DISTRIBUTION OF WITCH FLOUNDER, *GLYPTOCEPHALUS CYNOGLOSSUS*, IN THE SOUTHERN LABRADOR AND EASTERN NEWFOUNDLAND AREA AND CHANGES IN CERTAIN BIOLOGICAL PARAMETERS AFTER 20 YEARS OF EXPLOITATION

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ABSTRACT

Witch flounder were distributed throughout the study area from Hamilton Inlet Bank to the Northern Grand Bank. The main concentrations were located in Hawke Channel, the channel around Funk Island Bank, and the north slopes of the Grand Bank. While these are believed to be the main locations of three separate stocks, there was no apparent discontinuity in the distribution among the three NAFO Divisions investigated. It is clear, however, that the stock located in NAFO Div. 3K is considerably larger than the combined stocks of NAFO Div. 2J and 3L. Stocks showed minimal variations in depth and temperature preference. Depth and temperature preferences were demonstrated for different size and age-classes of fish. There were substantial reductions in the number of age groups composing the stocks; this was complemented by increases in mean sizes at age for each stock although the magnitude of this increase varied from one stock to another. There was evidence of reduced size and age at sexual maturity in some instances, however, in most cases the results are difficult to explain. These changes in population dynamics are discussed in relation to changes in exploitation over the past 20 years.

Prior to the early 1960's, fishing for witch flounder, *Glyptocephalus cynoglossus*, in the area of southern Labrador and eastern Newfoundland was practically nonexistent. When a significant fishery began in the early 1960's, catches were taken from the accumulated virgin stock in NAFO (Northwest Atlantic Fisheries Organization) Div. 2J, 3K, and 3L (Fig. 1) primarily by large offshore otter trawlers from Canada, Poland, and the Soviet Union. Significant catches were also taken by Newfoundland gill net fishermen in the deepwater bays of northeastern Newfoundland (Bowering and Pitt 1974) (Fig. 1).

Annual landings increased dramatically from <1,000 t in 1963 to peak at nearly 24,000 t in 1973 (Fig. 2). It should be noted, however, that catch statistics prior to 1973 were based upon a formula for breaking down catches of unspecified flounder catches into species and may not be totally accurate. Subsequent to 1973, landings declined nearly as dramatically as they had risen until they stabilized at about 3,000-5,000 t annually over the period 1980-85. In 1973, ICNAF (International Commission for the Northwest Atlantic Fisheries) decided to place catch quota regulations on witch flounder in this area; for management purposes witch flounder in Div. 2J, 3K, and 3L was treated as a single unit (Fig. 1). The first TAC (total allowable catch) was placed on this stock in 1974 at a level of 22,000 t, which was subsequently reduced to 17,000 t for 1975-80, based upon an assessment by Bowering and Pitt (1974). An updated assessment by Bowering and Baird (1980) advised a TAC of 8,000 t for 1981, and this TAC level was in effect up to 1986. The TAC for 1987 was further reduced to 4,000 t.

Although, for management purposes, witch flounder in Div. 2J, 3K, and 3L is considered a single population (stock), stock delineation studies have shown this not to be the case. Fairbairn (1981), using biochemical systematics (electrophoresis), distinguished two separate breeding stocks in this area, one in Div. 3K and one in Div. 3L. No data were available from Div. 2J. Bowering and Misra (1982), employing a new multivariate analysis technique on meristic data, corroborated Fairbairn's (1981) findings and also identified a separate stock in Div. 2J.

The purpose of this paper is to describe the distribution of witch flounder throughout this management zone during recent years and to examine age, growth, and sexual maturity patterns by di-

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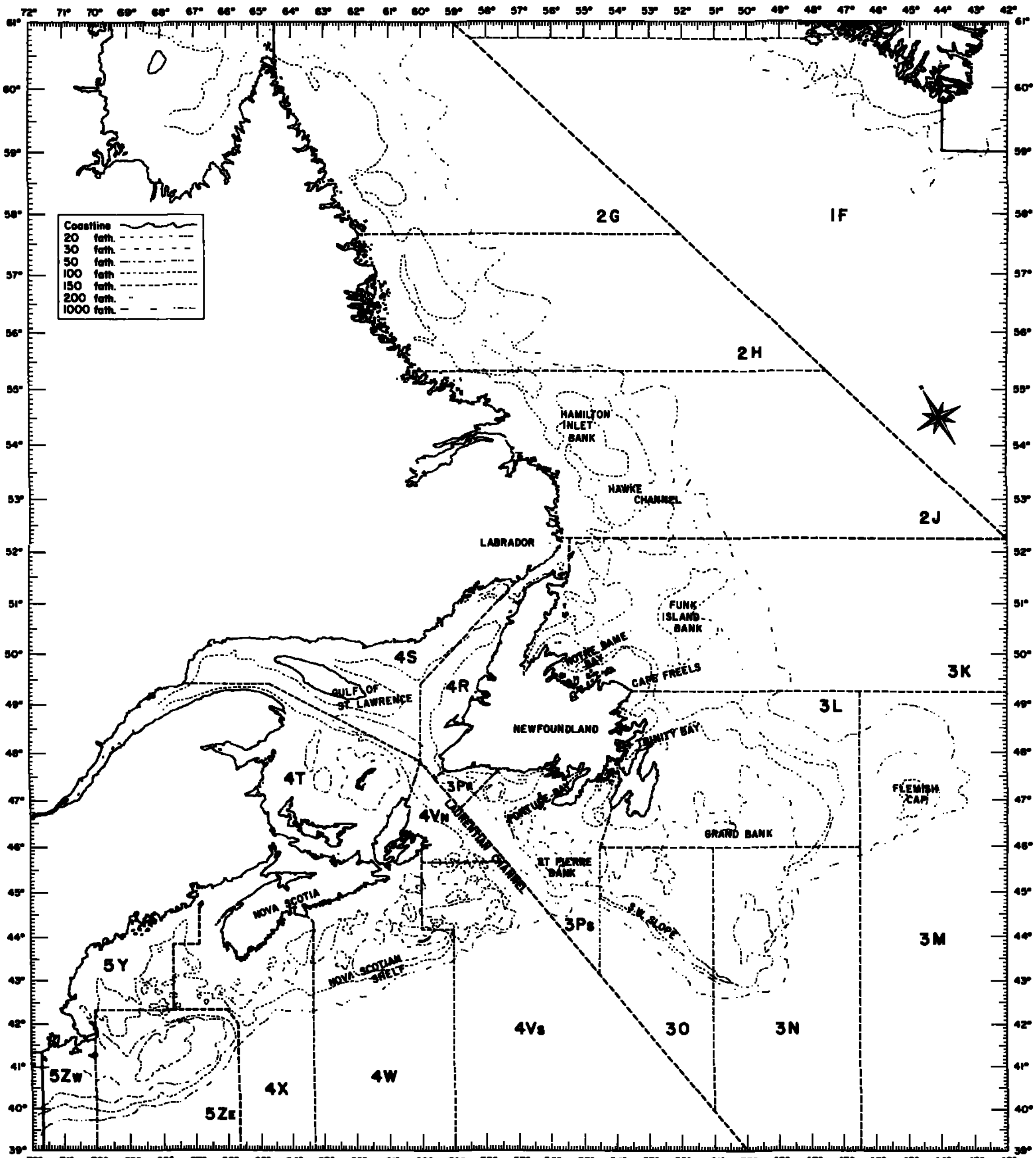

FIGURE 1.—Map of major place names mentioned in the text.

vision (since they contain different stocks) during, and subsequent to, years of heaviest exploitation.

MATERIALS AND METHODS

All data were collected during research vessel surveys for groundfish, carried out on an annual basis by Newfoundland-based research vessels or chartered vessels used for research purposes. All vessels used otter trawls with small mesh (12.7-28.1 mm) nylon liners in the cod end to prevent the escape of juvenile fish. Catch records of sets which experienced enough damage to the gear

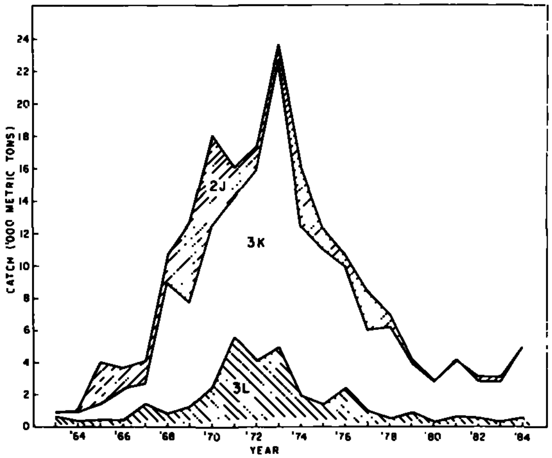

FIGURE 2.—Nominal catches of witch flounder in NAFO Div. 2J, 3K, and 3L from 1963 to 1984.

that overall catch might be affected were not included in the analyses. All fishing tows were of 30-min duration. At the end of each set, bottom temperature was measured using an expendable bathythermograph (XBT).

The geographic distribution and relative abundance is shown by indicating, in 1/2° latitude and 1° longitude rectangles, the average numbers of fish caught per 30-min set. A preliminary examination of distribution of witch flounder by year (all divisions) and season (Div. 3L only where enough seasonal data were available) showed no differences in geographic distribution; therefore, all trips were combined for the period 1977-83. These years were chosen for the distribution study since surveys during this period were based upon random distribution of sets throughout the fishing area whereas prior to this time some areas were surveyed using fixed station line transects not covering the whole area. The number of sets used in the presentation of the distribution is shown in Figure 3.

Ages were determined from otoliths (Powles and Kennedy 1967). Age composition is presented for males and females separately by division. Comparisons of age composition were made for Div. 2J for the periods 1973-78 and 1979-83, Div. 3K for the periods 1970-78 and 1979-83, and Div. 3L for the periods 1968-78 and 1979-83. For Div. 2J and 3K most data were collected during the last quarter, whereas for Div. 3L most data were collected over the last half of the year. However, considering the extent of the data and the very slow growth rate of witch flounder (Bowering 1976), slight differences in the timing of data collection are not sufficient to invalidate comparisons among divisions.

Growth (cm) was expressed in terms of log-log regressions ($\log_e$ Length $= a + b \log_e$ Age (years)). Growth curves were computed for each of the age compositions stated above using data for each fish and not mean length at age. Differences in weight at age were then calculated between the earlier period and later period for each division by applying the length-weight relationship of Bowering and Stansbury (1984) to the observed mean length at age.

The maturity rates were calculated as the length (cm) and age (years) at which 50% of fish were mature (M_{50}) as determined by probit analysis according to the method of Bliss (1952) as applied to witch flounder in the Gulf of St. Lawrence by Bowering and Brodie (1984). The results are presented with 95% fiducial limits. Males for Div. 2J were not included in the calculations due to too low numbers of immature fish in the samples to allow for a significant probit analysis.

RESULTS

Geographic Distribution and Relative Abundance

Witch flounder was caught throughout the stock management zone of Div. 2J, 3K, and 3L from the northern tip of Hamilton Bank to the northern half of the Newfoundland Grand Bank (Fig. 4). Catches were insignificant in the Hamilton Bank area of Div. 2J with mean numbers per 30-min set generally <1.0. The general area of highest abundance in this division was to the south in the Hawke Channel. Here mean numbers per set ranged from about 2.0 in rectangle Q16 to 11.0 in P17, the highest in Div. 2J (Fig. 4). In Div. 3K, mean numbers per set per rectangle were considerably higher than those in Div. 2J. For many rectangles the mean numbers per set were in excess of 10.0. The general areas of highest abundance occurred along the deep waters around Funk Island Bank where mean catches ranged from about 13 to 53 fish/set. The highest density occurred in rectangles P21, P22, Q22, Q23, and R24 where mean catches ranged from 43 to 53 fish/set. In Div. 3L the only significant catches occurred along the northern slope and northeast cape of the Newfoundland Grand Bank. In this area, catches ranged from about 2 to

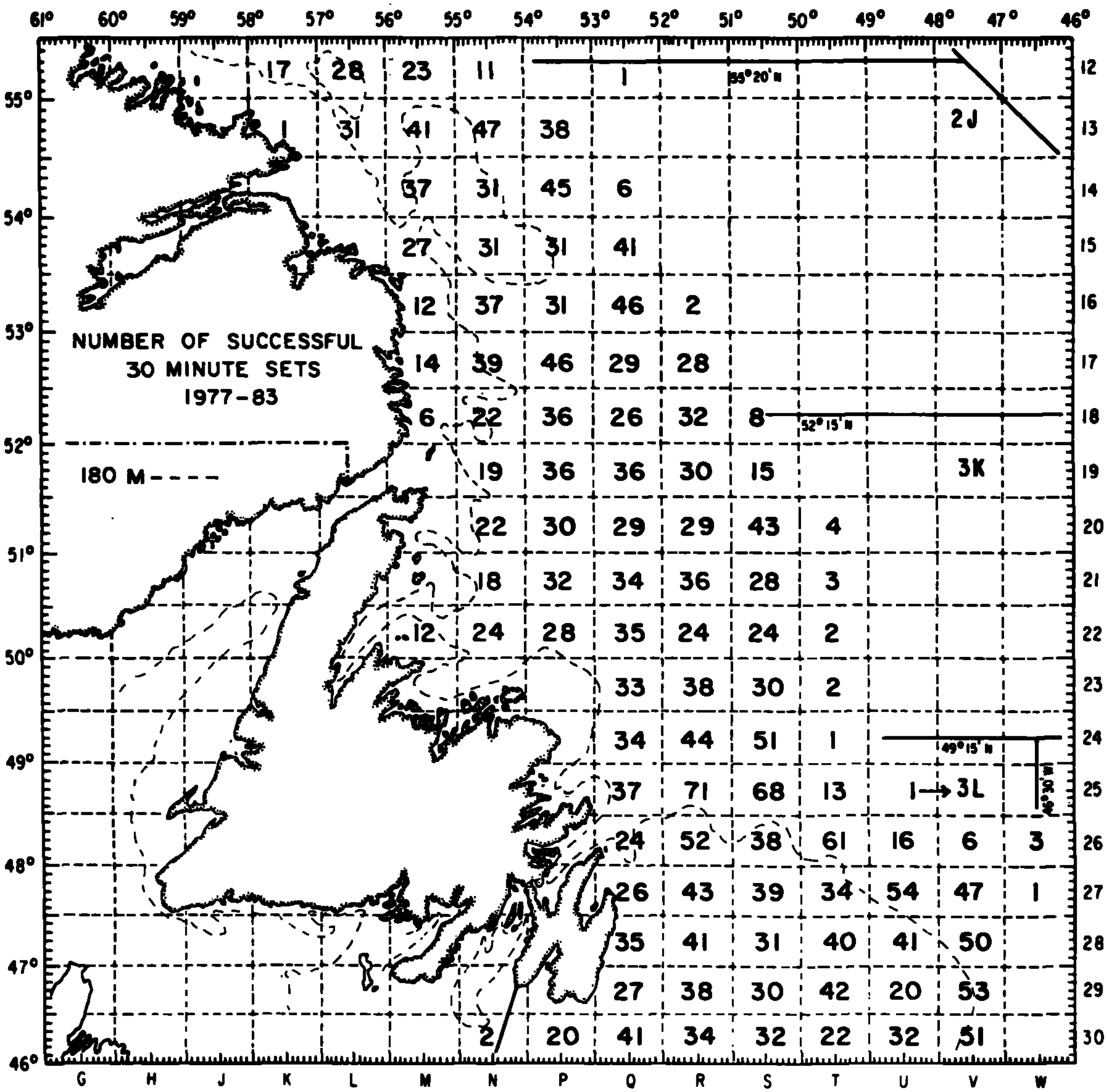

FIGURE 3.—Number of successful 30-min bottom trawl sets per (rectangle) in NAFO Div. 2J, 3K, and 3L by Canadian research vessels from 1977 to 1983.

15 fish. The highest mean catch was 23 and occurred in rectangle W27. This was based upon only 1 set however (Fig. 3). On the other hand, the second highest mean catch per set was 15 fish in the adjacent rectangle V27, based upon 47 sets (Figs. 3, 4). It should be noted also that some of the highest mean numbers per set occurred due east of Cape Freels along the dividing line between Div. 3K and 3L. Catches in the southern portion of Div. 3L were insignificant with most rectangles having mean catches of about 0.1 fish/set.

Distribution by Depth and Temperature

Distribution by 100 m depth intervals of witch flounder is presented in Figure 5. For Div. 2J, witch flounder were caught in depths ranging from 101 to 900 m. However, only the depth range

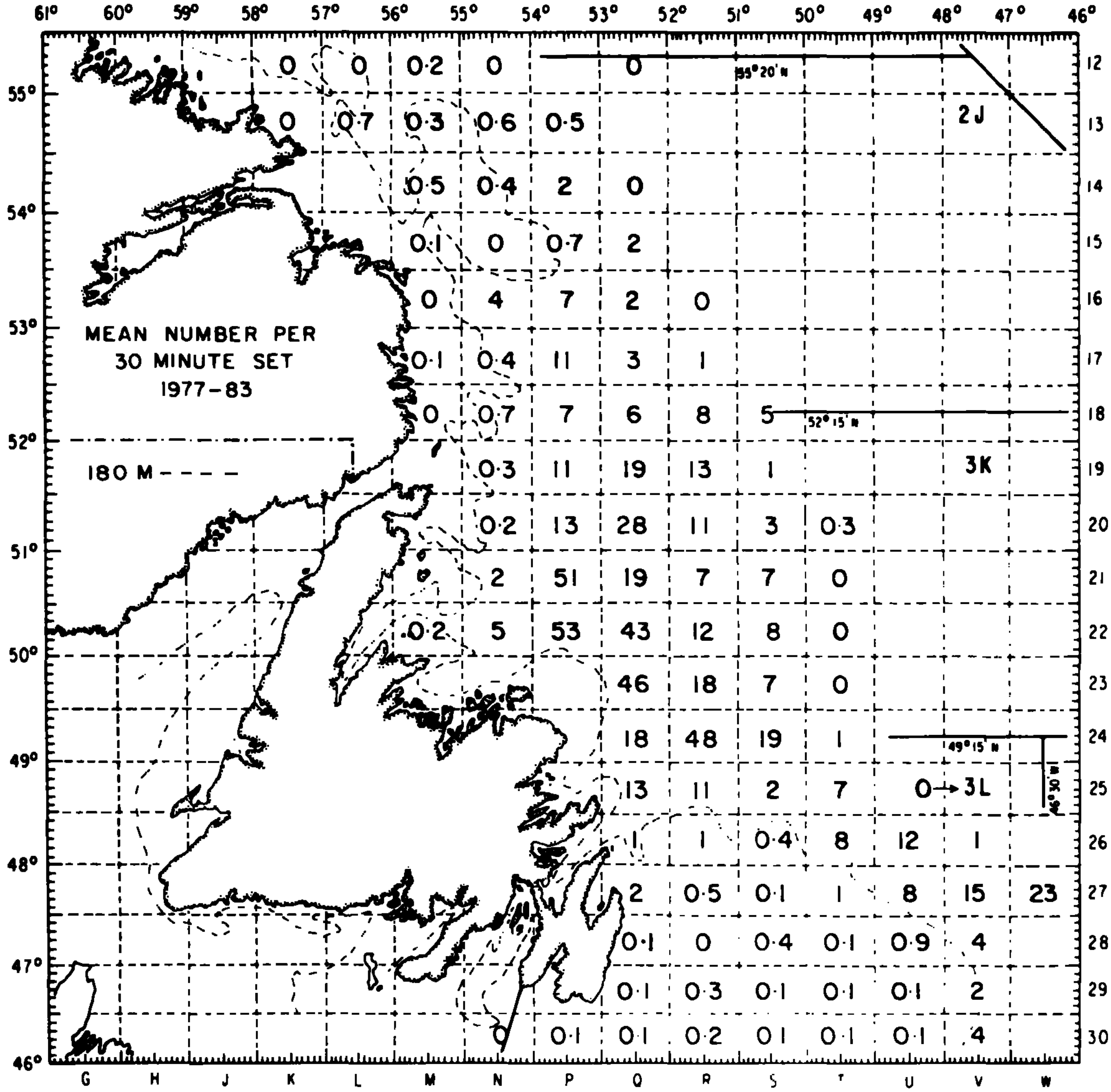

FIGURE 4.—Mean number of witch flounder caught per 30-min set per (rectangle) in NAFO Div. 2J, 3K, and 3L during 1977-83 by Canadian research vessels.

of 301-600 m showed any significant numbers with a peak at 501-600 m after which numbers declined rapidly to near zero. In Div. 3K witch flounder were caught in depths ranging from 201 to 900 m. Only one set was conducted in depths <201 m which yielded no catch (Fig. 5). The mean catch per set increased very sharply from this depth to peak at 401-500 m. The mean catch per set of about 47 fish at that depth interval was significantly different than mean catches in all other depths (Fig. 5). Mean catches beyond 500 m dropped off dramatically to near zero beyond 600 m. In Div. 3L witch flounder were caught in depths ranging from <101 to 800 m. No sets were conducted beyond 800 m (Fig. 5). Mean catches in depths <201 m were close to zero, based upon 864 sets. The increase in mean catch per set was similar to that of Div. 3K and peaked at 301-500 m, however, there was considerable overlap in confidence limits (Fig. 5). Unlike Div. 2J and 3K there

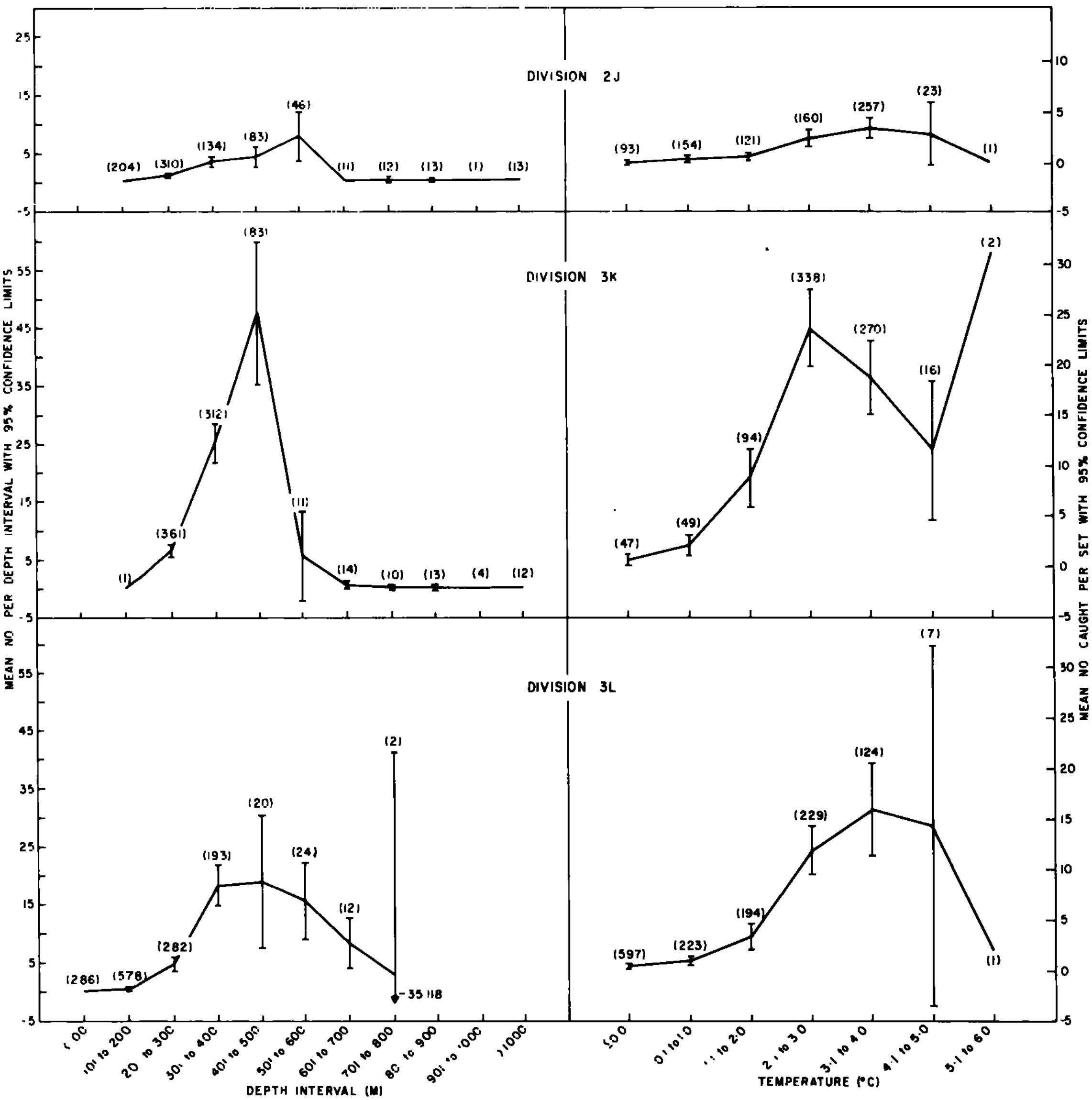

FIGURE 5.—Mean numbers of witch flounder caught per 30-min set per depth and temperature interval in NAFO Div. 2J, 3K, and 3L from 1977 to 1983 with 95% confidence limits. (Numbers in parentheses are number of sets observed.)

was not a marked decline in mean catch beyond the peak with substantial numbers of witch flounder being caught in depths up to 700 m.

Distribution of witch flounder by bottom temperature is also presented in Figure 5. Because of the very low catches in Div. 2J, it is difficult to identify discrete optimum temperatures. There was a slight increasing trend, however, from 1.1°-2.0°C to peak at 3.1°-4.0°C and decline beyond that. In Div. 3K witch flounder were caught in bottom temperatures from ≤0.0° to 6.0°C. There was a marked increasing trend from the 0.1°-1.0°C interval to peak at a temperature range of 2.1°-3.0°C beyond which the mean catch per set declined. The highest mean catch per set occurred at 5.1°-6.0°C. However, this resulted from one large catch in one of the two sets at this interval giving extremely wide 95% confidence limits. In Div. 3L an increasing trend was evidenced similar to that shown for Div. 3K, however, it was slightly less marked and peaked at 3.1°-4.0°C and then declined. The data were too few at the higher temperatures to evaluate the significance of the decline.

Since depth and bottom temperature are generally related, a mean catch per 30-min set by depth and temperature is presented in Figure 6. When depth and bottom temperature are combined the range of best catches for Div. 2J is about 201-600 m and 2.1°-5.0°C. For Div. 3K it is about 201-500 m and 2.1°-4.0°C. For Div. 3L the range of best catches appears to be about 301-600 m and 2.1°-4.0°C. Despite the variations in depth and temperature distribution throughout the three divisions shown in Figures 5 and 6, the depth and temperature relationships among the divisions did not differ greatly or at least not among the locations fished (Fig. 7).

Mean length (cm) and mean age (years) for each depth and temperature interval are presented in Figures 8 and 9 respectively. Mean lengths and ages by depth interval for the three divisions showed similar trends in that they were highest in the shallower depths and declined to reach a low at some intermediate depth then increased and stabilized. For the three divisions combined there was a significant decrease in mean length from about 52 cm at ≤100 m to about 43 cm at 401-500 m. Mean lengths increased beyond this to near 47 cm and stabilized in the 600-900 m range. The mean age decreased from near 11 years old at ≤100 m to about 8 years old at 401-500 m. It stabilized at about 10 years old beyond that.

For all three divisions there was a general declining trend in mean length and age from the lower to intermediate temperatures (Fig. 9). In all cases (except Div. 2J where catches were generally low), the lowest mean size and age occurred at the 3.1°-4.0°C range. For the three divisions combined, there was a significant decline in mean length from about 50.5 cm and 10.0 years old in the 0.1°-1.0°C temperature range to about 45.5 cm and 9 years old in the 3.1°-4.0° temperature range. Beyond this range the mean length and age increased again.

Age Composition

The age compositions of male and female witch flounder by division and time period are presented in Figure 10. For Div. 2J during 1973-78,

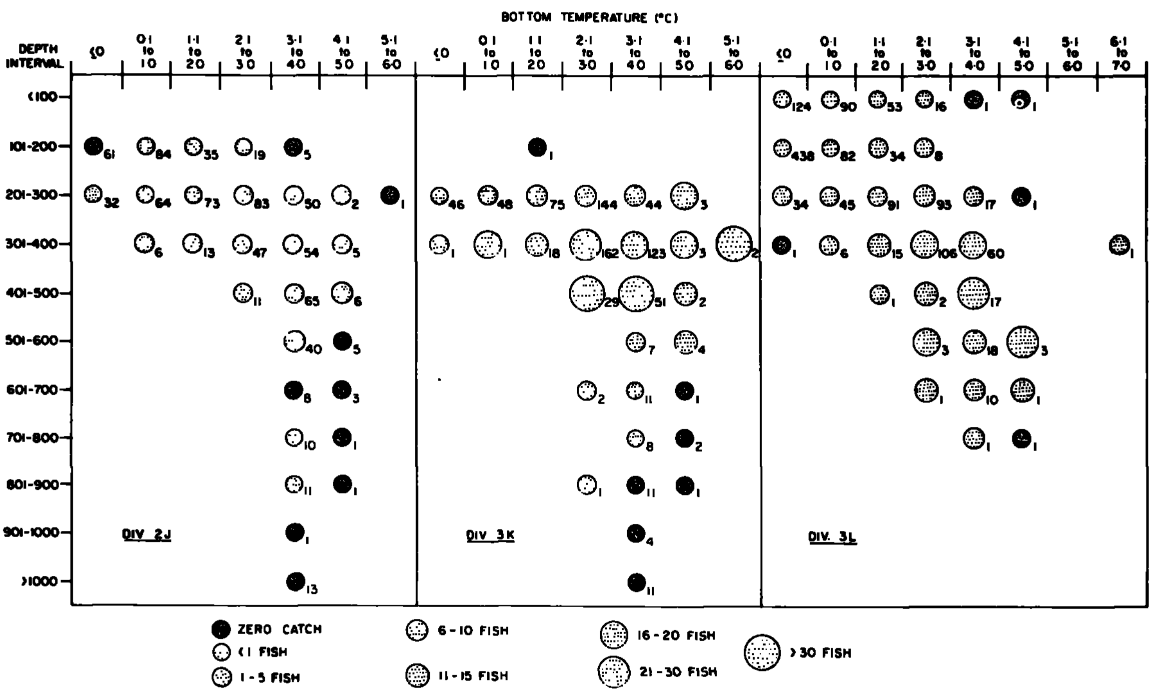

FIGURE 6.—Mean number of witch flounder caught per 30-min set by depth and temperature intervals in NAFO Div. 2J, 3K, and 3L from 1977 to 1983. (Numbers in parentheses are number of sets observed.)

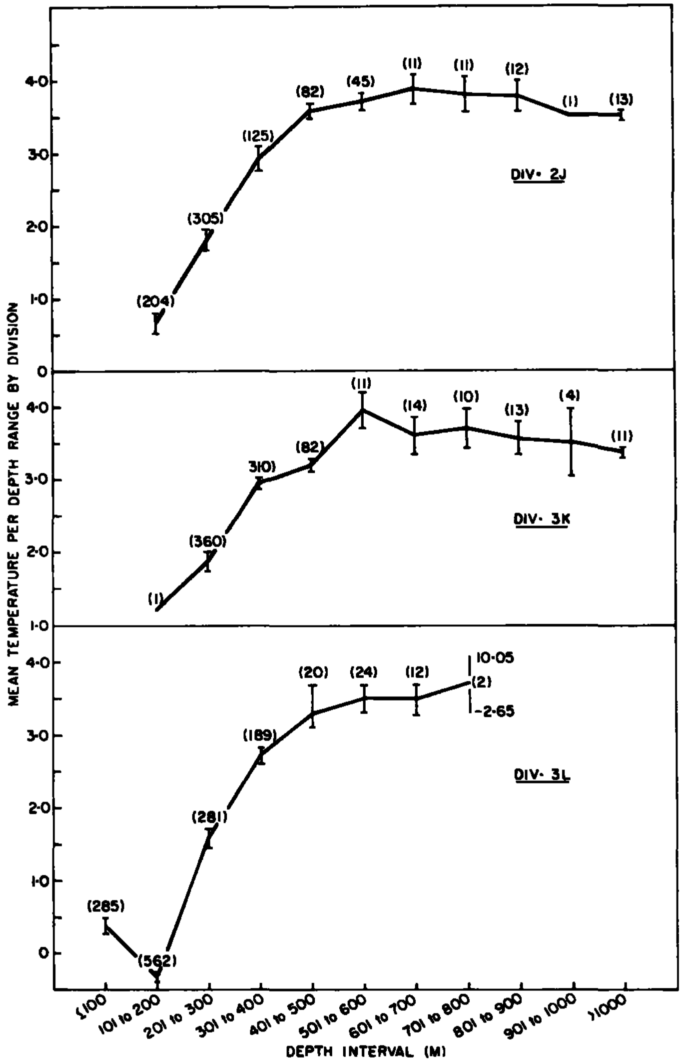

FIGURE 7.—Mean temperature with 95% confidence limits per depth interval in NAFO Div. 2J, 3K, and 3L from 1977 to 1983 as determined from research vessel surveys. The number of sets used in the calculations are shown in brackets for each depth interval.

males and females in the catches ranged from 6 to 18 years old and 4 to 21 years respectively. More than 50% of the males were older than age 10 and more than 50% of the females were older than age 12. In Div. 2J during 1979-83 the males and females ranged from 4 to 11 years old and 6 to 13 years old respectively. Less than 2% of the males were older than age 10 and less than 2% of the females were older than age 12.

For Div. 3K during 1970-78, males and females in the catches ranged from 3 to 16 years old and 3 to 22 years old respectively. About 50% of the males were older than 8 years while more than 50% of the females were older than 10 years. In Div. 3K during 1979-83 the males and females ranged from 2 to 13 years old and 2 to 14 years old respectively. About 30% of the males were older than 8 years with about 30% of the females older than 10 years.

In Div. 3L during 1968-78, males and females in the catches ranged from 2 to 18 years old and 4 to 23 years old respectively. About 50% of the males were older than 11 years and about 50% of the females were older than 12 years. During

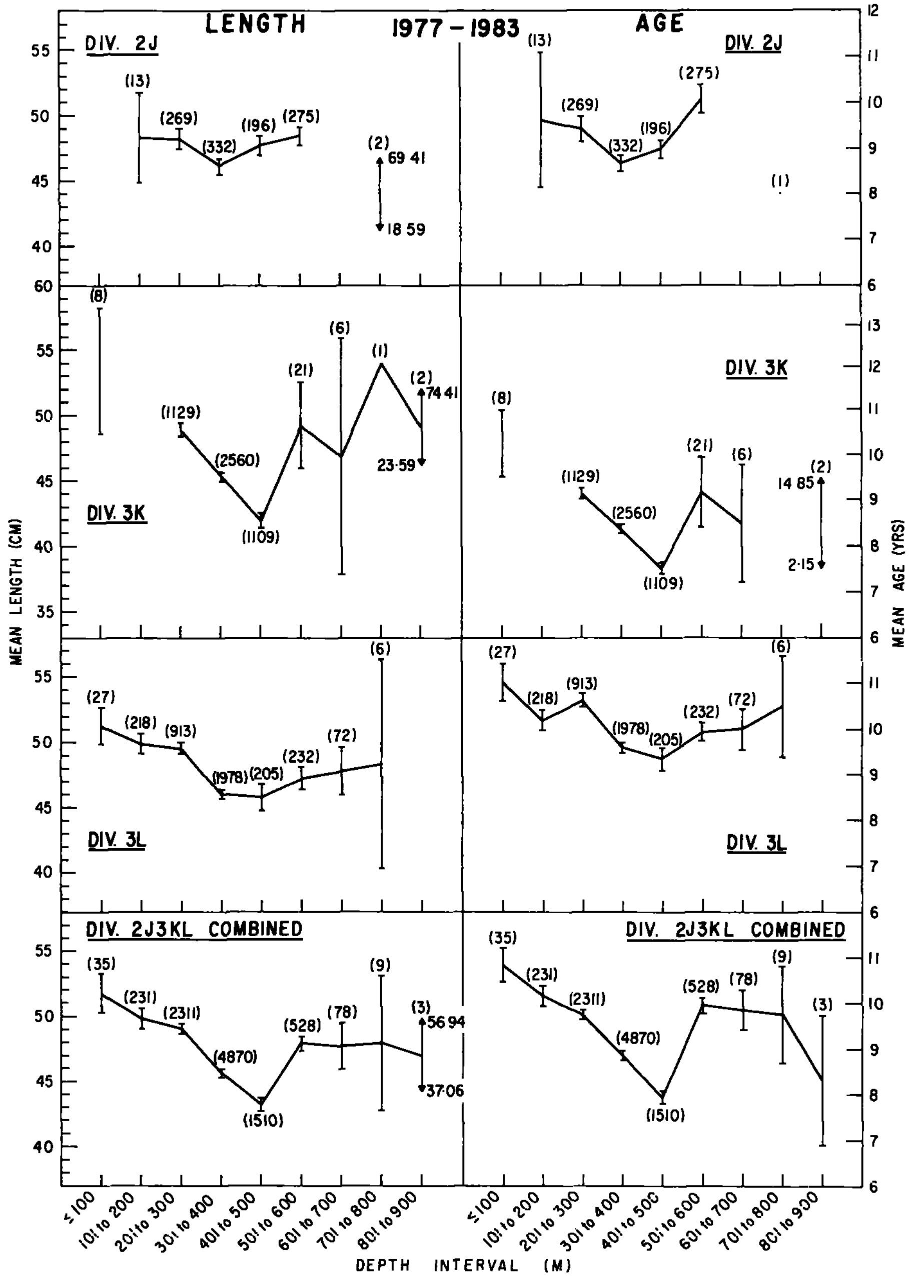

FIGURE 8.—Mean length (cm) and mean age (years) of witch flounder per depth interval in Div. 2J, 3K, and 3L separately and combined from research vessel surveys during 1977-83. (Number in brackets refers to the number of fish observed.)

1979-83 in Div. 3L, males and females ranged from 3 to 13 years old and 3 to 17 years old respectively. Only about 5% of the males were older than 11 years and about 8% of the females were older than 12 years.

Growth Curves

Growth curves of male and female witch flounder with mean lengths at age are presented in Figure 11 and Table 1. Clearly, males do not grow as fast as females over the life span. Growth rates

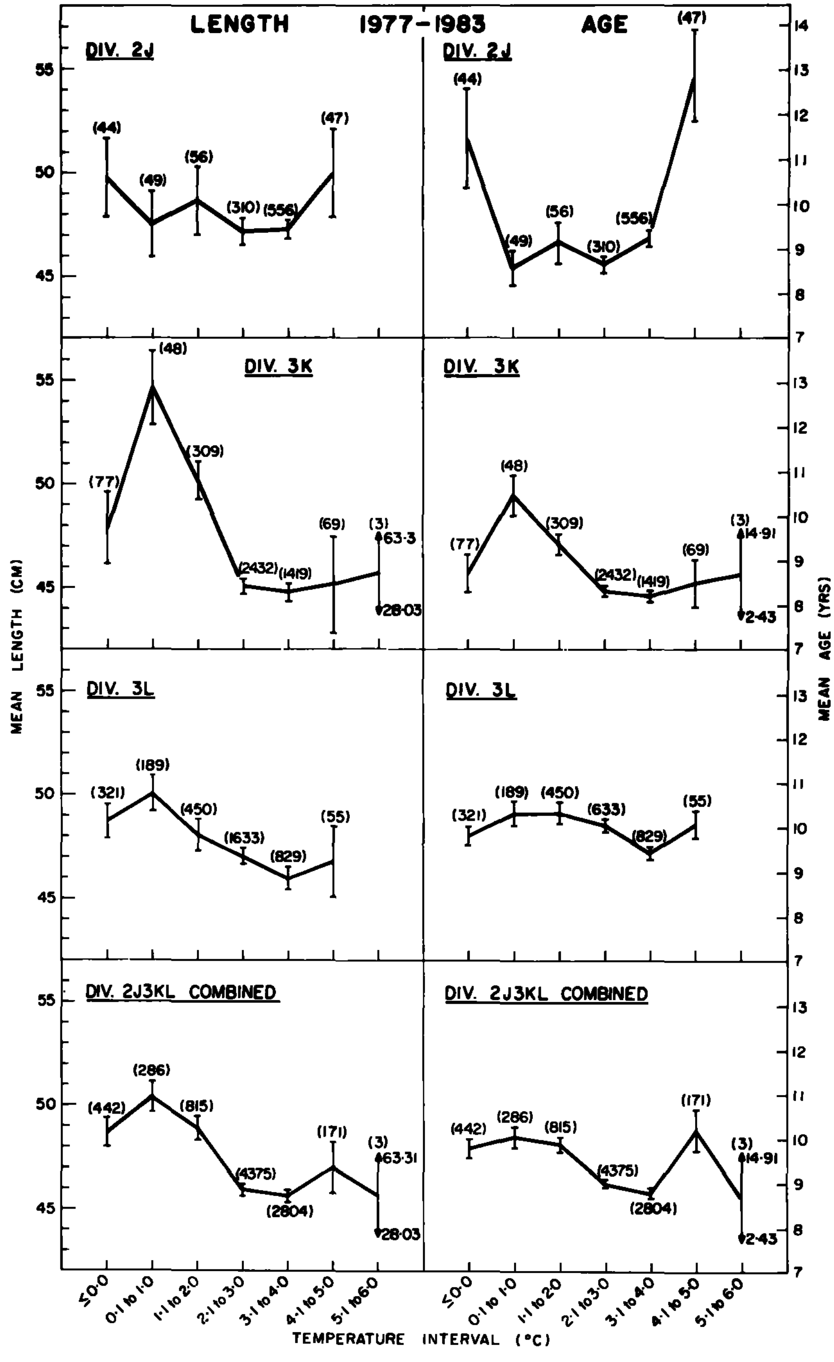

FIGURE 9.—Mean length (cm) and mean age (years) of witch flounder per temperature interval in Div. 2J, 3K, and 3L separately and combined from research vessel surveys during 1977-83. (Number in brackets refers to the number of fish observed.)

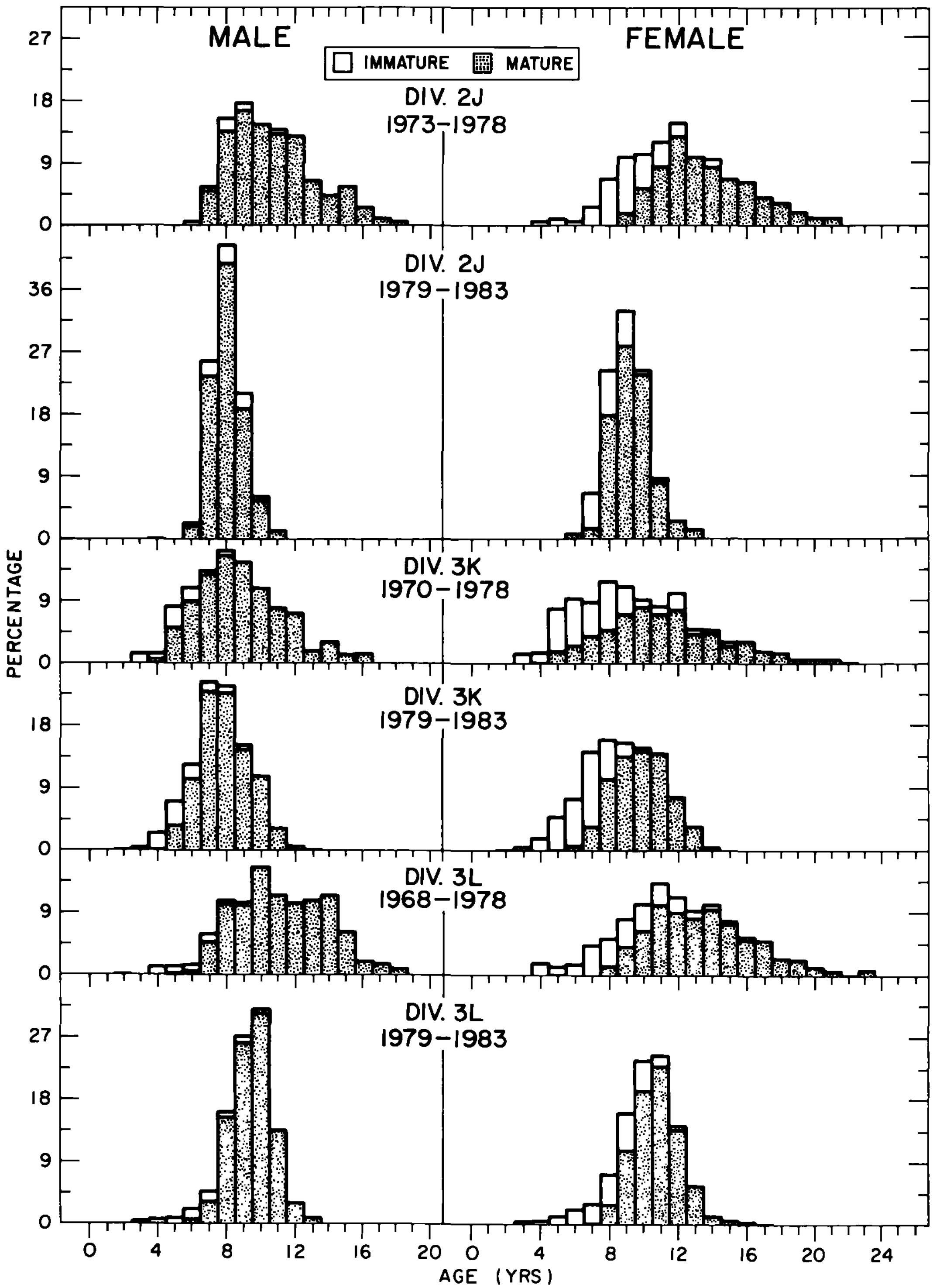

FIGURE 10.—Age compositions of male and female witch flounder in Div. 2J, 3K, and 3L for various time periods between 1968 and 1983. (Shaded areas represent proportions mature at each age.)

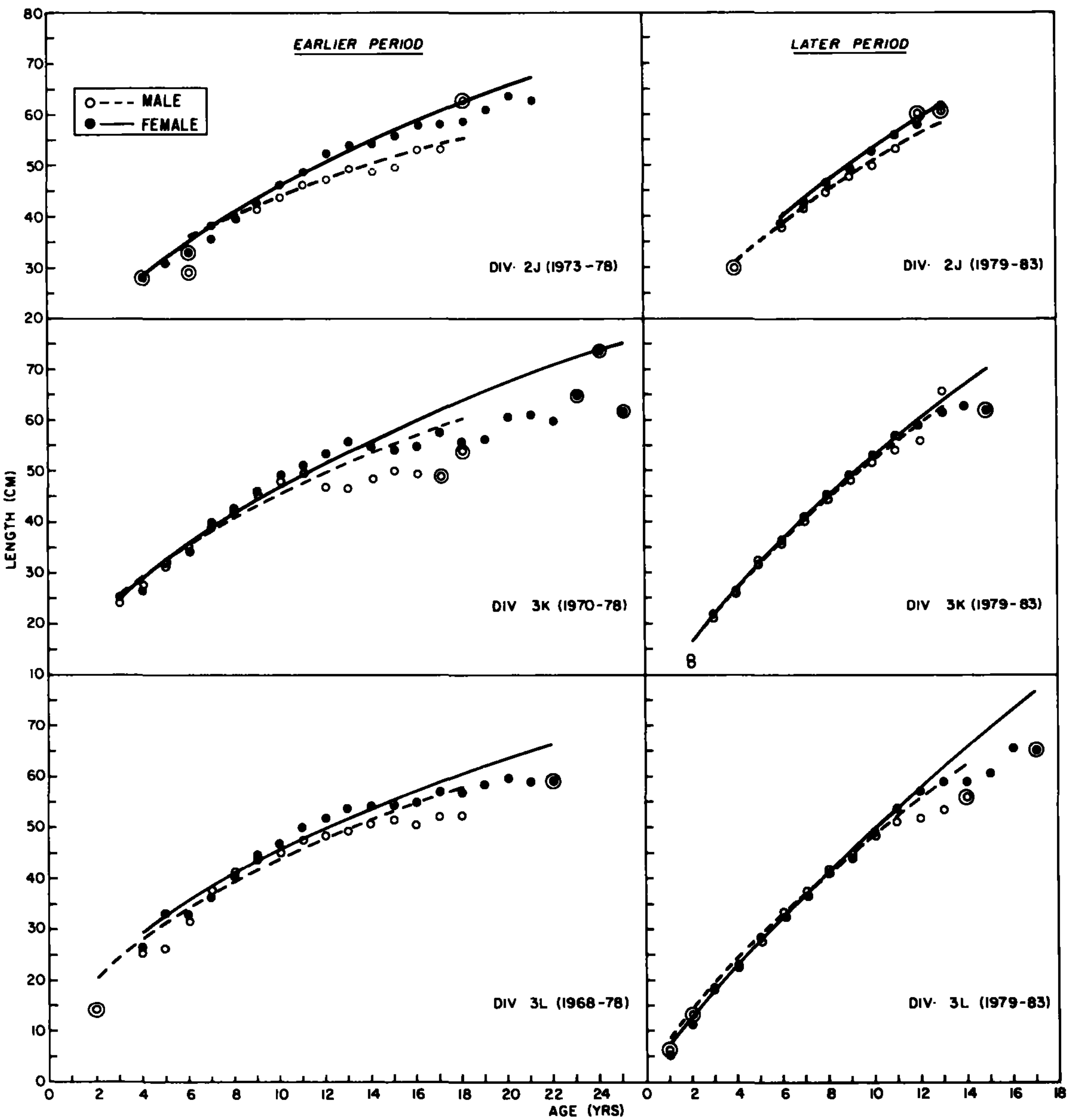

FIGURE 11.—A comparison between two time periods for growth curves of male and female witch flounder in NAFO Div. 2J, 3K, and 3L (circled points indicate only one observation).

(using slopes of the curves as an expression of rate of change of length with age) between the sexes are similar up to about ages 10-12 after which they diverge, particularly if the mean length at age is used as a criterion. While the curves do not appear to fit the mean data points very well in the older ages (and to a much lesser degree the very young ages), the correlation coefficients were all high (Table 1) and all highly significant ($P <$ 0.001). The main reason for this is that the number of observations over age 15 is usually <1%. Taking the 1968-78 males in Div. 3L as an example, even adding a second term to the regression (i.e., c (Log_e Age)^2) increases the amount of explained variation by <3%. In nearly all cases the mean data points in older ages are below the fitted lines (Fig. 11) suggesting that if observations were more numerous in the older ages, the actual

TABLE 1.—Regressions and correlation coefficients for age and growth ($\log_e$ length (cm) = a + b $\log_e$ age (years)) of male and female witch flounder in NAFO Divisions 2J, 3K and 3L.

Years	Division	Sex	Correlation coefficient (r)	Slope	Intercept
1973-78	2J	Male	0.80	0.40	2.86
		Female	0.89	0.52	2.63
1979-83	2J	Male	0.82	0.54	2.68
		Female	0.81	0.58	2.64
1970-78	3K	Male	0.82	0.48	2.71
		Female	0.88	0.52	2.65
1979-83	3K	Male	0.93	0.71	2.31
		Female	0.96	0.72	2.30
1968-78	3L	Male	0.78	0.48	2.67
		Female	0.80	0.48	2.71
1979-83	3L	Male	0.91	0.75	2.15
		Female	0.94	0.83	1.99

sizes at age are likely to be lower than here calculated. As a result, the predicted size at age is probably only meaningful up to about age 12 for males and age 15 for females for the earlier period, and age 10 for males and age 12 for females in the later period (Fig. 11). Predicted size for males in Div. 3L during the earlier period is also somewhat biased below age 6. Despite these concerns there has been a substantial increase in size at age of both males and females in all three divisions between the earlier periods and later periods (Fig. 12). A comparison of growth curves by division, for each sex and time period (Fig. 13), suggests that the size at age of witch flounder in Div. 3K is higher in all cases than that of Div. 3L. It is also higher than that of Div. 2J in the earlier period; however, in the later period the mean size at age of the younger fish in Div. 2J is generally higher.

Changes in mean size at age in terms of weight are presented in Table 2. With the exception of some of the younger age groups, where there was some small reduction in size at age over the time period, there was a substantial increase in weight at age for all commercial size age groups (age 7+). The amount of increase in weight at age varied (Table 2) among divisions but most age groups had increases in weight between 25 and 62%.

Sexual Maturity

The proportions of mature and immature witch flounder are shown in Figure 10. Most males caught were in a mature condition for all divisions and time periods. Few mature males caught were <6 years old and all were mature beyond 10 years old. The proportions of mature and immature fish at particular ages, however, varied among divisions and time periods. For females, few mature fish were caught <8 years old in most divisions and time periods, with the possible exception of Div. 3K during 1970-78. Most were mature beyond age 12. As with the males, the proportions mature and immature at particular ages varied among divisions and time periods (Fig. 10).

Lengths and ages at M_{50} with 95% fiducial limits are presented in Figure 14. For males there was no significant difference in length at M_{50} for either Div. 3K or 3L between the earlier and later periods (no data for Div. 2J). For females there was no significant change in M_{50} for Div. 3K between the 1970-78 and 1979-83 periods but there were statistically significant reductions in M_{50} from about 47.0 cm in 1973-78 to about 44.2 cm in 1979-83 for Div. 2J and from about 44.8 cm in 1968-78 to 41.5 in 1979-83 for Div. 3L (Fig. 14).

For males there was no significant change in age at M_{50} for Div. 3K between 1970-78 and 1979-83. However, the age at M_{50} for males in Div. 3L was significantly reduced from about 6.0 years in 1968-78 to 3.5 years in 1979-83 (no data available for Div. 2J). For females there was no significant change in age at M_{50} for Div. 3K between 1970-78 and 1979-83. There was a statistically significant reduction in age at M_{50} for Div. 2J from about 10.4 years in 1973-78 to 7.5 years in 1979-83. There was a slight overlap in fiducial limits for Div. 3L, however, for practical purposes the age at M_{50} was reduced from 9.8 years in 1968-78 to 7.8 years in 1979-83.

DISCUSSION

Distribution

Witch flounder are distributed throughout the management zone from the northern slopes of Hamilton Bank to the northern slopes of the Newfoundland Grand Bank. Bowering (1976) suggested that witch flounder reaches its northern limits in the Northwest Atlantic at the northern slopes of Hamilton Bank although catch statistics of NAFO occasionally reported commercial catches north of here. Unpublished data from surveys in Div. 2G and 2H by the Northwest Atlantic Fisheries Center, St. John's, Newfoundland have never reported catches of witch flounder in these areas and support the contention of Bowering (1976) and question the accuracy of some commercial catch reports. For the area surveyed, the distribution of witch flounder presented here is

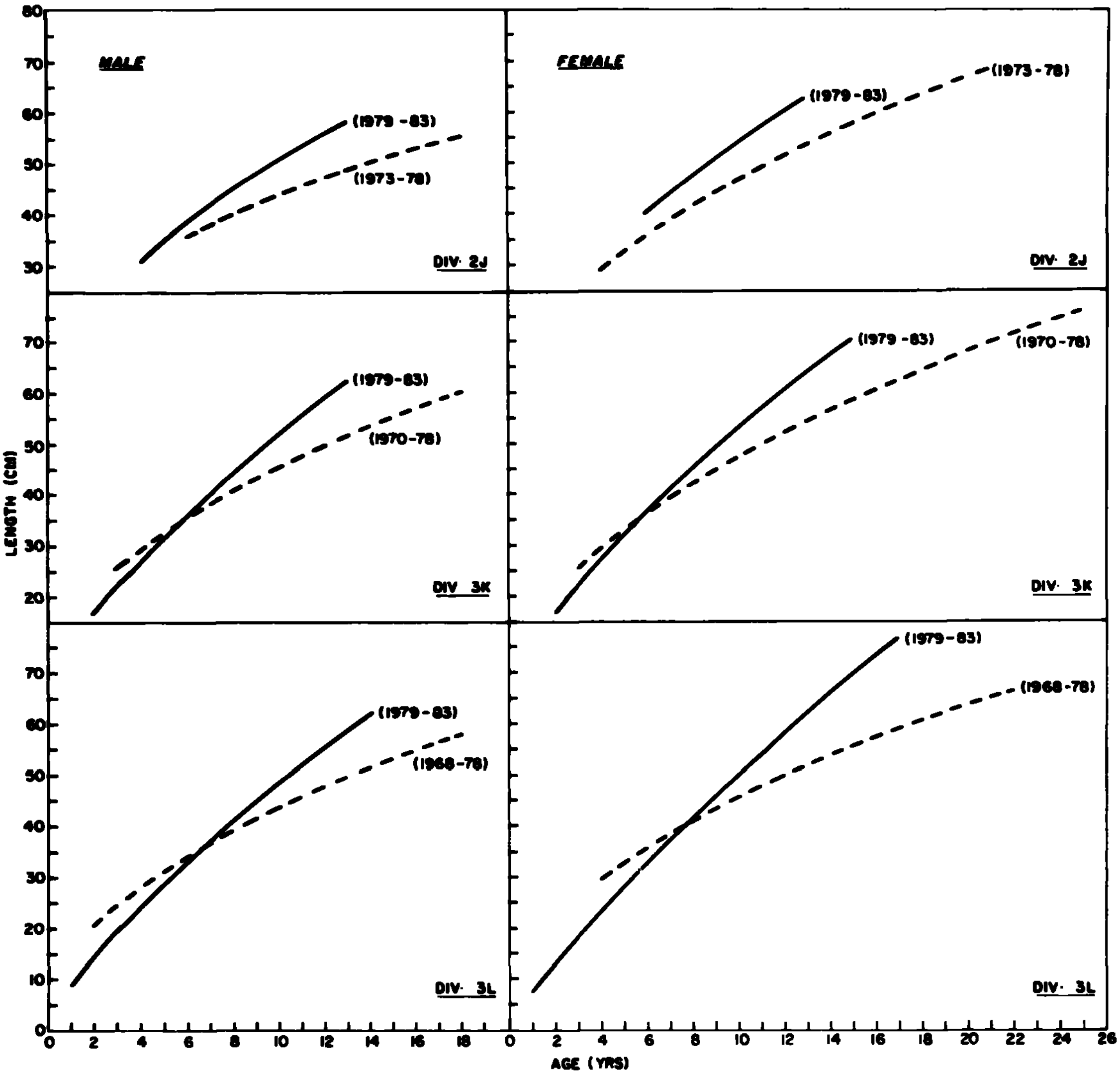

FIGURE 12.—A comparison between male and female witch flounder growth curves in NAFO Div. 2J, 3K, and 3L for earlier and later time periods.

somewhat similar to that published by Bowering (1976) for the 1958-74 period although there was little data available for the southern half of Div. 3K in the Bowering (1976) paper. Although there are no obvious discontinuities in distribution at division boundaries or elsewhere which could account for the occurrence of separate stocks, there are at least three separate stocks of witch flounder reasonably well defined by divisional boundaries as shown by Fairbairn (1981) and Bowering and Misra (1982). This is not to say that some transboundary migrations as adults or through larval drift does not occur when both quite likely do. The largest stock is located in the Div. 3K area according to the catch proportions (Fig. 2) and indices of relative abundance (Fig. 4) presented here. Bowering (1985) reported that minimum trawlable biomass estimates for the management zone during recent years are about 2,500 t, 36,000 t, and 7,800 t for Div. 2J, 3K, and 3L respectively, indicating that the biomass index in Div. 3K is nearly four times higher than Div. 2J and 3L combined.

The major offshore fishing effort towards witch flounder in this zone usually takes place in winter and early spring in areas where prespawning concentrations generally occur, particularly in the

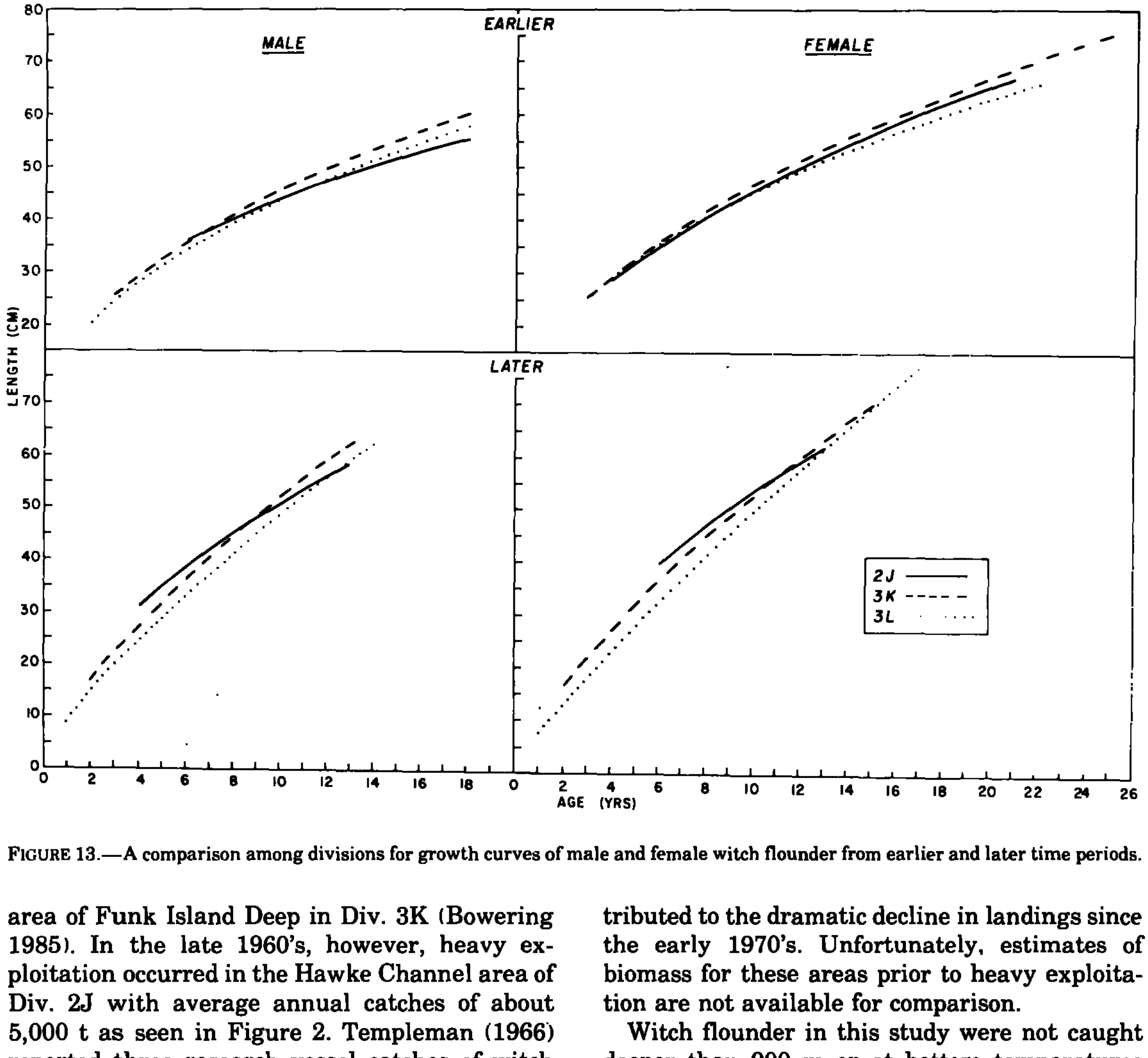

FIGURE 13.—A comparison among divisions for growth curves of male and female witch flounder from earlier and later time periods.

area of Funk Island Deep in Div. 3K (Bowering 1985). In the late 1960's, however, heavy exploitation occurred in the Hawke Channel area of Div. 2J with average annual catches of about 5,000 t as seen in Figure 2. Templeman (1966) reported three research vessel catches of witch flounder in Hawke Channel during April 1963 and 1964 of 2,300 kg, 1,400 kg, and 3,300 kg/hour where these fish appeared to be concentrated. Recent biomass levels of 2,500 t for this area as previously mentioned are now quite low in comparison to the annual catch during the late 1960's even if the catchability coefficient of the survey gear is considerably <1. According to results published in Bowering (1985) the age composition of commercial catches from the management zone in 1976 were as old as 25 years compared to a 15-yr-old maximum in 1984. In 1976, more than 40% of the commercial catch was older than age 12 whereas in 1984 <5% of the catch was older than age 12. It may be that concentrations during prespawning have depleted these stocks, particularly the older, mature fish. This may have contributed to the dramatic decline in landings since the early 1970's. Unfortunately, estimates of biomass for these areas prior to heavy exploitation are not available for comparison.

Witch flounder in this study were not caught deeper than 900 m or at bottom temperatures >7.0°C (higher temperatures were not encountered throughout the study area). Bowering (1976), for the Newfoundland Region as a whole during 1958-74, did not report catches of witch flounder beyond a depth of 869 m, but they were caught at bottom temperatures up to 10°C. Those catches at high temperatures were due mainly to the inclusion of catch data from the southern Grand Bank area (Div. 3N and 3O), where water temperatures are highly influenced by the Gulf Stream. Markle (1975), in studying young witch flounder on the slope off Virginia, caught them down to a depth of 1,408 m and a temperature of 11.3°C. He also found that they were caught in significantly deeper and cooler water in November compared to June. Such a comparison was not possible here. It should be pointed out, however,

TABLE 2.—Changes in mean size at age of witch flounder from 1973-78 to 1979-83 for Division 2J; 1970-78 to 1979-83 for Division 3K; and from 1968-78 to 1979-83 for Division 3L. Only ages common to both periods are included in the comparisons.

	Mean weight (g) Male				Mean weight (g) Female		
Age (yr)	Early	Late	% Difference	Age (yr)	Early	Late	% Difference
			Division 2J				
6	137.53	363.07	164.0	6	215.90	369.73	71.3
7	368.39	486.10	32.0	7	283.25	522.90	84.6
8	430.66	620.16	44.0	8	410.45	723.18	76.2
9	480.01	781.58	62.8	9	528.07	884.41	67.5
10	579.47	907.10	56.5	10	708.68	1,113.32	57.1
11	708.15	1,128.11	59.3	11	860.30	1,355.22	57.5
12	751.14	1,739.31	131.6	12	1,101.59	1,535.95	39.4
13	882.54	1,842.59	108.8	13	1,211.18	1,885.11	55.6
			Division 3K				
3	71.05	44.58	−37.3	3	84.24	47.46	−43.7
4	112.53	99.48	−11.6	4	102.27	99.48	−2.7
5	178.11	199.25	11.9	5	183.34	193.28	5.4
6	257.01	302.54	17.7	6	252.89	300.23	18.7
7	389.19	425.08	9.2	7	402.56	450.79	12.0
8	492.65	602.41	22.3	8	513.94	633.84	23.3
9	654.76	797.71	21.8	9	660.32	842.68	27.6
10	791.92	1,017.10	28.4	10	869.52	1,116.27	28.4
11	872.61	1,202.60	37.8	11	1,003.37	1,416.30	41.2
12	723.18	1,342.57	85.6	12	1,165.69	1,644.10	41.0
13	714.56	2,340.84	227.6	13	1,362.86	1,889.40	38.6
				14	1,277.29	2,062.18	61.5
				15	1,217.44	1,950.18	60.2
			Division 3L				
4	87.79	58.23	−33.7	4	93.95	59.68	−36.5
5	93.95	119.42	27.1	5	215.90	123.66	−42.7
6	179.51	213.39	18.9	6	208.90	209.79	0.4
7	326.43	324.28	−0.7	7	303.71	316.72	4.3
8	451.56	471.19	4.3	8	429.91	466.03	8.4
9	572.11	617.26	7.9	9	626.00	607.17	−3.0
10	632.86	822.34	29.9	10	729.69	845.70	15.9
11	767.38	990.45	29.1	11	920.52	1,168.74	27.0
12	821.16	1,032.36	25.7	12	1,046.37	1,477.51	41.2
13	870.14	1,151.31	32.3	13	1,196.39	1,632.47	36.4
14	962.30	1,367.11	42.1	14	1,211.96	1,628.61	34.4
				15	1,227.67	1,803.88	46.9
				16	1,265.96	2,362.17	86.6
				17	1,445.34	2,299.83	59.1

that Markle (1975) referred only to fish <5 years old, whereas this study has few fish <5 years old.

Witch flounder preferred depths and temperatures at intermediate levels among these samples in Div. 2J, 3K, and 3L. Preferred depth in Div. 3K is more clearly defined than preferred temperature; this is associated with the occurrence of smaller younger fish at intermediate values of the observed ranges. Powles and Kohler (1970) suggested that juveniles in the Gulf of St. Lawrence were in deeper water, separate from the adult, a built-in conservation mechanism for the young. S. J. Walsh (pers. comm.)[2] on the other hand, in examining the distribution of juvenile versus adult witch flounder in the Gulf of St. Lawrence also found that juveniles (<30 cm) had a well-defined preferred depth range whereas the adults (≥30 cm) were distributed over a much wider depth range. For demersal fish it is more common for younger fish to be found in shallower water with most of the larger fish in deeper water (e.g., See Bowering [1984] for Greenland halibut). There is some indication that young American plaice in the Newfoundland-Labrador area may also occupy some intermediate depth over the

[2]S. J. Walsh, Juvenile Flatfish Biologist, Department of Fisheries and Oceans, P.O. Box 5667, St. John's, Newfoundland A1C 5X1, Canada, pers. commun. 1986.

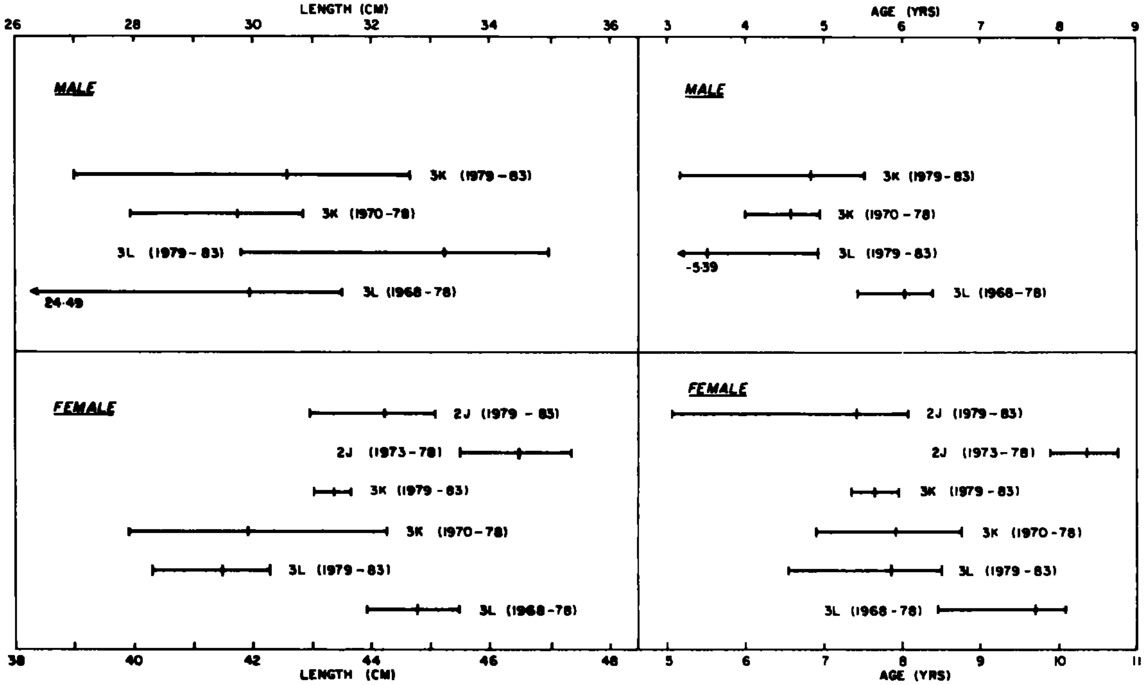

FIGURE 14.—A comparison of lengths (cm) and ages (years) at which 50% of male and female witch flounder are mature from NAFO Div. 2J, 3K, and 3L from earlier and later time periods.

range of its distribution (T. K. Pitt[3]), although the size-depth distribution is not as well defined as presented here for witch flounder. Walsh (1984) concluded, on the other hand, that juvenile plaice occupy the same depth ranges as the adult plaice on the Grand Bank. It should be noted that the results presented in the present paper reflect the depth and temperature preference of young versus old adult witch flounder and not juveniles versus adults as in the studies mentioned.

Age and Growth

The age compositions of witch flounder have changed substantially for all three NAFO Divisions over the study period, with a much shorter life span experienced in recent years. The impact of the reduced life span appears to be greatest on the Div. 2J stock. This may very well be the result of heavy exploitation on prespawning concentrations in the late 1960's when catches were double recent levels of estimated biomass (Bowering 1985). Bowering and Brodie (1984) showed a similar reduction in the life span of witch flounder in the Gulf of St. Lawrence. However, that reduction was more dramatic because it occurred over a shorter time. In 1976, the commercial catches in the Gulf of St. Lawrence comprised fish up to 26 years old compared with a maximum age of 16 years old by 1981. Bowering and Brodie (1984) attributed the sudden change in the population age structure to the fact that almost the entire fishable stock is located in a small area during the winter months when the fishery is most intense. This is particularly true for small stocks such as that in Div. 2J, where it may not be economical to direct effort when the fish are not densely concentrated. In Div. 3K, where the stock biomass is relatively high in comparison to that of Div. 2J and 3L, the fishery is spread more through the year, although the main effort is still directed towards prespawning concentrations. Therefore, the reduction in age groups could be over a longer time period and therefore less dramatic, which seems to be the case here. However, this argument can only be true if, because of such a pattern of fishing, the fishing mortality exerted in areas such as Div. 2J is much higher than for areas such

[3]T. K. Pitt, Section Head, Flatfish Research, Department of Fisheries and Oceans, P.O. Box 5667, St. John's, Newfoundland A1C 5X1, Canada, pers. commun. 1986.

as Div. 3K. Precise information on fishing mortality is unavailable.

The age composition for the 1970-78 period in Div. 3K indicates that little more than 10% of the population was older than 15 years. However, more than 40% of the commercial otter trawl catches in 1976 by both Canada and Poland in Div. 3K were comprised of fish 15 years and older, and more than 30% were 17 years and older (Bowering and Pitt 1977). Thus the impact of the fishery was greatest on the older age groups, and this could explain the rapidity of the disappearance of the population.

Accompanying the reduced age span was an overall increase in size at age for both sexes in all three divisions. The mean size at age for older fish showed a considerable increase from the earlier to later periods examined, whereas the mean size at age for the younger fish was not very different between the two periods. The substantial increase in size of older, commercially exploited fish may be the result of reduced abundance as indicated by the reduced age span. While there is no direct evidence here of density dependent growth, there have been studies published which show that it does occur. Bowering and Brodie (1984) showed that there was a systematic increase in mean size at age of witch flounder in the Gulf of St. Lawrence from 1976 to 1981 for age groups fully recruited to the commercial fishery accompanied by a significant reduction in the age span of the stock. They suggested it was likely the result of increased exploitation and subsequent reduction in abundance. They also showed that because of the increase in growth rate in particular the stock biomass remained relatively stable despite the fact that the stock abundance had been reduced. Unfortunately, estimates of stock abundance and biomass are not available for the earlier periods of this study for comparison.

Bowering (1976) ruled out temperature as a major contributing factor for changes in growth of witch flounder in the Canadian Northwest Atlantic for two reasons: 1) they mainly inhabit depths that are not usually subjected to wide fluctuations in bottom temperature and 2) the growth rates of witch flounder in the more southerly regions are much slower than in the more northerly regions, the opposite of what one would expect if temperature were considered to have a significant influence on its growth rate. Bowering and Brodie (1984) suggested that given the feeding behaviour of adult witch flounder as described by Rae (1969), competition with other species is unlikely to be a significant factor in changes in growth rate, and within species competition is likely to be a more important factor.

Sexual Maturity

It should be pointed out that immature males are not particularly well sampled by the survey gear, and, therefore, the maturity rates may be slightly biased. However, any bias would be consistent for males in all divisions. On the other hand, although younger females are also not well sampled, the first occurrence of mature fish in the samples is reasonably well established. Most of the data here were collected in late summer and early autumn, several months after spawning, and one could have some concern as to the interpretation of immature versus fully recovered gonad condition. I do not feel, however, that witch flounder in these areas studied present significant cause for concern in this regard. The Greenland halibut, a flatfish whose gonad condition is more difficult to interpret, was sampled from northern Labrador in the autumn for visual interpretation of gonad condition complemented by histological analysis by Walsh and Bowering (1981). They found no significant error in the visual (at sea) interpretation of gonad condition, at least for females.

Due to the time of year when sampling occurred, a slight bias in true size and age and maturity may occur; however, it should be consistent throughout the division and time periods examined. Therefore, comparisons should not be biased. Despite such concerns, for the data presented here, it would appear that there was a significant reduction in both mean length and mean age at 50% maturity for both Div. 2J and 3L females and Div. 3L males (for mean age only) over the study period. For Div. 3K there was no significant change in either mean length or mean age at 50% maturity for either males or females over the time period.

Molander (1925) found that for plaice and flounder in the Baltic, maturity appeared at a lower age but at a higher length with increased growth rate, and suggested that when growth rate was poor, the age at maturity was higher. Pitt (1975) found that for American plaice on the Newfoundland Grand Bank, the faster growing fish matured at an earlier age but at approximately the same size. Bowering and Brodie (1984) found similar results for witch flounder in the Gulf of St. Lawrence. It has been suggested, therefore, that sexual maturity may be more dependent upon body size than on age; the hormones that stimulate sexual maturity may only be produced when the fish and gonads reach a certain size or stage of development. Such a conclusion would not be reached from the results presented here for Div. 2J and 3L, and there are other exceptions in the literature such as those of Fleming (1960) and Pinhorn (1966) for cod in the Newfoundland and Labrador area. It should be noted, however, that although there are statistically significant reductions in mean sizes at maturity presented here, they may not be biologically significant; the actual relationships between size and age at sexual maturity is still unclear although some physiologists, such as Alm (1959), believe that it is closely related to initial growth rate. Since little is known about the early life history of witch flounder in the Newfoundland-Labrador area, such relationships between maturity, size, and age are difficult to evaluate conclusively.

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