Canadian Technical Report of Fisheries

and Aquatic Sciences No. 1080

April 1982

SOME ASPECTS OF GROWTH AND EXPLOITATION OF AMERICAN PLAICE (*Hippoglossoides platessoides*) IN THE CANADIAN MARITIMES AREA OF THE NORTHWEST ATLANTIC

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Cat. No. 97-6/1080 ISSN 0706-6457

ABSTRACT

Beacham, Terry D. 1982. Some aspects of growth and exploitation of American plaice (Hippoglossoides platessoides) in the Canadian Maritimes area of the Northwest Atlantic. Can. Tech. Rep. Fish. Aquat. Sci. 1080: iii + 43 p.

Variability in growth rates of American plaice (Hippoglossoides platessoides), as well as plaice size and age compositions in the commercial fishery, was investigated in the southern Gulf of St. Lawrence and the Scotian Shelf fisheries. Mean lengths-at-age for plaice derived from Canadian groundfish surveys indicated that linear regressions adequately described growth up to age 14 for females and age 9 for males. Females grew faster than did males, and both sexes grew faster in warmer waters than those in cooler waters. Instantaneous growth rates of female plaice were generally above 0.20 until age 11 in Div. 4T and age 8 in Divs. 4W and 4X, while those of males were above 0.20 until age 8 in Div. 4T and age 5 or 6 in Divs. 4W and 4X. In the 1970s, plaice of ages 10 and under constituted from 20 to 50% of the landings of females by Canadian otter trawlers and from 40 to 60% of the landings of males.

Key words: American plaice, growth, Hippoglossoides platessoides, Maritimes, population dynamics

RÉSUMÉ

Beacham, Terry D. 1982. Some aspects of growth and exploitation of American plaice (Hippoglossoides platessoides) in the Canadian Maritimes area of the Northwest Atlantic. Can. Tech. Rep. Fish. Aquat. Sci. 1080: iii + 43 p.

La variabilité des taux de croissance de la plie canadienne (Hippoglossoides platessoides), de même que la répartition des tailles et des âges des débarquements commerciaux de plie, ont été étudiées au sud du golfe Saint-Laurent et sur le plateau continental Scotian. Les longueurs moyennes par âge de la plie obtenues à partir des levés canadiens de poisson de fond ont montré que les régressions linéaires caractérisaient convenablement la croissance jusqu'à 14 ans pour les femelles et jusqu'à 9 ans pour les mâles. Les femelles ont grandi plus vite que les mâles, et les individus des deux sexes croissaient plus rapidement dans les eaux chaudes. Les taux instantanés de croissance des femelles se sont situés en général au-dessus de 0,20 jusqu'à 11 ans dans la division 4T et jusqu'à 8 ans dans les divisions 4W et 4X, alors que ceux des mâles se situaient au-dessus de 0,20 jusqu'à 8 ans dans la divsion 4T et jusqu'à 5 ou 6 ans dans les divisions 4W et 4X. Au cours des années 1970, de 20 à 50 % des femelles débarquées par les chalutiers canadiens et de 40 à 60 % des mâles étaient âgées de 10 ans ou moins.

Mots-clés: plie canadienne, croissance, Hippoglossoides platessoides, Maritimes, dynamique des populations.

INTRODUCTION

The American plaice (Hippoglossoides platessoides) is widely distributed in Northwest Atlantic Fisheries Organization Subarea 4 from the southern Gulf of St. Lawrence (Div. 4T) to the Scotian Shelf (Divs. 4VWX) (Scott 1976) (Fig. 1). Although widespread, plaice are most abundant in Divs. 4T and 4V at depths less than 100 fathoms (Halliday 1973). Powles (1965) outlined stock structure of plaice in Div. 4T, but little is known about stock boundaries or seasonal movements of plaice on the Scotian Shelf. Pitt (1969) has reviewed migrations of American plaice on the Grand Bank of Newfoundland.

Before the introduction of otter trawlers to the fishery in Div. 4T in 1947, only a few large plaice were landed as incidental catches in the line fishery for cod (Powles 1965). By the mid-1950s, a commercial fishery comprised largely of otter trawlers had developed, and Danish seiners were added to the fishery in 1958 (Powles 1969). An extensive fishery for plaice on the Scotian Shelf developed in the 1960s, with Canadian landings derived mainly from Div. 4V and Soviet landings from Div. 4W (Halliday 1973). The Canadian fishery for American plaice in the Maritimes is largely conducted by otter trawlers, although in Div. 4T, Danish and Scottish seiners can account for between 30 and 40% of the landings.

Growth of American plaice in the Northwest Atlantic has been investigated by Powles (1965), Pitt (1967), Lux (1970), and Minet (1973). However, age specific instantaneous growth rates may be analyzed to determine the age at which a year-class reaches maximum biomass in order to optimize yield from a fishery. Yield could be increased if exploitation of ages in which the instantaneous growth rate is greater than the instantaneous morality rate is reduced. An analysis of long-term trends in growth rates may indicate whether or not there is selective removal of fast-growing individuals by the fishery and thus if genetic change in the stock is plausible. Regional differences in growth rates may also be of value in defining stocks. The major purpose of this paper is to present some aspects of growth and changes in the size and age compositions of American plaice in the landings of the Canadian commercial fishery in relation to these problems.

MATERIALS AND METHODS

The stratified random design Canadian groundfish surveys upon which part of the analysis was based began in 1970 (Halliday and Kohler, MS 1971). The other part of the analysis involved examining the landings of American plaice in the Canadian commercial fishery from 1965-79. A #36 Yankee otter trawl with 3/4-inch (19 mm) mesh was

used in the July surveys of the research vessel A.T. CAMERON, and the September surveys of the E.E. PRINCE. Otoliths in the commercial and research samples were collected in a sampling design stratified by length, the design based on a method described by Gulland (1955). The age of American plaice was determined from otoliths similar to the method used for cod (Gadus morhua) by Kohler (1964). Total length of plaice was measured to the nearest cm in both the groundfish surveys and commercial samples.

Length and age compositions of American plaice were determined for 5-year intervals. The estimation of age compositions first required increasing the number sampled at each 1-cm length interval to the total catch of the sampled boat. Values from each sample were weighted by the ratio of catch weight of sampled boat to weight of sampled fish. Age-length keys were applied to the total length frequency to give age compositions. For the research surveys, only data from the July cruises on the Scotian Shelf and the September cruises in the southern Gulf of St. Lawrence were grouped in 5-yr intervals. Grouping of the data increased the number of fish sampled in the youngest and oldest ages, thereby allowing more reliable estimation of mean lengths and weights at these ages. However, grouping of the data in this way will allow only regional and long-term fluctuations in growth to the detected.

RESULTS

AGE AND LENGTH FREQUENCIES

Canadian groundfish surveys in Div. 4T indicated that the 1970-72 year-classes were relatively abundant, accounting for about 70% of the research catch of males and 65% of the catch of females in 1976. As 5-yr-olds, these year-classes each comprised about 30% of the annual research catch. The 1965 year-class on the Scotian Shelf was abundant. In Subdiv. 4Vn, over 20% of the annual catch of males and 15% of the catch of females during 1970 to 1974 were from the 1965 year-class. In Subdiv. 4Vs, about 30% of the males and 25% of the females caught annually between 1970 and 1974 were from the 1965 year-class, as were 20% of the males and 15% of the females in Div. 4W. The 1972 year-class was also relatively abundant, especially in Subdiv. 4Vs, where it comprised 25% of the annual catch of both males and females from 1976 to 1979, as well as 25% of the annual catch in Subdiv. 4Vn from 1977 to 1979.

On the Scotian Shelf, when the groundfish surveys were grouped in 5-yr intervals, the proportion of female plaice age 5 and under generally increased in the catch from Subdiv. 4Vn to Div. 4X (Fig. 2), whereas the length frequencies indicated no shift to smaller sizes (Fig. 3). Length frequencies and age compositions of male

plaice showed trends similar to the females, and are omitted for simplicity. Because all American plaice were caught with the same type of net, thus eliminating changes in selectivity, this result suggests that younger plaice in the southern areas were larger than those in the northern areas. The Div. 4T catch had age compositions similar to those of the southern areas (Fig. 2), probably due to the later timing of this cruise than on the Scotian Shelf, thus giving the plaice more time to grow. Length frequencies were similar for all areas surveyed (Fig. 3), except for those of Div. 4T in 1975 to 1979, which were skewed to smaller sizes. This may indicate improved recruitment of smaller plaice to the population in this period or increased availability to the research gear. At least 70% of the females caught during the groundfish surveys were under age 9 in all areas.

The landings of otter trawlers and Danish seiners have been the most extensively sampled for all the gears that have conducted the Canadian fishery for American plaice in the southern Gulf of St. Lawrence and the Scotian Shelf. Age compositions and length frequencies of plaice are presented in detail for otter trawl landings only. The analysis of landings from Danish seiners indicated that age compositions of plaice were generally younger and mean lengths less than those in the otter trawl landings. The number of samples available, along with the number of plaice measured and aged for each interval, is indicated in Table 1. Samples from landings were available only in Divs. 4T and 4V, and each area will be considered separately.

Div. 4T

Sampling the landings of otter trawlers in the 1970s indicated that mean lengths and ages of female American plaice were consistently larger than those of males (Table 1). Plaice age 10 and under accounted for 60% of the male landings and an average of 50% of the female landings in the 1970s. However, the groundfish surveys indicated an age structure of plaice considerably younger (Fig. 2) than that landed by otter trawlers (Fig. 4). Mean ages in the otter trawl landings were between 50 and 80% greater in the commercial landings than in the research catch. During 1975 to 1979, over 60% of the catch of females in the research gear was under 30 cm in length (Fig. 2), but only about 2% in the landings was under 30 cm in length (Fig. 5). Mean lengths and mean ages of plaice in the landings showed a slight increase in the late 1970s as compared with the early 1970s.

Subdiv. 4Vn

Mean length and age of American plaice landed by Canadian otter trawlers in Subdiv. 4Vn declined during 1975 to 1979 as compared with 1970 to 1974 (Table 1). Mean lengths and ages of females were consistently larger than those of males. Male plaice age 10 and under accounted for less than 40% of the landings in the 1970s, and plaice of the same age accounted for less than 20% of the landings of females

(Fig. 6). Age compositions and length frequencies of the landings were not available from 1965 to 1969 because the weight of the landings for each of the two vessels sampled was not available. The age composition of the landings was again consistently higher than that of the research catch (Fig. 3). Plaice 30-36 cm in length comprised over 50% of the landings of males (Fig. 7), similar to that of Div. 4T. From 1975 to 1979, plaice 36-42 cm in length comprised over 40% of the female landings, as was the case in Div. 4T.

Subdiv. 4Vs

Mean length of male plaice landed by Canadian otter trawlers in Subdiv. 4Vs decreased by less than 2 cm since the late 1960s, while that of female plaice has declined about .6 cm (Table 1). Plaice age 10 and under comprised about 60% of the landings of males in the 1970s, and about 40% of the landings of females (Fig. 8). Plaice 30 to 36 cm in length comprised at least 40% of the male landings in the 1970s, and plaice 36 to 42 cm in length comprised about 30% of the female landings (Fig. 9). Length frequencies and age composition in the landed catch were composed of considerably larger and older fish than in the research catch (Fig. 2, 3).

CHANGES IN LENGTH

The data covering the available age ranges for females suggests that growth of female plaice was essentially linear (Fig. 10). The data for males suggests a more curvilinear relationship (Fig. 11), but it is difficult to determine empirically because mean lengths in the older age groups were quite variable. Even though the surveys were grouped in 5-yr intervals, the number of otoliths read for males greater than age 12 was generally less than 15/age, and thus mean lengths and weights were variable in this older age group. For females, because there was no evidence of asymptotic growth, linear regressions were used to describe variability in growth rates. Bowering (1978) followed a similar procedure in describing growth of Greenland halibut (Reinhardtius hippoglossoides). Linear regressions were also fitted to the male mean length-at-age data to allow for a comparison with females. Linear regressions were fitted to the mean length-at-age data between ages 3 and 14 for females, and ages 3 and 9 for males. Linear regressions accounted for the variability in growth rates for the ages which were adequately sampled extremely well (all $r^2 \geq 0.95$) (Table 2). There was a general inverse relation between the intercept of the regression and latitude, which suggests that American plaice in more southerly areas grew faster than those in more northerly ones, as indicated in Fig. 5 and 6. Females generally grew faster than males, with average rates of 2.5 cm/yr and 2.3 cm/yr, respectively, over the ranges of ages investigated.

Regional variability in growth rates was investigated by comparing mean length-at-age of same-age plaice between 1970 and 1979

over all ages and among areas on an annual basis, with separate analyses for males and females. Sign test analysis (Mendenhall 1971, p. 369) was used to evaluate growth rates. When the mean length of plaice in a southerly area was greater than in a northerly area, the comparison was scored "+"; when it was lower, it was scored "-". Div. 4T was excluded because the survey in that area was in September, whereas on the Scotian Shelf it was in July. This sign test analysis indicated that American plaice of the same age were larger in more southerly areas than those in more northerly ones (Table 3). This same trend was evident in Fig. 10 and 11, although plaice in Subdiv. 4Vs were generally larger at older ages than those in Div. 4W, which accounts for the non-significance of the sign test (Table 3). A similar sign test analysis based on all areas on the Scotian Shelf indicated that age-4 and older females were larger than similar-aged males (356+, 44-, $P<0.01$).

The effect of bottom water temperatures on growth rates was investigated by comparing mean length at age 5 and mean bottom temperatures as derived from the July groundfish surveys. Mean length at age 5 was correlated with water temperature for males ($r=0.74$, $n=8$, $P<0.05$) and females ($r=0.79$, $n=8$, $P<0.05$) (Table 4). An increasing rate of growth of American plaice was coincident with increasing bottom water temperatures.

Table 5 indicates that the exponent in the length-weight relationship for female plaice was always larger than that of males, which suggests that the rate of increase in weight with respect to length was greater in females than in males. There was also a trend for an increasing exponent with time. The mean age of the catch tended to be higher in Div. 4V than in other areas, which may indicate that there was poorer recruitment to the populations in these areas than in the other ones, or that the young plaice were unavailable to the research gear.

Growth rates of American plaice as determined from samples of the landings of Canadian otter trawlers and Danish seiners were analyzed in order to investigate variability in growth rates. Although mean lengths-at-age of plaice in the commercial landings may be biased by discards of small plaice at sea, or discards of large plaice due to a jellied condition of the muscle (Templeman and Andrews 1956), or changes in mesh size and hence selectivity with time, the results from the analysis were in agreement with those of the groundfish surveys, where data has been collected in a standardized fashion.

To investigate if there were size differences between same-age plaice landed in the same year by otter trawlers and Danish seiners, I compared appropriate mean lengths for each sex over all years and all ages for plaice landed in Div. 4T and Subdiv. 4Vn by sign test analysis. This analysis showed that plaice of the same age landed by otter trawlers were larger than those landed by Danish seiners for both males (17+, 2-, $P<0.01$) and females (21+, 3-, $P<0.01$). This test was somewhat biased by the January-April grouping of otter trawl landings compared with the June-September grouping of

Danish seine landings in Subdiv. 4Vn. These groupings were necessary due to the different seasonal activities of these gears, but this grouping would make selectivity differences between gears less detectable, and thus different selectivities may be real, given similarities in discarding practices. Thus, otter trawlers landed larger members of a year-class as compared with Danish seiners.

Sign test analysis was also conducted comparing mean lengths of male and female plaice of the same age derived from commercial samples from Div. 4T and Subdivs. 4Vn and 4Vs. Females were always larger than males of the same age in landings of otter trawlers (36+, 5-, $P<0.01$) and Danish seiners (25+, 1-, $P<0.01$). Thus in commercial samples, where the youngest age represented is about 5 or 6, females were larger than males of the same age and must necessarily grow faster.

CHANGES IN WEIGHT

Mean weights-at-age for Div. 4T American plaice (September) and Scotian Shelf (Divs. 4VWX) (July) based on the groundfish survey cruises are presented in Table 6. In the more southerly areas (Divs. 4WX), males and females had a similar weight until age 3, whereas in the northerly areas (4T-4Vn), the sexes were of similar weight until age 6 (Table 6). After age 12, females could weigh twice that of males. There could be a large degree of annual variability in weights-at-age, with annual mean weights-at-age of Div. 4W American plaice indicated in Table 7. Weights of age 7 and younger Div. 4W plaice tended to be higher in the late 1970s than earlier in the decade. There has been no consistent unidirectional change with time.

Instantaneous growth rates of female plaice tended to be higher than those of male plaice (Table 8). Instantaneous growth rates of Div. 4T female plaice were generally above 0.20 up to age 11, and above 0.15 up to age 14. Div. 4T male plaice were generally below 0.20 by age 7. Div. 4W female plaice had instantaneous growth rates above 0.20 until about age 8, and above 0.15 until age 10. Instantaneous growth rates were more variable in areas with less plaice sampled for age (Table 6), and thus sampling variability tends to obscure trends. However, there is a tendency for American plaice in more southerly areas to have lower instantaneous growth rates than those in more northerly areas after age 8 or 9.

DISCUSSION

Studies on variability in growth rates of American plaice have usually investigated the effects of water temperature and stock biomass. Water temperatures and subsequent growth rates have been

linked in some stocks (Pitt 1967, 1975; Lux 1970; Minet 1973), with higher growth rates generally found at higher water temperatures. However, there may be an interaction between temperature and food availability, with slower growth rates not necessarily indicative of lower water temperature. Brett et al. (1969) showed that for sockeye salmon (Oncorhynchus nerka), the optimum temperature for growth was dependent upon the ration available, with fish growing faster at lower temperatures if less than maximum ration was provided. Stock density has also been suggested to have an impact on growth rates (Pitt 1975; Bannister 1977), and this avenue could be explored further when stocks have been defined.

Observed growth rates may also be influenced by changes in gene frequencies over time for genes controlling growth. The selective removal of fast-growing individuals by fishing has been suggested to account for the decrease in size with time of pink salmon (Oncorhynchus gorbuscha) (Ricker et al. 1978) and brown trout (Salmo trutta) (Favro et al. 1979). This mechanism could potentially be of significance in American plaice, owing to discarding and death of young, immature plaice (Jean 1963). However, mean lengths-at-age for Div. 4T plaice apparently changed little over 20 years, with those in the 1970s similar to those recorded by Powles (1965) for Div. 4T plaice between 1957-61. There has been no detectable downward trend in the 1970s in mean weights-at-age (Table 7). Pitt (1975) found that mean length-at-age increased for plaice in Divs. 3L and 3N between 1959 and 1972. These results suggest that either the fishery has not been selectively removing fast-growing individuals, or that environmental factors (temperature, stock biomass) rather than genetic changes have more influence on American plaice growth rates.

The present study indicated that mean lengths of same-age American plaice landed in Divs. 4T and 4V by Canadian otter trawlers were larger than those landed by Canadian Danish seiners. These differences are probably dependent upon the different selectivities of the gears, if the discarding practices are similar for both gears.

Mean lengths-at-age for southern Gulf of St. Lawrence plaice in the 1970s (Fig. 4, 5) were very similar to those between 1957 and 1961 (Powles 1965) and for plaice in Subdiv. 4Vn between 1970 and 1971 (Minet 1973). Plaice on the Scotian Shelf and the southern Gulf had larger mean lengths-at-age than those north of the southwestern Grand Bank of Newfoundland (Pitt 1967), but were smaller than those in NAFO Subarea 5 off New England in the United States (Lux 1970). Pitt (1967) demonstrated that there was a positive correlation between mean length-at-age and bottom temperature, and the present study supports this result. The present study indicated that plaice inhabiting warmer waters have higher rates of growth than those in cooler waters, but that there was no practical way of defining stocks of plaice based upon variability in growth rates presently available.

There was a considerable difference in length and age frequencies of plaice in the commercial landings and research catch. Some of this difference is due to the different selectivities of the different gear types, but studies in the southern Gulf of St. Lawrence

have indicated that over 40% of the plaice caught were discarded (Jean 1963; Belzile MS 1978). These discards were usually small plaice, although some large plaice may be discarded because of the "jellied" condition of their flesh (Templeman and Andrews 1956). There were also marked differences in size and age compositions of plaice in commercial landings and research catch of plaice in Subdiv. 4Vs, which is probably due in large part to discarding of plaice less than 30 cm in the commercial fishery (Belzile MS 1978).

The analysis of the landings of Canadian otter trawlers in the 1970s indicated that plaice age 10 and under usually accounted for at least 40% of the landings after discards. With discards included, this figure would be considerably higher, and Jean (1963) lists evidence to suggest that in the late 1950s over 70% of plaice caught in Div. 4T were discarded, and similar rates were found in the 1960s (Powles 1969). Instantaneous growth rates of plaice derived from the groundfish surveys were generally above 0.20 for females age under age 10 and for males under age 7 (Table 8). Instantaneous rates of natural mortality have been suggested to be about 0.25 for males and 0.20 for females for stocks in the Newfoundland area (Pitt 1973), or between 0.11 and 0.16 for sexes combined in Div. 4T (Powles 1969).

If the instantaneous rate of natural mortality is near 0.15, then this result suggests that yield is being lost from a year-class when the catch is concentrated upon younger fish, because at these ages the instantaneous growth rate is greater than the instantaneous mortality rate, resulting in a net increase in biomass of the year-class. The age at which a year-class reaches maximum biomass in Div. 4T would be past age 14 (Table 8). If natural mortality is 0.20 or above, yield is still being lost when the catch is concentrated upon younger fish, but the age at which a year-class reaches maximum biomass will decrease, which for Div. 4T plaice would be less than age 10.

The natural mortality estimates are variable for the different plaice stocks. If there is a link between growth rate and natural mortality (Gerking 1957; Ware 1975), then presumably plaice in more southerly areas should also have higher natural mortality rates than those in more northerly areas. The age at which a year-class reaches maximum biomass would then be greater in more northerly areas as compared with southerly areas. Further work is necessary to evaluate natural mortality rates for the different stocks of American plaice, as well as investigations concerning stock deliniation.

ACKNOWLEDGMENTS

I am indebted to all those people who have crewed the research vessels, sampled the landings in the commercial fishery, and aged the plaice. A. Vromans and B. Fowler assisted in some of the

analysis. Dr. S. Messieh (Marine Fish Division) made helpful comments on a draft of this manuscript. The manuscript was prepared with the assistance of the staff at the Pacific Biological Station.

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Table 1. Mean length (cm), mean age (yr), and sample sizes of American plaice derived from sampling landings of Canadian otter trawlers, 1965-79.

			Period		
	Area	Sex	1965-69	1970-74	1975-79
Mean length (cm)	4T	Male	33.9	33.3	34.7
		Female	35.3	39.2	40.9
	4Vn	Male	-	39.1	37.5
		Female	-	49.0	42.9
	4Vs	Male	38.1	37.7	36.6
		Female	49.5	46.1	43.4
Mean age (yr)	4T	Male	-	8.8	10.0
		Female	-	9.9	11.9
	4Vn	Male	-	11.6	11.2
		Female	-	13.7	12.5
	4Vs	Male	8.4	9.8	9.9
		Female	12.4	12.2	11.6
Number of samples	4T		9	6	30
	4Vn		2	5	6
	4Vs		5	16	44
Number measured	4T		1361	1202	5916
	4Vn		307	900	1135
	4Vs		881	3091	8727
Number aged	4T		0	209	1144
	4Vn		34	234	266
	4Vs		109	63	1877

Table 2. Growth rates (cm/yr) of American plaice caught in Canadian groundfish surveys in the southern Gulf of St. Lawrence and on the Scotian Shelf, 1970-79. Linear regressions of mean length-at-age on age were fitted for females between ages 3 and 14, and for males between ages 3 and 9.

	Females					Males				
	4T	4Vn	4Vs	4W	4X	4T	4Vn	4Vs	4W	4X
					1970-74					
Rate	2.80	2.78	2.51	2.14	2.60	2.40	2.51	2.20	1.95	2.09
S.E.	0.09	0.10	0.10	0.12	0.10	0.22	0.14	0.06	0.08	0.21
Intercept	9.08	8.07	13.96	15.49	15.29	10.47	8.89	14.56	15.17	15.62
r^2	0.99	0.99	0.99	0.97	0.99	0.96	0.98	0.99	0.99	0.95
					1975-79					
Rate	2.69	2.66	2.46	2.04	2.51	2.39	2.89	2.27	1.99	2.30
S.E.	0.08	0.10	0.08	0.10	0.17	0.13	0.07	0.21	0.18	0.18
Intercept	9.42	9.36	14.46	17.13	18.17	10.02	7.36	14.05	15.84	17.28
r^2	0.99	0.99	0.99	0.97	0.95	0.98	0.99	0.96	0.97	0.96

Table 3. Results of sign test analysis on mean lengths-at-age of American plaice as derived from Canadian groundfish surveys on the Scotian Shelf in July, 1970-79. When mean length-at-age of plaice in a southern area was greater than that of the northern area, the comparison was scored '+'; when it was lower, it was scored '-'.

	Area		
	4Vn	4Vs	4W
		Males	
4X	75+, 9-**	70+, 26-**	75+, 22-**
4W	70+, 26-**	50+, 72-	
4Vs	101+, 14-**		
		Females	
4X	106+, 10-**	106+, 35-**	119+, 23-**
4W	101+, 27-**	64+, 90-	
4Vs	109+, 15-**		

**P<0.01.

Table 4. Mean length (cm) at age 5 for American plaice caught during Canadian groundfish surveys in July and associated mean bottom water temperatures at time of surveys.

Area	Age 5		Bottom water temperature °C
	Male	Female	
	1970-74		
4Vn	22.2	22.2	3.65
4Vs	25.7	26.3	3.51
4W	24.8	26.3	5.63
4X	26.9	27.9	6.90
	1975-79		
4Vn	22.9	23.2	3.80
4Vs	26.4	27.4	3.99
4W	26.7	27.8	6.48
4X	30.2	31.7	7.19

Table 5. Length, weight, and age parameters for plaice caught in otter trawls during surveys of Canadian research vessels from 1970-79. Surveys in Division 4T were in September and surveys in the other areas were in July.

		Males				
		4T	4Vn	4Vs	4W	4X
			1970-74			
Mean length (cm)		24.9	27.0	29.9	25.5	26.0
Mean weight (kg)		0.16	0.20	0.27	0.15	0.17
Mean age (yr)		6.0	7.4	7.0	5.4	5.1
Length (cm)-	a	0.00604	0.00383	0.00387	0.00336	0.00435
Weight (g)	b	3.105	3.229	3.233	3.247	3.173
Relation	n	2610	625	1958	2265	435
$W=aL^b$	r^2	0.94	0.95	0.95	0.93	0.94
			1975-79			
Mean length (cm)		24.7	27.0	30.0	28.5	27.9
Mean weight (kg)		0.13	0.19	0.26	0.21	0.21
Mean age (yr)		6.0	7.0	7.2	6.5	4.7
Length (cm)-	a	0.00417	0.00269	0.00260	0.00525	0.00581
Weight (g)	b	3.197	3.320	3.336	3.138	3.099
Relation	n	3445	378	1466	1344	251
$W=aL^b$	r^2	0.90	0.92	0.94	0.88	0.94

Table 5 (cont'd)

		Females				
		4T	4Vn	4Vs	4W	4X
		1970-74				
Mean length (cm)		26.5	29.8	33.6	29.2	32.4
Mean weight (kg)		0.24	0.31	0.46	0.27	0.40
Mean age (yr)		6.3	8.0	7.8	6.5	6.6
Length (cm)-	a	0.00418	0.00234	0.00308	0.00259	0.00337
Weight (g)	b	3.219	3.366	3.299	3.326	3.252
Relation	n	3455	572	1993	2407	770
$W=aL^b$	r^2	0.97	0.98	0.98	0.98	0.97
		1975-79				
Mean length (cm)		27.4	31.5	34.3	32.2	34.0
Mean weight (kg)		0.22	0.34	0.45	0.34	0.48
Mean age (yr)		6.3	7.9	7.8	7.1	5.9
Length (cm)-	a	0.00228	0.00222	0.00227	0.00398	0.00276
Weight (g)	b	3.379	3.378	3.377	3.208	3.315
Relation	n	4634	491	1727	1675	449
$W=aL^b$	r^2	0.96	0.95	0.97	0.97	0.98

Table 6. Mean weights-at-age (kg) for American plaice caught during Canadian groundfish surveys in the southern Gulf of St. Lawrence (September) and Scotian Shelf (July). Number of otoliths read for each age is in parentheses.

	Males					Females				
Age	4T	4Vn	4Vs	4W	4X	4T	4Vn	4Vs	4W	4X
					1970-74					
3	0.04(251)	0.03(19)	0.08(63)	0.07(206)	0.07(68)	0.03(274)	0.03(13)	0.09(60)	0.07(149)	0.09(67)
4	0.07(407)	0.05(28)	0.11(92)	0.09(196)	0.13(75)	0.07(410)	0.05(32)	0.11(92)	0.11(154)	0.16(105)
5	0.11(364)	0.09(48)	0.15(127)	0.12(222)	0.15(77)	0.12(342)	0.08(31)	0.16(97)	0.15(174)	0.18(94)
6	0.15(314)	0.13(22)	0.20(161)	0.16(168)	0.21(41)	0.17(314)	0.14(38)	0.21(152)	0.19(139)	0.27(67)
7	0.19(285)	0.16(59)	0.24(186)	0.20(174)	0.20(24)	0.22(335)	0.18(47)	0.28(150)	0.25(170)	0.37(53)
8	0.22(252)	0.22(76)	0.31(201)	0.26(119)	0.29(28)	0.29(339)	0.23(59)	0.37(200)	0.33(156)	0.44(47)
9	0.26(196)	0.25(53)	0.37(136)	0.28(70)	0.36(15)	0.38(303)	0.30(45)	0.49(158)	0.40(114)	0.59(48)
10	0.31(123)	0.30(35)	0.50(88)	0.33(42)	0.21(8)	0.48(220)	0.44(37)	0.67(117)	0.46(85)	0.63(41)
11	0.36(85)	0.38(22)	0.51(45)	0.25(21)	0.43(4)	0.59(136)	0.49(15)	0.78(83)	0.49(65)	0.80(35)
12	0.43(69)	0.41(22)	0.61(35)	0.44(22)	0.78(2)	0.77(106)	0.75(16)	0.84(64)	0.80(49)	0.93(20)
13	0.49(55)	0.67(2)	0.74(12)	0.40(6)	1.01(1)	0.87(79)	0.67(14)	1.21(44)	0.86(23)	1.18(10)
14	0.50(40)	0.49(7)	0.72(9)	0.40(6)	0.78(2)	1.10(91)	0.61(11)	1.22(44)	1.31(17)	1.70(10)
					1975-79					
3	0.03(188)	0.03(11)	0.06(126)	0.07(143)	0.10(44)	0.03(177)	0.03(6)	0.06(85)	0.07(118)	0.11(43)
4	0.06(548)	0.05(27)	0.10(227)	0.11(187)	0.16(68)	0.06(486)	0.05(24)	0.11(199)	0.12(193)	0.17(79)
5	0.09(725)	0.08(75)	0.15(213)	0.16(183)	0.24(48)	0.09(775)	0.08(65)	0.17(237)	0.18(166)	0.28(66)
6	0.13(580)	0.13(59)	0.20(154)	0.20(242)	0.29(35)	0.14(633)	0.15(61)	0.26(181)	0.24(230)	0.34(51)
7	0.17(559)	0.17(63)	0.23(154)	0.21(196)	0.33(31)	0.20(636)	0.20(66)	0.32(184)	0.29(211)	0.40(50)
8	0.20(400)	0.23(40)	0.29(184)	0.28(125)	0.34(6)	0.28(597)	0.28(52)	0.38(157)	0.36(158)	0.55(29)
9	0.25(273)	0.32(43)	0.32(208)	0.30(64)	0.47(2)	0.37(391)	0.33(47)	0.48(170)	0.44(124)	0.74(19)
10	0.29(219)	0.33(29)	0.38(184)	0.35(53)	0.63(3)	0.46(282)	0.50(43)	0.55(177)	0.49(96)	1.00(15)
11	0.34(145)	0.40(32)	0.51(85)	0.37(21)	0.51(2)	0.39(245)	0.54(36)	0.69(160)	0.58(75)	1.11(12)
12	0.41(75)	0.41(17)	0.59(55)	0.48(22)	0.58(1)	0.69(162)	0.62(26)	0.79(120)	0.62(75)	0.93(7)
13	0.48(43)	0.56(7)	0.70(21)	0.53(7)	0.58(1)	0.83(137)	0.73(23)	0.98(71)	0.70(49)	1.31(8)
14	0.57(31)	0.46(2)	0.71(9)	0.58(4)	1.00(1)	1.00(96)	0.95(21)	1.20(43)	0.78(29)	1.32(8)

Table 7. Mean weights-at-age (kg) for female and male American plaice in Div. 4W caught during July groundfish surveys by the A.T. CAMERON, 1970-79. Number of otoliths read at each age is in parenthesis.

	Females				
	1970	1971	1972	1973	1974
3	0.06 (38)	0.08 (8)	0.08 (38)	0.09 (16)	0.07 (49)
4	0.09 (30)	0.11 (27)	0.12 (12)	0.13 (37)	0.11 (48)
5	0.12 (43)	0.15 (26)	0.15 (13)	0.20 (21)	0.15 (71)
6	0.17 (29)	0.17 (36)	0.18 (16)	0.21 (29)	0.24 (29)
7	0.24 (47)	0.24 (20)	0.24 (28)	0.22 (30)	0.27 (45)
8	0.39 (31)	0.36 (21)	0.39 (23)	0.29 (45)	0.34 (36)
9	0.46 (24)	0.53 (17)	0.41 (9)	0.37 (25)	0.37 (39)
10	0.69 (13)	0.59 (11)	0.56 (9)	0.32 (34)	0.52 (18)
11	0.76 (6)	1.01 (7)	0.64 (3)	0.33 (26)	0.52 (23)
12	1.15 (15)	1.36 (4)	1.42 (6)	0.44 (14)	0.61 (10)
13	1.10 (3)	1.07 (4)	1.19 (2)	0.57 (5)	0.66 (9)
14	0.81 (3)	1.69 (6)	1.21 (3)	0.76 (4)	0.50 (1)
15	1.20 (6)	1.57 (3)	0.66 (1)	0.59 (1)	1.35 (3)

	Females				
	1975	1976	1977	1978	1979
3	0.10 (35)	0.12 (5)	0.08 (6)	0.05 (44)	0.06 (28)
4	0.14 (64)	0.15 (26)	0.14 (15)	0.09 (67)	0.11 (21)
5	0.20 (38)	0.19 (44)	0.17 (32)	0.13 (24)	0.20 (28)
6	0.28 (56)	0.24 (39)	0.23 (51)	0.21 (69)	0.25 (15)
7	0.31 (33)	0.33 (44)	0.28 (50)	0.25 (48)	0.26 (36)
8	0.35 (23)	0.35 (13)	0.36 (39)	0.36 (53)	0.39 (30)
9	0.38 (21)	0.45 (18)	0.42 (20)	0.49 (37)	0.40 (28)
10	0.47 (22)	0.52 (17)	0.47 (18)	0.51 (18)	0.43 (21)
11	0.58 (13)	0.60 (20)	0.50 (15)	0.62 (12)	0.54 (15)
12	0.55 (22)	0.67 (21)	0.60 (12)	0.66 (12)	0.66 (8)
13	0.72 (16)	0.62 (6)	0.76 (10)	0.64 (11)	0.68 (6)
14	0.91 (11)	0.94 (5)	0.71 (6)	0.81 (2)	0.60 (5)
15	0.93 (6)	2.96 (1)	1.15 (5)	0.79 (5)	1.34 (2)

Table 7 (cont'd)

	Males				
	1970	1971	1972	1973	1974
3	0.06 (59)	0.08 (9)	0.07 (45)	0.11 (34)	0.07 (59)
4	0.09 (48)	0.10 (33)	0.11 (13)	0.11 (46)	0.08 (56)
5	0.10 (48)	0.14 (29)	0.13 (33)	0.15 (27)	0.12 (85)
6	0.15 (30)	0.16 (38)	0.15 (18)	0.19 (31)	0.18 (51)
7	0.21 (38)	0.26 (13)	0.20 (28)	0.18 (39)	0.19 (56)
8	0.32 (22)	0.34 (16)	0.29 (16)	0.20 (23)	0.22 (42)
9	0.31 (18)	0.31 (9)	0.35 (6)	0.23 (14)	0.25 (23)
10	0.50 (9)	0.43 (6)	0.45 (2)	0.21 (18)	0.38 (7)
11	0.24 (3)	- (0)	- (0)	0.25 (11)	0.30 (7)
12	0.44 (5)	0.46 (2)	0.72 (4)	0.36 (9)	0.50 (2)
13	0.54 (3)	0.66 (1)	- (0)	0.21 (2)	- (0)

	Males				
	1975	1976	1977	1978	1979
3	0.09 (34)	0.11 (8)	0.09 (16)	0.06 (46)	0.06 (39)
4	0.13 (53)	0.12 (52)	0.11 (18)	0.10 (47)	0.09 (17)
5	0.16 (25)	0.16 (41)	0.14 (44)	0.13 (38)	0.16 (35)
6	0.18 (47)	0.20 (39)	0.18 (57)	0.17 (58)	0.20 (41)
7	0.21 (23)	0.21 (32)	0.20 (47)	0.20 (50)	0.20 (44)
8	0.27 (28)	0.31 (14)	0.30 (18)	0.29 (41)	0.24 (24)
9	0.29 (7)	0.31 (16)	0.24 (11)	0.35 (19)	0.23 (11)
10	0.36 (20)	0.33 (10)	0.39 (9)	0.39 (8)	0.33 (6)
11	0.41 (6)	0.35 (7)	0.42 (2)	0.29 (3)	0.36 (3)
12	0.63 (4)	0.52 (5)	0.49 (3)	0.47 (7)	0.31 (3)
13	0.57 (3)	0.43 (2)	- (0)	0.73 (1)	0.40 (1)

Table 8. Mean instantaneous growth rate as measured by changes in weight for plaice caught in otter trawls during groundfish surveys of Canadian research vessels from 1970-79. Mean weights-at-age are listed in Table 6.

	Males				
Age	4T	4Vn	4Vs	4W	4X
			1970-1974		
3-4	0.582	0.600	0.370	0.313	0.648
4-5	0.481	0.557	0.310	0.255	0.143
5-6	0.310	0.379	0.288	0.288	0.336
6-7	0.236	0.208	0.182	0.223	-0.049
7-8	0.147	0.318	0.256	0.262	0.372
8-9	0.167	0.128	0.177	0.074	0.216
9-10	0.176	0.182	0.301	0.164	-0.539
10-11	0.150	0.236	0.020	-0.278	0.717
11-12	0.178	0.076	0.179	0.565	0.596
12-13	0.131	0.381	0.193	-0.095	0.249
13-14	0.020	-0.313	-0.027	0.000	-0.117
			1975-1979		
3-4	0.614	0.638	0.588	0.424	0.470
4-5	0.400	0.436	0.416	0.375	0.406
5-6	0.357	0.461	0.288	0.223	0.189
6-7	0.268	0.268	0.140	0.049	0.129
7-8	0.163	0.163	0.232	0.289	0.030
8-9	0.223	0.330	0.098	0.069	0.323
9-10	0.148	0.031	0.172	0.154	0.293
10-11	0.159	0.190	0.294	0.056	-0.211
11-12	0.187	0.025	0.146	0.260	0.129
12-13	0.158	0.199	0.170	0.041	0.000
13-14	0.172	-0.197	0.142	0.090	0.545

Table 8 (cont'd)

	Females				
Age	4T	4Vn	4Vs	4W	4X
			1970-1974		
3-4	0.736	0.616	0.223	0.396	0.633
4-5	0.525	0.495	0.375	0.310	0.118
5-6	0.348	0.535	0.272	0.236	0.405
6-7	0.258	0.251	0.288	0.274	0.315
7-8	0.276	0.245	0.279	0.278	0.173
8-9	0.270	0.266	0.281	0.192	0.293
9-10	0.234	0.383	0.313	0.140	0.066
10-11	0.206	0.108	0.152	0.063	0.239
11-12	0.266	0.426	0.074	0.490	0.151
12-13	0.122	-0.112	0.356	0.072	0.256
13-14	0.234	-0.094	0.008	0.413	0.223
			1975-1979		
3-4	0.547	0.693	0.640	0.483	0.435
4-5	0.490	0.468	0.435	0.406	0.499
5-6	0.409	0.592	0.425	0.288	0.194
6-7	0.357	0.288	0.208	0.189	0.163
7-8	0.337	0.337	0.172	0.216	0.319
8-9	0.279	0.164	0.234	0.201	0.297
9-10	0.218	0.416	0.136	0.107	0.301
10-11	0.249	0.077	0.227	0.169	0.095
11-12	0.157	0.138	0.135	0.067	-0.168
12-13	0.185	0.163	0.216	0.121	0.335
13-14	0.186	0.263	0.203	0.108	0.008

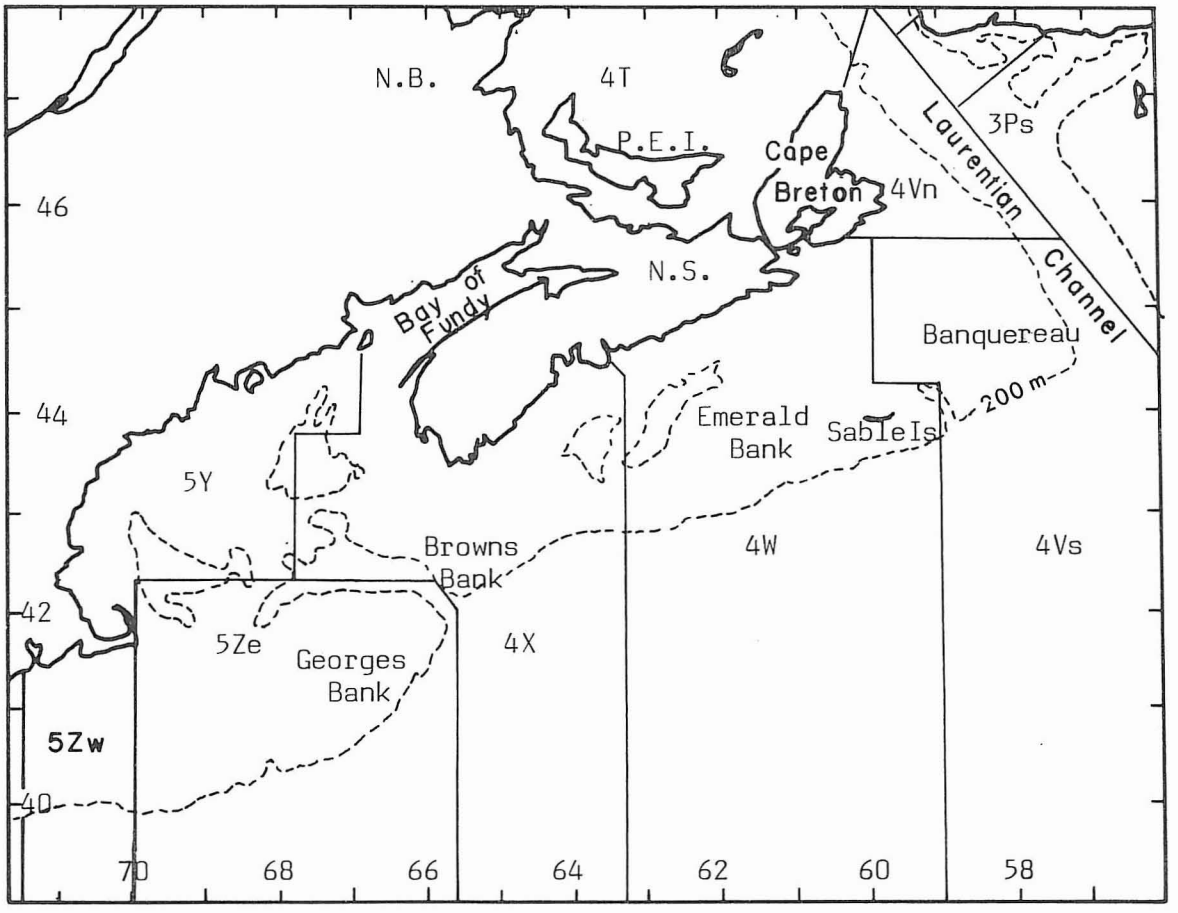

Fig. 1. Northwest Atlantic Fisheries Organization Divisions in Subarea 4.

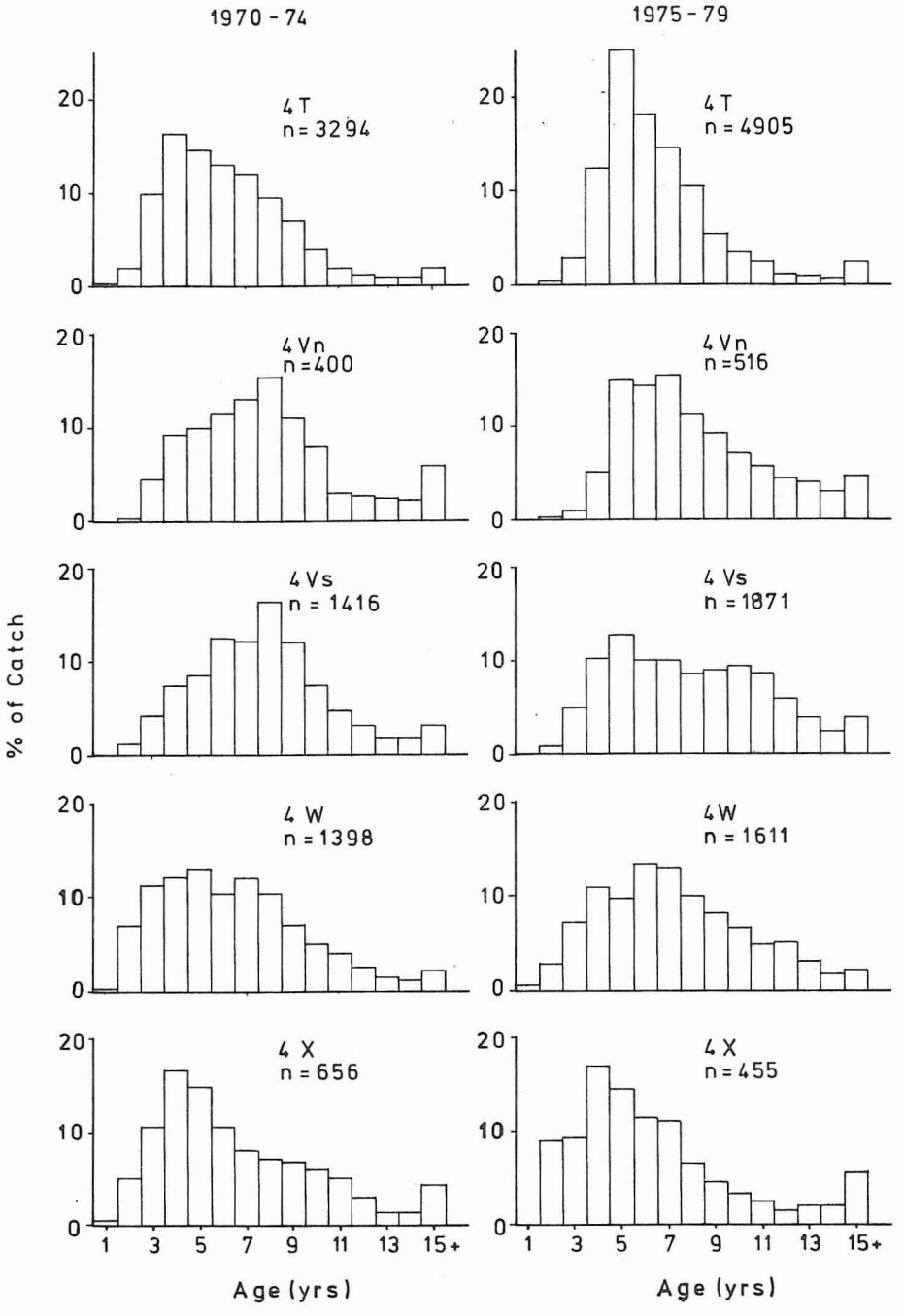

Fig. 2. Age compositions of female American plaice caught during Canadian groundfish surveys in Div. 4T (September) and Divs. 4VWX (July), 1970-79.

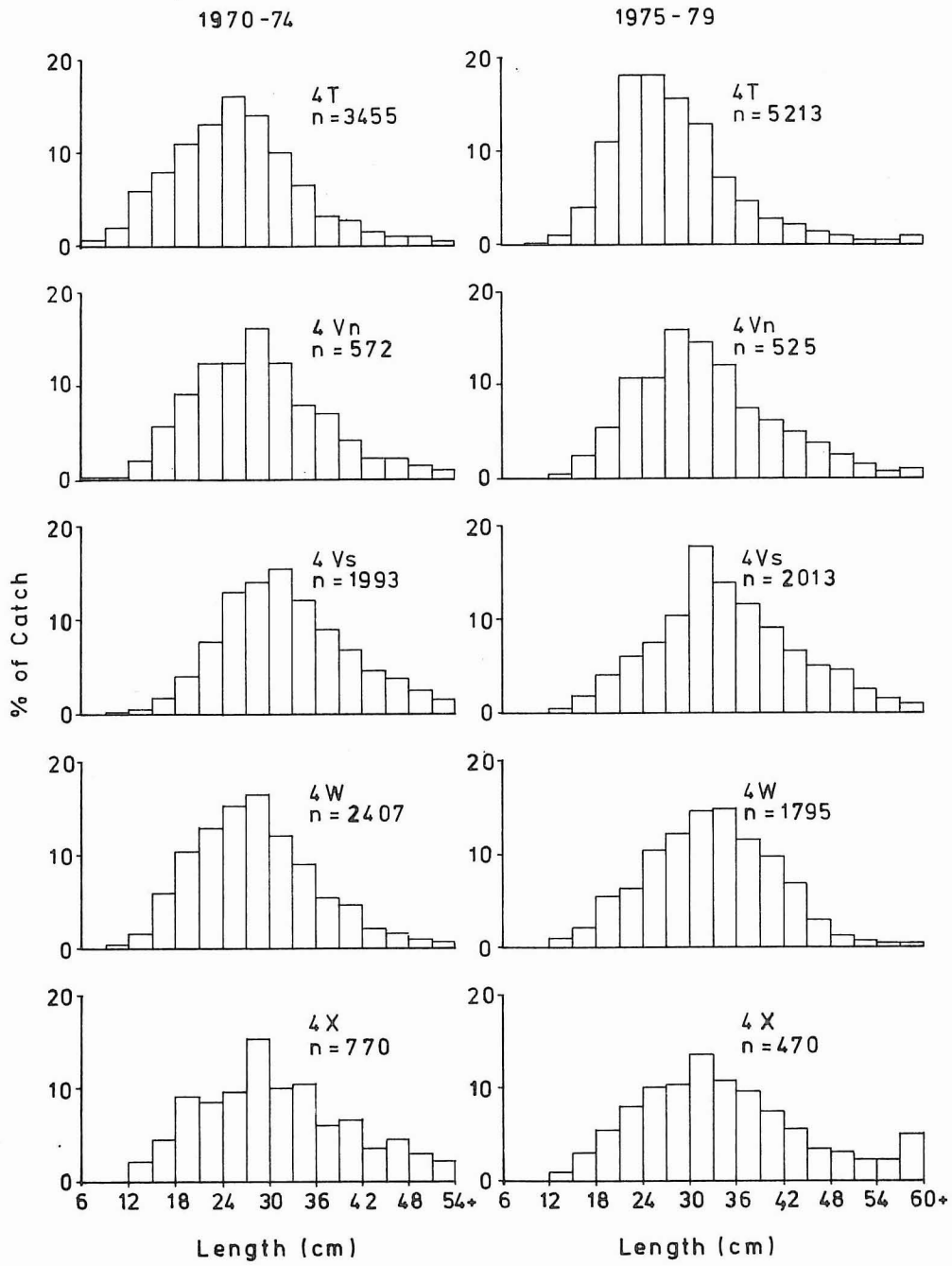

Fig. 3. Length frequencies of female American plaice caught during Canadian groundfish surveys in Div. 4T (September) and Divs. 4VWX (July), 1970-79.

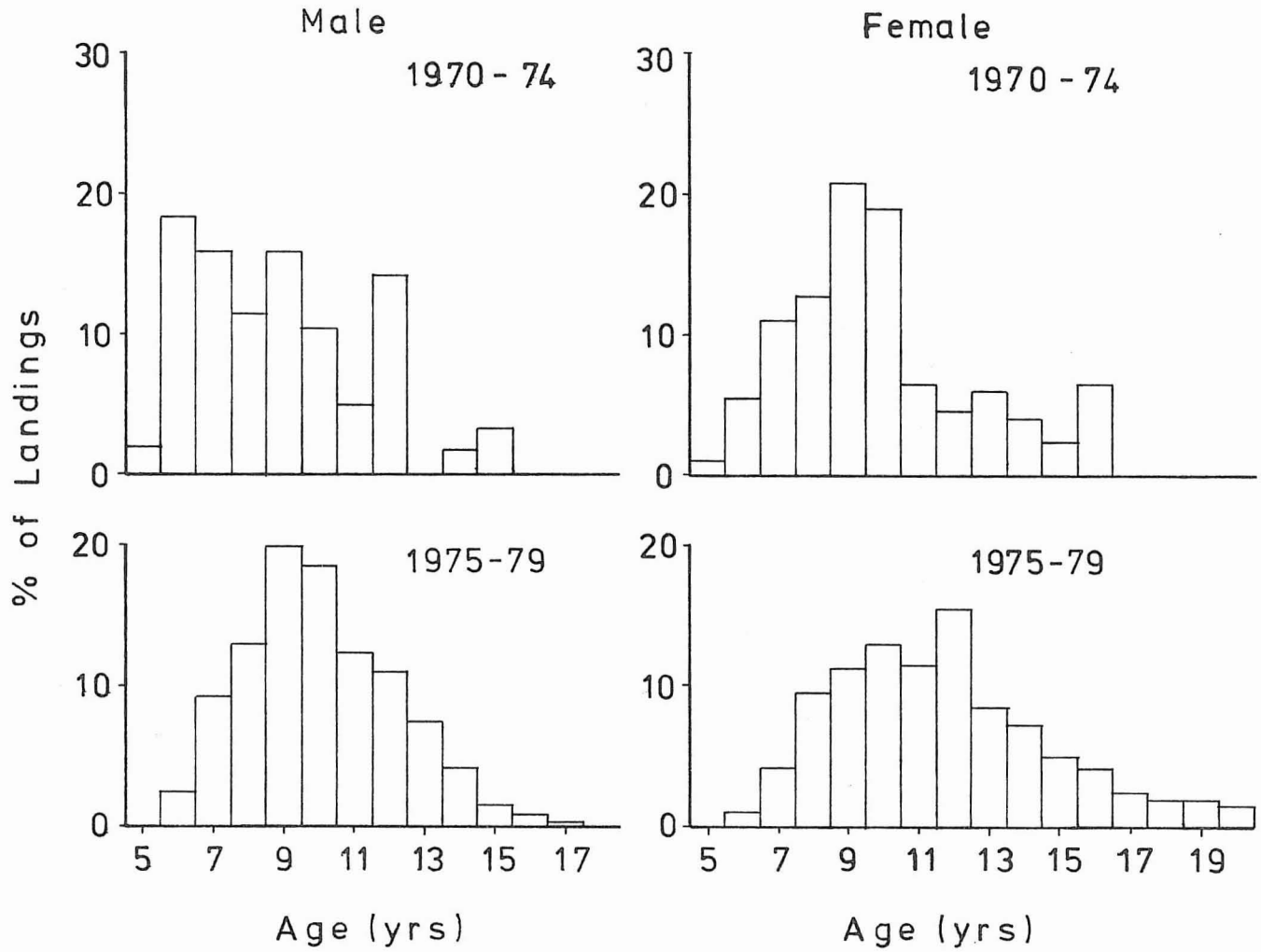

Fig. 4. Age compositions of American plaice landed by Canadian otter trawlers in Div. 4T, 1970-79.

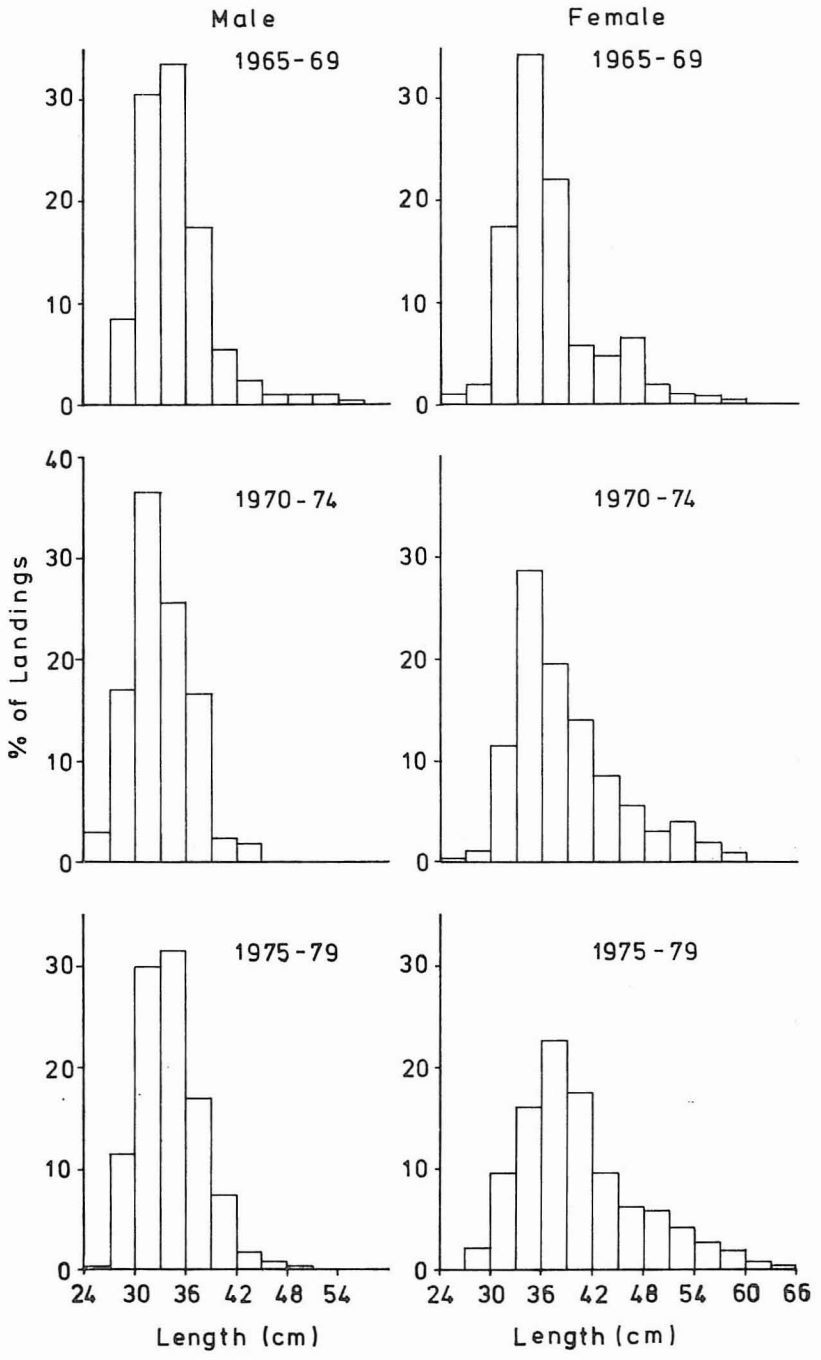

Fig. 5. Length frequencies of American plaice landed in Div. 4T by Canadian otter trawlers, 1965-79.

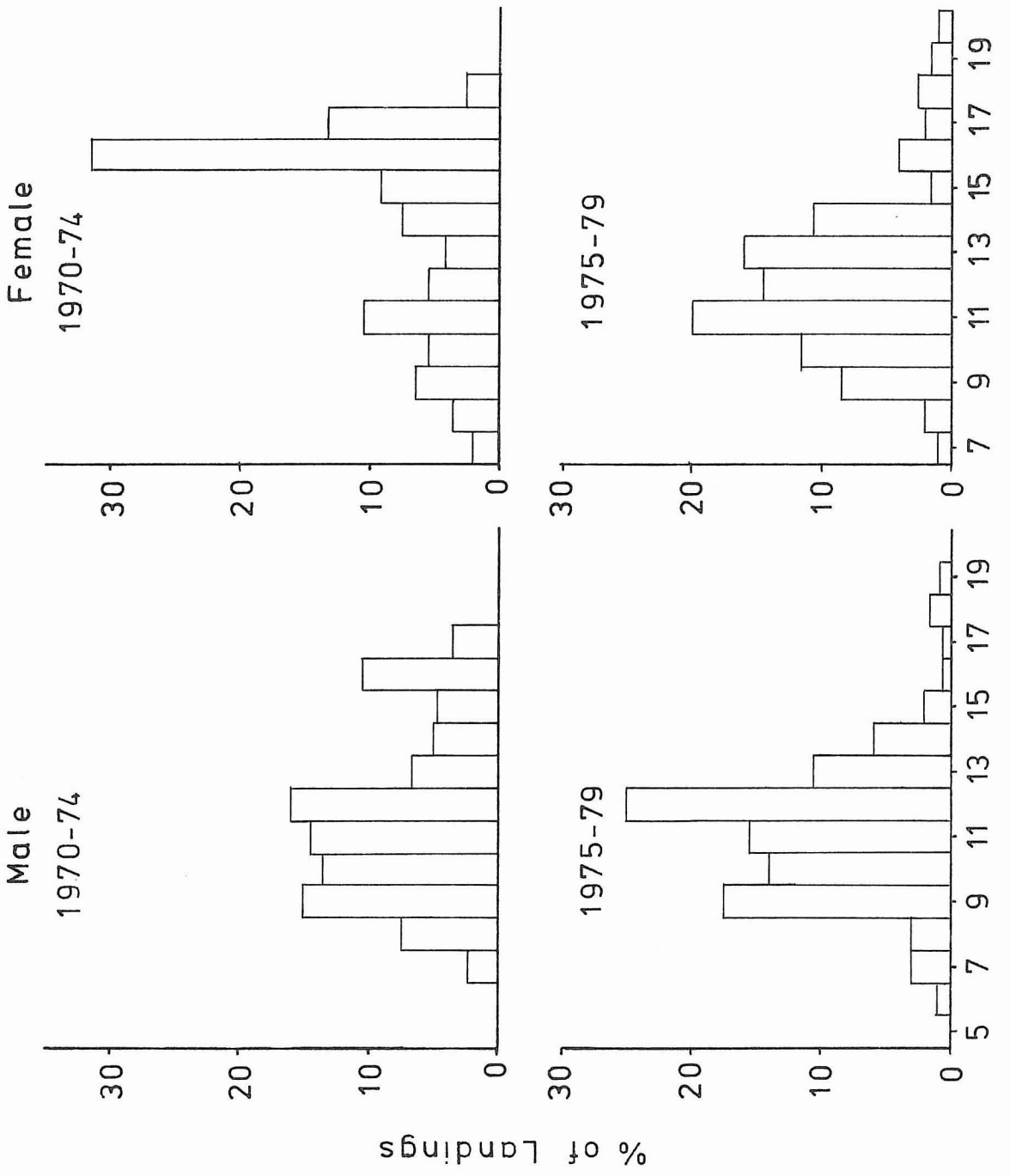

Fig. 6. Age compositions of American plaice landed by Canadian otter trawlers in Subdiv. 4Vn, 1970-79.

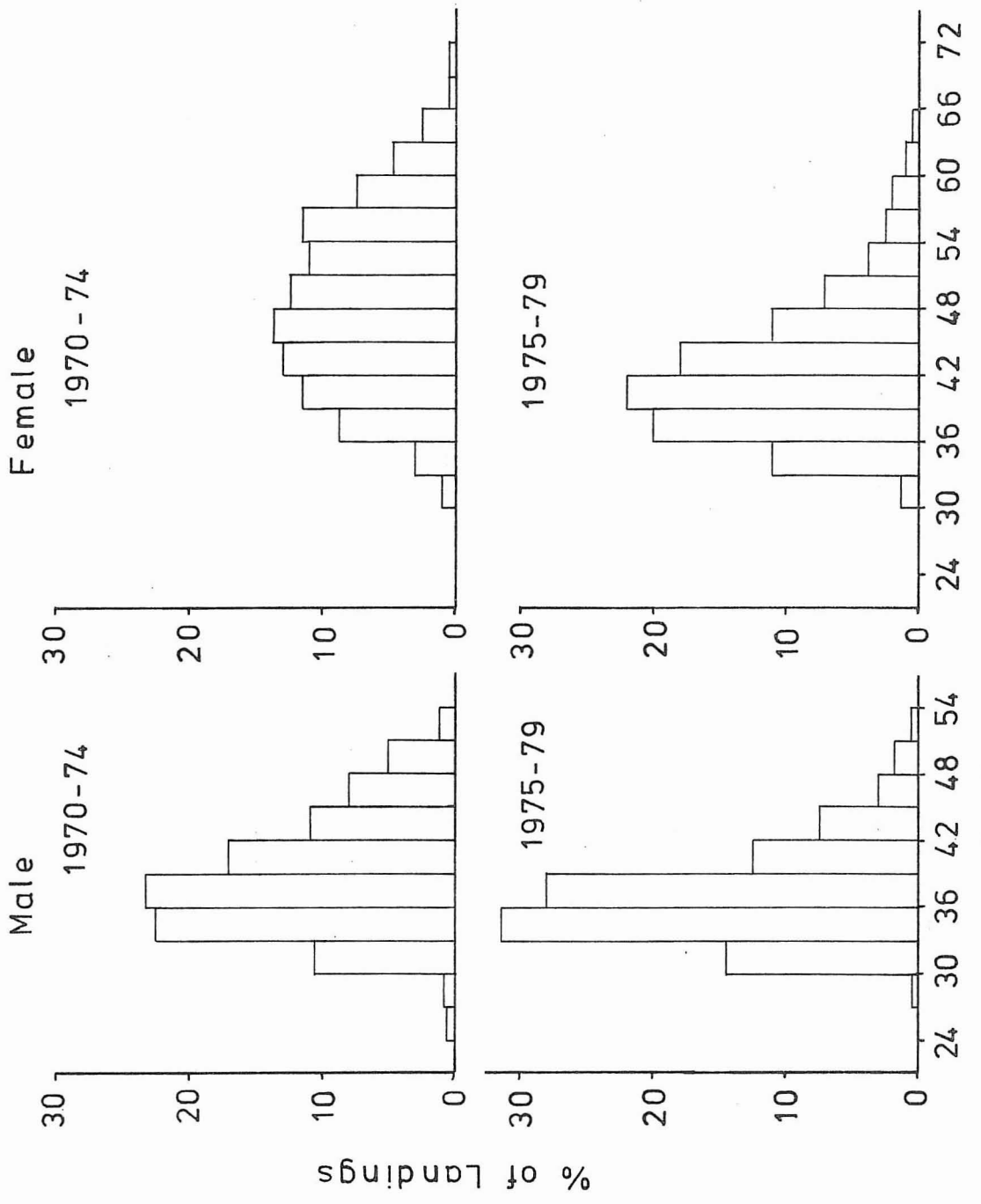

Fig. 7. Length frequencies of American plaice landed by Canadian otter trawlers in Subdiv. 4Vn, 1970-79.

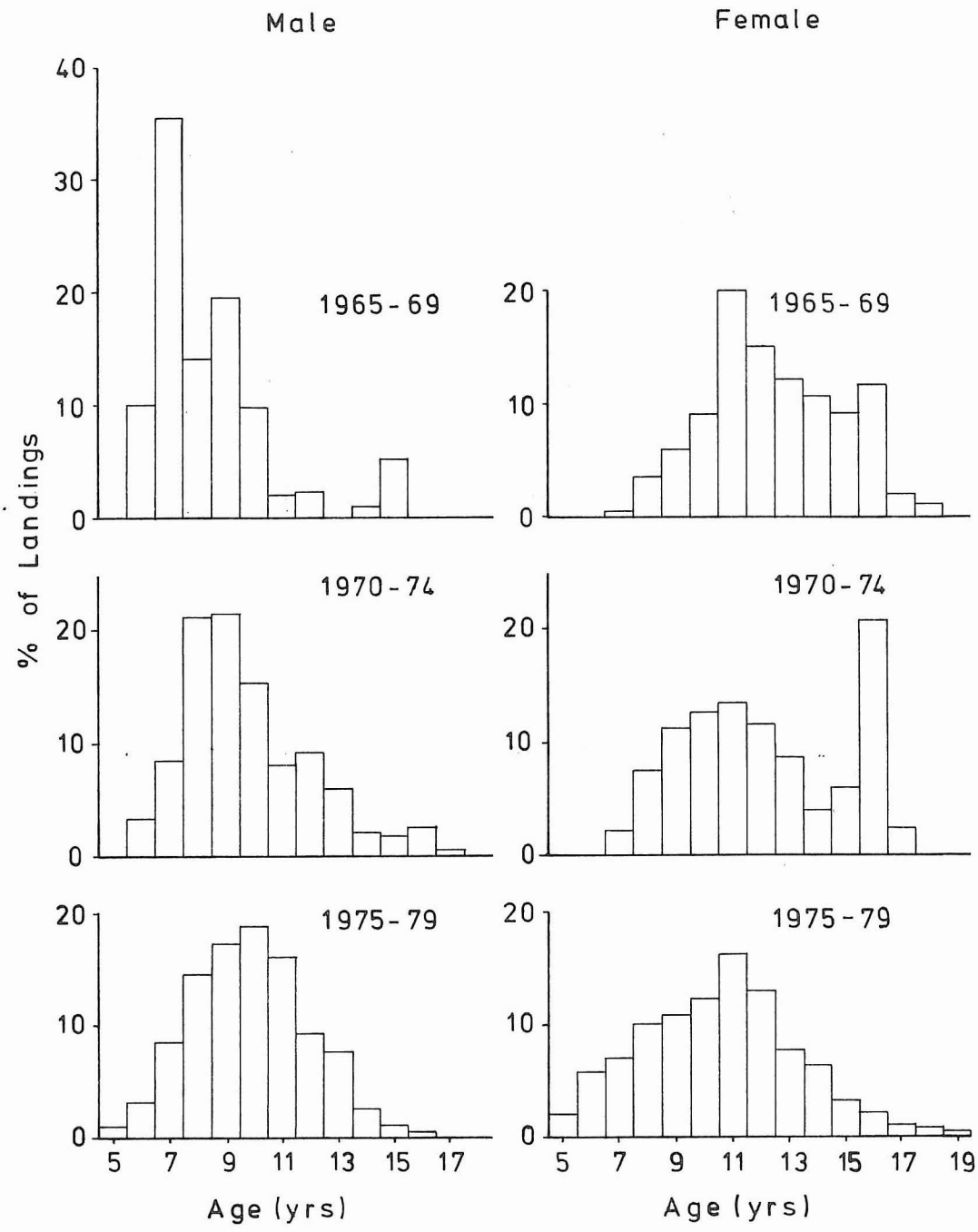

Fig. 8. Age compositions of American plaice landed by Canadian otter trawlers in Subdiv. 4Vs, 1965-79.

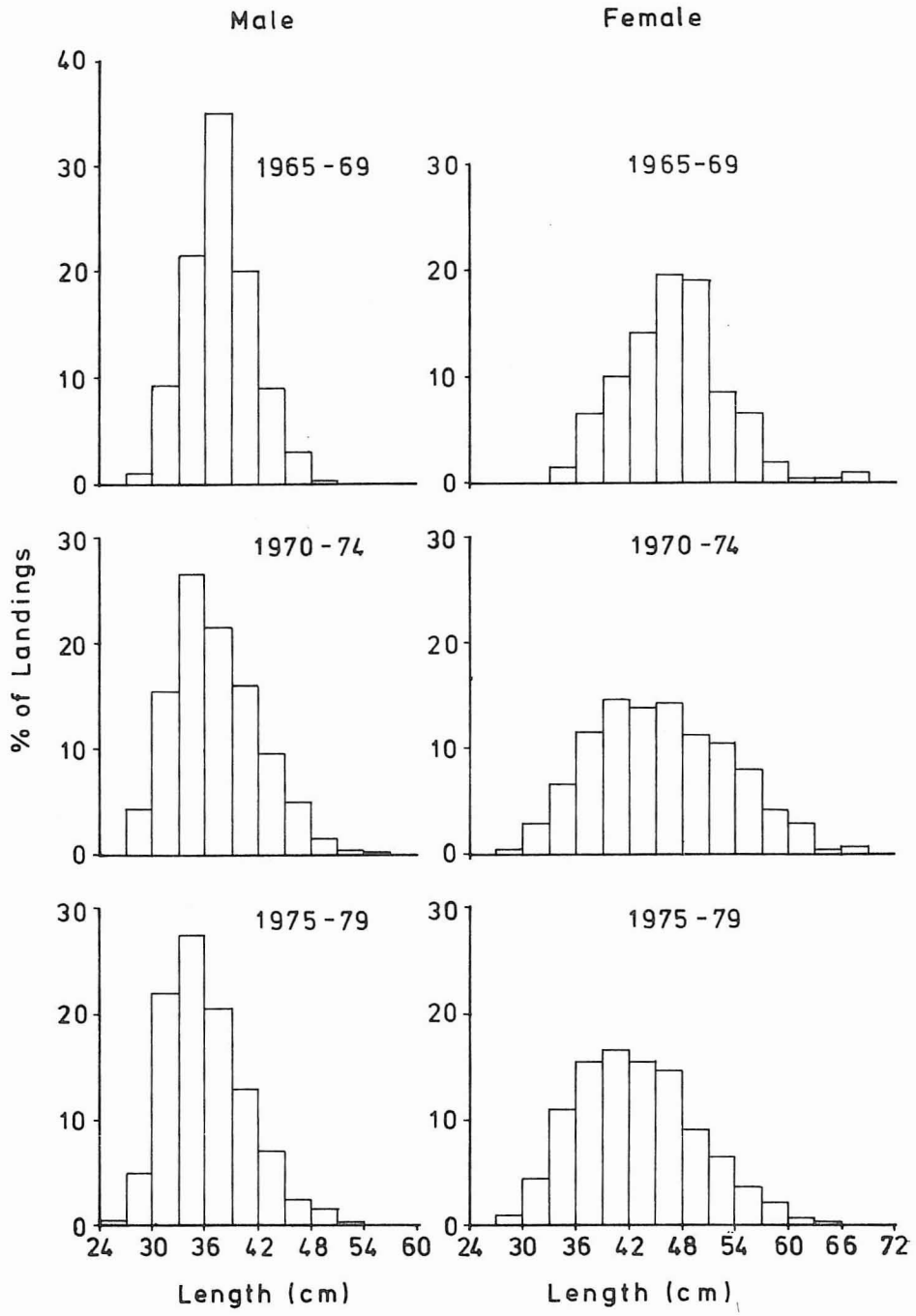

Fig. 9. Length frequencies of American plaice landed by Canadian otter trawlers in Subdiv. 4Vs, 1965-79.

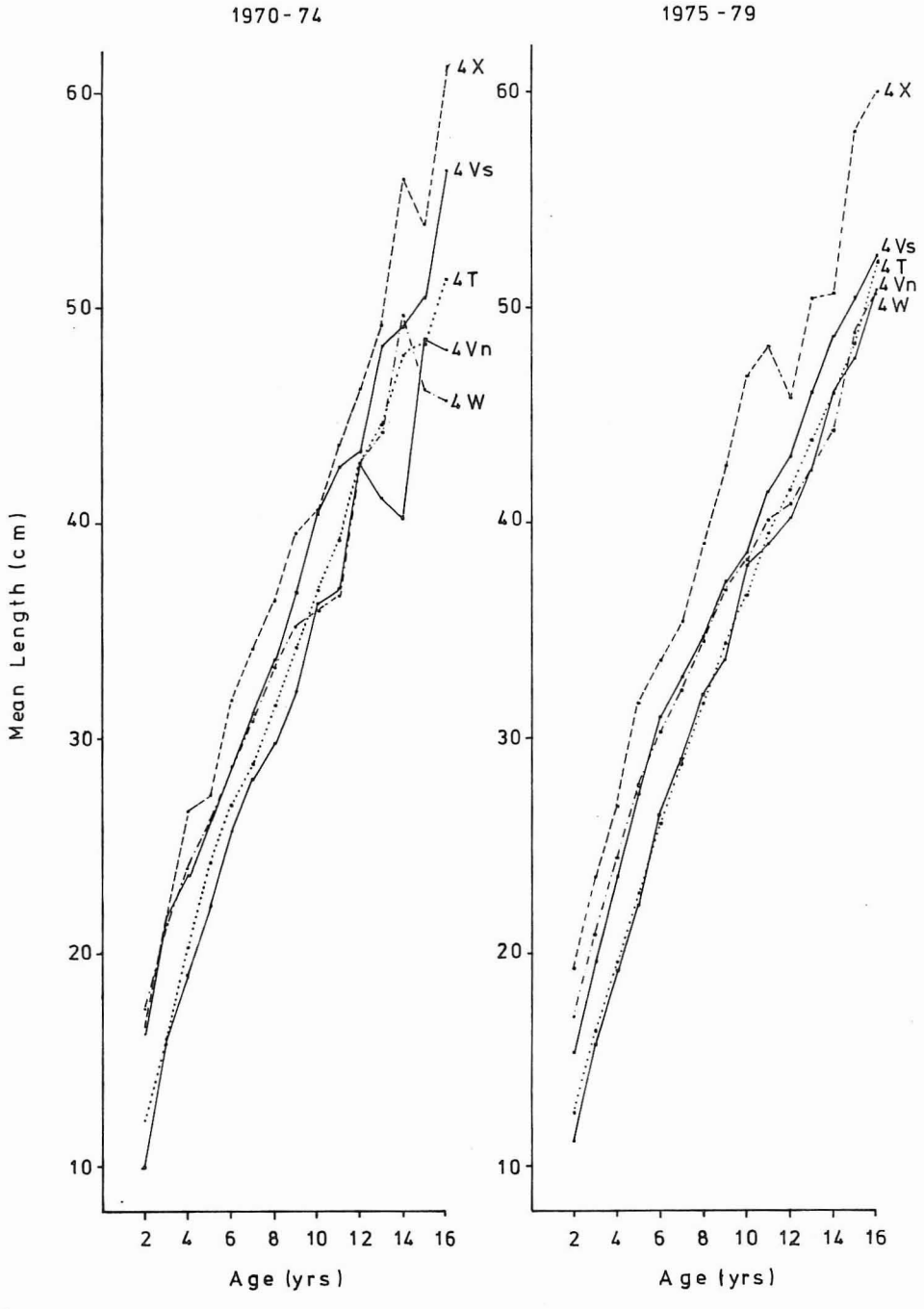

Fig. 10. Observed mean lengths-at-age for female American plaice caught during Canadian groundfish surveys, 1970–79.

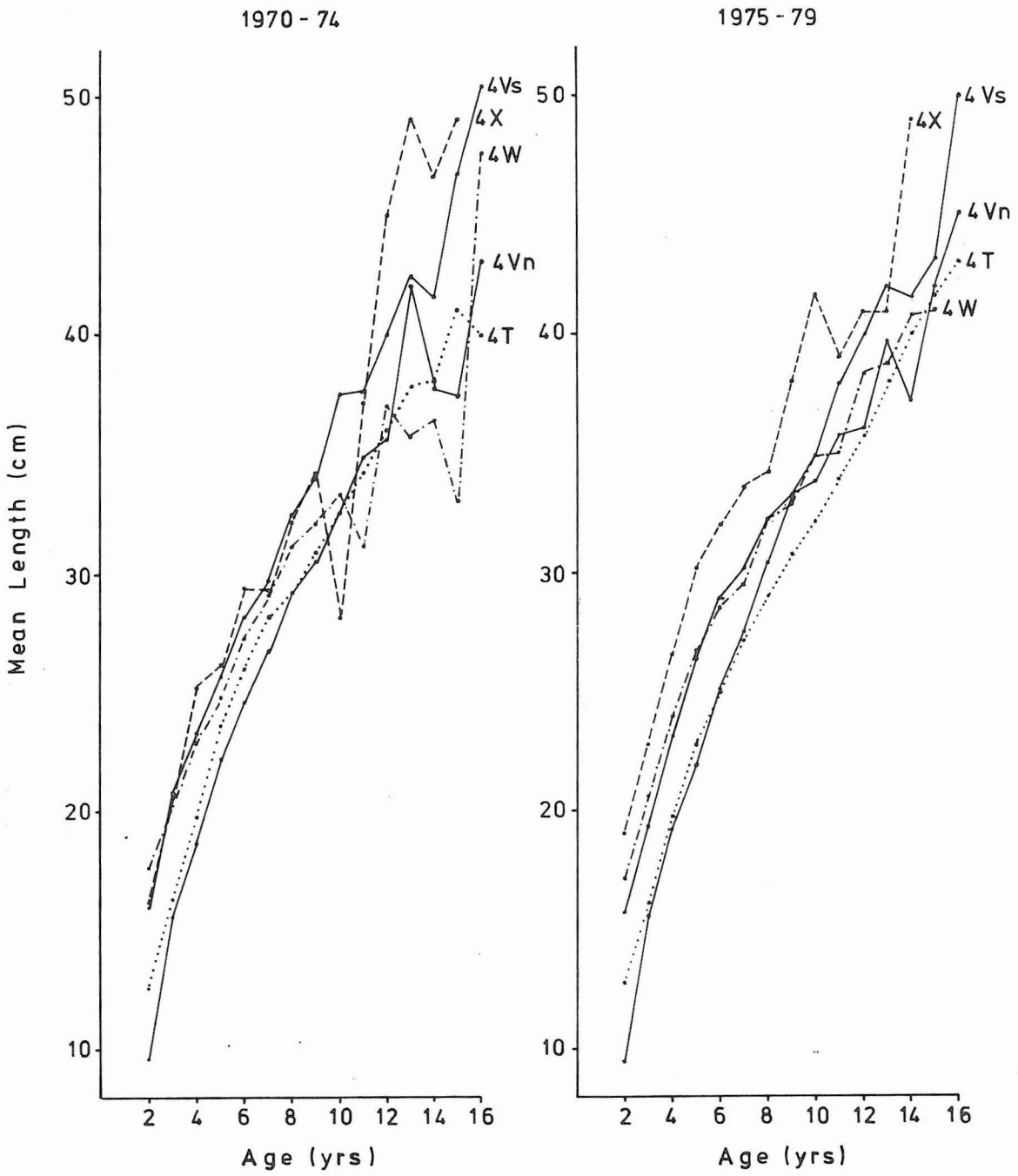

Fig. 11. Observed mean lengths-at-age for male American plaice caught during Canadian groundfish surveys, 1970-79.