AGE AND GROWTH OF THE WINTER FLOUNDER, *PSEUDOPLEURONECTES AMERICANUS*, ON GEORGES BANK

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ABSTRACT

Lengths calculated at each scale annulus from 510 winter flounder, *Pseudopleuronectes americanus*, collected on Georges Bank during 1963-66 provided a measure of growth up to 12 years of age. Growth was more rapid on Georges Bank than on inshore areas. Females grew faster than males after age 2. Fish from eastern Georges Bank grew slightly faster than those from western Georges Bank. Bertalanffy growth equations were computed for each sex.

The winter flounder, *Pseudopleuronectes americanus* (Walbaum), found in Atlantic coastal waters from Newfoundland to Cape Hatteras, is a common fish in the New England and middle Atlantic catch. Landings by commercial fishermen, mostly with otter trawls, averaged 12,000 metric tons annually in the period 1966-70. In addition, there is a large sport fishery since the species occurs in shallow coastal waters easily accessible to saltwater anglers. The estimated angler catch in 1965 was 13,000 tons (Deuel and Clark, 1968).

Most of the catch is made in the New England area where the species is found on both inshore and offshore grounds. There appear to be a number of distinct groups in this area, judging from movement of tagged fish and variation in numbers of fin rays (Perlmutter, 1947; Bigelow and Schroeder, 1953; Lux, Peterson, and Hutton, 1970). One of these groups is on Georges Bank where the fish are larger and have more fin rays than on inshore areas. There is almost no movement of winter flounder between Georges Bank and inshore grounds. The growth material presented here is for winter flounder from Georges Bank.

On the basis of size, color, and fin ray number, Kendall (1912) determined that the winter flounder from Georges Bank comprised a separate species, which he named *P. dignabilis*. Bigelow and Schroeder (1953), however, considered the differences as no more than racial, a view which presently prevails.

Studies of winter flounder growth on inshore areas, summarized by Berry, Saila, and Horton (1965), Poole (1966), and Kennedy and Steele (1971) indicated that age determination from hard body parts is difficult and that growth rate varied with area. Females grew faster than males, at least after the first few years.

There is no previous study on growth of winter flounder on Georges Bank although it has long been known that winter flounder there grow much larger than on inshore grounds (Bigelow and Schroeder, 1953).

MATERIALS AND METHODS

The fish for the study were obtained from research vessel and commercial catches in 1963-66. The research vessel samples were from National Marine Fisheries Service *Albatross IV* groundfish surveys (Grosslein, 1969). Since the otter trawl used had a ½-inch mesh liner in the cod end, both large and small fish were obtained. Six additional samples were collected from catches of commercial otter trawlers, and these contained only fish greater than 36 cm in total length.

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Manuscript accepted October 1972.
FISHERY BULLETIN: VOL. 71, NO. 2, 1973.

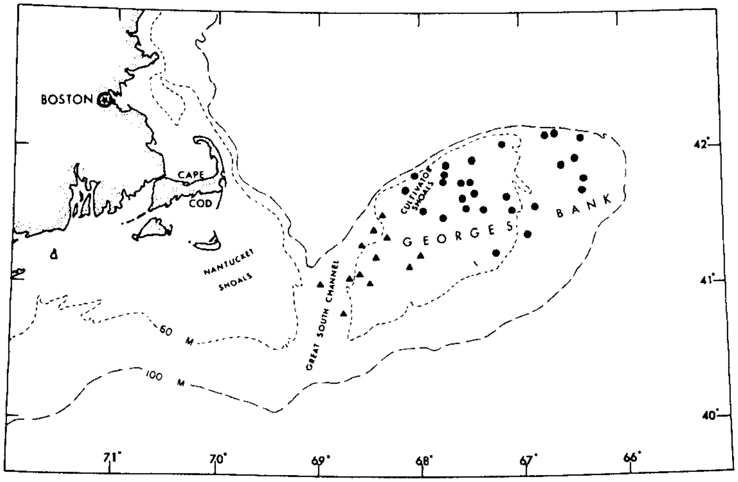

FIGURE 1.—Locations on Georges Bank where winter flounder were collected for age and growth studies. (Dots: eastern Georges Bank; triangles: western Georges Bank.)

Locations where samples were taken for the study cover most of the northern half of Georges Bank (Figure 1). Otter trawl catches from the *Albatross IV* groundfish surveys suggest that there are two somewhat separate areas of winter flounder abundance on Georges Bank. The area of greatest abundance extends from Cultivator Shoal eastward to about long 67°W. This is the area where most of the Georges Bank commercial catch is taken. The other area is southwest of Cultivator Shoal and extends westward from there to about long 69°W. The two areas are roughly shown by plotting catches of winter flounder from eight groundfish surveys on Georges Bank (Figure 2). Although sampling was relatively uniform over the entire Bank to a depth of 200 m (see figures in Grosslein, 1969), catches of five or more winter flounder per otter trawl station were made only in the above-defined areas. Growth was computed separately for fish from these two areas (Figure 2).

Scales were used for age determination since these appeared easier to interpret than otoliths and had the advantage of greater ease for calculation of lengths at earlier ages. The scales were removed from the eyed side of fish along the lateral line in the area just anterior to the caudal peduncle. Total length in millimeters and sex were recorded for each scale sample. Except where noted, lengths given herein are total lengths.

Impressions of the scales were made in

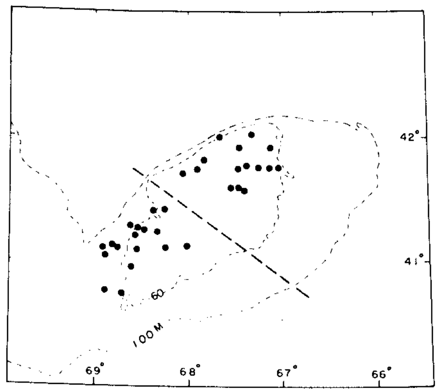

FIGURE 2.—Georges Bank stations (30-min otter trawl hauls) where five or more winter flounder were caught during fall groundfish surveys in 1963-70. (Dashed line indicates the boundary between east and west Georges Bank for the growth study.)

transparent cellulose acetate strips. These were viewed with a microprojector using 40× magnification, and year marks (annuli) were identified and counted. Criteria for distinguishing annuli were the same as those used for New England yellowtail flounder, *Limanda ferruginea*, (Lux and Nichy, 1969) which, like the winter flounder, have ctenoid scales. With the exception of the first year, spring and summer growth was characterized by widely spaced circuli (rapid length accretion) and fall and winter growth, by closely spaced circuli (slow length accretion). The outer edge of the zone of closely spaced circuli was considered to be the annulus. Slight checks in growth consisting of only a few closely spaced circuli were considered to be false annuli and were ignored in assigning age. In the first year all circuli are closely spaced. The annulus here was taken to be the outermost of these circuli.

Ages were assigned to each fish by the author and, independently, by an assistant. For some scales reliable growth calculation appeared impossible because of regeneration, erosion, resorption, or checks. These, making up about 15% of the total sample, were omitted from the calculations. As might be expected, the proportion of rejected scales was much higher for large fish (Table 1).

TABLE 1.—Length-frequency distribution of winter flounder collected on Georges Bank in 1963-66 and proportions included in the growth calculations, by 5-cm intervals.

Length interval (cm)	Total number of fish	Included in calculations	
		Number	Percent
11-15	4	4	100.0
16-20	11	11	100.0
21-25	18	18	100.0
26-30	27	26	96.3
31-35	28	28	100.0
36-40	80	73	91.2
41-45	108	101	93.5
46-50	158	133	84.2
51-55	94	69	73.4
56-60	55	38	69.1
61-65	15	8	53.3
66-70	4	1	25.0
Total	602	510	84.7

Age was determined, to the extent possible, for the rejected scales and length at age of these fish was compared with that of fish included in the growth calculations to determine if bias was introduced by the rejection of part of the sample (Figure 3). While the samples were rather small in the older ages, there appeared to be no difference in growth of the two groups of fish.

Totals of 412 fish from eastern Georges Bank and 98 from western Georges Bank were included in the calculations. All of the commercial samples, consisting of 225 fish, were from eastern Georges Bank.

Length at each annulus was calculated from measurements of anterior scale radii. The relationship of body length to scale length approximated a straight line, except for curvi-

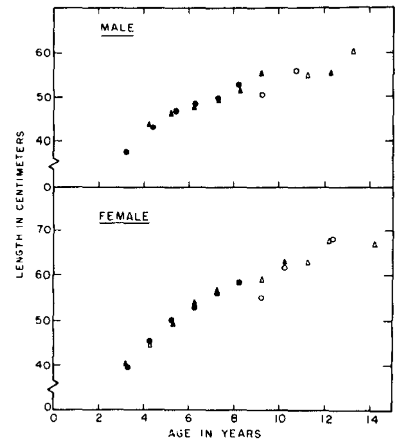

FIGURE 3.—Mean lengths at capture by age group for fish from commercial samples included in growth calculations (circles) and those rejected (triangles). (Open symbols represent fewer than three fish.)

linearity among the smallest fish (Figure 4). Direct proportion growth calculations therefore were made using the equation

$$l_n = C + \frac{S_n}{S}(l - C)$$

where l_n is the fish length at the time of formation of the nth annulus, C is the fish length at scale formation, S_n is the anterior scale radius to the nth annulus, S is the anterior scale radius at capture, and l is the

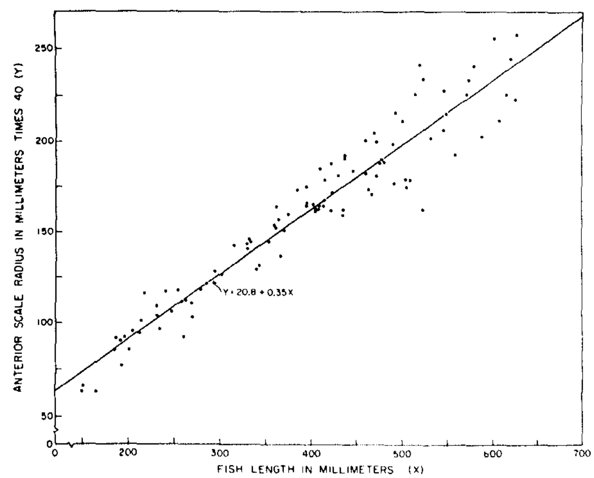

FIGURE 4.—Body-scale relationship of Georges Bank winter flounder based on measurements of 101 fish.

fish length at capture (Fraser, 1916). Two scales were measured for each fish. A nomograph was used to facilitate computations (Carlander and Smith, 1944).

For the value of C an estimated fish length at scale formation of 20 mm was used. This was based on examination of winter flounder 17 to 25 mm long collected in Massachusetts coastal waters in early June 1962 (Lux and Nichy, 1971). I have assumed that scale formation occurs at about the same length on Georges Bank where I have collected no fish of the above sizes.

Evidence, indicating that marks identified as annuli on the scales of winter flounder from Georges Bank were actual year marks, was obtained from several sources. The main lines of this evidence are summarized below.

1. There is a correlation between age and size in that increase in number of annuli is accompanied by an increase in fish size (Figure 5).
2. Lengths at various annuli calculated from scales correspond with empirical lengths at the same ages determined from reading scales (Figure 5).
3. There is agreement on length at age of fish from the same age-groups collected in different years (Table 2) and agreement on calculated growth among different year classes (Tables 3 and 4).
4. Distinguishing permanent marks consisting of unpigmented spots on the eyed side of the fish occurred in successive years in an estimated 4 to 13% of winter flounder from the 1959 year class on eastern Georges Bank (Lux, in press). This white spotting appears to occur in far less than 1% of the fish of a year class normally. White-spotted fish of the 1959 year class were collected in 1964, 1965, and 1966. Those from 1964 had 5 annuli on their scales; those from 1965, 6 annuli, and those from 1966, 7 annuli, showing that 1 annulus was added each year. The mean lengths of spotted fish from this year class showed regular increases over these 3 years (Table 5). Growth rate was unaffected by white spotting.

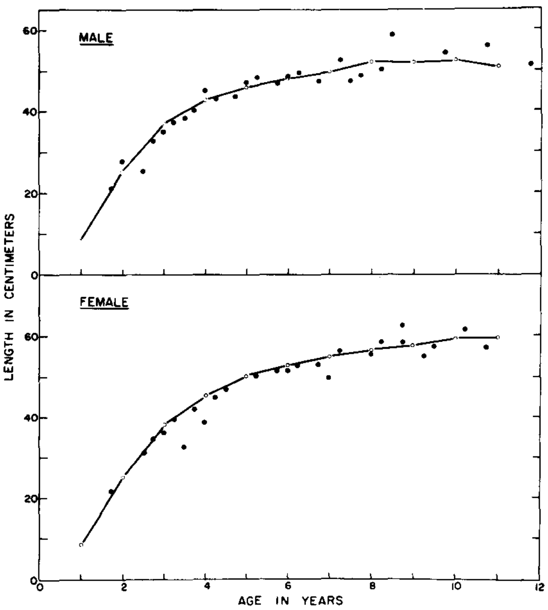

FIGURE 5.—Mean length at age from scale age determinations (dots) compared with mean calculated length at each annulus (open circles) for male and female winter flounder from eastern Georges Bank.

TABLE 2.—Number (n) of fish in each sample and mean length in centimeters (cm) at capture by age group for male and female winter flounder from eastern Georges Bank in 1963-66.

Age group	Year caught	Male		Female	
		n	cm	n	cm
II	1965	12	29.4	8	32.7
	1966	8	30.1	5	35.8
III	1964	2	38.2	4	39.4
	1965	5	38.4	3	32.7
	1966	27	39.3	38	39.2
IV	1963	—	—	1	47.8
	1964	18	43.8	18	45.0
	1965	—	—	2	46.6
	1966	11	43.4	10	42.9
V	1964	20	47.1	7	50.8
	1965	—	—	—	—
	1966	14	46.6	9	50.5
VI	1964	10	48.3	7	50.6
	1965	12	49.3	11	54.1
	1966	18	47.8	10	52.1
VII	1963	1	51.4	—	—
	1964	5	49.8	—	—
	1965	1	44.1	2	55.8
	1966	24	49.6	28	55.0
VIII	1964	6	54.3	1	61.0
	1965	1	58.9	—	—
	1966	4	51.0	7	56.6

TABLE 3.—Number (n) of fish in each sample and calculated mean length in centimeters (cm) at each annulus, for each year class and for all year classes combined, for male and female winter flounder collected on eastern Georges Bank in 1963-66.

Year class	Number of annuli																							
	1		2		3		4		5		6		7		8		9		10		11		12	
	n	cm	n	cm	n	cm	n	cm	n	cm	n	cm	n	cm	n	cm	n	cm	n	cm	n	cm	n	cm
												Males												
1955	2	6.2	2	19.2	2	33.6	2	40.8	2	44.6	2	46.6	2	47.8	2	49.0	2	50.0	1	50.4	1	50.8	—	—
1956	4	11.4	8	24.4	8	38.5	8	45.1	8	49.2	8	51.2	8	52.5	7	54.0	1	54.3	1	55.1	—	—	—	—
1957	5	8.6	8	23.8	8	38.1	8	43.8	8	47.4	8	49.7	8	51.0	3	54.2	2	53.4	—	—	—	—	—	—
1958	9	7.5	15	22.6	15	36.4	15	42.5	15	45.8	15	47.8	5	48.4	4	50.7	—	—	—	—	—	—	—	—
1959	46	9.8	56	28.0	56	39.0	56	43.9	56	46.5	36	48.4	24	49.2	—	—	—	—	—	—	—	—	—	—
1960	27	8.2	36	25.8	36	37.6	36	43.2	18	45.8	18	47.5	—	—	—	—	—	—	—	—	—	—	—	—
1961	11	7.8	16	23.4	16	36.1	14	42.6	14	45.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1962	12	8.3	16	24.9	16	36.3	11	41.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1963	34	7.1	39	24.7	39	35.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1964	8	8.6	8	25.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1965[1]	26	6.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	184	8.2	204	25.5	196	37.3	150	43.3	121	46.4	87	48.4	47	49.9	16	52.6	5	52.2	2	52.7	1	50.8	—	—
												Females												
1954	1	6.2	2	23.9	2	40.0	2	49.2	2	54.4	2	57.6	2	59.9	2	61.6	2	62.7	2	63.6	1	66.8	1	67.4
1955	1	8.2	3	28.1	3	40.6	3	46.6	3	50.4	3	52.1	3	53.7	3	54.7	3	55.7	2	55.4	2	56.0	—	—
1956	1	10.5	2	22.7	2	39.6	2	46.3	2	51.4	2	54.0	2	56.3	2	57.8	1	56.6	—	—	—	—	—	—
1957	3	9.1	3	25.6	3	39.9	3	46.3	3	50.2	3	52.8	3	54.6	3	55.9	3	56.9	—	—	—	—	—	—
1958	10	6.9	16	22.0	16	37.6	16	44.6	16	48.9	16	51.6	9	54.8	7	56.2	—	—	—	—	—	—	—	—
1959	43	10.8	47	29.5	47	40.8	47	47.2	46	50.8	39	53.4	28	55.0	—	—	—	—	—	—	—	—	—	—
1960	21	8.2	28	24.0	28	37.6	28	44.7	10	49.0	10	51.6	—	—	—	—	—	—	—	—	—	—	—	—
1961	10	7.2	15	23.6	15	37.8	11	44.6	9	48.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1962	7	6.4	13	19.3	13	32.2	10	40.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1963	38	7.9	46	24.7	38	36.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1964	2	8.7	5	24.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1965[1]	26	6.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	163	8.4	180	25.1	167	38.0	122	45.4	91	50.1	75	52.8	47	55.1	17	56.7	9	57.7	4	59.5	3	59.6	1	67.4

[1] Includes males and females.

RESULTS

The computed lengths at each annulus for male and female winter flounder from eastern and western Georges Bank in 1963-66 (Tables 3 and 4, Figure 5) show that females grow faster than males after the second year. This pattern of growth is similar to that of New England yellowtail flounder in which sexual maturity usually occurs at age 3 (Lux and Nichy, 1969). Limited evidence from the present study indicates that Georges Bank winter flounder also begin to attain maturity at age 3.

The fish from western Georges Bank appeared to grow a little less rapidly, at least in early years, than those from the eastern part of the Bank, and their growth is therefore presented separately (Tables 3 and 4, Figure 6). However, the sample from western Georges Bank is too small to precisely define growth there. Growth in length for both of the grounds is rapid until age 5 or 6. Then it tends to decrease sharply, especially for males (Figure 6).

Growth by year class on eastern Georges Bank (Table 3) suggested that fish from the 1959 year class grew slightly faster than those from other years. The data at hand, however, are inadequate for a conclusive examination of this question.

Following the first 2 years, the growth of fish on Georges Bank is faster than that of fish on inshore areas (Figure 6). Although the growth of this species on the inshore grounds apparently varies widely from place to place

TABLE 4.—Number (n) of fish in each sample and calculated mean length in centimeters (cm) at each annulus for each year class and for all year classes combined, for male and female winter flounder collected on western Georges Bank in 1963-66.

Year class	Number of annuli: 1		2		3		4		5		6		7		8		9		10		11	
	n	cm	n	cm	n	cm	n	cm	n	cm	n	cm	n	cm	n	cm	n	cm	n	cm	n	cm
											Males											
1958	3	6.3	6	17.9	6	31.2	6	39.0	6	44.3	2	49.0	2	50.8	—	—	—	—	—	—	—	—
1959	3	5.9	3	17.0	3	29.9	3	36.9	3	40.6	3	43.4	1	43.5	—	—	—	—	—	—	—	—
1960	12	6.4	14	21.1	14	34.4	5	38.8	5	42.2	4	45.4	—	—	—	—	—	—	—	—	—	—
1961	6	6.6	6	20.8	4	28.5	4	36.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1962	4	7.1	4	19.2	4	35.1	2	44.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1963	18	7.2	18	23.1	7	35.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1965[1]	1	9.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	47	6.8	51	21.0	38	33.2	20	38.6	14	42.8	9	45.5	3	48.4	—	—	—	—	—	—	—	—
											Females											
1954	1	8.6	1	25.2	1	38.8	1	46.4	1	50.5	1	54.2	1	56.6	1	58.8	1	60.4	1	61.6	1	62.4
1955	1	8.2	1	17.2	1	27.6	1	37.2	1	45.4	1	50.0	1	54.0	1	56.4	1	58.0	1	59.0	—	—
1956	3	7.3	3	21.9	3	35.5	3	44.5	3	49.7	3	53.4	3	55.9	2	58.4	2	60.0	1	61.0	—	—
1957	2	6.2	2	17.6	2	29.0	2	38.8	2	44.6	2	48.2	2	50.9	2	52.6	—	—	—	—	—	—
1958	1	6.7	1	20.0	1	30.2	1	37.4	1	40.9	—	—	—	—	—	—	—	—	—	—	—	—
1959	5	7.7	5	24.1	5	37.1	5	44.1	5	49.8	5	52.6	1	55.6	—	—	—	—	—	—	—	—
1960	12	7.3	14	21.8	14	33.5	14	39.8	14	44.5	1	53.6	—	—	—	—	—	—	—	—	—	—
1961	9	7.4	9	19.7	7	29.6	7	37.1	1	42.4	—	—	—	—	—	—	—	—	—	—	—	—
1962	2	6.8	2	20.3	2	36.2	2	42.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1963	4	7.1	5	23.5	4	37.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1964	1	14.0	1	26.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1965[1]	1	6.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	42	7.5	44	21.6	40	33.6	36	40.4	28	46.1	13	52.1	8	54.5	6	56.2	4	59.6	3	60.5	1	62.4

[1] Sex unknown.

TABLE 5.—Length-frequency distributions of white-spotted winter flounder of the 1959 year class obtained from commercial catches in 1964-66 from eastern Georges Bank.

Length (cm)	May-June 1964		April 1965		April 1966	
	Male	Female	Male	Female	Male	Female
46	3	1	1	—	—	—
47	3	—	3	—	4	—
48	2	—	—	—	2	—
49	4	—	3	—	—	—
50	1	1	3	—	5	—
51	1	—	1	1	1	—
52	—	3	—	—	2	3
53	—	2	1	3	—	—
54	—	—	1	4	—	4
55	—	—	—	1	—	3
56	—	—	—	2	1	4
57	—	—	—	1	—	3
58	—	—	—	1	—	2
59	—	—	—	—	—	3
60	—	—	—	—	—	1
Total	14	7	13	13	15	23
Mean	48.0	51.1	49.4	54.5	49.7	55.9

(Berry et al., 1965; Poole, 1966; Kennedy and Steele, 1971), it does not approach the rate on Georges Bank at any inshore location where it has been described. Growth of females was greater than males after the first few years in all areas, except off Newfoundland where there appeared to be no difference in the age range covered (Figure 6).

Calculated growth to the first annulus was about 7 or 8 cm for both sexes on Georges Bank (Tables 3 and 4). Although no 0-group fish were obtained from Georges Bank for length comparison, this size agrees closely with the lengths of 0-group winter flounder from inshore Massachusetts waters (Lux and Nichy, 1971). There the 0-group fish by late fall averaged 8.7 cm long in 1961 and 7.3 cm in 1962. There was no apparent growth difference with sex in these inshore fish, for in late October 1962 the males were 7.3 cm long (n =

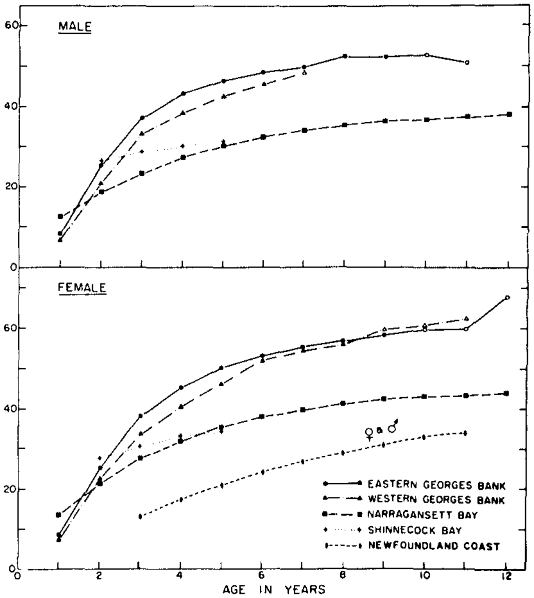

FIGURE 6.—Mean calculated lengths at each annulus for male and female winter flounder from Georges Bank compared with growth data for fish from Narragansett Bay, R.I. (Berry et al., 1965), Shinnecock Bay, N.Y. (Poole, 1966), and Conception Bay, Newfoundland (Kennedy and Steele, 1971). (Open symbols for Georges Bank represent fewer than five fish.)

10) and females, 7.2 cm (n = 18). Length in late fall of the first year in Connecticut waters in 1958 and 1959 was similar to the above, being about 7.0 cm standard length (Pearcy, 1962), which is about 8.7 cm total length. Lengths calculated at the first annulus on otoliths of winter flounder in Rhode Island waters by Berry et al. (1965) were somewhat greater, being 12.5 cm for males and 13.5 cm for females.

Bertalanffy growth equations of the form

$$l_t = l_\infty [1 - \exp(-K(t - t_0))]$$

in which l_t is length at age t, l_∞ is the theoretical maximum length, K is the rate of change in length increment, and t_0 is the age at which growth in length theoretically begins, were fitted by the method of Ricker (1958), to the mean lengths at each age for males and females from eastern Georges Bank (Table 3). The resulting equations

$$l_t = 550 [1 - \exp(-0.37(t + 0.05))] \quad \text{(male)}$$
$$l_t = 630 [1 - \exp(-0.31(t - 0.05))] \quad \text{(female)}$$

express the growth rates for fish of age 3 and beyond (Figure 7).

Estimates of l_∞ given here are principally for use in developing a mathematical expression of growth rather than to accurately portray maximum attained length. The l_∞ of 55.0 cm for males, for example, is somewhat shorter than the maximum observed length of 57.0 cm. Likewise, the l_∞ of 63.0 cm for females is considerably shorter than the 70.0 cm maximum observed.

Inclusion of more large and old fish in the samples might have altered the form of the computed growth curves slightly. Until more accurate equations are derived, however, those given above will provide reasonable accuracy for yield per recruit calculations for both eastern and western Georges Bank.

ACKNOWLEDGMENT

Robert N. Hersey, Northeast Fisheries Center, National Marine Fisheries Service, NOAA, Woods Hole, made independent age determinations of the fish included in this study and performed most of the growth calculations. His assistance is gratefully acknowledged.

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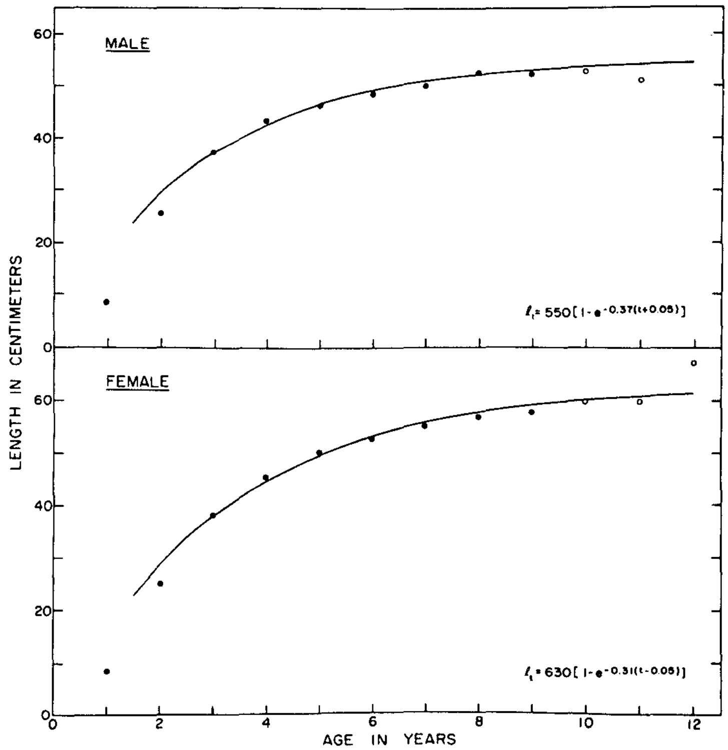

FIGURE 7.—Mean calculated lengths at each annulus for male and female winter flounder from eastern Georges Bank and the fitted Bertalanffy growth curves. (Open circles represent fewer than five fish.)

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