Growth and maturation of winter flounder, *Pleuronectes americanus*, in Massachusetts

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Winter flounder, *Pleuronectes americanus*, is an important commercial and recreational species along the Atlantic coast. Previous studies have shown that the winter flounder stock is composed of several substocks that may consist of estuarine specific populations (Saila, 1961; Poole, 1966a; Pierce and Howe, 1977). Coastal stocks of winter flounder are managed by individual states; area specific growth and maturity information is incorporated into spawning stock biomass-per-recruit models (ASMFC, 1992).

For management purposes, two stocks of winter flounder inhabit Massachusetts waters; one stock north of Cape Cod and the other stock south and east of Cape Cod (Lux et al., 1970; Howe and Coates, 1975; Pierce and Howe, 1977). For these stock units, growth parameters and sex ratios were reported from 1964 to 1968 coastal tag returns (Howe and Coates, 1975), but no studies using aged scale or otolith samples had been undertaken. Growth rates estimated from tagging may not be equivalent to those based on age-length data (Francis, 1988). The two methods often provide different results; faster growth rates are generally estimated from tag returns.

The primary objective of our study was to determine growth rates of juvenile and adult winter flounder based on aged scale samples. Our second objective was to determine average maturity schedules for the two winter flounder stock units, as maturation is an important life history parameter for spawning stock biomass-per-recruit analyses.

Materials and methods

Winter flounder were sampled during the 1983–91 Massachusetts Division of Marine Fisheries spring (May) bottom trawl surveys. State waters (0–3 mi) were surveyed with an otter trawl equipped with a fine mesh (13-mm stretch) codend liner that retained small fish. An average of 95 stations per year were surveyed in a stratified random manner, at a sampling intensity of 1 station per 19 square nautical miles. Additional details of trawl survey methodology were provided by Howe (1989). Captured winter flounder were measured to total length (±0.5 cm), sampled for scales and otoliths, and assigned sex and maturity stage based on examination of the gonads, by using established macroscopic criteria (Burnett et al., 1989). Because samples were collected at the end of the winter flounder spawning season, determination of sex and maturity stage was relatively straightforward. Scale samples, taken from the caudal peduncle region, were used for age determination. Scales were impressed in acetate and aged as described for Georges Bank winter flounder (Fields, 1988).

Von Bertalanffy growth curves were fitted to length-at-age data (1983–91 pooled) for males and females of each stock unit, by using mean lengths observed for ages 2–8. Data from age-1 fish were not included, as preliminary analysis suggested that the smaller fish of this age group were either not available or not effectively captured by the sampling gear. Mean lengths at age for older (>8 yrs) fish were not used in fitting growth models, because sample sizes were small. Statistical comparison of the results from this study and those of Howe and Coates (1975) was not attempted, as growth parameters derived from tagging and age-length information may not be equivalent (Francis, 1988).

Stock-specific maturity schedules based on aged fish were calculated for both males and females. For each sex within each stock unit, a logistic function was fitted to the proportion of mature winter flounder, ages 2–5, by using nonlinear regression. Lengths at 50% maturity (L_{50}) were the inflection point on these curves. Similarly, ages at 50% maturity (A_{50}) were determined from logistic curves fitted to observed maturity at age data.

Results

A total of 3,035 winter flounder (731 males and 986 females south and east of Cape Cod and 509 male and 809 female winter flounder north of

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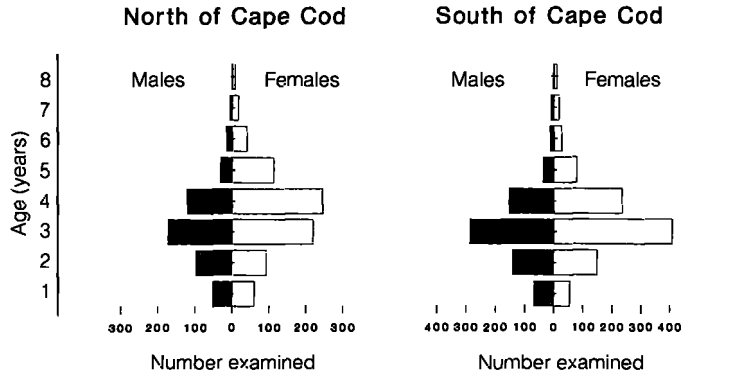

Figure 1
Sample sizes of male and female winter flounder taken from each stock area, 1983–91.

Cape Cod) were successfully aged and assigned maturity stages. Ages ranged from 1 to 16 years in the southern stock, and 1 to 15 years in the northern stock. For both stocks, females predominated at ages 3 and older (Fig. 1).

Growth rates of winter flounder differed for each gender and stock unit. Females grew faster than males, and obtained larger mean asymptotic lengths (Fig. 2). For each gender, winter flounder from the southern stock were generally larger at age than those from the northern stock, at ages 3–8. Mean lengths at age observed from our samples were similar to, but slightly smaller than, those determined from 1964–68 tag return data (Table 1).

For both stocks and sexes, maturation generally began at age 3 and was nearly complete at age 5. Maturation of age-3 and age-4 fish was quite variable and was somewhat sensitive to size at age (Fig. 3). Owing to their somewhat faster growth rate, winter flounder matured at younger ages south of Cape Cod. For females, A_{50}'s (and corresponding L_{50}'s) were 3.0 years (28.3 cm) south of Cape Cod and 3.3 years (28.7 cm) north of Cape Cod. For males, A_{50}'s (and corresponding L_{50}'s) were 3.1 years (28 cm) south of Cape Cod and 3.3 years (27.2 cm) north of Cape Cod.

Discussion

Adult winter flounder south and east of Cape Cod were larger at age than adults from other coastal populations. For example, age-5 female winter flounder in

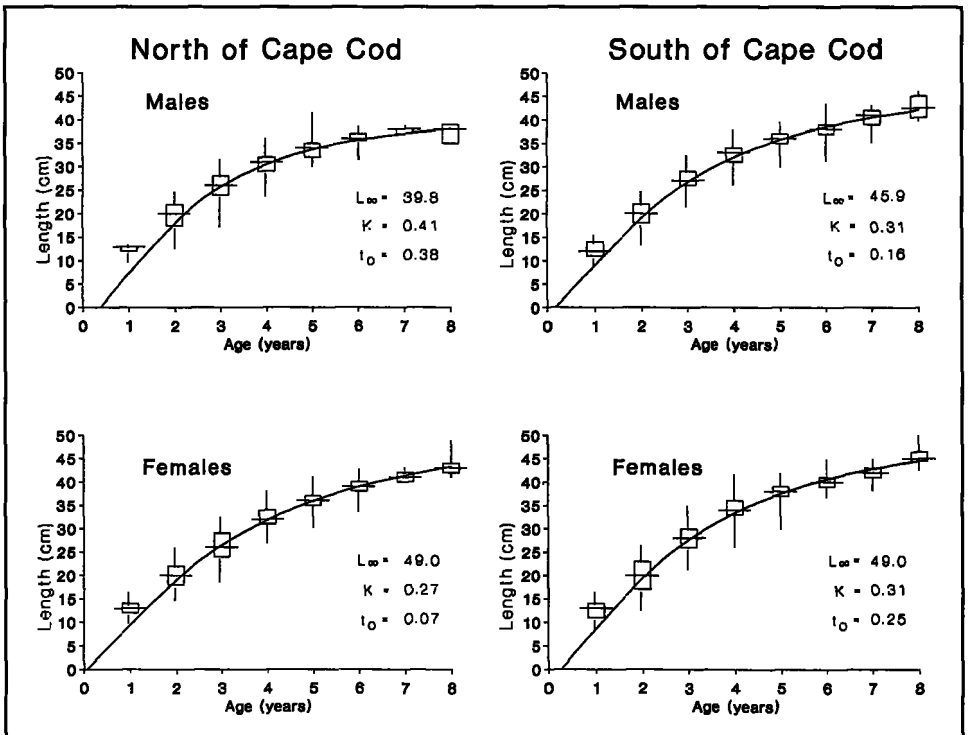

Figure 2
Distributions of length at age for male and female winter flounder sampled from both stock units. Von Bertalanffy growth curves are fitted through mean lengths, ages 2-8. Box plots of the median, quartiles, and range of lengths at age are shown.

Table 1

Calculated total length (cm) at age (yr) for female winter flounder in Massachusetts from 1983–91 scale samples (present study) and from 1964–68 tag returns (Howe and Coates, 1975).

	North of Cape Cod		South of Cape Cod	
Age	1964–68	1983–91	1964–68	1983–91
2	—	19.9	—	20.5
3	29.0	26.8	29.4	28.1
4	34.1	32.0	35.0	33.6
5	37.6	36.1	39.0	37.7
6	40.1	39.1	41.8	40.7
7	41.8	41.4	43.8	42.9
8	43.0	43.2	45.2	44.6

Massachusetts averaged 38 cm south and east of Cape Cod, versus 36 cm north of Cape Cod, 21 cm in Long Pond, Newfoundland (Kennedy and Steele, 1971), and 35 cm in Narragansett Bay, Rhode Island (Berry et al., 1965). On Long Island, New York, Poole (1966a) found that growth rates of winter flounder increased from south to north; age-5 females ranged from an average of 31 cm in Great South Bay to 36 cm in Peconic Bay. Only the offshore population on Georges Bank is known to have faster growth rates than winter flounder in Massachusetts waters south and east of Cape Cod (Lux, 1973; Howe and Coates, 1975). The area south of Cape Cod is the center of the species geographical range (ASMFC, 1992) and may provide better environmental conditions for growth of winter flounder than other coastal areas.

For both stocks of winter flounder in Massachusetts, growth was apparently not affected by changes in exploitation or biomass. Biomass of these stocks declined over 50% from 1983 to 1990 owing to high fishing mortality (Howe et al., 1990). However, no trends in mean lengths at age were observed for the 1983–91 period, and growth rates were similar to those observed by Howe and Coates (1975) for the 1964–68 period (Table 1), when winter flounder were more abundant and exploitation rates were lower[1]. Under high levels of exploitation, faster growing fish are differen-

[1] Foster, K. L. 1987. Status of winter flounder (*Pseudopleuronectes americanus*) stocks in the Gulf of Maine, southern New England, and middle Atlantic areas. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Northeast Fish. Sci. Cent. Ref. Doc. 87–06.

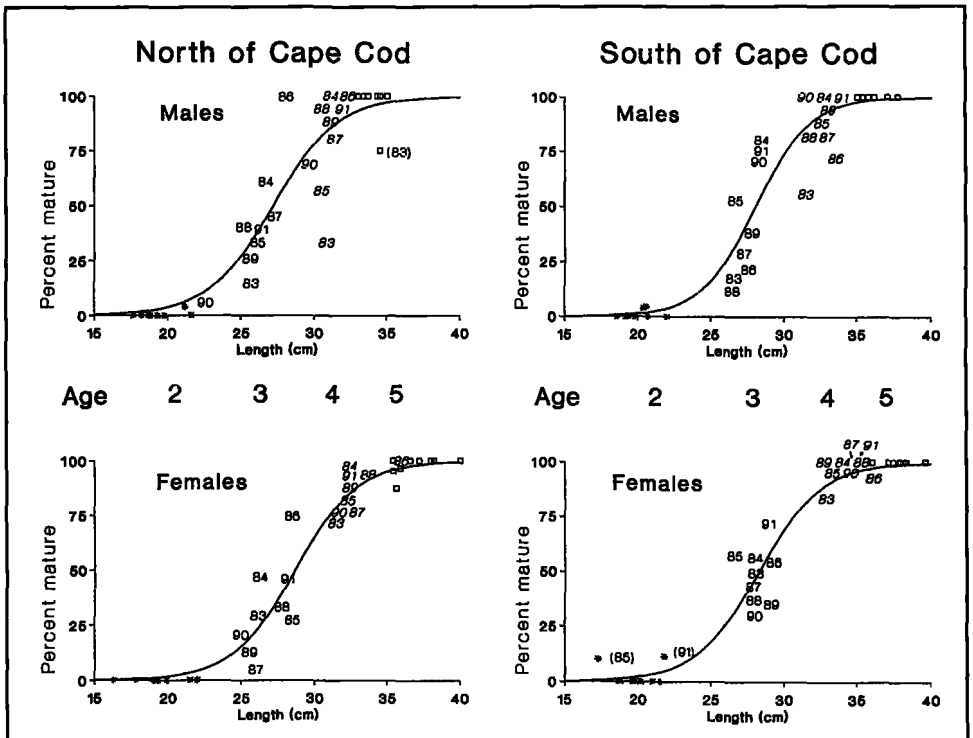

Figure 3

Variability in maturity and mean length at age for winter flounder, ages 2-5, observed from 1983–91 bottom trawl surveys. Percent mature at length of age-3 and age-4 fish are plotted by year of collection (age-4 fish shown in italics). Data for age-2 and age-5 fish are plotted by stars and squares, respectively; outliers are identified by year of collection in parenthesis.

tially removed from populations (Ricker, 1975), and thus we were unable to separate the effects of cropping faster growing fish from potential density dependent effects.

Winter flounder in Massachusetts waters mature at larger sizes than winter flounder from other coastal populations. For winter flounder in Massachusetts, only 50% of the females were mature at 28 to 29 cm; L_{50}'s of females in Newfoundland were 25 cm (Kennedy and Steele, 1971) and 27 cm in New Jersey (Danilla, 1978). Maturity ogives derived from our age-specific mean length at maturity data were similar to those reported from pooled length at maturity observations for Massachusetts winter flounder during the period 1985–89 (O'Brien et al., 1993). They found lengths at 50% maturity of females to be 27.6 cm south of Cape Cod and 29.7 cm north of Cape Cod. Because populations of long lived, late maturing fish are more susceptible to overexploitation than are populations with early maturity and shorter life spans (Pitcher and Hart, 1982), each substock of winter flounder may require different management strategies (including size limits) for optimal harvest levels.

Sex ratios of winter flounder favored females at older ages (Fig. 1), indicating a higher natural mortality rate for males. An increasing proportion of females by size was observed for winter flounder in Rhode Island, but the differences in sex ratios were thought to be related to the faster growth of females (Berry et al., 1965). Female winter flounder on Georges Bank live longer than males (Lux, 1973). A number of mature male winter flounder in Conception Bay, Newfoundland, failed to produce gametes, and there was a trend towards an increasing proportion of nonreproductive individuals with advancing age, leading to the possibility that males enter senescence at younger ages than do females, and thus have a higher natural mortality rate (Burton and Idler, 1984). A higher natural mortality rate for males has been found for other flounders, including European plaice, *Pleuronectes platessa*, (Bidder, 1925) and summer flounder, *Paralichthys dentatus*, (Poole, 1966b), and it may be a general pattern that male flounders have shorter life spans than females.

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