Abstract.–Smooth dogfish, *Mustelus canis*, were collected with weirs, seines, gill nets, trawls, and by hook and line from 1988 to 1990 in the Little Egg Harbor–Great Bay estuary of southern New Jersey to determine their foraging habits, growth, and seasonal, tidal, and diel patterns of abundance. Young of the year (YOY) were collected from May to October, with apparently newborn individuals dominating catches from May to July. Subadult and adult individuals were rare. Young of the year reached 550–700 mm total length (TL) by October, growing an estimated 1.9 mm TL/day and 6.0 g/day. Tidal and diel patterns suggest that smooth dogfish use shallow shoal and marsh creek habitats primarily during night hours. High catches during flood tides also suggest increased activity at that time. A comparison of abundance patterns among gears suggests that marsh creeks may be particularly important to newborn individuals during June–July. From an analysis of sex ratio patterns, young of the year do not appear to aggregate by sex or exhibit different emigration patterns between sexes. Smooth dogfish YOY feed primarily on small shrimps, *Crangon septemspinosa* and *Palaemonetes vulgaris*, polychaete worms, and the crabs *Callinectes sapidus*, *Libinia* sp., and *Ovalipes ocellatus*. The abundance of YOY within the estuary strongly suggests that estuaries are critically important nursery habitats for smooth dogfish within the Mid-Atlantic Bight.

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Seasonal abundance, growth, and foraging habits of juvenile smooth dogfish, *Mustelus canis*, in a New Jersey estuary*

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The smooth dogfish, *Mustelus canis*, is one of the most abundant inshore sharks in the western Atlantic (Smith, 1907; Bigelow and Schroeder, 1948, 1953; Hoese, 1962; Compagno, 1984). Despite its abundance, little ecological information, other than anecdotal accounts of growth, and seasonal and life history patterns, is available (Castro, 1983; Compagno, 1984). The most comprehensive accounts of smooth dogfish are found in two summaries by Bigelow and Schroeder (1948, 1953); however, little data on distribution, length frequency, or reproduction are presented in these general descriptive accounts. Food habits have been examined by Field (1907) and Breder (1921). Several studies have examined physical aspects of reproduction (Fowler, 1918; TeWinkel, 1950, 1963, 1964; Graham, 1967; Gilbert and Heath, 1972; Hisaw and Abramowitz[1]), other physiology and behavior (Parker, 1909, 1913; Ifft and Zinn, 1948; Clark, 1963; Gilbert, 1963) and growth (Moss, 1972; Francis, 1981). Although a small fishery for smooth dogfish has grown in recent years, with landings in excess of 780,000 lb and valued at over $100,000 during 1992,[2] the greatest value in smooth dogfish has probably been its extensive use as a subject for research in medical physiology, morphology, and molecular biology (e.g. Greig, 1977; Kalmijn, 1977; Hodgson and Mathewson, 1978; Casterlin and Reynolds, 1979, a and b; Bartlett, 1982; Barry et al., 1988).

In this study we examine aspects of smooth dogfish habitat during that part of the first year of life when estuaries are used as nurseries. More specifically, we collect data with a variety of gears within an estuary of southern New Jersey to determine seasonal abundance and habitat use patterns, growth, and food habits of smooth dogfish.

* Contribution 96-12 from the Institute of Marine and Coastal Sciences, Rutgers University, New Brunswick, New Jersey 08903.

[1] Hisaw, F. L., and A. A. Abramowitz. 1937. The physiology of reproduction in the dogfish, *Mustelus canis*. Annual Rep., Woods Hole Oceanogr. Inst. 1937: 21–22.

[2] Fishery Analysis Div., Fisheries Information Section, National Marine Fisheries Service, Gloucester, MA.

Materials and methods

Study area

The study was conducted in polyhaline (22–33‰) sections of the Little Egg Harbor–Great Bay estuary in southern New Jersey during 1988–90 (Fig. 1). Primary sampling was conducted within tidal marsh creek and adjacent bay shoal habitats with several gear types (Table 1). The four primary study creeks (Schooner, New, Foxboro, and Story Island creeks) were approximately 1.0 km long blind cul-de-sacs that received fresh water only through local runoff (Fig. 1). Story Island Creek was intertidal except for a shallow (<0.5 m) subtidal cove formed at the mouth at low tide. The other three creeks were subtidal with maximum depths of 0.5–2.0 m at low tide. All creeks had a mud substrate and were located 1.3–2.9 km from Little Egg Inlet (for a more complete description of the study creeks see Rountree [1992]). The marsh creeks are typically separated from the adjacent bay by a shallow sill formed at the creek mouth. Beyond the sill, Story Island and Foxboro creeks emptied onto extensive bay shoals (<2 m at high tide) bordering the relatively deep (4–9 m at high tide) Marshelder Channel (Fig. 1). In contrast, New and Schooner creeks each emptied directly into deep channels (Fig. 1).

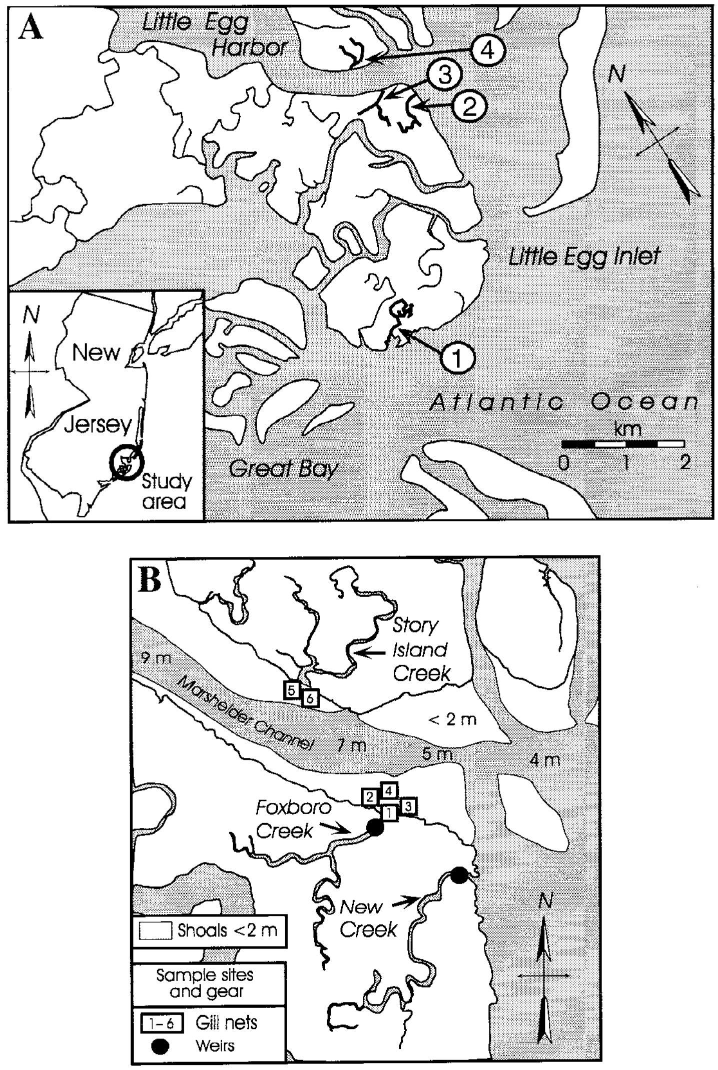

Figure 1

(**A**) Little Egg Harbor–Great Bay estuary indicating the location of four marsh creek (1=Schooner, 2=New, 3=Foxboro, and 4=Story Island) sampling sites for smooth dogfish, *Mustelus canis*. (**B**) Detail of the primary sampling area including Foxboro, Story Island, and New creeks. Gill-net sites include the mouth of Foxboro (net 1) and Story Island (nets 5 and 6) creeks, and the shallow bay shoals adjacent to Foxboro Creek (nets 2–4).

Sampling techniques

The creeks were sampled with weirs, seines, and gill nets (Table 1). Shallow bay shoal habitats adjacent to Foxboro and Story Island creeks were sampled with gill nets and hook and line (Fig. 1). Additional data were derived from extensive trawl collections made in many habitats throughout the estuary, including other marsh creeks and Marshelder Channel in the vicinity of Foxboro Creek (Szedlmayer et al., 1992; Szedlmayer and Able, in press).

Weir and seine sampling For each sampling event, a temporary weir was erected at high tide approximately 30 m above the creek sill. The creek was blocked off entirely by two wing nets (15.2 m × 3.0 m; 6.4-mm mesh) that ran at an angle from each creek bank to a weir (1.2 m wide × 3.0 m long × 3.0 m high; 6.4-mm mesh) located in the center of the creek channel. Deployment of the weir and wings began about 30 min before slack high tide and was completed within 1 h. Fish moving out of the creek with the ebb tide were led along the wings into the weir, where they were trapped by two sets of internal doors. Live fish were removed from the weir at low tide through a codend after raising the weir above the water line. The weir was removed from the creek after each sampling event.

In an effort to capture fish that did not move into the weir during the ebb tide, seine samples were taken at low tide (immediately prior to hauling the weir) within the approximately 100-m^2 triangular area enclosed by the wings. See Rountree and Able (1992) for a more complete description of the weir and seine sampling methods.

Intensive weir and seine sampling was conducted approximately fortnightly from April to November 1988 in Schooner and Foxboro creeks and from April to October 1989 in Schooner, Foxboro, and New creeks (Table 1). During 1988, consecutive day and night tides were sampled within each creek, whereas only night tides were sampled during 1989. Day and night tides were those in which at least the last two hours of flood occurred after sunrise or sunset, respectively. During 1988 and 1989 all creeks were sampled within a three-d period during each sampling week.

Gill-net sampling Standardized gill-net sampling at fortnightly intervals was conducted during May and July–November 1990 with six gill nets (23 m long × 1.8 m high; 38-mm^2 mesh; Table 1). One net was set on the sill at the mouth of Foxboro Creek, and three were set in the shallow bay shoals adjacent to the creek. Two additional nets were set in the mouth of Story Island Creek (Fig. 1). The first gill net was stretched across the mouth of Foxboro Creek so as to block fish passage completely. However, at Story Island Creek two nets were stretched across the creek mouth but did not completely block the creek entrance. Gill nets were deployed at night between 1600–2200 h at either high or low tide and were checked 2–6 times until 0900–1100 h the next day. Catches of smooth dogfish were standardized by catch per unit of effort (CPUE) which was determined "as the number of fish captured in a net check divided by the time elapsed since the previous check (expressed as number/net hours)." Sampling effort was similar on ebb and flood tides (298 and 252 net h, respectively; Table 1). These data were supplemented with data from irregular gill-net collections made on four dates during 1988 and on two dates during 1989 within either Foxboro or Schooner creeks (Table 1).

Other sampling Irregular collections with hook and line were made in the immediate vicinity of Foxboro Creek, although some collections were made in other areas of the bay (Table 1), and standardized otter-trawl tows (4.9-m opening, 19-mm-mesh wings, 6.3-mm-mesh liner) were made during the day at 13 locations throughout the Little Egg Harbor–Great Bay

Table 1

Sampling effort and size ranges of smooth dogfish, *Mustelus canis*, collected in the Little Egg Harbor–Great Bay estuary of southern New Jersey during 1988–90.

Gear	Year	Sampling period	Sampling effort	Young-of-the-year total length (mm)				Other total length (mm)			
				Mean (SE)	Min	Max	*n*	Mean (SE)	Min	Max	*n*
Weir	1988	Apr–Nov, fortnightly (day and night)	42 sets	421 (5)	285	539	68	— (—)	—	—	—
	1989	Apr–Oct, fortnightly (night)	27 sets	388 (9)	299	545	37	627 (—)	627	627	1
Seine	1988	Jul–Nov, fortnightly (day and night)	32 hauls	422 (7)	369	453	12	— (—)	—	—	—
	1989	Apr–Oct, fortnightly (night)	25 hauls	387 (29)	320	481	6	— (—)	—	—	—
Gill net	1988	Jun–Sep (irregular)		400 (11)	318	462	14	945 (131)	728	1,180	3
	1989	Aug–Sep (night)	138 h[1]	499 (12)	366	604	22	— (—)	—	—	—
	1990	May, Jul–Nov, fortnightly (night)	550 h	520 (3)	389	699	448	825 (68)	592	1,025	8
Hook-and-line	1988	Jun–July (day and night)	2 dates	473 (11)	418	515	9	1,123 (39)	1,070	1,200	3
	1989	Jun–Sep, irregular (day and night)	5 dates	380 (6)	321	517	48	— (—)	—	—	—
	1990	May–Jun, irregular (day and night)	7 dates	397 (7)	325	460	33	996 (158)	715	1,260	3
Otter trawl	1988	June–Dec, monthly (day)	342 tows	429 (9)	380	472	11	1,156 (11)	1,126	1,220	7
	1989	Jan, Mar–Jun, Sep–Oct, monthly Jul–Aug, fortnightly (day)	563 tows	419 (19)	371	522	7	— (—)	—	—	—
	1990	Apr–Dec, monthly (day)	560 tows	355 (11)	326	379	5	— (—)	—	—	—

[1] Total number of hours fished summed over all nets.

estuary (Table 1). Four replicate 2-min tows were made at each location. One of the trawl stations was located in Marshelder Channel in the vicinity of Foxboro and Story Island creeks. Trawl samples were collected monthly, except for fortnightly sampling during July, August and September 1989 and 1990 (Szedlmayer et al., 1992; Szedlmayer and Able, in press).

Sex ratio patterns

The sex ratio (percent female and male) was determined for each net check in which at least three fish were collected. The sex ratio of smooth dogfish observed at each net check was used as a proxy for the sex ratio of smooth dogfish schools. If this assumption is valid, then significant deviations from equal proportions would suggest that schools segregate by sex. We also tested for temporal changes in sex ratio, which would suggest differential timing of seasonal movements by sex. Deviations from expected ratios were tested by chi-square analysis (SAS Institute, Inc., 1988).

Growth rate

Temporal trends, and differences between sexes in absolute growth rates were estimated by linear regression of fish size on date of capture. Length outliers from each sampling period, which were assumed to represent age-1 or older individuals from an examination of length-frequency distributions (Table 1; Fig. 2), were removed prior to the regression. An-

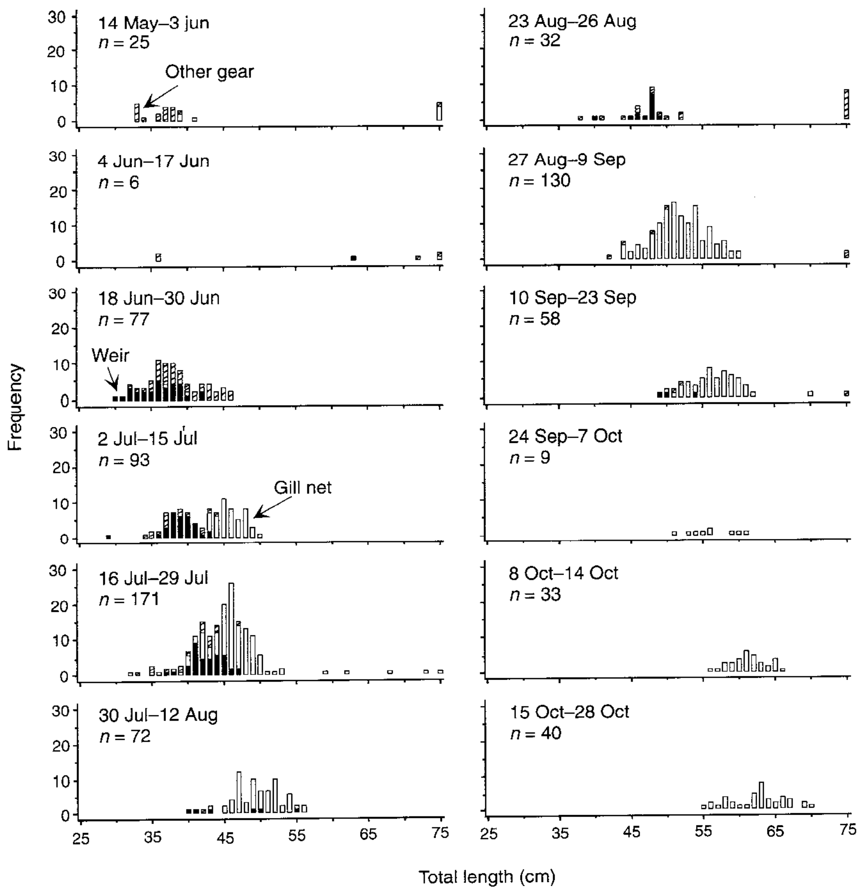

Figure 2

Total length (TL) frequency distribution of smooth dogfish over fortnightly sampling periods, based on data pooled over all years (1988–90) and sampling gears (weir, seine, hook and line, otter trawl, and gill net). Solid bars indicate weir or seine samples, open bars indicate gill-net samples, and striped bars indicate combined hook-and-line and otter-trawl samples. All individuals >75 cm TL are lumped into the 75-cm size class.

nual and sex-stage effects on growth rates were tested with an Analysis of Covariance (ANCOVA) with the following model:

Length = Year Sex Year*Sex Date Year*Date Sex*Date Year*Sex*Date,

with the SAS GLM procedure (Freund et al., 1986; SAS Institute Inc., 1988), where year and sex are class variables and date is a covariate. The test of the main effects (year and sex) represents a test for differences in y-intercepts, whereas the test of the interaction with the covariate represents a test for heterogeneity of slopes (Freund et al., 1986). Growth in terms of body weight was similarly tested.

Habitat use patterns

A statistical comparison of smooth dogfish abundances among marsh creeks was made by using an ANOVA, based on night-time weir sampling in Foxboro, Schooner, and New creeks conducted during 1989. We previously reported a comparison between day and night abundances of smooth dogfish in Foxboro and Schooner creek sampling during 1988 as part of a study of diel variation in marsh creek faunal composition (Rountree and Able, 1993). Descriptive statistics, based on night-time gill-net sampling in 1990, were used to compare catches between marsh creek and adjacent bay shoal habitats as well as between ebb- and flood-tide stages. Because time of day, tide stage, and seasonal effects could not be partitioned in the 1990 gill-net sampling, no attempts were made to statistically test hypotheses of habitat or tide stage differences in catches. For example, gill-net sampling was biased between habitats because nets stretched across creek mouths were presumably more efficient than those placed in the open bay. Additionally, because tide and diel cycles are not correlated, sampling on flood and ebb tides were sometimes conducted weeks apart (i.e. it was impossible to sample on both flood and ebb tides at the same location and time).

Foraging habits

Smooth dogfish collected in 1988–90 during gill-net, hook-and-line, and trawl sampling were measured live, packed in ice, and transported to the laboratory for freezing. Because of the large number of smooth dogfish captured during 1990 gill-net sampling, a subsample of at least three fish was retained from each net check for food habit analysis. The remaining fish were tagged and released. The released fish were tagged to prevent bias in the catch estimated from recaptures. Fish were tagged just posterior to the first dorsal fin with individually coded yellow T-bar anchor tags (total tag length, 40 mm; Hallprint Pty. Ltd., Holden Hill, South Australia). Because no tagged individuals were recovered during our gill-net sampling, CPUE adjustments were not necessary.

In the laboratory, thawed smooth dogfish were remeasured and weighed prior to stomach removal. The total stomach contents were then weighed and the prey items were identified to the nearest taxon, enumerated, and weighed (wet WT). An index of gut fullness (%full) that incorporates body weight rather than gut capacity (Hyslop, 1980) was calculated as

$$\%full = [(prey\ WT)/(total\ body\ WT - total\ gut\ WT)] \times 100,$$

where *prey WT* = the weight of a given prey species (or sum of all prey species);
total body WT = the total weight of the smooth dogfish; and
total gut WT = the weight of the entire gut contents (excluding the stomach itself).

Tidal and temporal (hour of the night) effects on stomach, large intestine, small intestine, and total digestive tract fullness were examined from 1990 gill-net samples. After having been thawed in the laboratory, the entire digestive tract was excised and sectioned into stomach, large intestine (spiral valve), and small intestine (colon and rectum). The total contents of each section, as well as the total for all sections combined, were then weighed. After pooling data from all collections for each tide stage, hourly mean fullness values were calculated for each gut section separately, as well as for the total. The effect of tide stage (ebb vs. flood) on gut fullness indices was tested separately for each section of the digestive tract and for the total digestive tract, with analysis of variance (ANOVA; Sokal and Rohlf, 1981). Use of the fullness index, described above, allowed us to reduce bias due to variation in dogfish size in the ANOVA. The data were arcsine-square-root transformed prior to analysis.

Results

Life history stages and seasonal abundance patterns

Most smooth dogfish collected in the study area were YOY according to size at date of capture (Fig. 2) and according to an assumed length of 80–90 cm at maturity (Castro, 1983; Compagno, 1984). A total of 720 YOY and 25 subadult (60–80 cm) to adult (80–130 cm TL) smooth dogfish were collected (Table 1). A single well-defined size cohort of YOY dominated catches on the basis of data pooled over all years and gears (Table 1; Fig. 2). The smallest individuals (<40 cm) collected during May, June, and early July had fresh umbilical scars. Although adults were not abundant, they were collected from May to September. Their relative rarity, however, may have been due to gear avoidance, because we frequently observed adults during night flood tides in the shallow bay in the vicinity of Foxboro and Story Island creeks from May to July. Additionally, on several occasions we observed adults that repeatedly came into contact with gill nets without becoming entangled. A few intermediate-size individuals (60–70 cm TL) were collected in June, July, and September. These individuals appeared to be small subadults from their length at date of capture (more strikingly, they were far more robust than the YOY and lacked umbilical scars) and were excluded from the growth analysis for the YOY.

The occurrence of YOY in the study area was highly seasonal. They appeared first in May and apparently left the study area by November (Figs. 3 and 4). The timing of fall migration out of the estuary was well defined by their absence in weir, gill-net, and trawl samples during November. The first appearance of YOY during the spring, however, was less well defined because of the lack of gill-net sampling during this period, despite their absence in April weir and seine sampling as well as January–April trawl sampling. Young of the year were abundant in weir and seine collections only during June and July (Fig. 3).

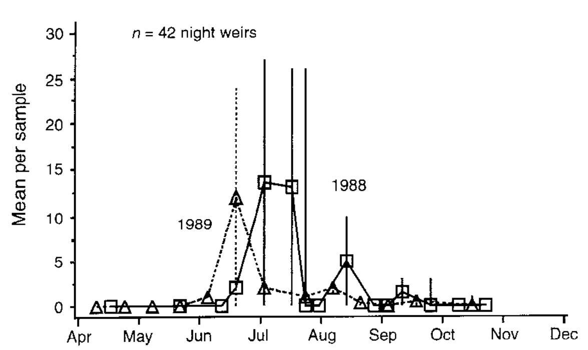

Figure 3

Seasonal abundance of smooth dogfish, based on night weir samples pooled from three subtidal marsh creeks (Foxboro, New and Schooner) during 1988 and 1989 (vertical lines represent one standard error about the mean). Smooth dogfish were absent from day weir samples.

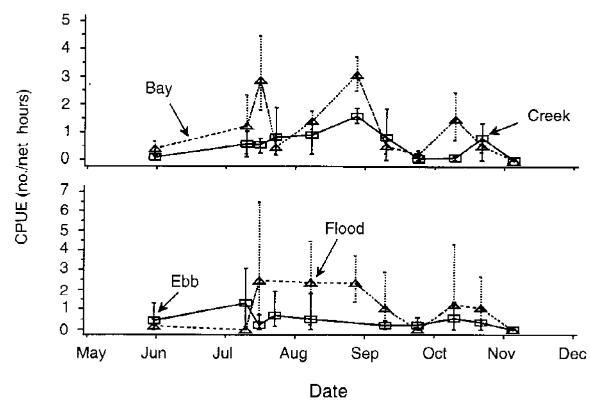

Figure 4

Seasonal abundance (CPUE expressed as the mean number per hour per net) of smooth dogfish collected with gill nets set in marsh creeks and in the adjacent shallow bay during 1990. Data are grouped by habitat (top) and tide stage (bottom) for comparison. Vertical lines are ranges.

In contrast, they were collected regularly in gill-net samples from both the bay shoal and marsh creek sill locations from June through October (Fig. 4). Peak CPUE in gill-net sampling occurred from July to August. Young of the year collected by weir tended to be smaller than those collected by other gears during June–August (Fig. 2). No tagged (n=138) YOY were recaptured during our sampling; however, two individuals were recaptured off North Carolina the following winter: one inshore near Cape Fear, North Carolina, in December 1990 and a second off the beach at Cape Hatteras, North Carolina, in March 1991.

Sex ratio

Sex ratios of the YOY did not differ significantly from 1:1, averaging 51.8 % (standard error [SE]=2.8) females per net check (n=55 net checks with three or more fish). No significant temporal effect on sex ratio was observed.

Growth

Young of the year exhibited a very rapid growth rate of 1.9 mm TL/day, or 6.0 g/day (Table 2), and reached 550–700 mm TL by the end of October (Fig. 2). There was a significant annual affect on growth rates for both length and weight (i.e. the slopes were not homogeneous among years; ANCOVA, $P \leq 0.0001$; Table 2; Fig. 5). No effect of sex on growth was observed (Table 2; Fig. 5). Because the slopes were heterogeneous among years, differences in intercepts among years could not be tested; however, a significant dif-

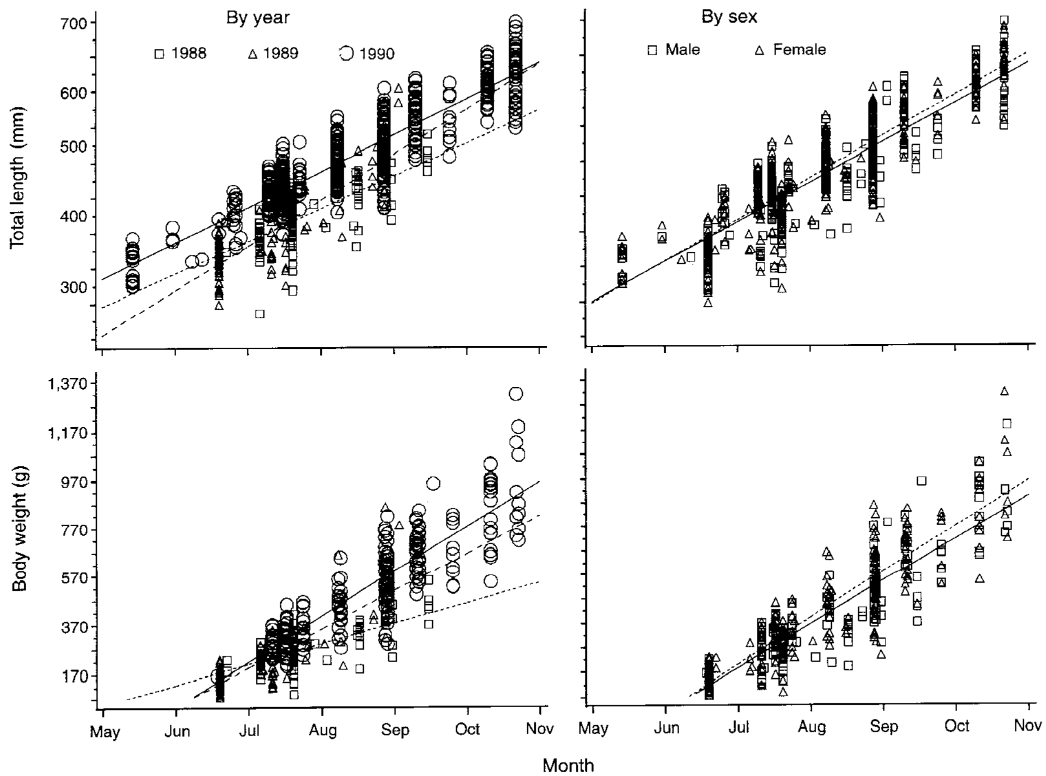

Figure 5

Comparison of total length (TL) and body weight (WT) growth rates of smooth dogfish by sampling year and sex. Linear regression parameter estimates and statistics are given in Table 2.

Table 2

Growth rates of young-of-the-year smooth dogfish collected from the Little Egg Harbor–Great Bay estuary of southern New Jersey between 1988 and 1990, estimated by linear regression of total length and body weights on dates of capture. All parameter statistics are significant at $P \leq 0.0001$.

	Length (mm TL/d)			Weight (g/d)		
	Slope (SE)	r^2	n	Slope (SE)	r^2	n
Year[1]						
1988	1.51 (0.14)	0.50	114	2.70 (0.28)	0.47	103
1989	2.09 (0.11)	0.74	120	5.08 (0.31)	0.73	101
1990	1.66 (0.04)	0.82	486	6.04 (0.24)	0.76	208
Sex[2]						
Male	1.84 (0.05)	0.78	345	5.78 (0.22)	0.80	181
Female	1.93 (0.05)	0.79	329	6.20 (0.23)	0.78	196
Pooled	1.91 (0.04)	0.78	720	6.01 (0.15)	0.79	412

[1] Growth rates are highly significantly different among years (ANCOVA, $P \leq 0.0001$) for length and weight.
[2] Samples sizes are lower because sex was not determined for some individuals during 1988. Growth rates are not significantly different between sexes.

ference in the y-intercepts between sexes was observed for weight (ANCOVA, $P \leq 0.001$; Fig. 5), suggesting that females may have been born slightly heavier (approx. 42 g) than males. A highly significant length-weight relationship was obtained (Fig. 6). No differences in the length-weight relationship were found between sexes.

Habitat use patterns

Habitat type (tidal creek versus adjacent bay shoals), time of night, and tide stage (ebb versus flood) had a strong effect on CPUE of smooth dogfish in gill-net collections (Figs. 4 and 7). Most smooth dogfish were captured on flood tides (Fig. 4), with flood tide CPUE averaging 1.1 fish/net h (SE=0.2), and ebb tide CPUE averaging 0.5 fish/net h (SE=0.1). Catches were greatest at 2100 h (3 fish/net h) and declined sharply by 0300 h (<0.6 fish/net h), and dropped to near zero by 0600 h (Fig. 7). Catches tended to be greater in the bay shoal habitat than at the creek sills (Fig. 4), with CPUE averaging 1.2 fish/net h (SE=0.2) and 0.6 fish/net h (SE=0.1), respectively. Abundance of YOY in weir samples varied significantly ($P \leq 0.5$) among Foxboro, Schooner, and New creeks, averaging 3.7, 0.3, and 0.8 individuals/weir, respectively.

Foraging habits

Dominant prey of YOY smooth dogfish included the shrimps *Crangon septemspinosa* and *Palaemonetes vulgaris,* polychaetes, and the crabs *Callinectes sapidus*, *Libinia* spp., and *Ovalipes ocellatus* (Table 3). The diet of YOY included several other small decapod crabs, razor clam *(Ensis directus)*, and small fishes (*Menidia menidia* and *Fundulus heteroclitus*). Often, YOY dogfish stomachs contained the walking legs or chelae of crabs, rather than entire individuals. Soft shell individuals of the various crab species were also frequently consumed. Whole crabs, other than those recently molted, were rarely observed.

There were no strong tidal or hourly trends in gut fullness (Fig. 8). No empty stomachs were found. Stomach fullness averaged 5.04 % body wt (SE=0.21, n=136), and 4.21 % body wt (SE=0.21, n=107) for individuals captured during flood and ebb tides, respectively. Stomach fullness increased slightly from early evening (averaging about 4 % body wt at 1900 h) to early morning (averaging about 5 % body wt at 0600 h). Three fish examined during mid-afternoon also had high levels of food in their stomachs (4–6 % body wt at 1200–1300 h). Intestine fullness remained remarkably constant regardless of time of night (hourly means ranging from 0.4–0.5% body wt, and 1.5–1.9 % body wt for the small and large intestine, respectively). We did not observe any strong decline in stomach fullness or any increase in intestinal fullness that would suggest noncontinuous feeding.

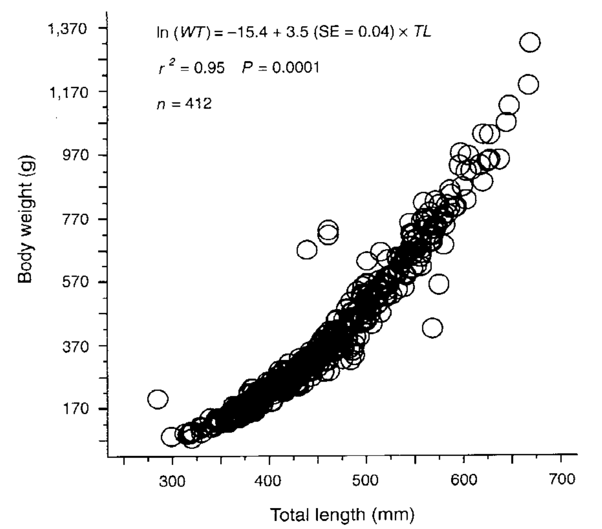

Figure 6
Total length (TL)-body weight (WT) relationship for smooth dogfish based on data pooled over all years and gears (n=412, r^2=0.96, $P \leq 0.0001$).

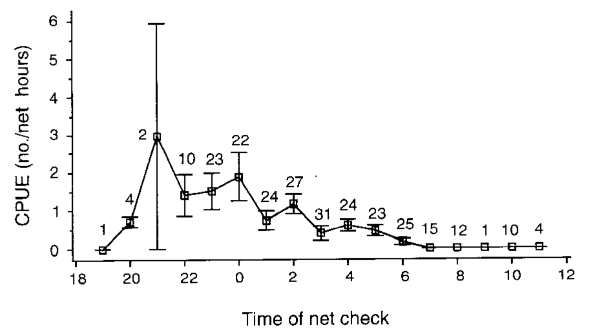

Figure 7
Hourly mean abundance (CPUE per hour per net) of smooth dogfish collected during the night with gill nets set in marsh creeks and adjacent bay habitats during 1990. Data are grouped by ebb- and flood-tide stage. Vertical lines are ranges.

Discussion

Life history stages and seasonal abundance patterns

Smooth dogfish are seasonal residents in New Jersey estuaries; adults are present April–September,

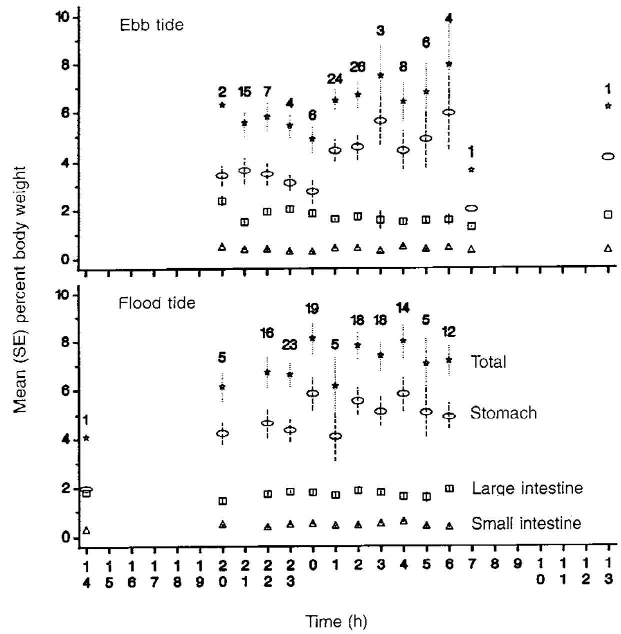

Figure 8

Hourly change in total digestive tract, stomach, large intestine, and small intestine fullness expressed as mean percent of body weight for smooth dogfish caught during ebb (top) or flood tide (bottom). Vertical bars are ranges in percent of body weight for individual fish. Numbers above symbols indicate the number of stomachs sampled during that hour.

and YOY are present May–October (Figs. 2–4). Most adults, however, appear to leave the estuary by mid-July (Rountree, personal observ.). The rarity of adult individuals in our samples results partly because they avoid gear and partly because they do not appear to use the shallow creeks and thus were not captured in weir sampling. However, adults were frequently observed in the bay and are often caught by local fishermen during late spring–early summer (Rountree, personal observ.). The near absence of subadults, however, in our collections may reflect a true rarity in the estuary.

The coincidental arrival of both mature adults and newborn YOY to Mid-Atlantic Bight estuaries suggests that adults use estuaries as a parturition ground. However, we did not observe any evidence of parturition within the estuary during our study, other than the capture of YOY presumably only days old (Rountree, personal observ.). It is not known whether parturition actually occurs in the estuaries or in inshore marine waters (surf zone to inner shelf) or in both. Uncertainty of the importance of estuaries as parturition habitats is underscored by the fact that the use of estuaries and coastal waters is characteristic only for the northern Atlantic population. The same species may only inhabit deeper shelf waters in other areas (Bigelow and Schroeder, 1948; Baughman and Springer, 1950; Hildebrand, 1953).

The size of smooth dogfish at birth has been widely reported as 34–39 cm (Bigelow and Schroeder, 1948; Hildebrand, 1953; Heemstra, 1973; Castro, 1983; Compagno, 1984), despite the fact that Bigelow and Schroeder (1953) later reported size at parturition to be 29–37 cm TL (11.5–14.5 inches). Because we collected post parturition individuals as small as 28 cm TL (Fig. 2), we suggest that a range of 28–39 cm TL at parturition is more accurate. However, we know of no published data on size at parturition, other than anecdotal accounts (Field, 1907; Smith, 1907; Fowler, 1918; Baughman and Springer, 1950; Hildebrand, 1953; Graham, 1967). Until length-frequency data of full-term embryos can be compared with length-frequency data for post parturition YOY, our estimate of 28–39 cm at birth should be used cautiously. Assuming this estimate is correct, we conclude from the size distribution of YOY that parturition of YOY in New Jersey waters occurs from mid-May through July (Figs. 2 and 5). Similar periods of parturition

Table 3

Food habits of 85 young-of-the-year smooth dogfish (mean, 417 mm; range 318–586 mm TL) collected in Little Egg Harbor–Great Bay estuary with gill net, trawl, and hook and line from April to November 1988–90. Percent frequency of prey among stomachs, mean number and weight of prey per stomach, and mean gut fullness index (100 × prey weight/body weight) are given for all prey occurring in at least 1% of the stomachs. The combined rank is a rank of the sum of the ranks for each measure. No stomachs were empty.

Prey species (or category)	Percent frequency	Mean (SE) number	Mean (SE) weight	Mean (SE) fullness	Combined rank
Crangon septemspinosa	65	1.41 (0.20)	0.32 (0.06)	0.21 (0.04)	1
Polychaete	47	0.48 (0.06)	0.17 (0.04)	0.09 (0.03)	5
Unidentified crabs	47	0.48 (0.06)	0.58 (0.13)	0.21 (0.04)	1
Palaemonetes vulgaris	32	1.34 (0.42)	0.54 (0.19)	0.25 (0.08)	3
Callinectes sapidus	12	0.22 (0.06)	0.86 (0.40)	0.27 (0.14)	4
Libinia sp.	9	0.12 (0.04)	0.53 (0.26)	0.14 (0.07)	6
Ovalipes ocellatus	9	0.12 (0.04)	0.22 (0.11)	0.06 (0.03)	7
Miscellaneous	8	0.09 (0.03)	0.04 (0.02)	0.01 (0.01)	11
Unidentified fish	8	0.09 (0.04)	0.07 (0.04)	0.02 (0.01)	8
Unidentified bivalve	7	0.08 (0.03)	0.02 (0.01)	0.01 (0.01)	14
Cancer sp.	5	0.09 (0.04)	0.06 (0.03)	0.02 (0.01)	10
Ensis directus	5	0.05 (0.02)	0.06 (0.03)	0.02 (0.01)	13
Upogebia affinis	2	0.06 (0.03)	0.13 (0.08)	0.04 (0.02)	9
Menidia menidia	2	0.02 (0.02)	0.12 (0.09)	0.04 (0.03)	12
Isopoda	1	0.04 (0.03)	<0.01	<0.01	16
Carcinus maenus	1	0.01 (0.01)	<0.01	<0.01	17
Neopanopeus sp.	1	0.01 (0.01)	<0.01	<0.01	17
Fundulus heteroclitus	1	0.01 (0.01)	0.10 (0.10)	0.04 (0.04)	15
Unidentified shrimps	1	0.01 (0.01)	<0.01	<0.01	17
Pagurus longicarpus	1	0.04 (0.04)	<0.01	<0.01	17
Total crabs	95	1.06 (0.11)	2.26 (0.48)	0.70 (0.16)	
Total shrimps	98	2.76 (0.46)	0.86 (0.20)	0.46 (0.09)	
Total other	89	0.96 (0.11)	0.73 (0.20)	0.29 (0.08)	
Total		4.79 (0.44)	3.85 (0.53)	1.46 (0.18)	

have been reported elsewhere (Bigelow and Schroeder, 1948, 1953; Graham, 1967; Castro, 1983; Compagno, 1984; Hisaw and Abramowitz[1]).

Growth rate

Our estimates of growth rates, based on length-frequency analysis, suggest that smooth dogfish YOY grow very fast during the nursery period (nearly 2 mm TL/day) and attain a size of 55–70 cm TL (mean=63 cm) by the time they leave the estuary in the fall. That such high growth rates are possible is confirmed by a single tag return (out of 17 fish tagged during 1989 weir sampling) in which a YOY male grew 44 mm in 24 days, averaging 1.8 mm TL/day. Similar growth-rate estimates have previously been reported. Hisaw and Abramowitz[1] suggested that smooth dogfish females grow about 20–30 cm per year, which corresponds to lengths of 48–70 cm TL by their first year. Moss (1972) later used tooth width and tooth replacement data to estimate a growth rate of 1.4–1.7 mm TL/day for the first year, which overlaps with our growth-rate estimates (Table 2). Extrapolation from the von Bertalanffy growth curve provided by Moss (1972) suggests that fish reach about 60 cm by the end of their first six months of life (roughly October). This estimate agrees well with our estimate. Moss's (1972) growth estimate also reveals no difference in growth between sexes during the first year, which agrees with our observations.

The significant annual differences in our growth rate estimates probably resulted from annual differences in the timing of peak abundance of YOY in the weir samples (Fig. 3) and to sampling bias among the gears. The bimodal length-frequency pattern observed in July (Fig. 2) was caused by the later occurrence of YOY during 1989 compared with 1988 (Fig. 3) and results in an increased slope of the regression of length on date for 1989 compared with 1988 and 1990. Bigelow and Schroeder (1953) and Graham (1967) also noted annual variation in peak abundance of YOY. The cause of this annual variation is not known at this time.

The statistically significant differences in the y-intercepts for weight between sexes is puzzling. If real, it suggests that females are larger at birth than males and, given that adult females tend to be larger than adult males (Bigelow and Schroeder, 1948; 1953; Castro, 1983; Compagno, 1984), that this size difference is maintained throughout life despite equal growth rates. However, data on actual size at birth are necessary to confirm this hypothesis.

Habitat use patterns

Smooth dogfish exhibit a strong nocturnal pattern in habitat use. We have previously reported from weir sampling that smooth dogfish appear to use subtidal marsh creeks exclusively during the night (Rountree and Able, 1993). In fact, no dogfish have been collected during the day in the creeks that we studied despite intensive sampling (Table 1). The hourly YOY CPUE pattern in the more recent gill-net sampling supports this observation (Fig. 7). Additionally, smooth dogfish are known to exhibit a nocturnal activity rhythm (Casterlin and Reynolds, 1979a). Also, individuals that were trapped in the creeks by the weir and its wings appeared to become increasingly stressed as low tide approached. Stressed individuals were often observed to thrash around with their heads out of the water. These patterns strongly suggest that YOY smooth dogfish undergo nocturnal tidal migrations in and out of the bay shoal and marsh creek habitats during the night.

Bay shoal habitats may be important YOY habitats within the estuary. Young of the year were very abundant within Foxboro and Story Island creeks, which bordered extensive shoal areas (Fig. 1), but were much less abundant at New Creek and Schooner Creek, which both empty directly into deep channels. Abundances in Foxboro Creek weir samples were significantly greater than in either Schooner or New creek. The low abundance in New Creek weir collections is particularly striking because YOY were abundant in Foxboro Creek despite it being located less than 300 m away. The importance of bay shoals adjacent to marsh creeks is supported by our observations (from informal gill-net sampling) that smooth dogfish were more abundant in Schooner Creek during 1987 prior to dredging of the adjacent shoal (Rountree, personal observ.).

It is noteworthy that smooth dogfish YOY were abundant in subtidal creek weir collections only during June–July (despite regular sampling from April to November) but were abundant in gill-net collections just outside the creeks through October (Figs. 3 and 4). Additionally, YOY captured by weirs in creeks tended to be smaller than those captured by other gears in bay habitats (Fig. 2). These patterns suggest that creek habitats are more important for newborn and smaller individuals than for older and larger individuals.

Foraging habits

The diet of YOY smooth dogfish comprised mainly benthic crustaceans and polychaetes (Table 3). Prey of YOY are typical of the dominant shallow estuarine faunal components in the area (Sogard and Able, 1991; Rountree and Able, 1992; Szedlmayer and Able, in press). The prevalence of *Crangon septemspinosa* and *Palaemonetes vulgaris* in the diet may explain the importance of the creek habitats to the smallest individuals during June and July because abundances of these two prey species exhibit a strong peak in marsh creeks at that time (Rountree and Able, 1992). Although smooth dogfish collected in shallow bay shoal and marsh creek habitats exhibited very full stomachs (Table 3; Fig. 8), the role of foraging behavior in the apparent tidal movements of smooth dogfish into these habitats is uncertain because of our lack of day samples. If the shoal and creek habitats were important foraging habitats, we would expect to see much higher gut fullness during ebb tide (when fishes are presumably leaving the shallows). Instead we observed slightly higher fullness values during flood tide.

The only published data on smooth dogfish feeding habits were produced more than seventy years ago (Fields, 1907; Breder, 1921). Breder (1921) also examined food habits of YOY from New Jersey (based on size information he gives) and reported a similar diet to that presented here. Bigelow and Schroeder (1953) later published a summary of dogfish food habits based on these studies but primarily considered the diet of adults. Interestingly, American lobster, *Homarus americanus,* figured prominently in the food habits of smooth dogfish taken from Cape Cod (Fields, 1907) but were not observed during our study presumably owing to the scarcity of settled juvenile lobsters in southern New Jersey estuaries (although pelagic-stage juveniles are common, [Able, unpubl. data]).

Conclusions

Young-of-the-year smooth dogfish use New Jersey estuaries as nurseries during late spring through fall, when pups grow rapidly to a size of 55–70 cm TL, prior to migration from the estuaries by the end of October. Smooth dogfish make tidal migrations into shallow bay shoal and tidal marsh creek habitats primarily at night, possibly to take advantage of high concentrations of small crustacean prey. As a result, shallow bay shoal and tidal marsh creek habitats appear to be critical nursery areas for smooth dogfish in New Jersey estuaries.

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