age-0 *P. dentatus* have been captured in small numbers from Chesapeake Bay (Orth and Heck, 1980; Weinstein and Brooks, 1983) and the Eastern Shore of Virginia (Richards and Castagna, 1970). Poole (1966) hypothesized that Virginia waters and the sounds of North Carolina constitute primary nursery areas for summer flounder, but an insufficient number of specimens have been captured to substantiate this hypothesis. Recruitment and distribution patterns of age-0 summer flounder have been investigated in estuaries in North Carolina (Powell and Schwartz, 1977; Miller et al., 1984; Burke et al., 1991)

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and New Jersey (Able et al., 1990); however, the studies in Virginia reporting the capture of age-0 summer flounder were not directed specifically at this species (Richards and Castagna, 1970; Orth and Heck, 1980; Weinstein and Brooks, 1983). Thus the third objective of this study was to assess the region's importance as a nursery area.

Methods

Sampling sites were located on the seaside (eastern border) and bayside (western border) of Virginia's Eastern Shore and on the western shore of Chesapeake Bay (Fig. 1) because the Chesapeake Bay and Eastern Shore were hypothesized to be prime nursery grounds (Poole, 1966). The eastern border of the Eastern Shore peninsula is an extensive system of barrier islands enclosing salt marshes and shallow bays that are 1–2 m deep at mean high water (MHW). The bays and salt marshes are transected by main channels that are 3–20 m deep at MHW. On the western border of the peninsula, there are shallow creeks, 1–6 m deep at MHW, which extend into upland areas. Fringing and pocket marshes, much less extensive than the seaside salt marshes, occur along creek margins. Seagrass beds are present at the mouth of most creeks. The mouth of the York River (Fig. 1) is 3.7 km wide; it has extensive shoal areas along its margins and a main channel 18 m deep. Salt marshes, with channels 1–3 m deep, and seagrass beds are present in the shoal areas.

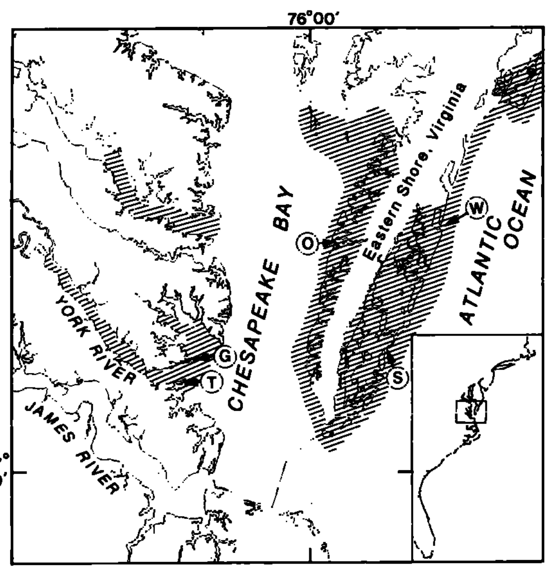

Figure 1
Locations of sampling sites for *Paralichthys dentatus* on Virginia's Eastern Shore and in Chesapeake Bay and its tributaries. Letters indicate sites with regular, fixed station sampling; shading indicates areas in which rivers, creeks, and nearshore locations were sampled during 1986 preliminary investigations and supplemental investigations in July 1987 and June 1988.

Between 1986 and 1989, three different types of 4.9-m semi-balloon otter trawls with 19.1-mm bar mesh in the wings and upper body were used to sample areas 1–11 m in depth. Only bar mesh sizes are noted in this paper. The first unlined trawl, used in 1986 and July 1987, had 6.4-mm mesh in the lower body and codend. We added a 3.2-mm mesh liner to the codend in September to capture the newly settled juveniles. Because ctenophores and jellyfish could clog the mesh, mesh sizes of the unlined trawl were increased to 19.1 mm in the lower body and to 15.9 mm in the codend in August 1987. To compare the sampling efficiency of the lined and unlined trawls, both trawls were towed at each station from September 1987 onward. All trawls were fished with a 4.8-mm link tickler chain to increase catches of flatfish (see Creutzberg et al., 1987).

Two 6.1-mm seines were used to sample shallow (<1 m) habitats. A beach seine (6.4-mm mesh) was used in April and May 1986 and a bag seine (3.2-mm mesh) was used from November 1986 until December 1988. A 3.2-mm link chain was attached to the leadline of both seines to increase catches of flatfish.

Trawling and seining were conducted from April 1986 to August 1989 during daylight hours (Norcross and Hata, 1990). While designing the study from April to August 1986, sampling was conducted at least once in most navigable waters of the Eastern Shore and at the mouth of the York River (Fig. 1). Over the next two years, September 1986–September 1988, samples were collected at fixed stations at five sites (Fig. 1): Wachapreague and Sand Shoal Channels, Occohannock Creek, and Guinea and Tue Marshes (also see Wyanski, 1990). At each site, deep (5–11 m) water stations were located in the middle of channels, whereas shallow (<5 m) water stations were situated along channel margins. All stations had sand or fine-grained substrates. Samples were collected semi-monthly from September 1986 through

August 1987, and at monthly intervals thereafter. During expected periods of peak age-0 summer flounder abundance in 1987 and 1988, additional samples were collected throughout the study area (Fig. 1).

Sampling was reduced spatially and further reduced temporally in 1989. Sampling was eliminated at Occohannock Creek, the site at which the fewest number of summer flounder were captured. Sampling was conducted April through August at the other four sites. Only trawling was continued.

We measured the total length (TL) of each summer flounder and used the length-frequency data to identify age-0 individuals. A birthdate of 1 January (Smith et al., 1981) was used when designating year class, although age-0 summer flounder may have been collected the preceding October through December. For each gear, data from all sampling efforts were pooled by month and by year class and catch per unit of effort (CPUE) was calculated as the mean number of age-0 summer flounder per 15-m seine haul or 5 minutes of trawl sample. To make sample sizes more similar among the treatment groups (year class) in statistical analyses, the 15-month time period over which a year class was sampled was separated into two time intervals: October–June and September–December. July and August data were not included in analyses because of bias produced by the clogging of meshes.

Some data were eliminated from statistical analyses owing to changes in the gear. Only seine data for the 1987 and 1988 year classes were compared because a different seine was used in 1986. Unlined trawl data for the 1986 year class were eliminated because the mesh size was smaller than in subsequent years. Because of nonrandom (fixed) station locations and nonindependent samples, nonparametric statistical tests were used to analyze the CPUE data. For each gear, the Mann-Whitney test or Kruskal-Wallis test was used to compare monthly CPUE values among years (Zar, 1984). If the null hypothesis in the Kruskal-Wallis test was rejected, a multiple comparison test (Dunn, 1964) was used to determine which means were significantly different. If P was <0.05, the results were considered significant.

Results

We were able to identify the age-0 year class for 15 months (October through December of the next year) using length frequencies from all four years of data combined (Fig. 2). Table 1 shows the application of these monthly size-at-age criteria to identify the age-0 specimens in individual years. Sizes ranged from 11 mm to the largest age-0 specimen of 285 mm. Little to no change in mean size was observed from October to May, whereas rapid size changes were apparent from June to September.

Though sampling effort and gear varied among years, age-0 summer flounder were caught within Virginia waters in each year of the study. Over the four years of sampling, age-0 *P. dentatus* were captured each month but not during every month of every year (Table 2). Summer flounder exhibited a prolonged period of recruitment to inshore waters as age-0 specimens were captured in Virginia estuaries from October to May (Table 2, Fig. 2). Newly settled specimens (<20 mm) were collected throughout the fall and winter of 1986–87; however, they were not collected in the fall and winter of 1987–88 and 1988–89. When age-0 specimens first appeared in April of 1988 and 1989, they were already >20 mm.

The highest CPUE values were reported for April through September (Table 2). Comparisons of CPUE

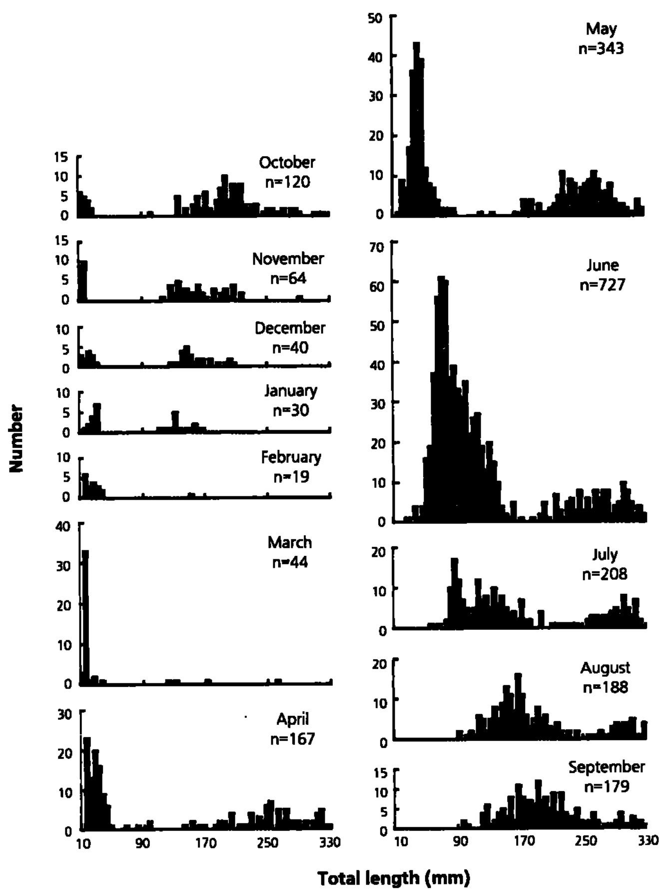

Figure 2

Combined monthly length frequencies of age-0 and age-1 *Paralichthys dentatus* in Virginia captured at all sites shown in Figure 1 from 1986 through 1989.

Table 1

Length ranges (mm) of age-0 summer flounder, *Paralichthys dentatus*, from all sites by year class for 15 months.

	1986 Year class	1987 Year class	1988 Year class	1989 Year class
Oct	—	11–27	—	—
Nov	—	13–19	—	—
Dec	—	14–32	—	—
Jan	—	17–34	—	—
Feb	—	17–38	—	—
Mar	—	14–27	—	—
Apr	26–69	15–48	22–83	36–41
May	22–60	21–80	24–32	17–88
Jun	54–140	27–160	35–160	35–144
Jul	96–190	68–180	86–180	57–160
Aug	30–220	93–240	115–210	90–210
Sep	96–265	147–275	176–222	—
Oct	100–285	170–265	172–245	—
Nov	119–218	—	—	—
Dec	131–185	168–209	—	—

data pooled over the five sampling sites for each of the three gear types showed a general pattern of reduced age-0 summer flounder abundance in Virginia estuaries between 1986 and 1988; there was a slight increase in 1989, based on trawl data (Table 3). The CPUE of the seine and the unlined trawl decreased an order of magnitude per year from 1986 to 1988.

Twice as many summer flounder (101 vs. 54) were captured in seven seine hauls in April and May 1986 as in 527 seine hauls over the next two years (Table 3). For October–June data, CPUE in seine hauls was significantly greater in 1987 than in 1988 (Table 4) as no *P. dentatus* were captured in 1988. Seining, though successful in 1986, did not yield many age-0 flounder in 1987–1988 (Tables 2 and 3), and thus was discontinued.

The unlined trawl data revealed no significant differences in CPUE between years (Table 4). We did not include 1986 unlined trawl data in analyses, but the high CPUE values for this gear type in May and June provided additional evidence that abundance was greater in 1986 compared with 1987–1989.

The lined trawl data for October–June revealed significant differences in CPUE among years (Table

Table 2

Catch per unit of effort (CPUE) of age-0 summer flounder, *Paralichthys dentatus*, by year class for 15 months from all sites. Seine CPUE = number of age-0 flounder/15 m haul; trawl CPUE = number of age-0 flounder/5 min; — = no of sample taken.

	1986 year class (1985–86)			1987 year class (1986–87)			1988 year class (1987–88)			1989 year class (1988–89)		
		Trawl			Trawl			Trawl			Trawl	
Month	Seine	Lined[1]	Unlined[2]	Seine[3]	Lined[1]	Unlined	Seine[3]	Lined[1]	Unlined[4]	Seine[3]	Lined[1]	Unlined[4]
Oct	—	—	—	—	0.03	—	0	0	0	0	0	0
Nov	—	—	—	0.08	0.36	—	0	0	0	0	0	0
Dec	—	—	—	0.24	0.16	—	0	0	0	0	0	0
Jan	—	—	—	0.13	0.14	—	0	0	0	—	—	—
Feb	—	—	—	0.13	0.21	—	0	0	0	—	—	—
Mar	—	—	—	0.29	0.50	—	0	0	0	—	—	—
Apr	16.60[5]	—	—	0.79	0.75	—	0	0.05	0	—	0.06	0
May	9.00[5]	—	13.81	0.33	1.51	—	0	0.13	0	—	1.14	0.29
Jun	—	—	4.08	0.04	3.98	—	0	0.06	0.06	—	3.27	2.00
Jul	—	—	2.01	0.17	3.84	1.38[2]	0	0.14	0.18	—	1.88	2.00
Aug	—	—	3.70	0.08	—	0.96[4]	0	0.26	0.37	—	0.71	1.28
Sep	—	0.87	—	0	0.29	0.65[4]	0	0.22	0.61	—	—	—
Oct	—	0.69	—	0	0.42	1.65[4]	0	0.35	0.43	—	—	—
Nov	0[3]	0.56	—	0	0	1.00[4]	0	0.13	0	—	—	—
Dec	0[3]	0.31	—	0	0	0.17[4]	0	0	0	—	—	—

[1] Semi-balloon otter trawl (3.2-mm mesh liner).
[2] Semi-balloon otter trawl (6.4-mm mesh).
[3] Bag seine (3.2-mm mesh).
[4] Semi-balloon otter trawl (15.9-mm mesh).
[5] Beach seine (6.4-mm mesh).

4); CPUE was higher in 1987 than in 1988. No other differences were detected. For September–December data, there were no significant differences in CPUE among the 1986, 1987, and 1988 year classes (Table 4).

Gear efficiency changed as fish size increased. The unlined trawl with 15.9-mm mesh in the codend produced generally lower CPUE values than the lined trawl during April through June (Table 2). As the age-0 specimens increased in size, the CPUE values for the unlined trawl became higher than those for the lined trawl.

Discussion

The prolonged time of age-0 summer flounder recruitment to the inshore waters of Virginia is more extended than entry times for North Carolina waters where age-0 *P. dentatus* enter estuaries from December through April (Deubler, 1958), January through April (Burke et al., 1991), or February through April (Warlen and Burke, 1990). October through May recruitment to Virginia also agrees with reports of transforming larvae of *P. dentatus* (≤20 mm TL) entering New Jersey inlets from October through May (Able et al., 1990). Age-0 summer flounder were not collected from October through May during all years of our study. They may appear in the fall or winter but often are not evident until April. Similar variation in timing of and size at first collection was reported in New Jersey, where age-0 flounder (<50 mm) were collected in the fall and during May but only occasionally during the winter months (Able et al., 1990). Thus, appearance of summer flounder in Virginia estuaries seems to be more similar to that of New Jersey (fall and late spring) rather than to that seen in North Carolina (winter and early spring). The time of first entrance in New Jersey, Virginia, and North Carolina estuaries corresponds with spawning periods of September–December north, and November–

Table 3

Summary of collection data from all sites by year class for age-0 *Paralichthys dentatus*: number of 15-m seine hauls, number of age-0 flounder captured, seine catch per unit of effort (CPUE) = number of age-0 flounder/haul, number of trawl tows, total minutes tow time for lined and unlined trawls, number age-0 flounder captured, trawl CPUE = number of flounder/5 min tow.

	Year class			
	1986	1987	1988	1989
Seine				
Number of hauls	46	295	232	0
Number of flounder	108	54	0	0
CPUE	1.20	0.18	0.00	—
Lined Trawl				
Number of tows	282	739	320	93
Number of minutes	1410.0	3664.5	1578.5	426.0
Number of flounder	192	670	30	96
CPUE	0.68	0.91	0.10	1.13
Unlined Trawl				
Number of tows	125	206	334	94
Number of minutes	613.8	1015.5	1657.8	467.0
Number of flounder	436	192	33	97
CPUE	3.55	0.94	0.10	1.04

Table 4

Summary of statistical tests used to compare catch per unit of effort (CPUE) for *Paralichthys dentatus* between years for various gear and time intervals. H_0 = the null hypothesis; U = Mann-Whitney (MW) statistic; H = Kruskal-Wallis (KW) statistic; Q = multiple comparison statistic (Dunn, 1964); df = degrees of freedom; * = significant results at 0.05 level of significance.

Gear	Months	H_0	Statistic	P	Test
Seine	Oct–Jun	1987=1988	U=72*	<0.001	MW
Unlined trawl	Oct–Jun	1988=1989	U=34	>0.20	MW
Unlined trawl	Sep–Dec	1987=1988	U=14	0.10<P<0.20	MW
Lined trawl	Oct–Jun	1987=1988=1989	H=10.310* df=2	0.005<P<0.01	KW
		1987=1988	Q=3.22*	0.002<P<0.005	MC (D)
		1987=1989	Q=1.64	0.2<P<0.5	MC (D)
		1988=1989	Q=1.21	P>0.5	MC (D)
Lined trawl	Sep–Dec	1986=1987=1988	H=5.734 df=2	0.05<P<0.10	KW

February south, of Chesapeake Bay as suggested by Smith (1973).

There are several possible explanations for the interannual differences in timing of recruitment to the inshore waters and size at first collection: 1) abundance is so low in some years that age-0 fish are not encountered; 2) newly settled summer flounder are utilizing habitats that were not sampled; and 3) summer flounder juveniles do not enter estuaries at the same time and size in all years.

The first explanation seems plausible for the 1988 year class which apparently had no October 1987–March 1988 recruitment and extremely low numbers in summer (Table 2). However, there also was no October–March recruitment in 1988–89, yet abundance indices in May–August 1989 were comparable to those in 1987, a year with October–May recruitment. We sampled a limited number of fixed sampling sites, thus in years of relatively low abundance, an uneven distribution of the fish would appear as though recruitment did not occur.

Newly settled summer flounder may be utilizing certain habitats which were not sampled because of location or gear accessibility. Habitats, such as eelgrass beds, would be difficult to sample with trawl and seine gear (Able et al., 1990) and therefore the flounder would be unavailable to the gear. Newly recruiting summer flounder are most abundant in marsh creeks in New Jersey (Szedlmayer et al., 1992). In some years of our study, the flounder could have been present in eelgrass beds or marsh creeks that we did not sample. From our data, it would then appear as if winter recruitment had not taken place.

Recruitment of summer flounder juveniles may not be represented by a characteristic place, time, and size of fish. Able et al. (1990) suggested that some juveniles utilize the continental shelf as a nursery and thus enter estuaries at a larger size. This could explain the apparent lack of fall/winter recruitment that we observed in the 1988 and 1989 year classes. Variability in time of recruitment to inshore waters of Virginia observed over the three years of fall/winter sampling in this study is analogous to that in New Jersey waters. Newly recruiting summer flounder were collected in southern New Jersey estuaries from November 1988 through May 1989, but no summer flounder juveniles were collected in the corresponding months of 1987 and 1988 (Szedlmayer et al., 1992).

Variation of year-class strength in fish populations has been a topic of investigation since it was first proposed by Hjort (1914), but fluctuations in year-class strength must be identified before causes of the variation can be investigated. Four years of sampling did not provide sufficient data to define a "normal" level of recruitment; however, it appears that there was relatively poor recruitment of age-0 summer flounder to Virginia waters in 1988 compared with 1986, 1987, and 1989 (Tables 2 and 3), suggesting that there was large interannual recruitment variability. This decrease in year-class strength was verified by catches of age-1 summer flounder in Chesapeake Bay and nearshore coastal waters one year later (Desfosse et al.[1]). The highest CPUE values for the seine and trawls occurred in spring 1986, suggesting that the 1986 year class was possibly the strongest of the four year classes. Given the larger mesh size in the seine and unlined trawl in spring 1986, these high CPUE values are probably underestimates when compared with CPUE values for the seine and lined trawl in 1987–89.

We cannot speculate what effect poor year-class strength of summer flounder will have on the fishery two to four years later because it is not known what percentage of the fishable population is dependent on Virginia nursery areas. If Virginia waters are a primary nursery area, the impact to the fishery could be great. Because our data and those of Desfosse et al.[1] documented poor year classes in 1987–89, the Virginia Marine Resources Commission (VMRC) closed the nearshore (<3 miles) trawl fishery for summer flounder effective 1 July 1989 (Travelstead[2]) as a precautionary measure to protect those year classes.

Estimation of summer flounder juvenile recruitment is biased by small-scale distribution patterns, mesh size, and gear performance under certain conditions. Gear efficiency changes with size of fish. The 3.2- and 6.4-mm mesh seines and trawls used in our study captured smaller specimens in the winter and spring than did the 15.9-mm mesh trawl, but these gear become less efficient with increasing fish size, probably due to increased gear avoidance. Despite similar mesh sizes, the sampling effectiveness of the bag seine decreased more rapidly than did the lined trawl, probably because of the movement of age-0 summer flounder to deeper habitats at 60–80 mm TL (see Wyanski, 1990). No age-0 summer flounder were captured by seine later than August. We agree with Williams and Deubler (1968) that environmental factors, such as current velocity and mechanical clogging of nets, can also have a pronounced effect on sampling success for flounder. We found that gear efficiencies depend on season (e.g. density of jellyfish) and size of flounder.

[1] Desfosse, J. C., J. A. Musick, A. D. Estes, and P. Lyons. 1989. Stock identification of summer flounder (*Paralichthys dentatus*), in the southern Mid-Atlantic Bight. Virginia Inst. Mar. Sci., Gloucester Point, VA 23062. Ann. Prog. Rep. WB-86-01-03.

[2] Travelstead, J. VMRC, Newport News, Virginia 23607. Personal commun., June 1989.

To develop an index to monitor interannual variation in year-class strength of summer flounder, we suggest sampling in Virginia estuaries during April, May, and June with a small mesh (e.g. 3.2 mm) lined beam trawl. Beam trawls (Kuipers, 1975; Kuipers et al., 1992) have been found to be more effective at capturing flatfishes than have otter trawls (Gunderson and Ellis, 1986) which were used in this study. We recommend using a beam trawl with tickler chains to increase catch, particularly on sand or fine-grained sediment. Diver observations and catch comparisons of flatfishes by beam and otter trawls in Alaskan waters (Norcross, unpubl. data) support this recommendation.

Though summer flounder can be captured through October (Fig. 2), the fish are larger but fewer from July to October. This pattern of increasing densities during the period of settlement, followed by a continuous decrease has also been observed in plaice (*Pleuronectes platessa*) in the North Sea (Veer et al., 1990). Thus we recommend sampling during the period of increasing densities, because later in the season low numbers of captured individuals reduce the sensitivity of the catch data to reflect year-class strength.

Data presented here support the hypothesis of Poole (1966) that Virginia waters are a nursery ground for summer flounder. Variation in CPUE during the four years of our study makes it difficult to conclude that this area is a "primary" nursery during all years.

In addition to Virginia, summer flounder use areas in New Jersey (Szedlmayer et al., 1992), Delaware (Malloy and Targett, 1991) and North Carolina (Burke et al., 1991) as nursery grounds. The same sample gear and strategy need to be used throughout the range of summer flounder (New Jersey to North Carolina) to compare the relative importance of specific locations as nursery areas. A multi-year study combined with sampling over a finer spatial scale would allow interannual variation in primary nursery locations to be determined.

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