32610

Biology and Exploitation of Winter Flounder *(Pseudopleuronectes americanus)* in the Canadian Maritimes Area of the Northwest Atlantic Ocean

Terry D. Beacham

Department of Fisheries and Oceans
Fisheries Research Branch
Pacific Biological Station
Nanaimo, British Columbia V9R 5K6

September 1982

Canadian Technical Report of Fisheries and Aquatic Sciences No. 1113

Government of Canada Fisheries and Oceans
Gouvernement du Canada Pêches et Océans

Canadian Technical Report of Fisheries and Aquatic Sciences

These reports contain scientific and technical information that represents an important contribution to existing knowledge but which for some reason may not be appropriate for primary scientific (i.e. *Journal*) publication. Technical Reports are directed primarily towards a worldwide audience and have an international distribution. No restriction is placed on subject matter and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries management, technology and development, ocean sciences, and aquatic environments relevant to Canada.

Technical Reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report will be abstracted in *Aquatic Sciences and Fisheries Abstracts* and will be indexed annually in the Department's index to scientific and technical publications.

Numbers 1-456 in this series were issued as Technical Reports of the Fisheries Research Board of Canada. Numbers 457-714 were issued as Department of the Environment, Fisheries and Marine Service, Research and Development Directorate Technical Reports. Numbers 715-924 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Technical Reports. The current series name was changed with report number 925.

Details on the availability of Technical Reports in hard copy may be obtained from the issuing establishment indicated on the front cover.

Rapport technique canadien des sciences halieutiques et aquatiques

Ces rapports contiennent des renseignements scientifiques et techniques qui constituent une contribution importante aux connaissances actuelles mais qui, pour une raison ou pour une autre, ne semblent pas appropriés pour la publication dans un journal scientifique. Il n'y a aucune restriction quant au sujet, de fait, la série reflète la vaste gamme des intérêts et des politiques du Ministère des Pêches et des Océans, notamment gestion des pêches, techniques et développement, sciences océaniques et environnements aquatiques, au Canada.

Les Rapports techniques peuvent être considérés comme des publications complètes. Le titre exact paraîtra au haut du résumé de chaque rapport, qui sera publié dans la revue *Aquatic Sciences and Fisheries Abstracts* et qui figurera dans l'index annuel des publications scientifiques et techniques du Ministère.

Les numéros 1-456 de cette série ont été publiés à titre de Rapports techniques de l'Office des recherches sur les pêcheries du Canada. Les numéros 457-714, à titre de Rapports techniques de la Direction générale de la recherche et du développement, Service des pêches et de la mer, ministère de l'Environnement. Les numéros 715-924 ont été publiés à titre de Rapports techniques du Service des pêches et de la mer, Ministère des Pêches et de l'Environnement. Le nom de la série a été modifié à partir du numéro 925.

La page couverture porte le nom de l'établissement auteur où l'on peut se procurer les rapports sous couverture cartonnée.

Canadian Technical Report of

Fisheries and Aquatic Sciences No. 1113

September 1982

BIOLOGY AND EXPLOITATION OF WINTER FLOUNDER (*Pseudopleuronectes americanus*) IN THE CANADIAN MARITIMES AREA OF THE NORTHWEST ATLANTIC OCEAN

Terry D. Beacham

Department of Fisheries and Oceans

Fisheries Research Branch

Pacific Biological Station

Nanaimo, British Columbia V9R 5K6

Canada

Cat. No. Fs 97-6/1113 ISSN 0706-6457

ABSTRACT

Beacham, T. D. 1982. Biology and exploitation of winter flounder (*Pseudopleuronectes americanus*) in the Canadian Maritimes area of the Northwest Atlantic Ocean. Can. Tech. Rep. Fish. Aquat. Sci. 1113: iv + 33 p.

Variability in growth rates, median size and age at maturity, and size and age compositions of fish in landings in the commercial fishery was investigated for winter flounder (*Pseudopleuronectes americanus*) in the southern Gulf of St. Lawrence (Div. 4T) and on the southern Scotian Shelf (Divs. 4WX). Mean lengths-at-age for winter flounder derived from Canadian groundfish surveys indicated that linear regressions adequately described winter flounder growth up to age 12 for females and age 9 for males, and they also indicated females grew between 20-35% faster than did males. Winter flounder in Div. 4X grew about 70% faster than did those in Div. 4T. Instantaneous growth rates of females were generally above 0.20 for ages 6 and under and for males above 0.20 for ages 5 and under and these ages constituted from 45-70% of the landings of otter trawlers in the Canadian winter flounder fishery from 1975-79. For winter flounder in Div. 4T from 1975-79, median length and age at maturity for males was 18.8 cm and 3.7 yr and for females 20.6 cm and 4.0 yr. Median length at maturity declined for winter flounder in Div. 4X.

Key Words: exploitation, fishery, growth, maturity, Northwest Atlantic, *Pseudopleuronectes*, winter flounder.

RESUME

Beacham, T. D. 1982. Biology and exploitation of winter flounder (Pseudopleuronectes americanus) in the Canadian Maritimes area of the Northwest Atlantic Ocean. Can. Tech. Rep. Fish. Aquat. Sci. No. 1113: iv + 33 p.

La variabilité du taux de croissance, de la taille et de l'âge médians à la maturité, et des compositions par taille et par âge a été étudiée pour la plie rouge (Pseudopleuronectes americanus) des débarquements de la pêche commerciale dans le sud du golfe Saint-Laurent (div. 4T) et dans la partie sud du plateau continental Scotian (div. 4WX). Les données sur la longueur moyenne pour chaque âge, tirées des levés sur le poisson de fond canadien, montraient que les régression linéaires décrivaient correctement la croissance de la plie rouge jusqu'à 12 ans pour la femelle et jusqu'à 9 ans pour le mâle, et elles indiquaient aussi que la femmelle se développait entre 20 et 35 % plus vite que le mâle. La plie rouge de la div. 4X croissait 70 % plus vite environ que celle de la div. 4T. En général, les taux de croissance instantanés dépassaient 0,20 pour les femelles de 6 ans et moins et pour les mâles de 5 ans et moins; entre 45 et 70 % de la plie rouge capturée au Canada entre 1975 et 1979 par les chalutiers à plateaux se situaient dans ces âges. Entre 1975 et 1979, la longueur et l'âge médians à maturité de la plie rouge dans la div. 4T était de 18,8 cm et 3,7 ans pour les mâles et de 20,6 cm et 4 ans pour les femelles. La longueur médiane à maturité a diminué pour la plie rouge de la div. 4X.

Mots-clés: exploitation, pêche, croissance, l'Atlantique nord-ouest, Pseudopleuronectes, la plie rouge.

INTRODUCTION

The winter flounder (Pseudopleuronectes americanus), while found offshore in a few shoal areas, is generally a coastal species. Along the coast of Nova Scotia, it found in bays, particularly the Bay of Fundy (Northwest Atlantic Fisheries Organization Div. 4X) (Fig. 1), and the southern Gulf of St. Lawrence (Div. 4T) (Halliday 1973). The only sizeable offshore population is found on Sable Island Bank (Div. 4W) (Scott 1976). Little is known about stock structure off Nova Scotia, although seasonal movements (McCracken 1963) and diurnal movements (Tyler 1971) have been investigated.

The Canadian fishery is almost entirely coastal and catches are made by small, inshore vessels (Halliday 1973). Nominal catches are highest in Div. 4T and Div. 4X, and in the 1970s were about 3,000 t annually for both areas combined ICNAF Statistical Bulletins). The USSR exploited winter flounder on Sable Island Bank in the 1960s and early 1970s (Halliday 1973), but the fishery by 1977 was almost entirely Canadian.

Growth rates of winter flounder in Canadian waters have been investigated by Kennedy ans Steele (1971). However, if mortality rates are known, 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 mortality rate is reduced. Details on size and age at sexual maturity are necessary in order to evaluate spawning stock size. This paper presents data on growth, size and age at maturity, and changes in size and age of winter flounder in the landings of the 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). 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 winter flounder was determined from otoliths by a method similar to that used for cod (Gadus morhua) by Kohler (1964). Total length of winter flounder was measured to the nearest cm in both the groundfish surveys and commercial samples.

Length and age compositions of winter flounder were determined for 5-year intervals. The estimation of age compositions first required raising 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. As the Canadian fishery is conducted by small, inshore vessels and is seasonal, over 80% of the samples of the landings from the commercial fishery were collected from May through August. Monthly distributions of the available samples were outlined by Cleary (1979). For the research surveys, only data from the July surveys in Div. 4X and September surveys in Div. 4T were grouped in 5-yr intervals. Grouping of the data increased the number of fish sampled in the analysis 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 be detected.

The transition from the immature to the mature condition in fish usually occurs over a range of length and age in the form of a sigmoid curve. Powles (1965) outlined the classification of the gonads used in assessing maturity of winter flounder in the present study. From the percentages of mature winter flounder (gonads in ripening, ripe, spawning, spent, or recovering condition) in 2-cm length intervals, the median (50% mature point) was calculated by probit analysis following the technique of Leslie et al. (1945). Median age at maturity was calculated by grouping the data in 1-yr intervals.

RESULTS

AGE AND LENGTH FREQUENCIES

Winter flounder has been caught on Canadian groundfish surveys since the 1950s, but effort directed towards ageing this species in the surveys began in 1975. The surveys in the southern Gulf of St. Lawrence indicated that the 1972 year-class was relatively strong, accounting for about 40% of the research catch in 1977 and 35% in 1978. There was no consistent trend in relative year-class sizes for winter flounder on the Scotian shelf.

Length frequencies of female winter flounder caught in the September surveys in Div. 4T had a considerably higher proportion of smaller fish than did those in the July surveys in Div. 4X, although the age distributions were similar (Fig. 2). Length frequencies and age distributions of male winter flounder showed similar trends and are omitted for simplicity. No data are presented for catches of

winter flounder in the other statistical areas because of insufficient sample sizes. All winter flounder were caught with the same type of net, thus eliminating changes in selectivity accounting for different length and age frequencies. The length and age frequencies of winter flounder in the research catch suggest that younger winter flounder were larger in Div. 4X than in Div. 4T. About 50% of the females caught during the groundfish surveys were age 5 or younger.

The landings of otter trawlers have been the most extensively sampled for all gears that have taken part in the Canadian fishery for winter flounder.

In Div. 4T, the mean length and mean age of the landed catch decreased from 1975-79 as compared with 1970-74 (Table 1). Less than 5% of the females landed were over 42 cm in the 1970s, but over 10% of landed females were over 42 cm in length in the 1960s (Fig. 3). Length frequencies of landings of males showed trends similar to those of females, with less than 5% of the landed males in the 1970s over 39 cm. From 1975-79, about 45% of the landed females were age 6 or less (Fig. 3), and about 65% of the landed males were age 6 or less. Landed females were usually most abundant in the 24- to 33-cm range, as were males. From 1975-79, length frequencies and age compositions of landed winter flounder in Div. 4T were similar to those in the research surveys (Fig. 2, 3), which suggests that there was little discarding in this fishery.

Mean length of the landed catch was usually greater in Div. 4X than in Div. 4T (Table 1). Length frequencies and age compositions could not be determined from 1960-74 because catch weights from each vessel were not available. Length and age compositions of the landed catch in the 1950s were similar to those of the late 1970s (Fig. 4). From 1975-79, about 70% of the landed females were age 6 or less, as was the case for males. In the same interval about 30% of the landed females were over 42 cm, about three times higher than in Div. 4T. About 30% of the landed males were over 39 cm, being six times higher than those in Div. 4T. Length and age distributions of winter flounder landed by Canadian otter trawlers in Div. 4X in 1975-79 were similar to those in the groundfish surveys (Fig. 2, 4), as was the situation in Div. 4T.

CHANGES IN LENGTH

The data from the groundfish surveys covering the available age ranges for females suggests that growth was essentially linear after age 2 (Fig. 5). The data for males was less abundant, but it suggests a more curvilinear relationship (Fig. 5), based upon the Div. 4T data. For females, because there was little evidence of asymptotic growth over the range of ages in this analysis, 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

comparisons with females. Linear regressions were fitted to the mean length-at-age data between ages 2 and 12 for females and ages 2-9 for males.

Linear regressions accounted for the variability in female mean length-at-age reasonably well ($r^2 \geq 0.86$) (Table 2). In Div. 4T, females grew about 35% faster per year than did males, while in Div. 4X, they grew 20% faster per year than did males over the range of ages investigated. Growth rates of winter flounder in Div. 4X were at least 70% faster per year than those in Div. 4T (Table 2). Growth rates of winter flounder before age 2 were considerably faster than the values in Table 2. Age-2 females caught by the research gear were about 23 cm in length in July in Div. 4X and 18 cm in September in Div. 4T, suggesting growth of about 9 cm/yr after 2.5 growing seasons in Div. 4X and 6 cm/yr after 2.8 growing seasons in Div. 4T. However, the mean lengths of age-2 winter flounder in the population will be less than that observed because winter flounder are only partially recruited to the research gear at age 2. Only the larger ones are susceptible to capture, either because smaller winter flounder being unavailable to the research gear or because they remain inshore. Growth to age 2 was therefore somewhat less than 6-9 cm/yr and growth after age 2 somewhat faster than this analysis suggests.

The effect of water temperatures on growth rates was investigated by comparing mean length for age 4 and mean bottom temperatures as derived from the July groundfish survey in Divs. 4W and 4X and the September groundfish survey in Div. 4T. With bottom temperatures of (mean of all sets during 1975-79) 2.33°C for Div. 4T, 6.48°C for Div. 4W, and 7.19°C for Div. 4X, mean length at age 4 was correlated with water temperature for males ($r=0.97$) and females ($r=0.99$). An increasing rate of growth of winter flounder from northerly to southerly areas (Table 2), and a similar increasing trend in mean length-at-age (Fig. 5) was coincident with increasing bottom water temperatures.

Table 3 illustrates that the mean weight and length of winter flounder caught by the research gear was greater at lower latitute, whereas the mean age of the catch was less. Mean length, weight, and age of males were less than those of females in all areas. To investigate if there were size differences between same-age winter flounder landed by the commercial fishery in the same year between areas in the samples, I compared appropriate mean lengths over all years and all ages by sign test analysis (Mendenhall 1971). When winter flounder in Div. 4X were larger than those in Div. 4T, the comparison was scored '+'; when they were smaller, it was scored '-'. The analysis showed that winter flounder of the same age in the same year that were landed in Div. 4X from June through October were larger than those landed in Div. 4T from June through October for both males (14+, 0-, $P<0.01$) and females (17+, 0-, $P<0.01$) (Table 4). Females were also larger than males of the same age in Div. 4T (18+, 2-, $P<0.01$) and Div. 4X (18+, 1-, $P<0.01$) (Table 4). Thus there were both regional and sexual differences in growth rates of winter flounder.

CHANGES IN WEIGHT

Mean weights-at-age for Div. 4T winter flounder (September) and Divs. 4WX winter flounder (July) based upon the Canadian groundfish surveys are indicated in Table 5. Males and females were of similar weight until about age 5 in Divs. 4T and 4X. However, females were heavier than males by at least age 4 in Div. 4W. Mean weights-at-age were greater in more southerly areas as compared with northerly ones. Instantaneous growth rates were derived from the weights-at-age in Table 5. Instantaneous growth rates of females were generally above 0.20 up to age 6, and those of males were above 0.20 up to age 5 (Table 6).

SEXUAL MATURITY

Median length at sexual maturity declined for both male and female winter flounder in Div. 4T from 1975-79 as compared with 1970-74 ($P<0.05$) (Table 7). Maturity ogives based on length indicated that virtually all of the winter flounder greater than 30 cm total length were mature (Fig. 6). From 1975-79, median ages at maturity (and 95% confidence limits) were 3.66 yr (3.30-4.05) for males and 3.98 yr (3.78-4.19) for females (Table 8).

For winter flounder in Div. 4W, median lengths at maturity for males were greater during 1965-69 than in the 1970s (Table 7). Median lengths at maturity increased by about 1 cm from 1975-79 as compared with 1970-74 (Fig. 7), but sample sizes were small in the former period, and this increase was not significant ($P>0.05$) (Table 7). Median length at maturity for females increased from 1975-79 as compared with 1970-74, but the difference was again not significant ($P>0.05$).

Median length at sexual maturity for winter flounder in Div. 4X declined during 1959-64 to 1975-79 ($P<0.05$) (Table 7). All females greater than 35 cm in total length were mature in the 1970s, but about 90% were mature in the 1960s (Fig. 8). Median age at maturity could not be calculated for winter flounder in Div. 4W or 4X as all winter flounder greater than age 2 were mature. These data suggest that median age at maturity was lower for winter flounder in Divs. 4W and 4X than for those in Div. 4T.

DISCUSSION

Studies on variability in growth of winter flounder have indicated that there is regional variability in growth rates (Kennedy and Steele 1971), with winter flounder in more southerly areas being

larger at most ages than those in more northerly areas. This result suggests that water temperature influences growth rates of winter flounder. The influence of stock biomass on growth rates was not investigated in the present study because the stock structure of winter flounder on the Scotian Shelf was uncertain and it was difficult to determine reliable estimates for stock biomass. However, in flatfish, stock density has been suggested to have an impact on growth rates (Pitt 1975; Bannister 1977), and this question could be explored further when additional information is available.

Mean lengths-at-age for winter flounder in the research cruises in the southern Gulf of St. Lawrence and the Scotian Shelf from 1975-79 were larger than those reported by Kennedy and Steele (1971) for winter flounder near Newfoundland, but generally less than those recorded by Berry et al. (1965) for winter flounder off Rhode Island, U.S.A. However, mean lengths-at-age for Div. 4X winter flounder were similar to those recorded by Berry et al. (1965), and the results of the present study further illustrate regional variability in winter flounder growth rates.

The analysis of the landings of Canadian otter trawlers indicated that from 1975-79, winter flounder age 6 or less comprised between 45% and 70% of the landings of females, and over 65% of the landings of males. Instantaneous growth rates of winter flounder, as derived from research cruises between 1975-79, were generally above 0.20 for females less than age 6 and for males less than age 5. Natural mortality rates of winter flounder have been reported to range between 0.30 and 0.36 (Dickie and McCracken 1955; Saila et al. 1965) and 0.27 for winter flounder off Massachusetts (Howe and Coates 1975). If natural mortality is about 0.30, then yield is lost from a year-class when winter flounder less than age 3 or 4 comprise a substantial portion of the catch, 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. However, further work is necessary to evaluate rates of natural mortality for winter flounder in different areas. If there is a link between growth rate and natural mortality (Gerking 1957; Ware 1975), then presumably the slower-growing northern stocks should have lower rates of natural mortality than the faster-growing southern stocks.

Variability in median size and age at sexual maturity for winter flounder in the Northwest Atlantic has been investigated by Kennedy and Steele (1971). Median ages at sexual maturity for winter flounder from Conception Bay, Newfoundland (Div. 3L) from 1962-63 were about 5.1 yr for males and 6.4 yr for females (Kennedy and Steele 1971), greater than recorded for any winter flounder stock in the present study. However, median lengths at maturity were 21 cm for males and 25 cm for females in Kennedy and Steele's study, similar to the results for the present study. These results and the data from the present study indicated that winter flounder caught in warmer waters matured at younger ages than did winter flounder in colder waters. This same trend was noted by Gunter (1950), who noted that fish inhabiting regions of higher water temperature grew faster initially, attained sexual maturity earlier, and were of smaller final

size than the same species in colder water. Alm (1959) noted that fish with a higher initial rate of growth attained sexual maturity earlier than did slower-growing fish of the same species, and the results of the present study support that view.

The decline in median length at sexual maturity for winter flounder in Div. 4X and possibly Div. 4T may have occurred for two reasons. If it is assumed that size at maturity has a genetic component (Alm 1959), then there has been selection for fish that mature at smaller sizes. Commercial exploitation would remove genotypes that mature at a larger size, and this mechanism could account for the decline in median length at maturity. Alternatively, a decline in median length at maturity may be attributable to a decline in growth rates, if age at maturity is relatively constant. Future research should identify stock boundaries and investigate variability in annual growth rates in relation to changes in stock biomass, and incorporate this variability in models used to assess stock status.

ACKNOWLEDGMENTS

I am indebted to all those people who have crewed the research vessels, sampled the landings in the commercial fishery, and aged the winter flounder. A. Vromans and B. Fowler assisted in some of the analysis. Dr R. G. Halliday (Marine Fish Division) and three referees made helpful comments on a draft of this manuscript. The manuscript was prepared with the assistance of the staff at the Pacific Biological Station.

REFERENCES

Alm, G. 1959. Connection between maturity, size and age in fishes. Rep. Inst. Freshwater Res. Drottningholm 40: 145 p.

Bannister, R. C. A. 1977. North Sea plaice. pp. 243-282. In: Fish Population Dynamics, J. A. Gulland (ed.). John Wiley and Sons, New York. 372 p.

Berry, R. J., S. B. Saila, and D. B. Horton. 1965. Growth studies of winter flounder, (Pseudopleuronectes americanus) (Walbaum), in Rhode Island. Trans. Amer. Fish. Soc. 94: 259-264.

Bowering, W. R. 1978. Age and growth of the Greenland halibut, Reinhardtius hippoglossoides (Walbaum) in ICNAF Subareas 2-4. Int. Comm. Northw. Atl. Fish. Res. Bull. 13: 5-10.

Cleary, L. MS 1979. Flatfish of the Scotian Shelf. Can. Atl. Fish. Sci. Adv. Comm. Res. Doc. 79/27. 49 p.

Dickie, L. M., and F. D. McCracken. 1955. Isopleth diagrams to predict equilibrium yields of a small flounder fishery. J. Fish. Res. Board Can. 12: 187-209.

Gerking, S. D. 1957. Evidence of ageing in natural populations of fishes. Gerontologia, 1: 287-305.

Gulland, J. A. 1955. Estimation of growth and mortality in commercial fish populations. U.K. Min. Agr. Fish. Invest. Ser. 2, 18(9): 1-46.

Gunter, G. 1950. Correlation between temperature of water and size of marine fishes on the Atlantic and Gulf coasts of the United States. Copeia 1950(4): 298-304.

Halliday, R. G. 1973. The flatfish fisheries of the Scotian Shelf. Int. Comm. Northw. Atl. Fish. Redbook. Part III: 79-99.

Halliday, R. G., and A. C. Kohler. MS 1971. Groundfish survey programmes of the St. Andrews Biological Station, Fisheries Research Board of Canada - objectives and characteristics. ICNAF Res. Doc. 71/35. Serial No. 2520.

Howe, A. B., and P. G. Coates. 1975. Winter flounder movements, growth, and mortality off Massachusetts. Trans. Amer. Fish. Soc. 104: 13-29.

Kennedy, V. S., and D. H. Steele. 1971. The winter flounder (Pseudopleuronectes americanus) in Long Pond, Conception Bay, Newfoundland. J. Fish. Res. Board Can. 28: 1153-1165.

Kohler, A. C. 1964. Variations in the growth of Atlantic cod (Gadus morhua L.). J. Fish. Res. Board Can. 21: 57-100.

Leslie, P. H., J. S. Perry, and J. S. Watson. 1945. The determination of the median body-weight at which female rats reach maturity. Proc. Zool. Soc. London, 115: 473-488.

McCracken, F. D. 1963. Seasonal movements of the winter flounder, Pseudopleuronectes americanus (Walbaum), on the Atlantic Coast. J. Fish. Res. Board Can. 20: 551-586.

Mendenhall, W. 1971. Introduction to probability and statistics. Third edition. Duxbury Press, Belmont, California. 465 p.

Parker, R. R., and P. A. Larkin. 1959. A concept of growth in fishes. J. Fish. Res. Board Can. 16: 721-745.

Pitt, T. K. 1975. Changes in abundance and certain biological characteristics of Grand Bank American plaice, Hippoglossoides platessoides. J. Fish. Res. Board Can. 32: 1383-1398.

Powles, P. M. 1965. Life history and ecology of American plaice (Hippoglossoides platessoides F.) in the Magdalen Shallows. J. Fish. Res. Board Can. 22: 565-598.

Saila, S. B., D. B. Horton, and R. J. Berry. 1965. Estimates of the theoretical biomass of juvenile winter flounder, Pseudopleuronectes americanus (Walbaum) required for a fishery in Rhode Island. J. Fish. Res. Board Can. 22: 945-954.

Scott, J. S. 1976. Summer distribution of groundfish on the Scotian Shelf, 1970-74. Fish. Mar. Serv. Res. Dev. Tech. Rep. 635: 51 p.

Tyler, A. V. 1971. Surges of winter flounder, Pseudopleuronectes americanus, in the intertidal zone. J. Fish. Res. Board Can. 28: 1727-1732.

Ware, D. M. 1975. Relation between egg size, growth, and natural mortality of larval fish. J. Fish. Res. Board Can. 32: 2503-2512.

Table 1. Mean length (cm), mean age (yrs), and sample sizes of winter flounder derived from sampling landings of Canadian otter trawlers, 1948-79.

			Period				
	Area	Sex	1948-59	1960-64	1965-69	1970-74	1975-79
Mean length (cm)	4T	Male	32.1	30.8	32.4	30.5	26.6
		Female	33.1	33.1	35.6	33.6	27.7
	4X	Male	32.6	-	-	-	36.5
		Female	38.1	-	-	-	38.8
Mean age (yrs)	4T	Male	6.1	-	-	7.2	6.2
		Female	5.4	-	-	7.9	6.2
	4X	Male	5.0	-	-	-	5.8
		Female	6.0	-	-	-	6.0
Number of samples	4T		4	11	15	5	13
	4X		70	3	1	1	15
Number measured	4T		500	2013	1814	1000	2399
	4X		6841	326	162	359	2896
Number aged	4T		73	0	0	181	566
	4X		781	0	0	91	560

Table 2. Growth rates (cm/yr) of winter flounder caught during Canadian groundfish surveys in Div. 4T in September and Div. 4X in July, 1975-79. Linear regressions of mean length on age were fitted for males from ages 2-9 and for females from ages 2-12.

	Males		Females	
	4T	4X	4T	4X
Rate	1.45	2.72	1.94	3.24
S.E.	0.22	0.49	0.10	0.19
Intercept	16.49	19.26	15.80	14.23
r^2	0.89	0.86	0.98	0.98

Table 3. Length, weight, and age parameters for winter flounder caught during Canadian groundfish surveys, 1975-79. Surveys in Div. 4T were in September and cruises in Divs. 4WX were in July.

		Males			Females		
		4T	4W	4X	4T	4W	4X
Mean length (cm)		24.9	29.6	33.4	27.5	34.1	36.5
Mean weight (kg)		0.20	0.31	0.55	0.30	0.50	0.77
Mean age (yr)		5.5	4.8	5.0	5.9	5.7	5.7
Length (cm)-	a	0.013	0.027	0.022	0.004	0.041	0.010
Weight (g)	b	2.995	2.744	2.858	3.323	2.654	3.088
Relation	n	493	65	144	770	77	241
$W=aL^b$	r^2	0.90	0.86	0.93	0.94	0.84	0.96

Table 4. Mean length-at-age (cm) for male and female winter flounder landed during June through October by Canadian otter trawlers in Div. 4T and 4X, 1975-77.

	1975		1976				1977			
	Male	Female	Male		Female		Male		Female	
Age	4T	4T	4T	4X	4T	4X	4T	4X	4T	4X
2			-	24.9	-	25.0	-	-	-	-
3	19.1	17.4	-	29.1	-	29.3	16.9	31.4	17.9	32.3
4	20.3	22.7	21.7	32.5	21.9	32.7	19.9	34.3	21.3	36.1
5	25.0	26.8	24.5	35.0	25.4	36.6	23.6	36.9	24.4	36.7
6	27.5	28.7	25.6	36.8	26.4	39.2	27.7	39.6	30.1	41.9
7	28.5	29.9	27.9	38.4	28.5	40.1	31.0	42.5	33.7	45.4
8		33.6	29.5	40.4	30.7	42.9	33.6	42.7	34.5	45.1
9		34.7	32.2	41.2	33.2	45.9	-	-	35.6	49.4
10		31.3	33.9	44.4	33.5	45.9	-	-	35.6	46.9
11		35.0	35.4	44.4	35.9	46.8	-	45.7	-	52.8
12			34.3	-	36.2	51.9	33.0	-	-	-
13			-	47.0	-	51.6	-	-	-	-
14			-	50.0	-	56.0	-	-	45.0	-
15			-	-	-	56.0	-	-	-	-

Table 5. Mean weights-at-age (kg) for winter flounder caught during Canadian groundfish surveys in the southern Gulf of St. Lawrence (Div. 4T) in September and on the Scotian Shelf (Divs. 4WX) in July, 1975-79. Number of otoliths read for each age is in parenthesis.

	Males			Females		
Age	4T	4W	4X	4T	4W	4X
2	0.06(7)	- (0)	0.16(3)	0.06(10)	- (0)	0.16(1)
3	0.10(20)	- (0)	0.20(13)	0.11(36)	- (0)	0.21(6)
4	0.14(48)	0.25(5)	0.41(16)	0.15(55)	0.35(6)	0.44(16)
5	0.18(66)	0.32(7)	0.56(11)	0.21(88)	0.43(14)	0.57(16)
6	0.23(65)	0.46(2)	0.78(11)	0.29(105)	0.48(7)	0.79(17)
7	0.26(45)	0.59(2)	0.78(4)	0.39(91)	0.75(5)	0.96(12)
8	0.29(31)	- (0)	0.88(2)	0.48(63)	0.62(2)	1.19(5)
9	0.28(9)	- (0)	0.94(3)	0.51(29)	0.64(1)	1.33(1)
10	0.40(6)	- (0)	- (0)	0.62(18)	- (0)	1.60(1)
11	0.39(2)	- (0)	- (0)	0.67(9)	- (0)	1.31(1)
12	0.42(2)	- (0)	- (0)	0.86(5)	- (0)	- (0)

Table 6. Mean instantaneous growth rates of winter flounder as derived from weights-at-age in Table 5.

	Males			Females		
Age	4T	4W	4X	4T	4W	4X
2-3	0.511	-	0.223	0.606	-	0.272
3-4	0.337	-	0.718	0.310	-	0.740
4-5	0.251	0.247	0.312	0.337	0.206	0.259
5-6	0.245	0.363	0.331	0.323	0.110	0.326
6-7	0.123	0.249	0.000	0.296	0.446	0.195
7-8	0.109	-	0.121	0.208	-0.190	0.215
8-9	-0.035	-	0.066	0.061	0.032	0.111

Table 7. Median length (cm) at sexual maturity of winter flounder in Divisions 4T, 4W, and 4X as calculated from groundfish surveys from 1959-64, 1965-69, 1970-74, and 1975-79. 95% confidence limits are in parenthesis.

	Males			
Division	1959-64	1965-69	1970-74	1975-79
4T	-	-	21.03 (19.90-22.23)	18.76 (18.09-19.46)
4W	-	24.27 (22.93-25.68)	21.99 (19.09-25.31)	22.94 (19.10-27.56)
4X	29.18 (27.11-31.41)	28.82 (27.50-30.20)	28.01 (26.49-29.59)	25.37 (23.31-27.60)

	Females			
Division	1959-64	1965-69	1970-74	1975-79
4T	-	-	22.77 (21.95-23.61)	20.58 (20.03-21.14)
4W	-	-	23.35 (21.49-25.37)	25.08 (23.33-26.96)
4X	31.59 (30.58-32.63)	28.29 (27.44-29.17)	28.10 (26.85-29.40)	25.58 (23.25-28.16)

Table 8. Percentage of sexually mature winter flounder by age and sex caught during Canadian groundfish surveys in the southern Gulf of St. Lawrence (Div. 4T), 1975-79. Number of fish sampled at each age is in parentheses.

Age	Male	Female
2	0.0 (10)	0.0 (13)
3	29.1 (24)	14.0 (43)
4	56.6 (53)	50.0 (62)
5	81.3 (80)	84.5 (103)
6	87.2 (94)	90.3 (134)
7	96.3 (54)	99.1 (106)
8	82.9 (35)	100.0 (76)
9	100.0 (6)	100.0 (27)

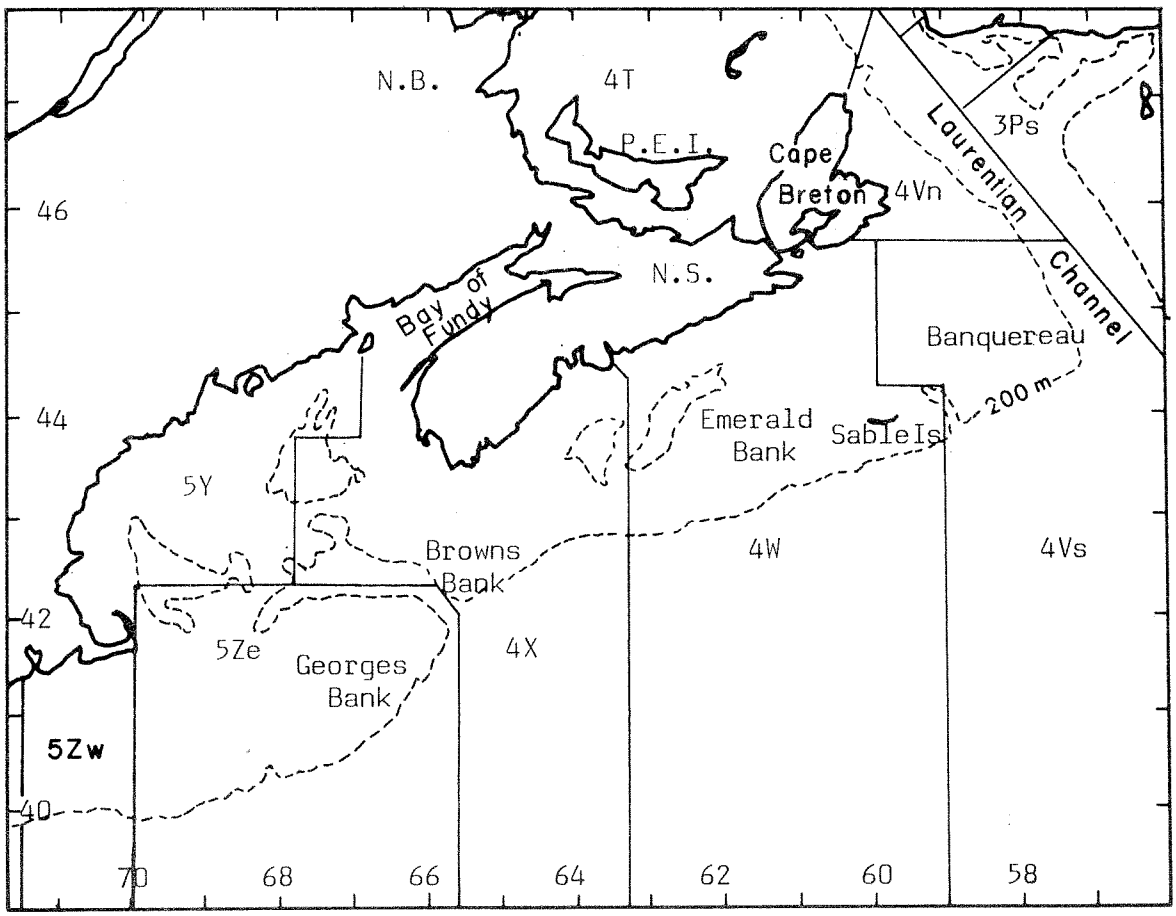

Fig. 1. Northwest Atlantic Fisheries Organization Division in Subarea 4.

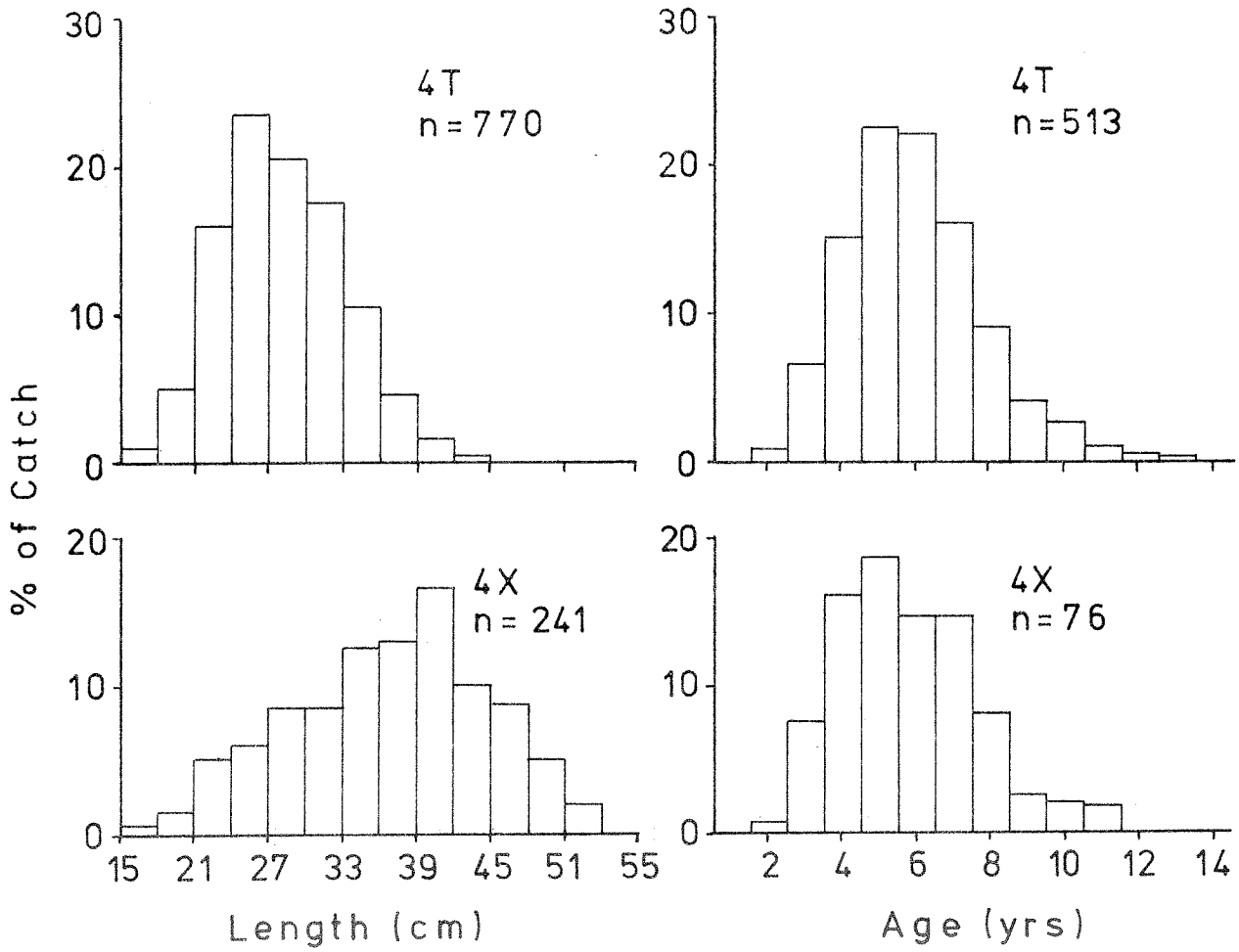

Fig. 2. Length frequencies and age compositions of female winter flounder caught during groundfish surveys in Div. 4T (September) and Div. 4X (July), 1975-1979.

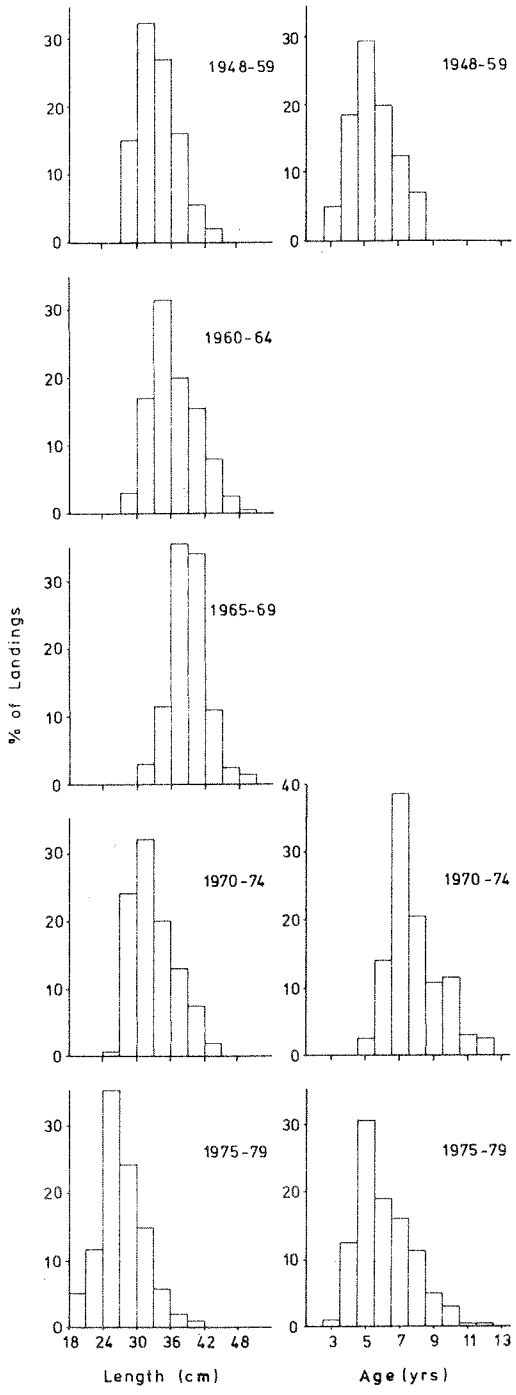

Fig. 3. Length frequencies and age compositions for female winter flounder landed by Canadian otter trawlers in Div. 4T, 1948-1979.

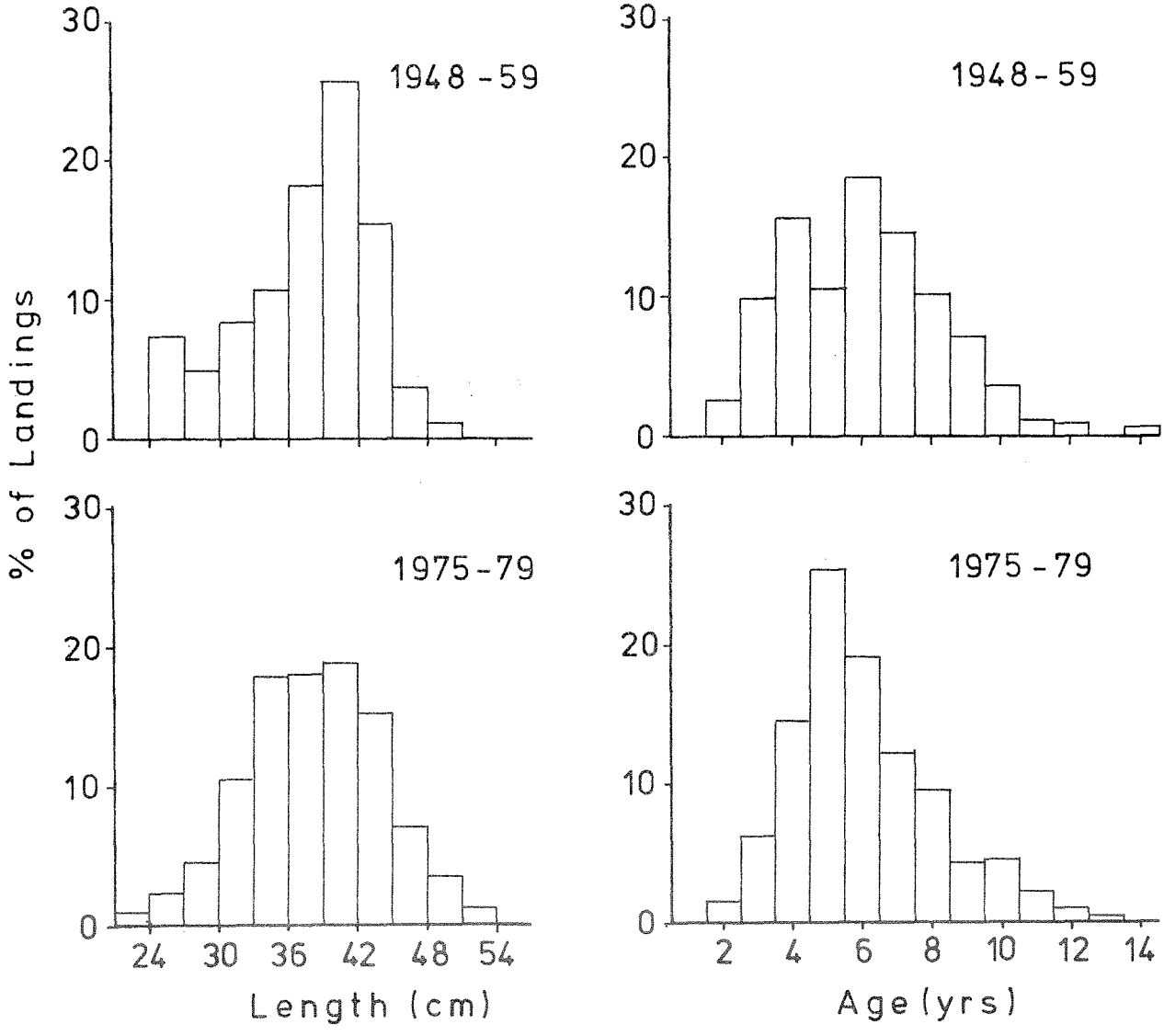

Fig. 4. Length frequencies and age compositions for female winter flounder landed by Canadian otter trawlers in Div. 4X, 1948-1959 and 1975-1979.

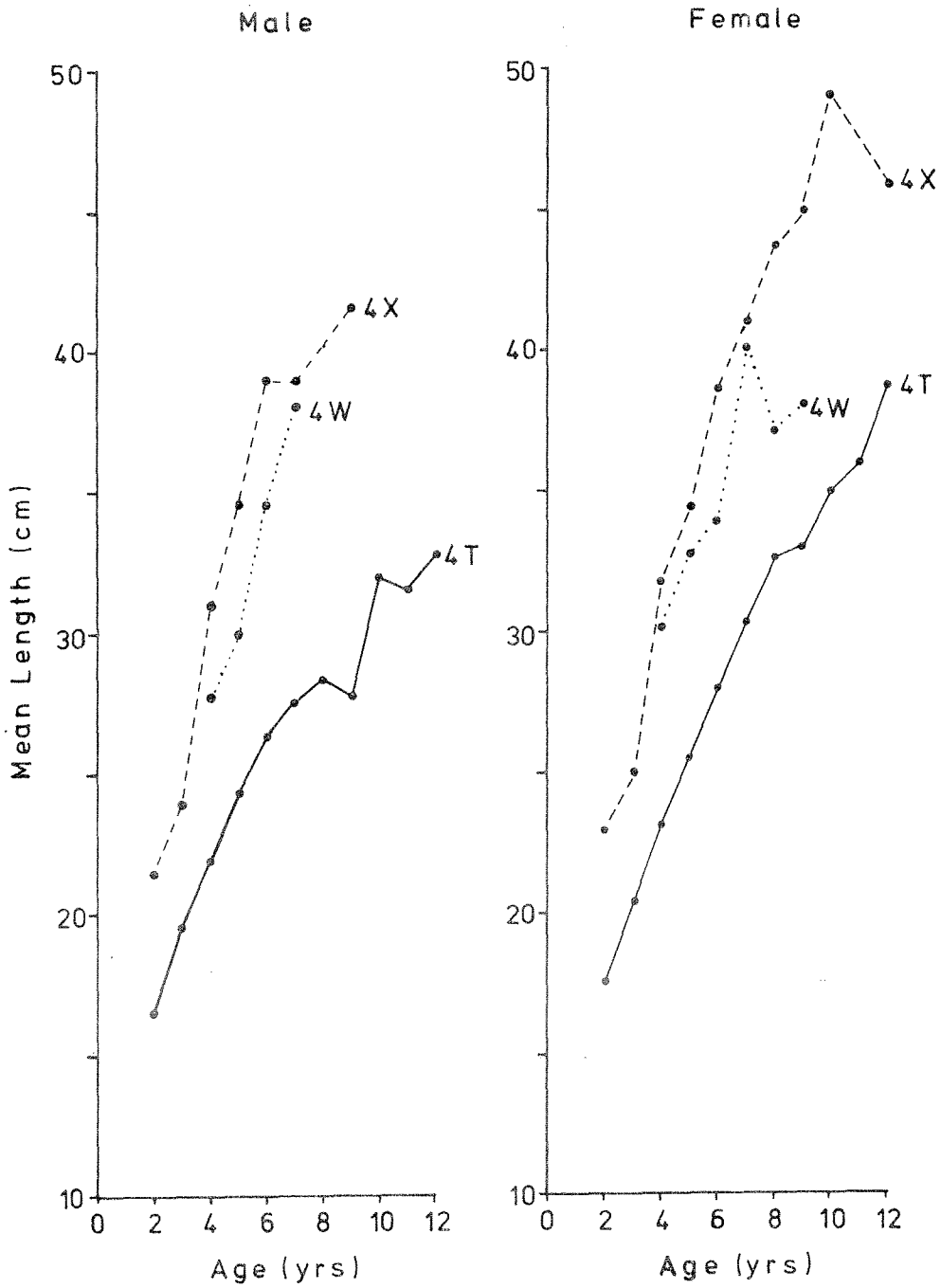

Fig. 5. Observed mean lengths-at-age for winter flounder caught during Canadian groundfish surveys, 1975-1979. Number of otoliths read for each age is indicated in Table 5.

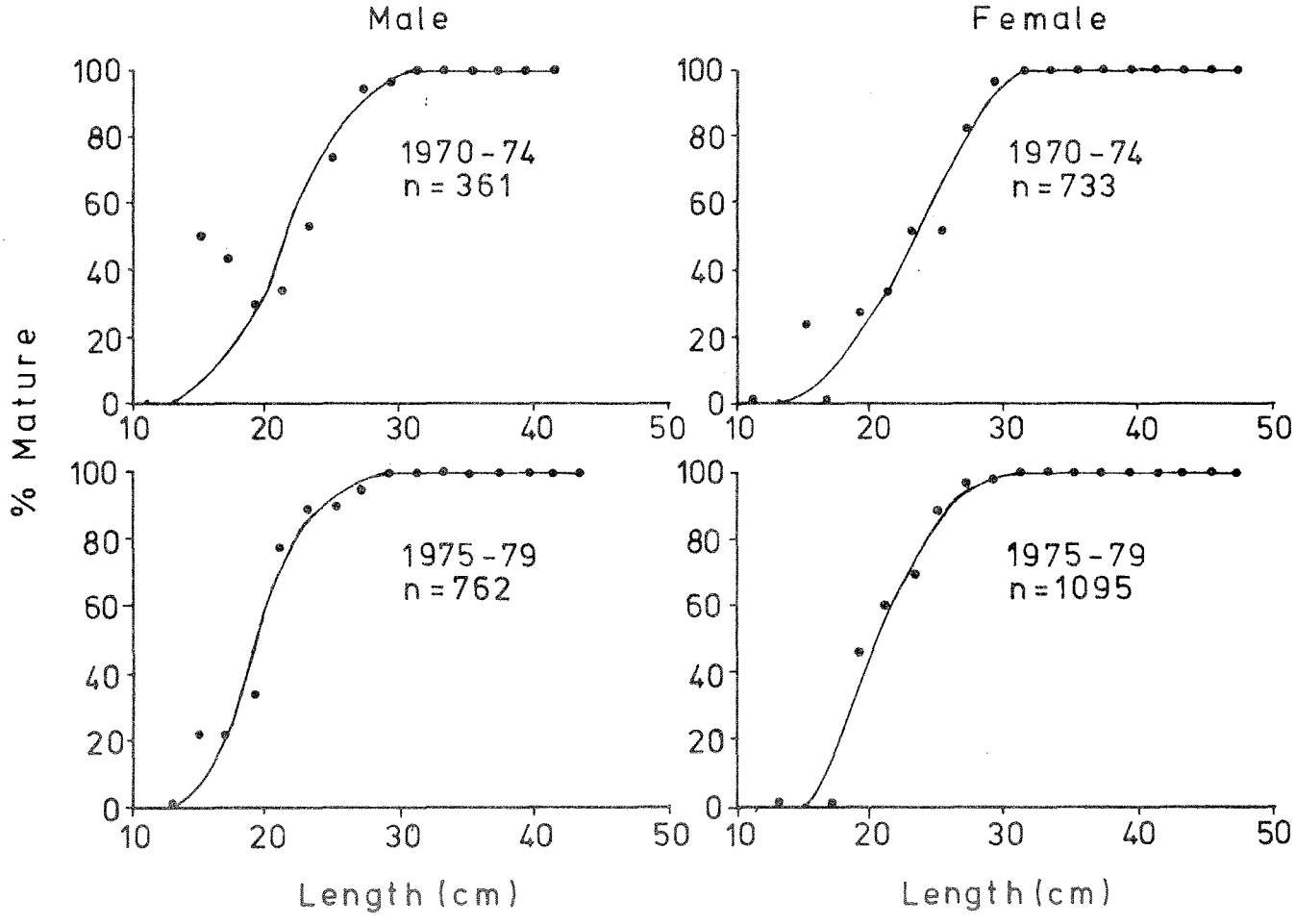

Fig. 6. Maturity ogives for winter flounder caught during Canadian groundfish surveys in Div. 4T, 1970-1979.

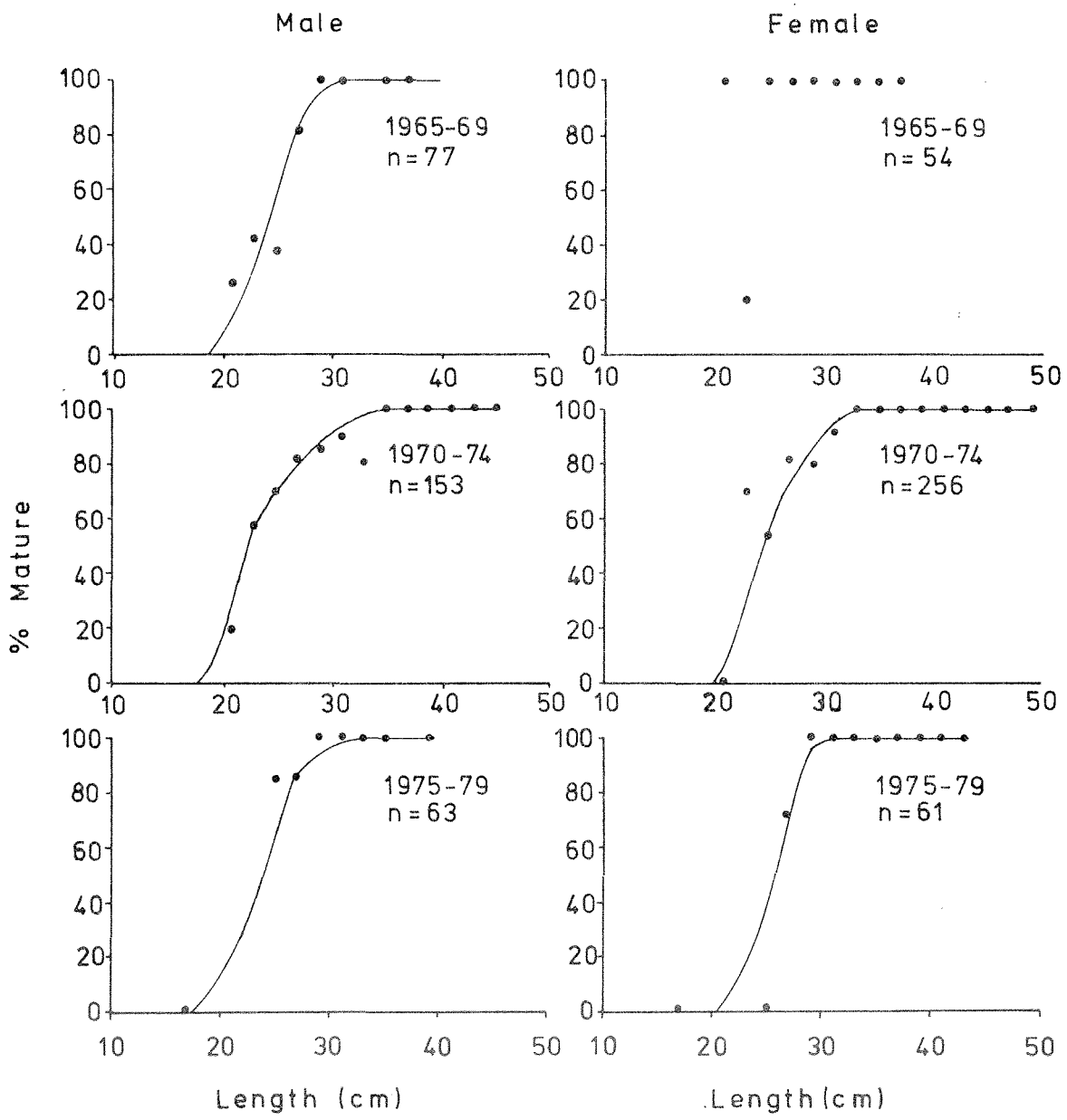

Fig. 7. Maturity ogives for winter flounder caught during Canadian groundfish surveys in Div. 4W, 1965-1979.

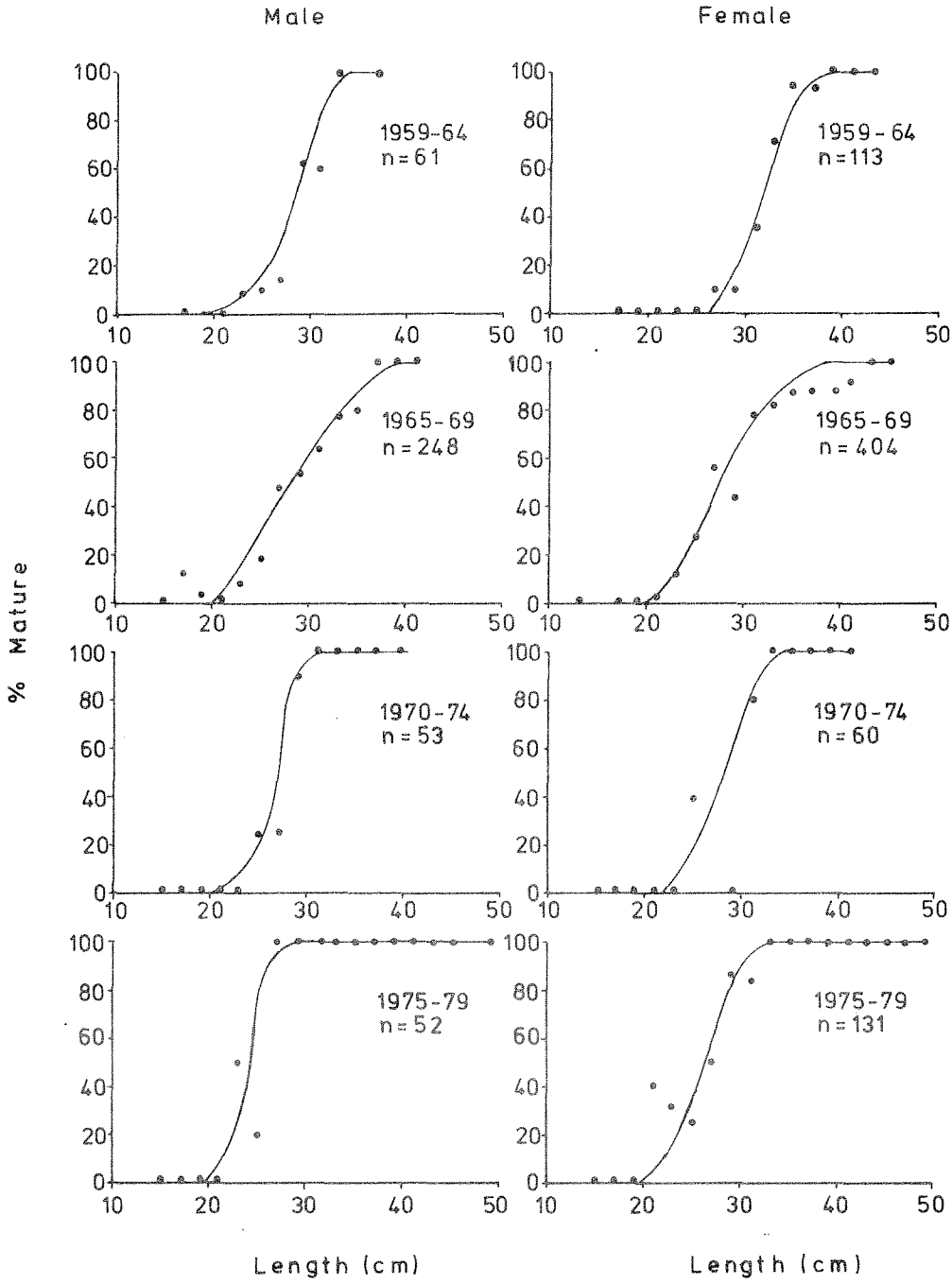

Fig. 8. Maturity ogives for winter flounder caught during Canadian groundfish surveys in Div. 4X, 1959-1979.