Transactions of the American Fisheries Society 123:112–114, 1994

Reproductive Biology of the Smooth Flounder in Great Bay Estuary, New Hampshire

MICHAEL P. ARMSTRONG[1] AND BETHANY A. STARR

Zoology Department, University of New Hampshire
Durham, New Hampshire 03824, USA

Abstract.—The smooth flounder *Pleuronectes putnami* is the only small, boreal flatfish species of inshore waters along the east coast of North America. Insights into the selection forces that shape the evolution of flatfish life histories can be gained by comparing the life history traits of smooth flounder with those of the larger, deeper-dwelling flatfishes. We examined several aspects of the reproductive biology of a population of smooth flounder in Great Bay estuary, New Hampshire. All males examined were sexually mature, including age-0 fish as small as 73 mm total length. Females matured during their first or second year at a mean length of 97.7 mm. The small size and young age at maturity suggest that the species is subject to high mortality, slow growth, or both. This would be consistent with their existence in highly variable boreal estuaries. Fecundity of 46 females 87–172 mm long ranged from 4,600 to 52,000 ova. The sex ratio overall did not differ significantly from 1:1. However, most of the largest fish were females and most of the smallest were males. There was no seasonal effect on sex ratios.

The smooth flounder *Pleuronectes putnami* is a small pleuronectid flatfish that occurs along the east coast of North America from Labrador south to about Massachusetts Bay. It is strictly an inshore fish, inhabiting shallow estuaries, river mouths, and sheltered bays (Bigelow and Schroeder 1953; Scott and Scott 1988). It is the smallest common flatfish in the Gulf of Maine area, reaching a maximum size of about 300 mm total length. In Great Bay estuary, New Hampshire, smooth flounder are most abundant in the oligomesohaline areas (M.P.A., personal observation). There is no evidence that their distribution extends seaward beyond the lower reaches of the estuary (Burn 1980).

Little research has been done on smooth flounder because they are commercially unimportant and because they reside in the upper portions of boreal estuaries, where relatively little sampling has been undertaken. Bigelow and Schroeder (1953) and Scott and Scott (1988) summarized the biological information for the species, most of which is general or anecdotal in nature. Laszlo (1972) studied age, growth, and food habits of smooth flounder from Great Bay estuary, and Laszlo (1972) and Laroche (1981) described the eggs and larvae. Little else is known about the reproductive biology of this species. Miller et al. (1991) noted that smooth flounder are the only small, boreal flatfish in the inshore waters of the northwest Atlantic Ocean, and they believed that valuable insights could be gained by comparing the life history traits of this species with those of the larger, deeper-dwelling flatfishes. Our study provides new information on length at maturity, sex ratios, and fecundity for this unique North American flatfish.

Methods

This study was conducted in Great Bay estuary, New Hampshire. The study area is a typical boreal estuary with large seasonal changes in temperature and salinity, a short growing season, and extensive intertidal mudflat habitat. Eelgrass, salt marsh, and rocky intertidal habitats also occur there. Great Bay estuary has a strong salinity gradient along its length and little vertical stratification because of strong, tide-driven currents.

Smooth flounder were collected with an otter trawl during March–November 1991. All specimens were fixed immediately in 10% formalin. Total length (mm), wet weight (g), and sex were recorded for all fish, and gonads were examined macroscopically to determine their maturity. Gonads of mature smooth flounder captured in September–November were well developed in preparation for spawning, which takes place in December–January (Scott and Scott 1988). Immature gonads were identified by their small size and lack of developing ova or sperm. Length at 50% maturity was determined by probit analysis (Trippel and Harvey 1991). Three random subsamples were taken from well-developed ovaries. The number of ova was calculated as $F = D \times W$, where F is the total number of mature ova, D is the number of ova in a subsample divided by the

[1] Present address: Massachusetts Division of Marine Fisheries, 18 Route 6A, Sandwich, Massachusetts 02563, USA.

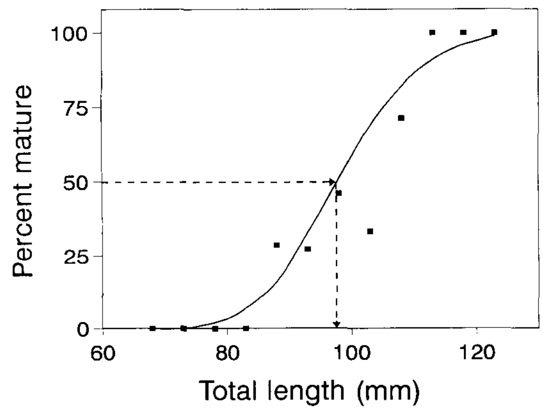

Figure 1.—Relationship between sexual maturity and total length of female smooth flounder. The curve was fitted by a probit function. Length at 50% maturity = 97.7 mm (dashed lines).

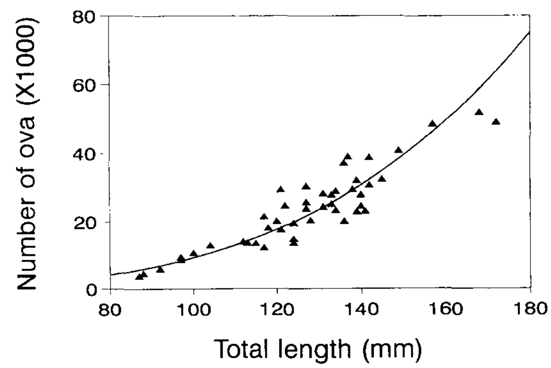

Figure 2.—Fecundity (thousands of ova) of smooth flounder from Great Bay estuary, New Hampshire. The regression equation is: $\log_e$ (number of ova) = −7.2464 + 3.5569·$\log_e$ (total length, mm); $N = 46$, $r^2 = 0.88$.

weight of the subsample, and W is the total ovary weight. The mean number of ova from the three subsamples was used in a least-squares regression of number of ova on fish length. Sex ratios were calculated for smooth flounder caught in March–November 1991. These fish were grouped by length and season of capture. Chi-square analysis was used to test for significant deviations from a 1:1 sex ratio. Ice cover prevented collecting samples of smooth flounder in December–February.

Results and Discussion

Sexual maturity was determined for 239 males (73–142 mm) and 122 females (68–148 mm). These fish were randomly selected from all fish less than 150 mm that we captured. All males examined were judged to be sexually mature. The smallest mature males had spawned the previous December–January and were less than 1 year old (Laszlo 1972). No immature males were found in samples collected in October–November, suggesting that all males mature at age 0. Females matured at 87–107 mm (Figure 1). Smooth flounders in this size range are age-0 or age-1 fish (Laszlo 1972). We calculated length at 50% maturity to be 97.7 mm (95% confidence interval, 93.9–102.0 mm) by probit analysis. A female smooth flounder of this length would be a large age-0 fish or a small age-1 fish. Faster-growing females, therefore, matured at the same age as males, whereas slower-growing females matured 1 year later. The size and age at first maturity seems to be a compromise that meets the needs of reproduction, growth, and survival (Stearns 1976; Roff 1991). The small size and young age at sexual maturity suggest that smooth flounder are subject to high mortality, slow growth, or both. This would be consistent with their existence in boreal estuaries where salinity, temperature, food availability, and other critical habitat factors are highly variable and may be stressful or limiting.

Fecundity was determined for 46 females ranging from 87 to 172 mm. The number of ova present ranged from 4,581 to 51,854 (Figure 2). The relationship between length and fecundity was slightly curvilinear, so both variables were transformed to natural logarithms and the relationship was expressed as $\log_e$ (number of ova) = −7.2464 + 3.5569·$\log_e$ (total length, mm). This equation yielded estimates of fecundity at length that were similar to estimates for yellowtail flounder *Pleuronectes ferrugineus* (Howell and Kesler 1977) but about 50% greater at any given size than those for winter flounder *Pleuronectes americanus* (Klein-MacPhee 1978). However, these comparisons must be viewed with caution because yellowtail and winter flounders are immature at sizes below about 250 mm and smooth flounder only rarely exceed 200 mm.

The male : female ratio for all fish combined was 1.1:1, not significantly different from the expected 1:1 ratio ($P > 0.05$). However, significant differences were found when the sex ratios were calculated for three size-groups (Table 1). Males dominated the smallest size-group and were present in only small numbers in the largest group. Both sexes were equally represented in the middle size-group. There appeared to be no seasonal effects on sex ratio, although sample sizes varied considerably between seasons (Table 1) and no samples were taken in December–February. There

TABLE 1.—Sex ratios (males : females) of smooth flounder by total length (mm) and season of capture. Total number of fish in each category is the sum of male and female numbers. Asterisks indicate ratios significantly different from 1:1 ($P < 0.05$).

Total length (mm)	Spring	Summer	Fall
50–100	126:82*	96:67*	79:22*
101–150	161:150	134:104	50:38
>150	2:21*	14:31*	0:14*

was no evidence to suggest geographic separation of the sexes during any time of the year. Similar results have been found for summer flounder *Paralichthys dentatus* (Morse 1981).

There is little understanding of the forces that mold the life histories of flatfishes (Roff 1991). Smooth flounder are interesting because their entire life is spent in nearshore waters and the expectation is population isolation over a well-defined latitudinal gradient. Under such conditions, differences in life history traits would be clearly defined over the range of the species (Miller et al. 1991). Changes in traits such as fecundity, size or age at maturity, sex ratio, timing of spawning, and growth rate can be correlated with clinal changes in biological and physical variables such as predation pressure, primary or secondary production, presence or absence of competitors, and temperature. Great Bay estuary is at the southern end of the smooth flounder's current range. The life history attributes of these southern fish should be compared with those of fish from northern parts of the range to provide insights into the selection forces that shape the evolution of flatfish life histories.

Acknowledgments

We thank Hunt Howell for helpful comments on the manuscript. Brian Nelson and Tiffany Clark helped with the field and laboratory work. This study was supported in part by a grant from the Wallopp–Breaux Trust Fund, U.S. Fish and Wildlife Service.

References

Bigelow, H. B., and W. C. Schroeder. 1953. Fishes of the Gulf of Maine. U.S. Fish and Wildlife Service Fishery Bulletin 74:1–577.

Burn, P. R. 1980. The parasites of smooth flounder, *Liopsetta putnami* (Gill), from the Great Bay estuary, New Hampshire. Journal of Parasitology 66: 532–541.

Howell, W. H., and D. H. Kesler. 1977. Fecundity of the southern New England stock of yellowtail flounder, *Limanda ferruginea.* U.S. National Marine Fisheries Service Fishery Bulletin 75:877–880.

Klein-MacPhee, G. 1978. Synopsis of biological data for the winter flounder, *Pseudopleuronectes americanus* (Walbaum). NOAA (National Oceanic and Atmospheric Administration) Technical Report NMFS (National Marine Fisheries Service) SSRF (Special Scientific Report Fisheries) 414. (Also: Food and Agricultural Organization of the United Nations Fisheries Synopsis 117.)

Laroche, W. A. 1981. Development of larval smooth flounder, *Liopsetta putnami,* with a redescription of development of winter flounder, *Pseudopleuronectes americanus* (Family Pleuronectidae). U.S. National Marine Fisheries Service Fishery Bulletin 78:897–909.

Laszlo, P. T. 1972. Age–growth, food and reproduction of the smooth flounder, *Liopsetta putnami* (Gill), in Great Bay, New Hampshire. Doctoral dissertation. University of New Hampshire, Durham.

Miller, J. M., J. S. Burke, and G. R. Fitzhugh. 1991. Early life history patterns of Atlantic North American flatfish: likely (and unlikely) factors controlling recruitment. Netherlands Journal of Sea Research 27:261–275.

Morse, W. W. 1981. Reproduction of the summer flounder, *Paralichthys dentatus* (L.). Journal of Fish Biology 19:189–203.

Roff, D. A. 1991. The evolution of life-history variation in fishes with particular reference to flatfishes. Netherlands Journal of Sea Research 27:197–207.

Scott, W. B., and M. G. Scott. 1988. Atlantic fishes of Canada. Canadian Bulletin of Fisheries and Aquatic Sciences 219.

Stearns, S. C. 1976. Life history tactics: a review of ideas. Quarterly Review of Biology 51:3–47.

Trippel, E. A., and H. H. Harvey. 1991. Comparison of methods used to estimate age and length of fishes at sexual maturity using populations of white sucker (*Catastomus commersoni*). Canadian Journal of Fisheries and Aquatic Sciences 48:1446–1459.

Received August 27, 1992
Accepted September 20, 1993