Department of Fisheries and Oceans
Canadian Stock Assessment Secretariat
Research Document 97/106

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Ministère des pêches et océans
Secrétariat canadien pour l'évaluation des stocks
Document de recherche 97/106

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Status of witch flounder in Div. 4VWX in 1997

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Abstract

Research vessel surveys show that witch flounder in Div. 4VWX declined in abundance from the mid 1980s to the early 1990s but improved strength of year classes spawned since about 1990 has resulted in an increase in total population estimates in the last few years. This increase in abundance should be reflected in higher abundance of fishable sizes in the next year or two, but the extent to which this might improve fishing success in presently exploited areas is not known. The split in management units between Div. 4VW and Div. 4X is supported by witch distributional data, but associations with witch in adjacent Divisions to the north and south of Div. 4VWX need to examined. Managerial control of exploitation level would be enhanced if witch were managed separately from the other small flatfish species.

Résumé

Les relevés par navire de recherche indiquent un déclin de l'abondance de la plie grise des divisions 4VWX du milieu des années 1980 au début des années 1990, mais le frai des classes d'âge plus fortes apparues depuis 1990 environ a donné lieu à une augmentation de la population totale estimée au cours des dernières années. Cet accroissement devrait correspondre à une plus forte abondance de poissons de taille récoltable d'ici un an ou deux, mais la mesure dans laquelle cela pourrait se traduire par un meilleur succès de la pêche dans les zones actuellement exploitées n'est pas connue. La division des unités de gestion entre les divisions 4VW et 4X est appuyée par les données sur la répartition des plies, mais la possibilité d'associations avec des plies se trouvant dans les divisions situées au nord et au sud de 4VWX devra être étudiée. Un meilleur contrôle de la gestion du taux d'exploitation pourrait être obtenu si les plies étaient gérées de façon distincte des autres petites espèces de poissons plats.

INTRODUCTION

Witch flounder occur in the Northwest Atlantic from off southern Labrador to Cape Hatteras (Fig. 1), usually at 50 - 300 m in water of 2 to 6^0 C but they have been recorded between 18 and 1570 m and at -1 to 11^0 C. They occur most commonly in deep holes and channels and along the shelf slope on muddy bottom. There is no evidence that witch undertake extensive migrations but there are seasonal changes in concentration associated with spawning. The spawning period is protracted, and on the Scotian Shelf is thought to occur from May to October with a peak in July-August. The post-larval, pelagic phase is unusually long, lasting up to one year, and it is thought that the first few years of demersal life are spent in much deeper water than the adults, providing what has been considered a natural conservation mechanism(Powles and Kohler,1970). Food consists primarily of worms supplemented by other benthic invertebrates such as small crustaceans and bivalve molluscs. Witch is a long-lived, slow-growing species; a maximum age of about 30 yr. and a maximum size of 78 cm (weight of about 5 kg) have been recorded.

MATERIALS AND METHODS

Estimates of population distribution, abundance and size structure are provided by two series of research vessel (RV) surveys. A summer RV survey (stratified-random design) has been conducted in Div. 4VWX in 1970-97. Note that all analyses presented use data from standard strata to 200 fm only unless otherwise specified. Data for three 200-400 fm strata occupied in 1995-97 are reported separately. A spring RV survey (stratified-random design) has been conducted in Div. 4VW, in 1986-97. In this case also, analyses are restricted to standard strata to 200 fm. (An earlier survey series in Div. 4VW in 1978-1984, using a different stratification scheme, is not used.)

An industry survey, conducted in summer (coincidentally with the summer RV survey) by the ITQ fleet (ITQ survey) in Div. 4X in 1995-97, using a fixed station design, also provides estimates of population distribution and abundance. Length frequencies of witch were not collected during this survey. Spatial coverage differed from the RV survey: in 1995 fewer strata were occupied by the ITQ survey, and in all years the ITQ survey included a stratum (499) that encompasses more coastal areas. The analyses of the results of this survey are provisional.

Canadian fishery statistics continue to show a substantial portion of flatfish landings from Div. 4VWX as unspecified flounders. Much of this problem stems from the fact that there is no difference in price paid for plaice, yellowtail and winter flounder. However, there has historically been a higher price paid for witch flounder, and this practice continues today, providing an incentive for witch landings to be separated out by fishermen and recorded separately in the statistical system. Consultations with fishermen and within DFO confirm that, as a result of this price differential, recorded witch landings

do not share the reporting problems that prevail for other flounder species. Thus, none of the flatfish landings unassigned as to species are attributed to witch.

Commercial landings by domestic vessels were obtained from NAFO files for 1977-88 and from ZIF files for 1989-97. Data from these sources overlapped for the years 1989-1993 and the two data sets agreed almost exactly. NAFO nominal catch data for foreign fleets do not agree well with observer data. The latter, which are estimates based on 100% observer coverage from 1987, are the more reliable and thus are the ones used here.

Several commercial data sets are summarized by "eastern" and "western" Div. 4X, defined as Unit Areas mno and pqrs, respectively.

The distribution of commercial fishing is described from ZIF data by geographical coordinates, available for 1994-97. The size composition of domestic landings is described from port samples, and of domestic and foreign catches from observer data. Commercial catch rates in 1989-97 are described for specific fishing areas and for the main fleet components, from ZIF data.

The length-weight relationship used to weight up commercial samples by landing or catch weights was based on summer RV survey data, 1970-97 combined. The equation was:

$$W = 0.0024\ L^{3.27}$$

An exploratory analysis of total mortality was conducted using length frequencies from the summer RV survey series. This length-based approach utilizes von Bertalanffy growth parameters to determine catch curves based on length composition data (Sparre, 1985).

RESULTS

The Commercial Fishery

Catch Regulation: Witch flounder on the Scotian Shelf came under catch quota as one of three species regulated under a general flatfish Total allowable Catch (TAC) established by ICNAF in 1974. This multi-species TAC (for witch flounder, American plaice and yellowtail flounder) was necessitated by the failure of the various national statistical agencies to report catch statistics separately for these species, much of the catch being recorded as unspecified flounder. Catches of Scotian Shelf flatfish continue to be regulated under a multi-species TAC but, from 1994, this TAC has been partitioned between Div. 4VW and Div. 4X and winter flounder has been added to the species covered under the Div. 4X portion. The history of TAC regulations is in Table 1.

Canadian landings: Domestic landings from Div. 4VWX varied between 1400 and 2300 t in 1977-85 but increased to about 3000 t in 1986-88 before dropping to 600-800 t in 1994-96 (Table 2). Prior to 1994, the majority of the catch came from Div. 4VW, and most of that came from Subdiv. 4Vn. Div. 4X catches were mainly in the range of 400-500 t until 1990-92 when they rose to 600-800 t, falling subsequently to 300-400 t. Substantial changes in fishery management practices in 1993 may have had an effect on subsequent levels of landings. Landings in recent years (1992-95) were concentrated in summer months in Div. 4VW and in the first five months of the year in Div. 4X, and this pattern continued in 1996 and appears also to be the case in 1997 (Table 3). Small boats less than 150 grt (tonnage classes 0-3) accounted for almost all of the landings of witch after 1992 (Table 4), otter trawlers being the predominant gear type in Div. 4X and seiners predominating in Subdiv. 4Vn.

The geographical distribution of commercial fishing was similar in 1994-97 (Fig.2). There was a concentration of catches in Subdiv. 4Vn, particularly in the northern part. In Subdiv. 4Vs, a more diffuse concentration of fishing occurred, primarily in its eastern part. In Div. 4X, catches came mainly from two locations; north and west of LaHave Basin and in the Gulf of Maine. There was not a complete separation of these fishing locations as there were also some catches in the deep water north of Browns Bank.

Size Compositions: In recent years, port and observer samples of witch flounder taken in the domestic fishery have come predominantly from small otter trawlers fishing in Div. 4X and from Scottish and Danish seiners fishing in Subdiv. 4Vn, reflecting the volume of landings. (An inventory of port samples is in Table 5.) .) The limited sampling available suggests that witch landed by seiners in Subdiv. 4Vn in 1994 -97 had a modal length of 35-36 cm and were predominantly between 32 and about 45 cm (Fig 3). Observer samples corroborate this conclusion (Fig. 4). In 1991-93, port samples had modal lengths of 40-42 cm but only one sample per year is available. The data suggest a declining trend in the mean size of fish landed from about 42 cm in 1990 to 36 cm in 1996, with 1997 data available to date indicating an increase (to 39 cm) (Table 6).

Small trawlers fishing in eastern Div. 4X landed witch with a modal size of 43 cm in 1991, decreasing to 36 cm by 1994 but then increasing again to 41 cm by 1996 (Fig. 5). Mean sizes showed the same trend (Table 6), also, sampling suggests a decline in the size of fish landed for 1991-92 (Table 6, Fig.6). However, port sampling was at low levels in both eastern and western Div. 4X. Observer data for small trawlers in Div. 4X (Fig. 7) are scant, but in 1995-96, the two years with the greatest number of fish measured, the frequencies are similar to those of port samples.

Catch Rates: Seiners in Subdiv. 4Vn appear to have experienced a reduction in catch rate from 1990, but there was an increasing trend from 1993-94 and preliminary data for 1997 suggest catch rates had returned to earlier levels (Table 7, Fig. 8). Otter trawlers fishing in eastern Div. 4X had increasing catch rates from 1989 to 1992, but experienced a decline thereafter through 1996. However, preliminary 1997 data suggest some slight improvement. Those trawlers fishing in western Div. 4X experienced steadily declining

catch rates from 1989 to 1996 but some modest improvement is suggested by 1997 data to date. Further analysis of these catch rates is required before their usefulness as indicators of stock abundance changes can be evaluated, as many other factors influence commercial fishing success.

Foreign Catches: Foreign witch flounder catches in Div. 4VWX in 1987-97 were minor (Table 8) and, except for bycatches in the French cod fishery in Subdiv. 4Vn in the early 1990s, were taken as bycatch in the small mesh silver hake fishery, primarily in Div. 4W. Bycatches of witch in the silver hake fishery were well sampled (by the observer program), except in 1994 when only 3 t were caught. These bycatches were composed of fish rather smaller than those observed in domestic fisheries, fish of 20-25 cm occurring consistently whereas fish of this size were absent from domestic landings, and modal values were predominantly 34-35 cm (Fig. 9). Note that separator grates, and additional restrictions on fishing area, were introduced in 1994. Both measures may have affected the size composition of witch caught.

Geographical Distribution of the Resource

Div. 4VWX does not delimit distinctly separate concentration of witch flounder. To the contrary, the eastern part of the management unit includes the western bounds of a major Laurentian Channel concentration (Fig.1). The western part (Div.4X) is close to the southern limits of commercial concentrations of the species, and there is continuity in witch distribution in western Div. 4X and the rest of the Gulf of Maine.

Summer RV surveys in Div. 4VWX show witch distributed throughout the area, mainly in water deeper than 50 fm (1994-97 surveys illustrated, Fig. 10). The primary concentration occurred in Sydney Bight (Subdiv. 4Vn) extending south (into Subdiv. 4Vs) along the slope of the Laurentian Channel. There were concentrations also in the holes north of Banquereau Bank, in the Gully, north of Emerald and LaHave basins, and in the approaches to the Bay of Fundy. There was a notable scarcity of records from the Emerald and LaHave basins themselves and from the outer slopes of the banks from Sable to Browns, which is the area of warmest bottom temperatures on the Scotian Shelf.

The composite distribution of catches in the spring surveys in Div. 4VW for 1988-97 (illustrated in five year periods, Fig. 11) show a similar distribution as in summer surveys. The spring surveys did not extent far into Sydney Bight because of ice coverage but concentrations of witch are observable along the slope of the Laurentian Channel, in the holes north of Banquereau Bank, in the Gully and along adjacent parts of the outer slope, and northeast of Emerald Bank.

The distribution of witch catches in the Div. 4X ITQ survey agree well with those in research vessel surveys (Fig. 12).

Research Vessel Abundance Estimates

Population size estimates for Div. 4VW from summer RV surveys (Fig. 13) varied strongly in the 1970s but the unusually high values in 1974 represented, at least in large part, an availability problem in that year. The size composition of witch caught in 1974 was similar to those in adjacent years; there was no recruitment event that could explain an abundance change of the magnitude observed. Population size in the early 1980s was stable but declined in the late 1980s and early 1990s. Population biomass showed increases only in 1996-97, whereas population numbers increased after 1992, and the estimate for 1997 was the highest in the series (except for 1974). (Abundance estimates in 1970-81 may not be directly comparable to those for subsequent years as there was a change in survey vessel and gear between 1981 and 1982.)

In Div. 4X, the artifact in 1974 data is not observed but, otherwise, trends were very similar to Div. 4VW (Fig. 13). Indeed the relative trends in biomass were virtually identical in the two areas. Population numbers decreased proportionately more than in Div. 4VW in the late 1980s and early 1990s and the increase in numbers from 1992 was less marked than in Div. 4VW.

Abundance estimates from research vessel surveys, when separated into fish greater than and less than 35 cm, provide estimates of trends in the fished portion of the population and of recruitment, respectively (Fig. 14). In summer surveys, the fished part of the population was fairly stable in abundance in the mid-1980s but declined in the late 1980s and early 1990s to lows in 1992-93 in both Div. 4VW and Div. 4X. Modest increases occurred in 1996-97. There was an increase in pre-recruit abundance in both areas after 1992 and, in both cases, pre-recruit abundance is presently the highest by far in the 28 year time series. The index of small witch less than 15 cm, which are probably 2 year olds, form a substantial part of the pre-recruit index. The size composition of witch in Div. 4VWX summer surveys in recent years, compared to estimates for 1970-97 combined, show more clearly a series of modes in the 1993-97 period, in the 6-20 cm range, which were more pronounced by far than any previously recorded in the data series (Fig. 15). These small fish were most prevalent in Div. 4VW, but were distributed also into Div. 4X (Fig. 16).

Spring surveys show essentially the same trends in Div. 4VW (Fig. 17) and the summer ITQ Survey in Div. 4X is in general agreement with regard to overall abundance trend in 1995-97 (Table 9).

Summer survey data in 1995-97 include coverage of three deep strata along the outer edge of the Scotian Shelf in 201-400 fm. Abundance and biomass estimates for these strata varied from 0.2-0.5 million fish and 48-68 t, indicating that only a small part of the population occurs deeper than 200 fm. However, the primary mode in the length frequency of these fish was at about 25 cm (range mainly between 17 and 38 cm) (Fig 18), thus they were mainly in the pre-recruit category.

Growth and Mortality

Although there are no current data on the growth of witch on the Scotian Shelf, there are data from earlier studies that give insight into its growth pattern (Table 10, Fig. 19). Powles and Kennedy (1967) provide an analysis of growth in the area of Middle Bank, near the boundary between Subdiv. 4Vs and Div. 4W. Also Burnett *et al.* (1992) provide data for the Gulf of Maine that may be more indicative of growth in western Div. 4X. Data for the Gulf of St. Lawrence (Bowering, 1976) may represent growth in Subdiv. 4Vn.

An exploratory analysis of total mortality (Z) was conducted, for sexes separately, using summer RV survey data summarized by management units Div. 4VW and 4X, in conjunction with von Bertalanffy growth parameters from the Gulf of St. Lawrence and Middle Bank, and from Middle Bank and the Gulf of Maine, respectively. Thus, there were two sets of estimates made for each management unit based on growth parameters determined for these, or immediately adjacent, Divisions. Catch curves were calculated for fish 40 cm and larger, as inspection of the length frequency data indicated that modal length was slightly less than 40 cm (except for females in Div. 4X) (Fig. 20). Fish of 40 cm and above were about 8-10 yrs old and older, according to the von Bertalanffy parameters used (Fig. 20). Annual length frequencies were highly variable, thus 5 yr running averages of the frequencies were used in the Z calculations, the estimates being assigned to the middle year of each block.

Estimates of Z for Div. 4VW witch based on Scotian Shelf growth parameters were all significant at the 5% level and quite stable throughout the data series. Those using Gulf of St. Lawrence parameters gave no significant fits for males and substantially lower estimates for females than those obtained using Scotian Shelf parameters (Fig. 21). Estimates of Z for Div. 4X males were consistent between the two sets of growth parameters used, but rather different for females (Fig. 21). The Scotian Shelf parameters provided no significant estimates for Div. 4X females prior to the early 1980s. An alternative set of calculations for Div. 4X females of 50 cm and larger gave results that were more consistent with those for males but, again, agreement between the estimates for the two sets of growth parameters was not very good.

This analysis suggests that the level of Z in Div. 4X was moderate to low over the time period of the surveys, whereas in Div. 4VW it was moderate to high. There were no strong trends in the estimates over time. However, there are a number of issues that require further investigation before confidence can be placed on estimates derived by this method. The analysis is sensitive to the growth parameters used and those available do not pertain to the main areas of fishing on the Scotian Shelf. The management units on which the analysis is based do not correspond to natural production units (stocks) and combination of length frequencies from different stock units in the same analysis could confound the results. The length frequency data are scant on an annual basis,

necessitating the use of multi-year averaging. Estimates are strongly dependent on the length span used in the analysis, and the appropriateness of 40 cm as the starting length needs to be examined in the context of commercial fishing patterns and of changes in these over time.

DISCUSSION

Witch flounder populations in both Div. 4VW and Div. 4X declined substantially in abundance between the mid 1980s and the mid 1990s and the fished part of the population is at about the lowest level observed. There are, however, a number of strong year classes in the population, spawned in the early 1990s, that have not yet reached fishable sizes. The distribution of these pre-recruits is strongly localized, occurring predominantly in the Gully and in the deep holes to the north of Banquereau in Div. 4VsW. It is not known to what extent this recruitment will contribute to the populations presently being fished in Subdiv. 4Vn and in Div. 4X. It should not be assumed, therefore, that abundance will increase greatly in these areas. In any case, witch year classes can be expected to progressively contribute to the fishery over a substantial number of years beginning at about age 6 and any concentration of fishing on recruiting age groups at this time would be detrimental to potential future yields.

There is an area of relatively low abundance of witch in the central Scotian Shelf which separates areas of higher witch abundance in Div. 4VW and Div. 4X. Thus the subdivision of the management unit Div. 4VWX into Div. 4VW and Div. 4X is an appropriate one, allowing exploitation to be controlled for each area of higher population abundance separately. However, it seems unlikely that either of these management units encompasses a self-propagating stock; there are likely important links to witch populations to the north and east in the case of Div. 4VW and to the west and south in the case of Div. 4X. Stock structure, and its relationship to present management units, requires investigation.

The inclusion of witch flounder in a general flatfish TAC is unnecessary as there appears to be reasonable confidence that landings statistics are not being confounded by inclusion of witch landings in the unspecified flounder category. Managerial control over the level of witch landings would be enhanced, therefore, if separate regulatory measures were established for witch flounder.

ACKNOWLEDGMENTS

The contributions of a number of colleagues to this report are acknowledged, in particular those of W. Stobo and M. Fowler who supplied various data summaries relating to witch flounder in the course of their own work on other flatfish species, and G. Black who supplied numerous graphical products from survey data. We are grateful also to P Comeau for providing Fig. 12 from the ITQ surveys and to K. Zwanenburg for providing Fig. 1, a product of the ECNASAP Project and for providing a review of this document.

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Table 1. History of TACs for flounders in Div. 4VWX and of their partitioning between Div. 4VW and Div. 4X from 1994.

Year(s)	TAC (t)		
	Div. 4X	Div. 4VW	Div. 4VWX
1974-75	-	-	32000
1976-77	-	-	28000
1978-93	-	-	14000
1994	4500	5500	10000
1995	3375	4125	7500
1996	3375	3500	6875
1997	3000	3000	6000

Table 2. Canadian witch flounder landings from NAFO (1977-88) and ZIF (1989-97) data, by Div. and Subdiv. and by eastern and western Div. 4X (from 1989). Landings in 1997 are to July.

YEAR	4Vn	4Vs	4W	4VW	4Xmno	4Xpqrs	4Xu	4X	4VWX
1977	980	503	422	1905				402	2307
1978	977	554	436	1967				172	2139
1979	993	575	206	1774				283	2057
1980	1064	728	186	1978				320	2298
1981	694	416	156	1266				421	1687
1982	531	256	97	884				527	1411
1982	662	215	114	991				482	1473
1984	886	301	119	1306				431	1737
1985	1256	373	52	1681				452	2133
1986	1342	679	108	2329				553	2882
1987	1804	749	125	2678				472	3150
1988	1768	417	109	2294				529	2823
1989	1339	269	154	1762	247	160	115	522	2284
1990	734	416	146	1296	206	243	188	636	1932
1991	965	327	38	1330	353	238	9	600	1930
1992	706	235	84	1025	432	396	0	828	1853
1993	449	64	20	532	240	121	12	373	905
1994	243	28	4	276	160	220	3	382	658
1995	255	54	8	317	128	172	0	301	618
1996	331	35	20	386	168	232	0	401	787
1997	113	20	6	140	83	198	0	281	421

Table 3. Canadian catch of witch flounder by month by Div. and Subdiv. and by eastern and western Div. 4X from ZIF data, 1992-97. Data for 1997 are to July.

1992-1995 Average

AREA	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL
4VN	2	4	2	4	131	82	52	38	41	24	34	0	413
4VS	1	4	7	14	11	18	13	10	2	5	4	5	95
4W	0	1	1	10	3	3	3	5	1	1	1	0	29
4VW	4	8	10	28	146	104	67	53	44	29	39	5	537
4Xmno	61	49	43	12	13	11	7	5	2	5	10	20	240
4Xpqrs	7	15	43	32	33	18	18	12	15	20	8	6	227
4Xu	0	0	0	0	0	-	0	0	0	-	1	1	4
4X	68	65	86	44	46	29	25	17	17	25	2	0 28	471
4VWX	72	73	96	72	192	133	92	70	61	54	59	33	1008

1996

AREA	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL
4VN	-	-	-	-	68	82	19	30	35	29	69	0	331
4VS	1	6	1	5	3	6	4	9	0	1	0	0	35
4W	0	1	0	0	0	3	2	5	2	0	0	5	20
4VW	1	7	1	6	71	90	24	45	37	31	69	5	386
4Xmno	30	40	13	2	5	8	4	18	2	8	6	32	168
4Xpqrs	46	24	43	15	19	15	17	20	14	10	5	5	232
4Xu	-	-	-	0	0	-	-	0	-	0	-	0	0
4X	76	64	56	17	24	23	21	37	16	18	11	37	401
4VWX	77	70	57	22	95	114	46	82	53	49	80	42	787

1997

AREA	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL
4VN	-	-	-	-	66	40	7						113
4VS	0	7	0	1	1	5	6						20
4W	0	0	1	0	0	5							6
4VW	0	7	1	1	67	50	13						140
4Xmno	17	36	2	3	14	9	1						83
4Xpqrs	0	63	13	30	46	37	8						198
4Xu	-	0	0	-	-	0							0
4X	18	99	15	33	61	46	9						281
4VWX	18	106	16	34	128	97	23						421

Table 4. Canadian witch flounder landings by gear and vessel tonnage class, by Div. and Subdiv. and by eastern and western Div. 4X from ZIF data, 1989-97. Data for 1997 are to July.

Year	Class	4Vn	4Vs	4W	4VW	4Xmno	4Xpqrs	4Xu	4X	4VWX
1989	OTB 0-3	55	72	60	186	141	147	110	398	584
	OTB 4+	112	109	9	231	5	3	-	8	239
	Seines	1147	83	69	1299	101		3	104	1403
	Other	25	5	16	46	1	10	2	12	58
	Sum	1339	269	154	1762	247	160	115	522	2284
1990	OTB 0-3	40	69	9	117	158	196	181	535	652
	OTB 4+	54	209	4	267	1	1	-	2	269
	Seines	637	137	120	894	46	-	6	52	946
	Other	3	2	14	18	2	45	0	47	65
	Sum	734	416	146	1296	206	243	188	636	1932
1991	OTB 0-3	39	17	6	62	160	235	2	397	459
	OTB 4+	146	248	10	405	10	3	0	13	418
	Seines	778	60	12	850	175	-	7	182	1032
	Other	1	2	9	13	7	0	0	8	20
	Sum	965	327	38	1330	353	238	9	600	1930
1992	OTB 0-3	23	8	1	32	282	394	-	676	708
	OTB 4+	47	180	46	272	7	1	0	9	281
	Seines	633	46	33	711	141	-	-	141	852
	Other	3	2	4	9	2	0	0	2	12
	Sum	706	235	84	1025	432	396	0	828	1853
1993	OTB 0-3	7	11	1	19	117	121	10	248	267
	OTB 4+	10	11	14	35	1	0	1	2	37
	Seines	431	36	3	471	120	-	1	121	592
	Other	0	6	2	8	1	-	-	1	9
	Sum	449	64	20	532	240	121	12	373	905
1994	OTB 0-3	8	3	1	12	66	212	0	278	290
	OTB 4+	0	1	1	2	3	2	-	4	6
	Seines	233	24	1	259	90	-	-	90	348
	Other	1	0	2	3	1	6	3	10	12
	Sum	243	28	4	276	160	220	3	382	658
1995	OTB 0-3	14	7	0	20	81	169	0	249	270
	OTB 4+	0	3	3	6	1	1	0	2	8
	Seines	241	44	4290	47	-	-	47	337	
	Other	0	-	0	1	0	3	-	3	3
	Sum	255	54	8	317	128	172	0	301	618
1996	OTB 0-3	16	10	4	30	131	231	0	362	391
	OTB 4+	0	1	2	3	1	1	-	2	5
	Seines	314	22	14	350	36	-	-	36	387
	Other	1	2	0	3	0	-	0	0	4
	Sum	331	35	20	386	168	232	0	401	787
1997	OTB 0-3	3	1	1	5	62	197	0	259	264
	OTB 4+	-	7	0	7	0	0	-	1	8
	Seines	110	12	5	128	21	-	-	21	149
	Sum	113	20	6	140	83	198	0	281	421

Table 5. Number of port samples of witch flounder landings in Div. 4VWX by vessel/gear class and by Div. and Subdiv. and by eastern and western Div. 4X, 1988-97. Inventory for 1997 is incomplete.

Year	Class	4Vn	4Vs	4W	4VW	4Xmno	4Xpqrs	4Xu	4X	4VWX
1988	OTB 4+	-	3	-	4	-	-	-	-	4
	Seines	2	-	-	2	-	-	-	-	2
	Sum	2	3	-	6	-	-	-	-	6
1989	OTB 4+	-	3	-	4	-	-	-	-	4
	Sum	-	3	-	4	-	-	-	-	4
1990	OTB 4+	-	-	-	1	-	-	-	-	1
	Sum	-	-	-	1	-	-	-	-	1
1991	OTB 0-3	-	-	-	-	2	2	-	4	4
	OTB 4+	1	1	-	2	-	-	-	-	2
	Seines	1	-	-	1	1	-	-	1	2
	Sum	2	1	-	3	3	2	-	5	8
1992	OTB 0-3	-	-	-	-	2	1	-	3	3
	OTB 4+	-	2	-	2	-	-	-	-	2
	Seines	1	-	-	1	-	-	-	-	1
	Sum	1	2	-	3	2	1	-	3	6
1993	OTB 0-3	-	-	-	-	2	-	-	2	2
	OTB 4+	2	-	-	2	-	-	-	-	2
	Seines	1	-	-	1	-	-	-	-	1
	Sum	3	-	-	3	2	-	-	2	5
1994	OTB 0-3	-	1	-	1	6	1	-	7	8
	OTB 4+	-	-	-	-	1	-	-	1	1
	Seines	4	1	-	5	-	-	-	-	5
	Sum	4	2	-	6	7	1	-	8	14
1995	OTB 0-3	-	-	-	-	2	2	-	4	4
	Seines	8	1	-	9	-	-	-	-	9
	Sum	8	1	-	9	2	2	-	4	13
1996	OTB 0-3	-	1	-	1	2	1	-	3	4
	OTB 4+	-	-	-	-	1	-	-	1	1
	Seines	7	2	-	9	2	-	-	2	11
	Sum	7	3	-	10	5	1	-	6	16
1997	OTB 0-3	-	1	-	2	1	3	-	4	6
	Seines	4	5	-	9	-	-	-	-	9
	Sum	4	6	-	11	1	3	-	4	15

Table 6. Mean length (cm)of witch flounder in port samples of commercial landings from seiners fishing in Subdiv. 4Vn and otter trawlers fishing in eastern and western Div. 4X in 1991-97(to date).

	Seiners	Otter Trawlers	
Year	4Vn	4Xmno	4Xpqrs
1991	41.7	42.6	46.6
1992	40.4	40.7	47.2
1993	39.2	41.2	----
1994	39.2	39.1	41.9
1995	37.9	41.4	41.6
1996	35.9	41.7	40.4
1997	38.6	42.1	41.1

Table 7. Witch flounder: summary of catch and fishing effort, and estimated catch rate in catch per hour fished and per day fished, when main species caught was witch, for Scottish and Danish seiners in Subdiv. 4Vn and small otter trawlers in eastern and western Div. 4X, 1989-97. data for 1997 are to July.

FISHING AREA/ GEAR TYPE	YEAR	TOTAL CATCH (t)	CATCH WITH HOURS FISHED	HOURS FISHED	KG/HR	CATCH WITH FISHING DAYS	FISHING DAYS	TONS/ FISHING DAY
4VN	1989	1147	74	434	170	286	207	1.38
Seines	1990	637				55	28	1.96
	1991	778	630	3858	163	652	622	1.05
	1992	633	508	2854	178	517	446	1.16
	1993	431	335	2067	162	335	347	0.96
	1994	233	150	1049	143	151	152	0.99
	1995	241	145	800	181	158	139	1.13
	1996	314	229	1234	186	232	167	1.39
	1997	110	51	207	248	51	26	1.95
4Xmno	1989	141	39	608	65	49	64	0.77
OTB 0-3	1990	158	25	394	63	33	40	0.81
	1991	160	88	1271	69	88	94	0.94
	1992	282	176	2429	72	177	178	0.99
	1993	117	78	1857	42	78	136	0.58
	1994	66	39	729	53	40	59	0.67
	1995	81	55	1434	39	55	103	0.54
	1996	131	103	2865	36	103	204	0.51
	1997	62	53	1266	42	53	94	0.56
4Xpqrs	1989	147	43	375	115	53	35	1.53
OTB 0-3	1990	196	52	476	109	73	54	1.34
	1991	235	139	1732	80	140	149	0.94
	1992	394	204	2773	73	211	237	0.89
	1993	121	56	1060	53	56	89	0.63
	1994	212	76	1654	46	77	130	0.59
	1995	169	73	1798	41	73	130	0.56
	1996	231	108	2785	39	108	198	0.54
	1997	197	85	1676	51	85	122	0.70

Table 8. Foreign catch of witch flounder from Observer data, 1987-97. Catches for 1997 are to July. (Observer coverage was 100% in all years.)

YEAR	4Vn	4Vs	4W	4VW	4X	4VWX
1987	2	1	24	27	0	27
1988	0	0	37	37	0	38
1989	1	0	23	24	0	24
1990	22	0	35	57	1	58
1991	5	0	50	54	10	64
1992	1	0	30	32	4	35
1993	0	0	46	46	4	49
1994	0	0	2	2	0	3
1995	0	0	19	19	0	19
1996	0	0	25	25	0	25
1997	0	0	16	16	1	17

Table 9a. Stratified weight (kg) and number per tow for summer RV and ITQ surveys in Div. 4X, 1995-97, A) for all strata sampled and B) for those strata sampled during both surveys in all years. (Strata 471, 478, 482, and 484 not sampled in 1995 ITQ survey. Numbers not recorded for all sets in ITQ survey in 1997. Stratum 499 not sampled in RV surveys, and 483 not sampled in ITQ surveys.)

Survey	Kg. per tow			No. per Tow		
	1995	1996	1997	1995	1996	1997
A) ALL STRATA						
RV	.44	1.21	2.21	1.57	4.00	4.71
ITQ	.35	.39	.56	1.02	1.23	-.-
B) STRATA IN COMMON						
RV	.54	1.37	2.62	2.36	4.40	5.43
ITQ	.46	.47	.49	1.39	1.56	-.-

Table 9b. WITCH FLOUNDER: Comparison of RV and ITQ surveys by stratum for strata in common.

Strata	Type	No. of Tows			Ave. Depth			Kg.per Tow			No. per Tow			Ave. Wt. Per Fish		
		1995	1996	1997	1995	1996	1997	1995	1996	1997	1995	1996	1997	1995	1996	1997
470	RV	2	2	2	85	86	71	0.07	1.01	31.40	2.98	9.92	49.90	0.03	0.10	0.63
	ITQ	4	5	5	93	92	94	-	0.85	0.21	-	2.12	0.21	-	0.40	1.00
472	RV	4	3	4	77	58	85	0.52	-	0.11	1.04	-	0.49	0.50	-	0.22
	ITQ	3	12	12	64	71	71	-	0.44	0.26	-	0.09	0.35	-	5.00	0.75
473	RV	2	2	2	50	48	48	-	-	-	-	-	-	-	-	-
	ITQ	2	2	2	48	48	49	-	-	0.53	-	-	1.06	-	-	0.50
474	RV	2	2	2	38	45	45	-	-	-	-	-	-	-	-	-
	ITQ	1	1	2	48	49	47	-	-	-	-	-	-	-	-	-
475	RV	2	2	2	49	48	47	-	-	0.15	-	-	0.47	-	-	0.31
	ITQ	2	1	2	50	49	51	-	-	-	-	-	-	-	-	-
476	RV	4	4	4	75	78	73	0.40	0.54	0.89	4.81	2.78	3.84	0.08	0.20	0.23
	ITQ	15	17	14	79	78	81	0.07	1.00	0.76	0.14	4.37	2.72	0.50	0.23	0.28
477	RV	5	5	5	62	61	66	0.08	0.12	-	0.42	0.57	-	0.19	0.21	-
	ITQ	6	11	11	63	64	65	1.80	0.58	0.38	5.05	1.44	0.58	0.36	0.40	0.67
480	RV	8	8	8	46	46	43	-	0.04	0.03	-	0.12	0.12	-	0.30	0.27
	ITQ	9	8	7	43	43	41	-	-	0.81	-	-	1.14	-	-	0.71
481	RV	7	9	9	80	75	67	1.34	1.86	0.12	2.73	6.13	0.54	0.49	0.30	0.22
	ITQ	17	19	20	71	77	74	0.06	0.41	0.45	0.12	0.58	0.74	0.50	0.70	0.62
485	RV	3	3	3	73	76	87	-	6.68	1.78	-	14.67	5.19	-	0.46	0.34
	ITQ	16	17	17	77	78	74	2.09	1.16	1.18	5.61	3.99	0.62	0.37	0.29	2.76
490	RV	5	4	4	45	39	44	1.31	-	-	2.00	-	-	0.65	-	-
	ITQ	8	9	10	48	46	43	-	-	0.28	-	-	-	-	-	-
491	RV	3	3	3	85	89	75	1.07	0.90	0.70	3.40	2.64	1.61	0.31	0.34	0.43
	ITQ	5	5	5	69	73	71	0.46	1.39	0.83	0.71	3.34	-	0.65	0.42	-
492	RV	2	3	3	89	95	71	1.35	2.40	1.96	3.64	9.69	8.60	0.37	0.25	0.23
	ITQ	8	8	9	62	58	62	0.31	-	1.23	1.71	-	-	0.18	-	-
493	RV	3	2	3	44	45	36	0.36	1.46	3.23	0.31	2.12	5.07	1.14	0.69	0.64
	ITQ	4	5	5	35	41	42	0.62	0.56	0.55	1.55	1.95	-	0.40	0.29	-
494	RV	2	2	2	26	36	26	0.42	-	0.51	0.68	-	0.94	0.62	-	0.54
	ITQ	5	4	3	36	31	33	-	-	0.46	-	-	-	-	-	-
495	RV	2	2	2	39	50	43	-	-	-	-	-	-	-	-	-
	ITQ	7	7	7	40	41	42	-	-	-	-	-	-	-	-	-

Table 10. Parameters of the von Bertalanffy equation describing the growth pattern of witch flounder, selected from the literature.

Applicable Area	Source	Males			Females		
		K	L inf.	t_0	K	L inf.	t_0
Middle Bank, Scotian Shelf	Powles and Kennedy (1967)	0.13	61.1	0.25	0.08	79.1	-0.09
Gulf of Maine	Burnett et al. (1992)	0.1533	58.045	-0.012	0.1482	61.986	0.0542
Gulf of St. Lawrence	Bowering (1976)	0.232	44.201	0.864	0.136	54.92	0.296

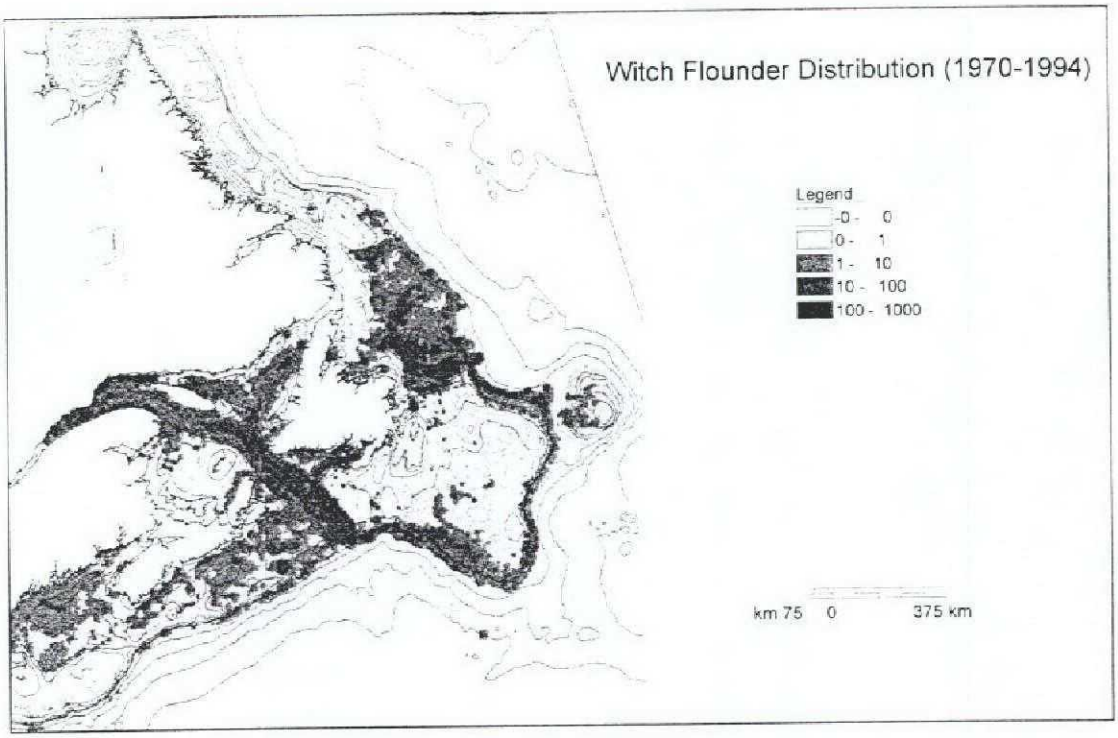

Fig. 1. The distribution of witch flounder in the Northwest Atlantic from research vessel surveys. (Provided by K. Zwanenburg, ECNASAP Project.)

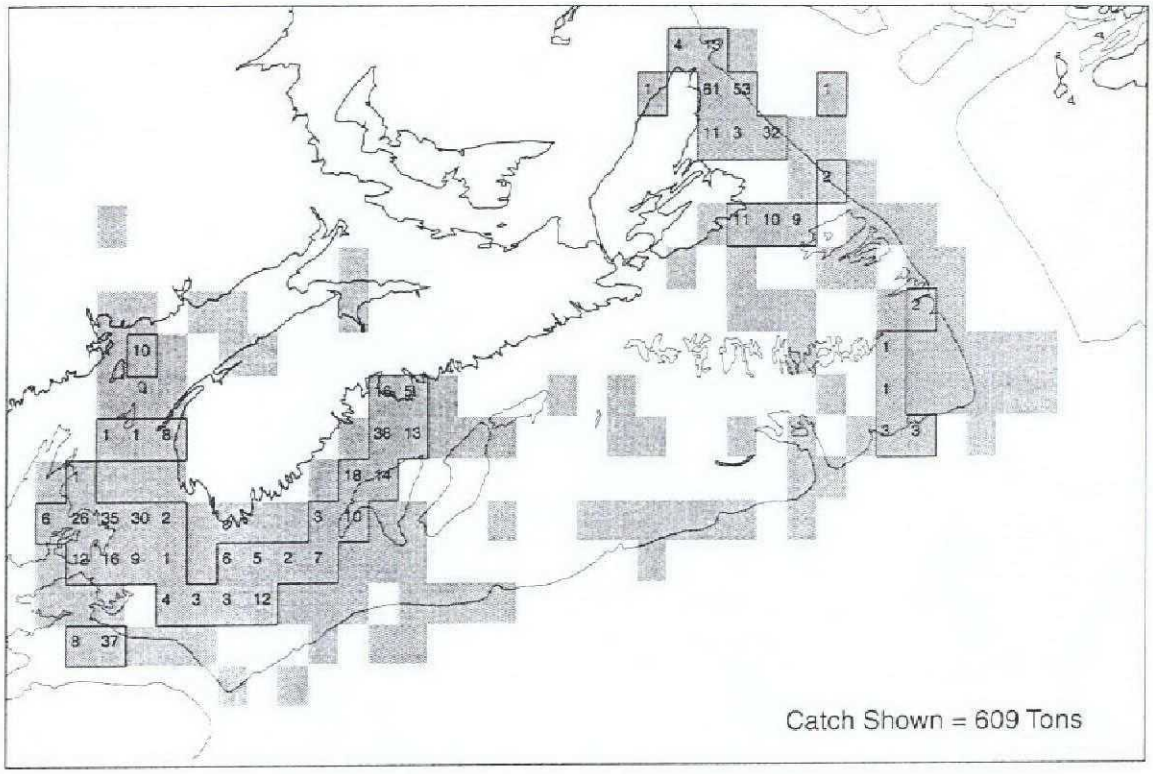

Fig 2.A) The distribution of witch flounder catches (from logbooks) by the Canadian fleet in 1994.

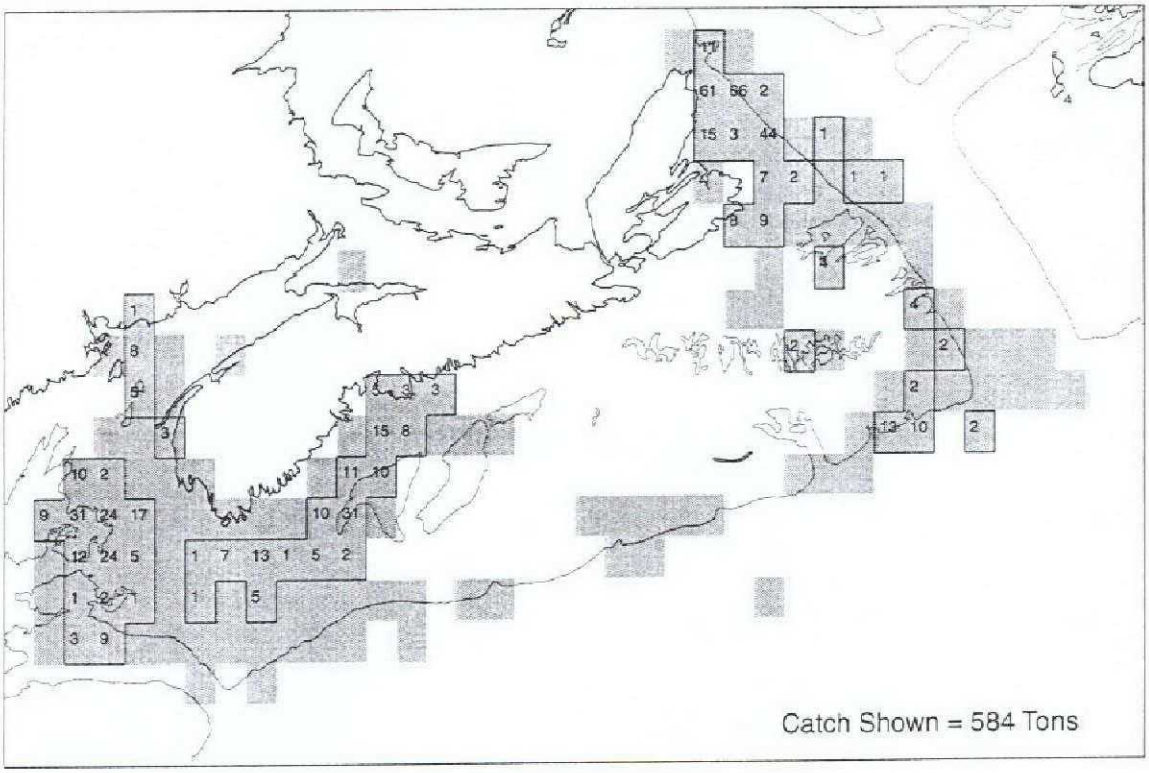

Fig 2.B) The distribution of witch flounder catches (from logbooks) by the Canadian fleet in 1995.

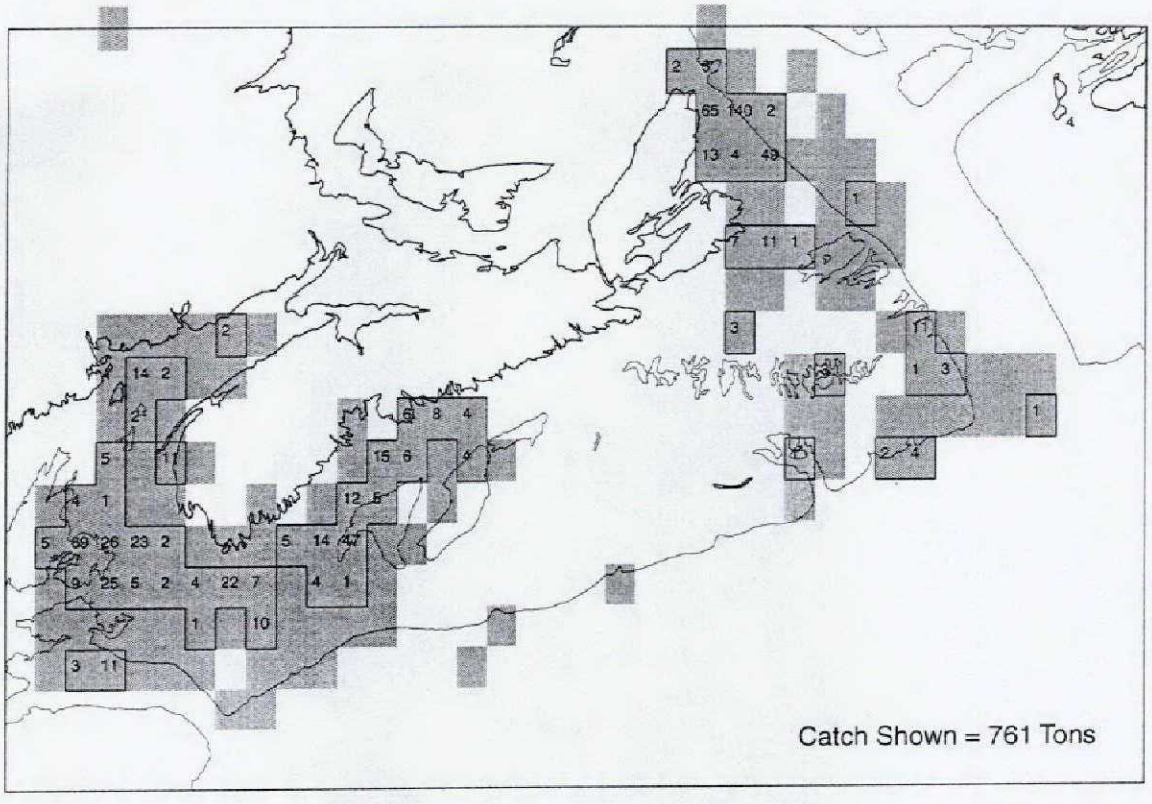

Fig 2.C) The distribution of witch flounder catches (from logbooks) by the Canadian fleet in 1996.

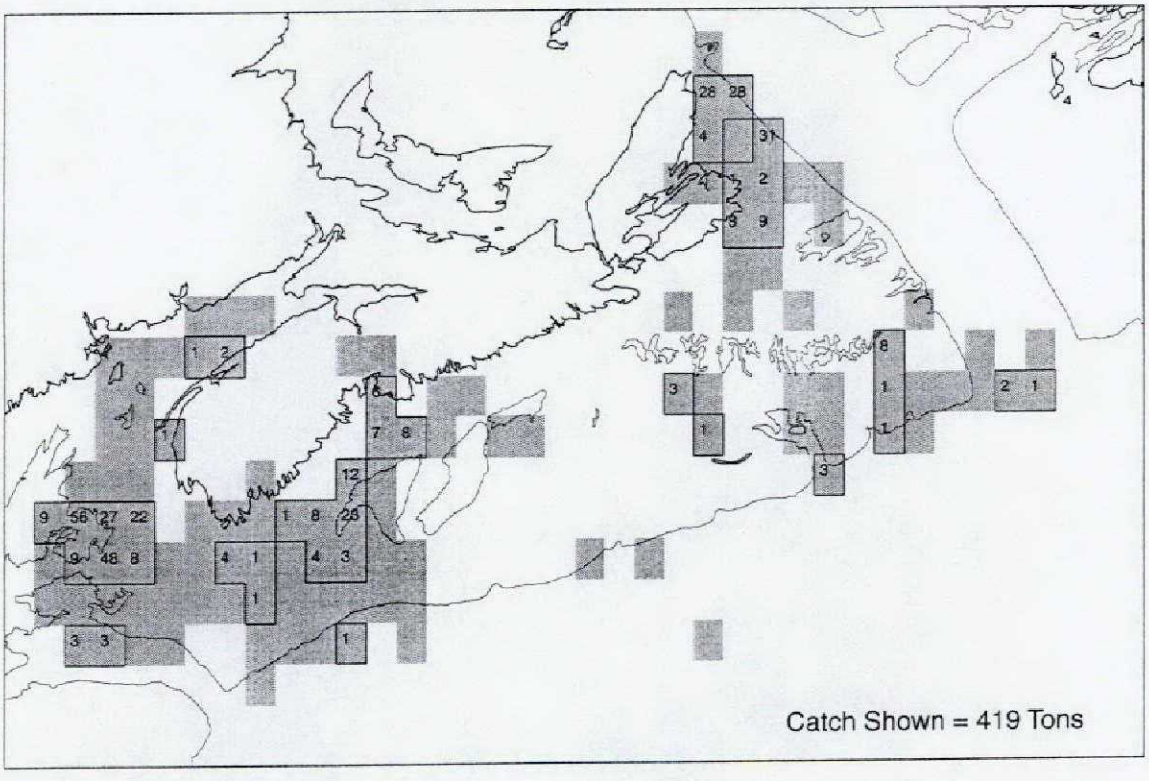

Fig 2.D) The distribution of witch flounder catches (from logbooks) by the Canadian fleet in 1997 to July.

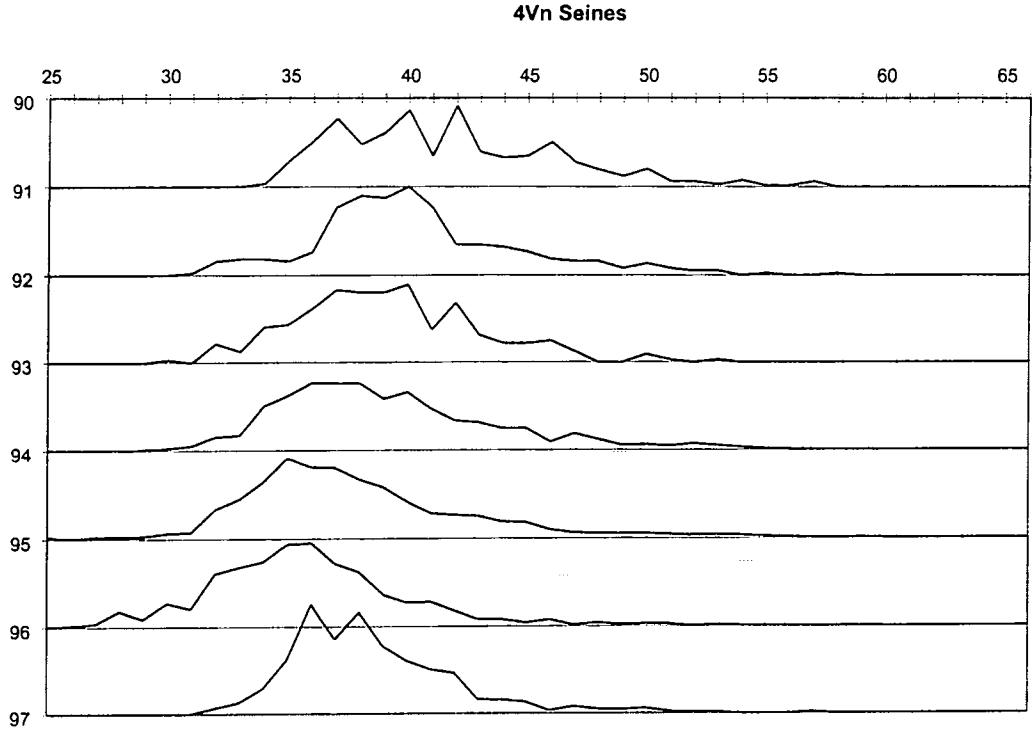

Fig 3. Size composition of landings by Danish and Scottish seiners fishing in Subdiv. 4Vn, 1990-97 (to date), from port sampling.

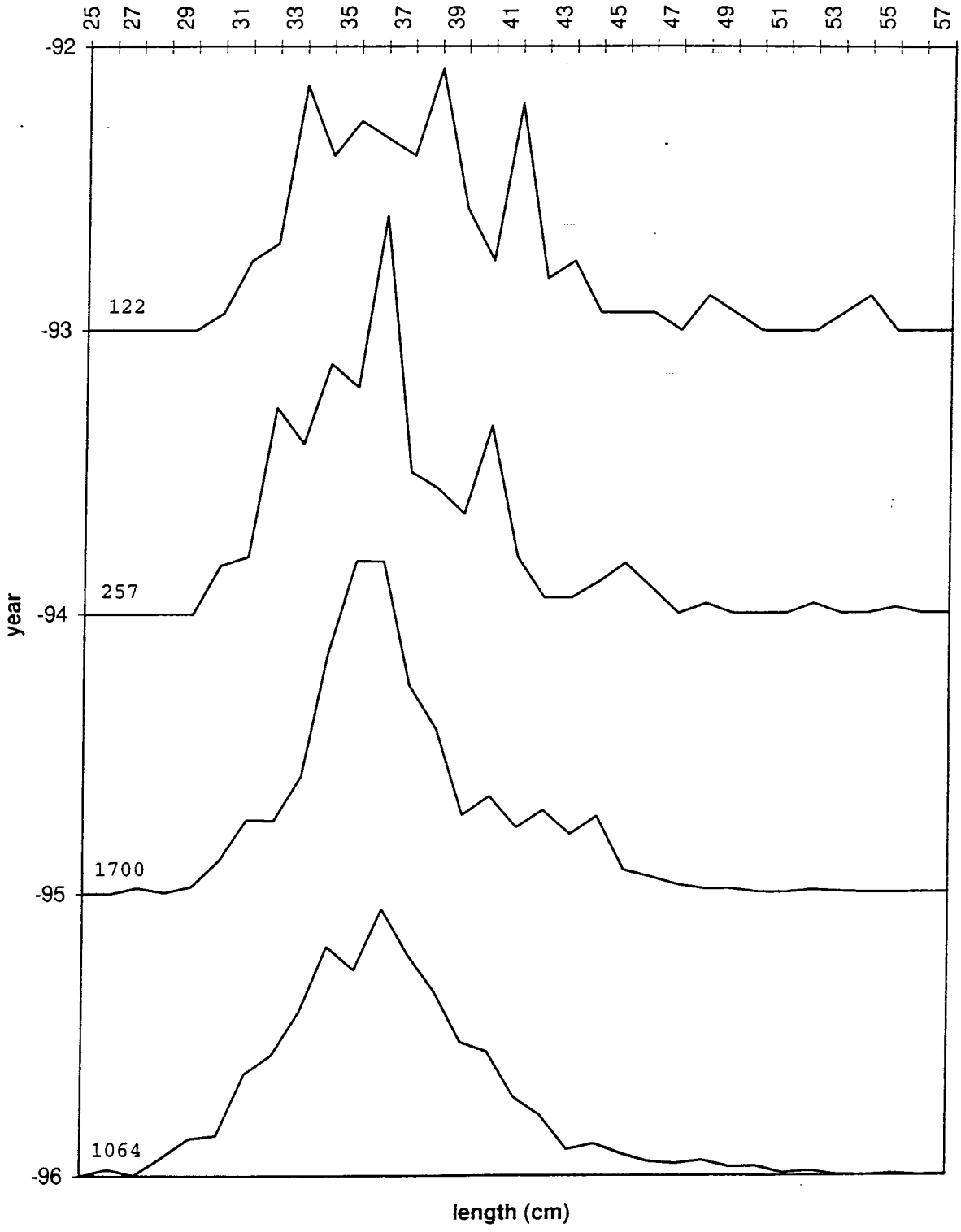

Fig. 4. Size composition of catches by Scottish and Danish seiners fishing in Subdiv. 4Vn, 1993-96), from observer sampling

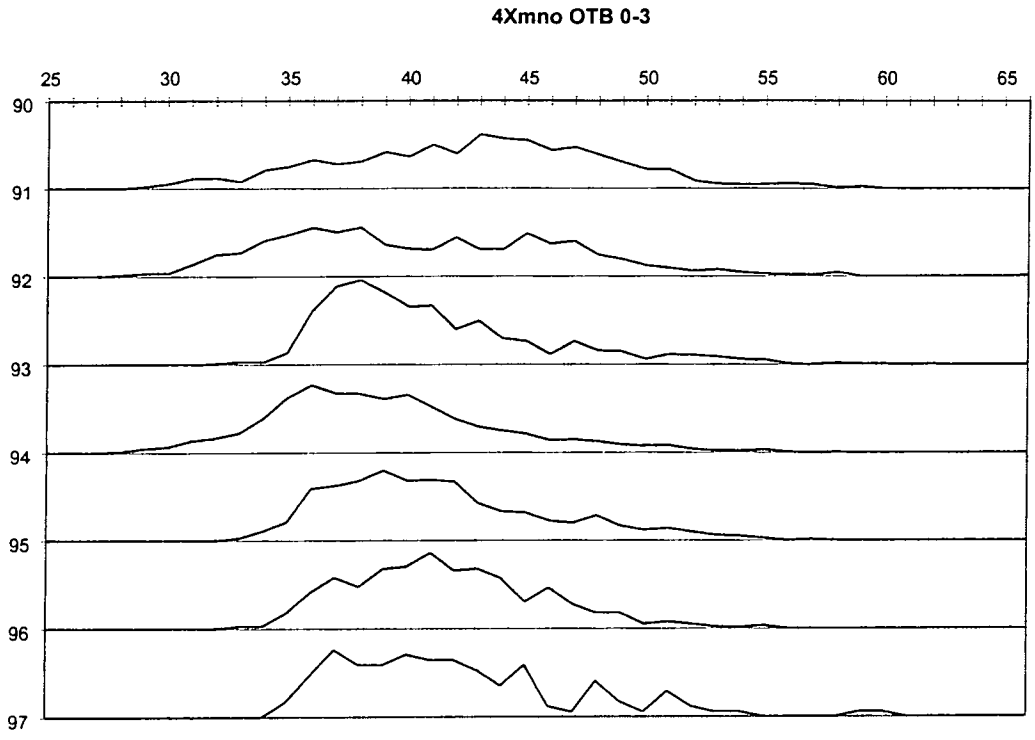

Fig 5. Size composition of landings by small otter trawlers (TC 0-3) fishing in eastern Div. 4X,, 1990-97 (to date), from port sampling.

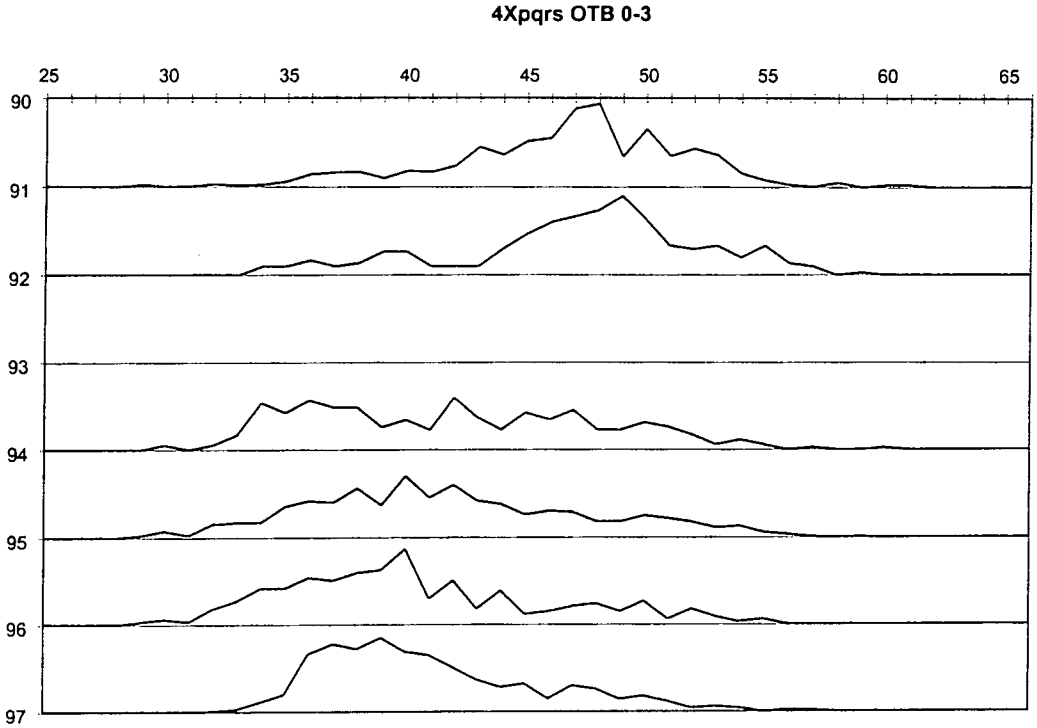

Fig 6. Size composition of landings by small otter trawlers (TC 0-3) fishing in western Div. 4X,, 1990-97 (to date), from port sampling.

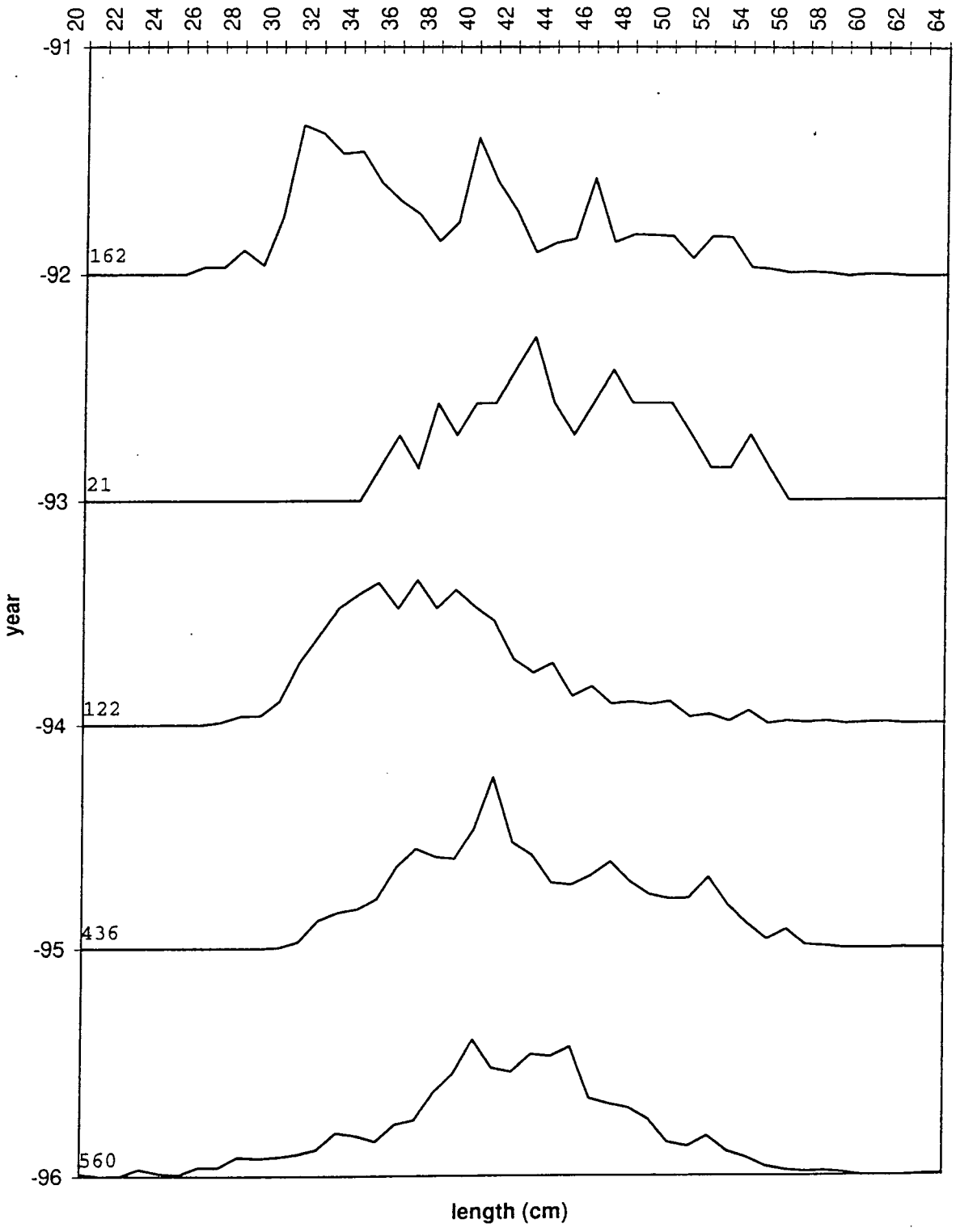

Fig. 7. Size composition of catches by small otter trawlers (TC 0-3) fishing in western Div. 4X, 1993-96, from observer sampling.

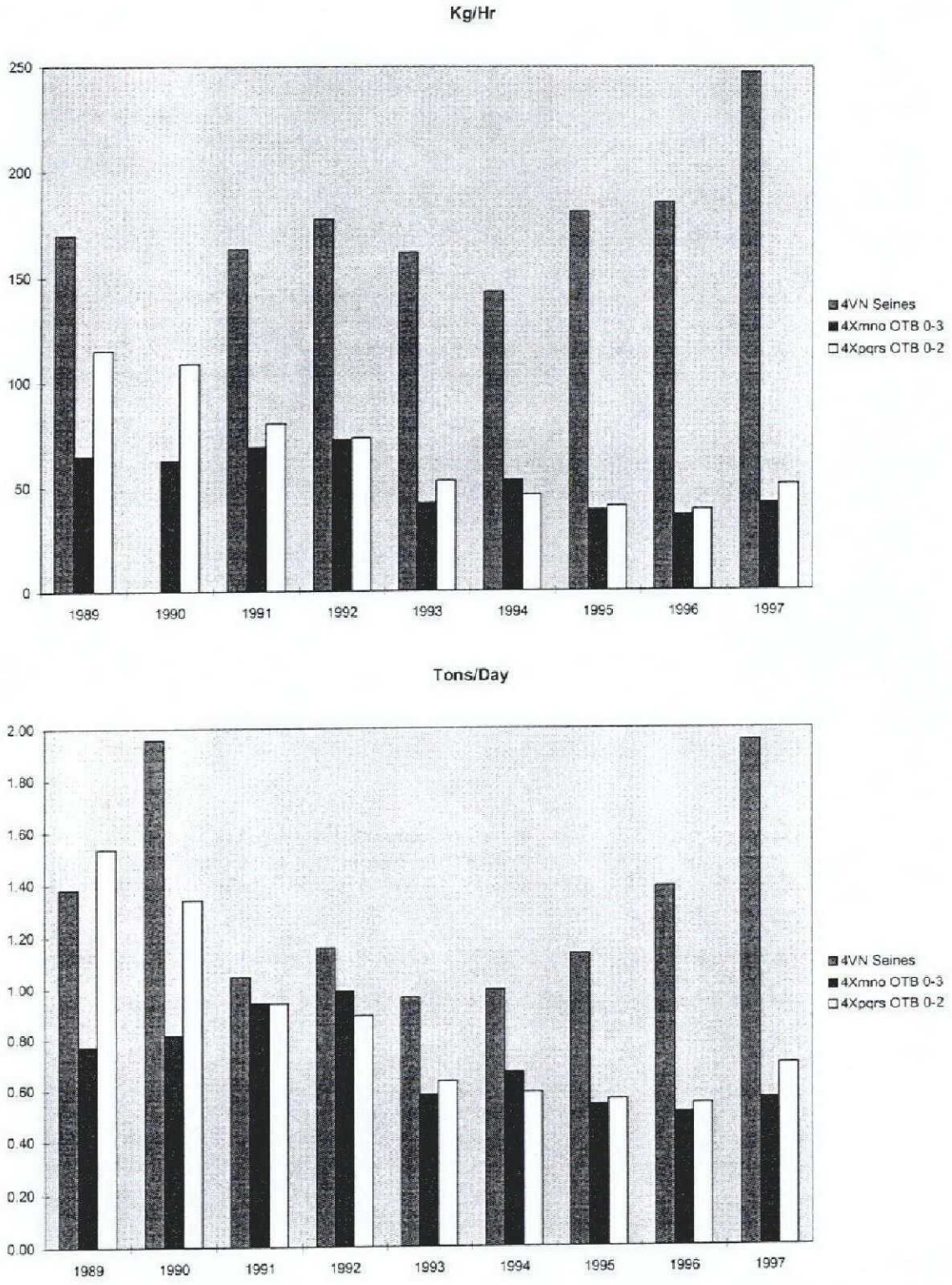

Fig 8. Catch rates of witch flounder (from logbooks) by Danish and Scottish seiners fishing Subdiv. 4Vn and of small otter trawlers (TC 0-3) fishing in eastern and western Div 4X, 1989-97 (to date). Top: Kg per hour, bottom: tons per day fished.

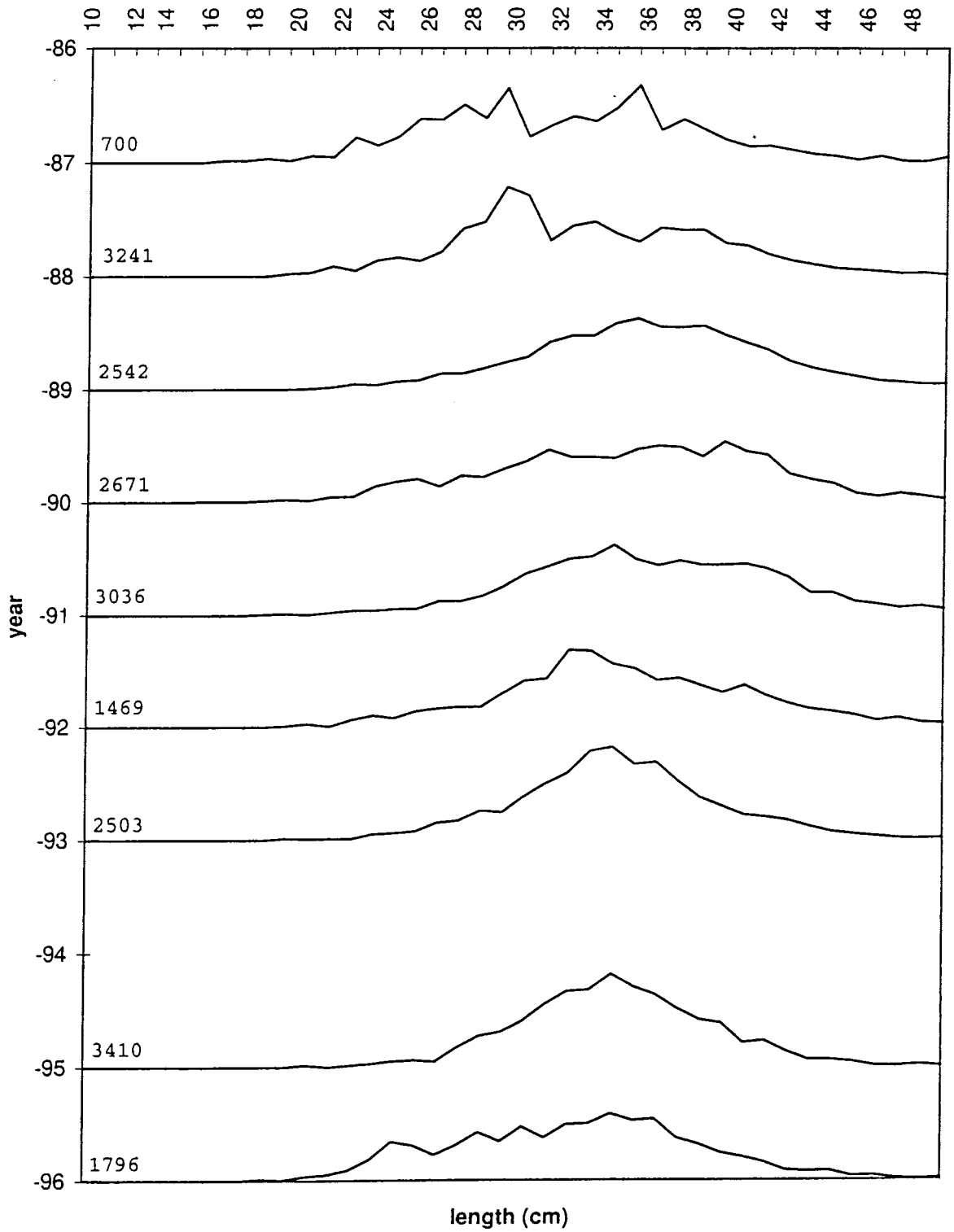

Fig. 9. Size composition of catches by foreign vessels in the small-mesh silver hake fishery in Div. 4WX, 1987-96, from observer sampling.

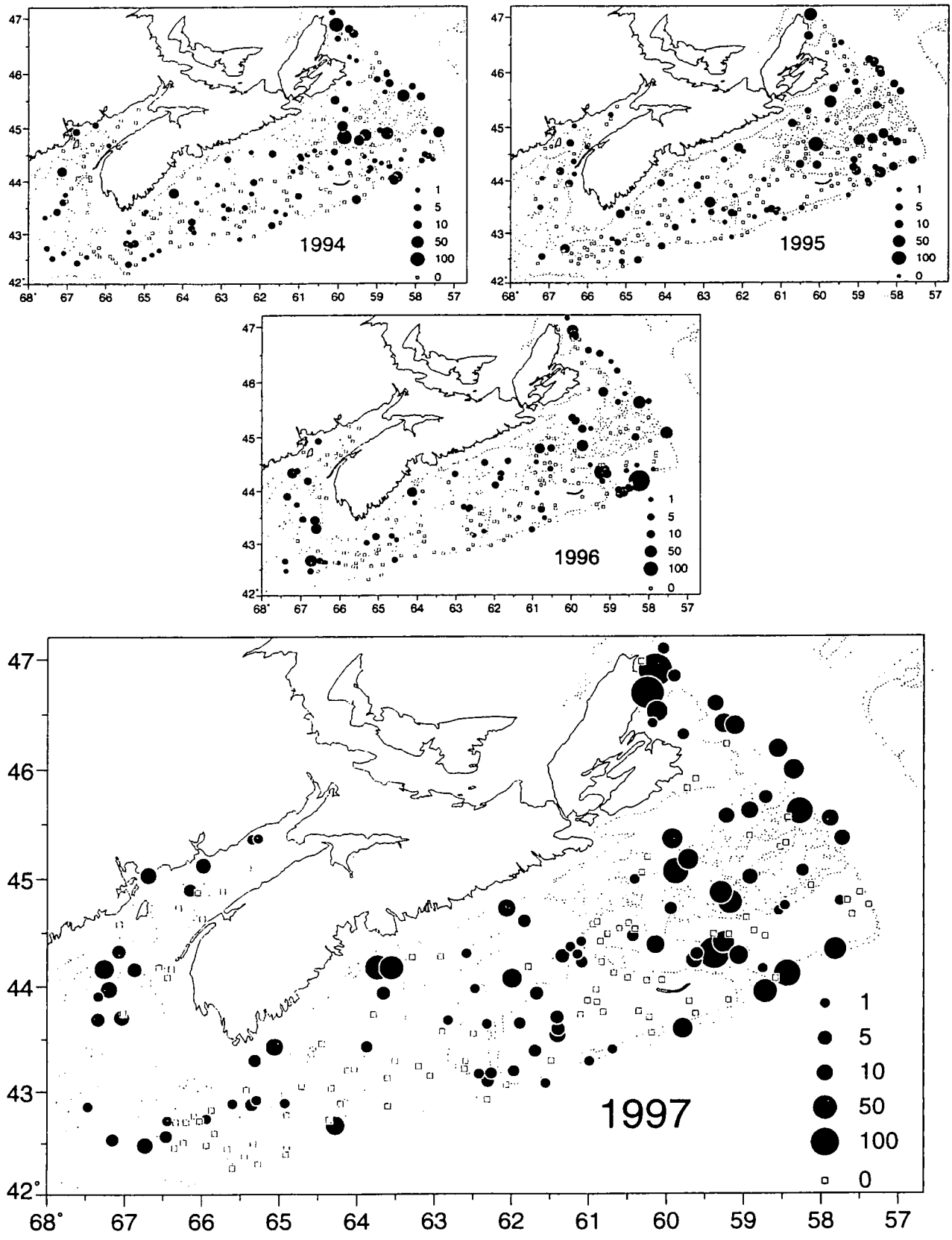

Fig. 10. The Distribution of witch flounder in Div. 4VWX (number per tow) from summer RV surveys, 1994-97

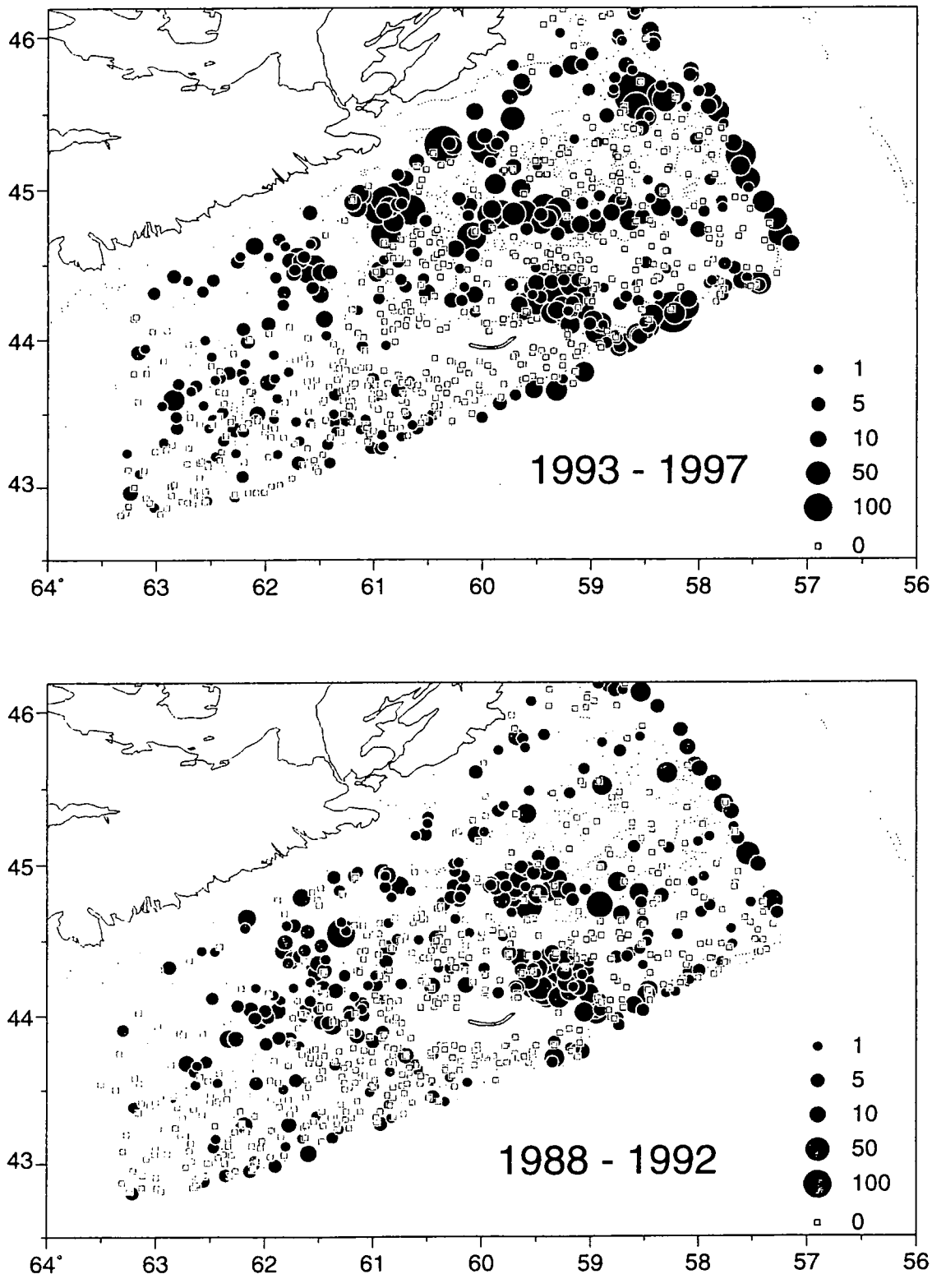

Fig. 11. The Distribution of witch flounder in Div. 4VW (numbers per tow) from the spring RV surveys, 1988-92 and 1993-97.

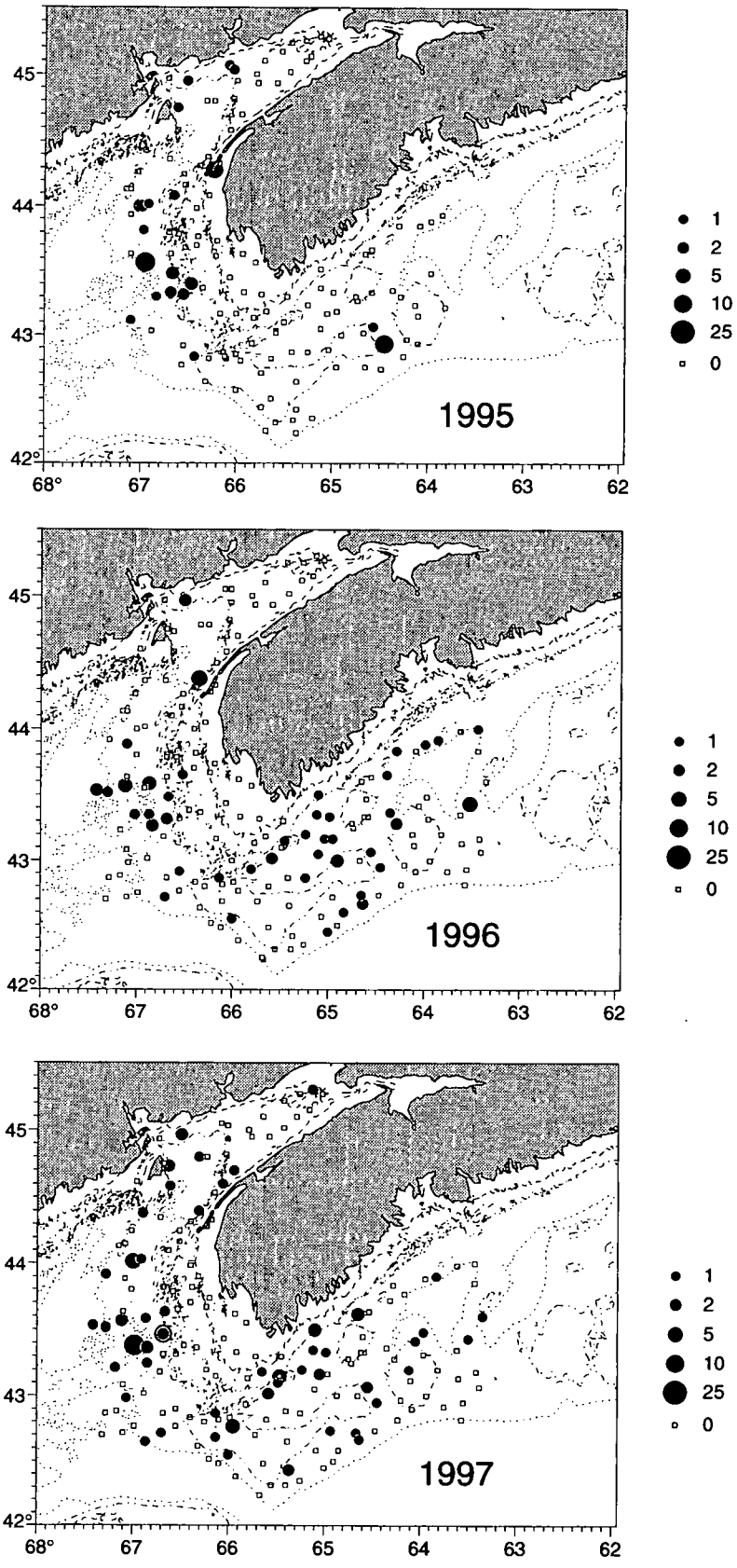

Fig.12. The Distribution of witch flounder in Div. 4VW (kg per tow) from ITQ surveys, 1995-97.

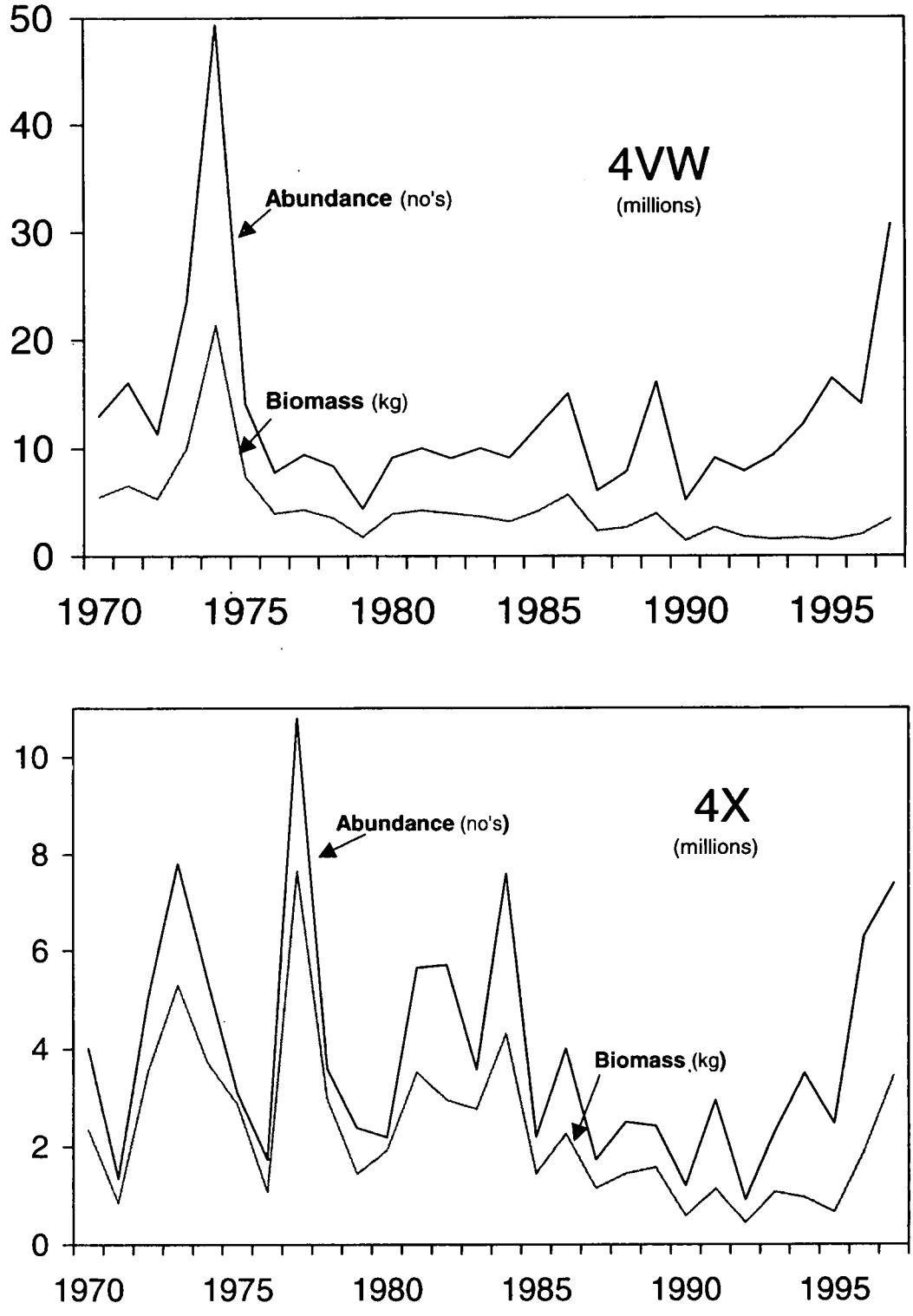

Fig.13. Abundance and biomass of witch flounder in Div. 4VW and Div. 4X based on summer RV surveys, 1970-97

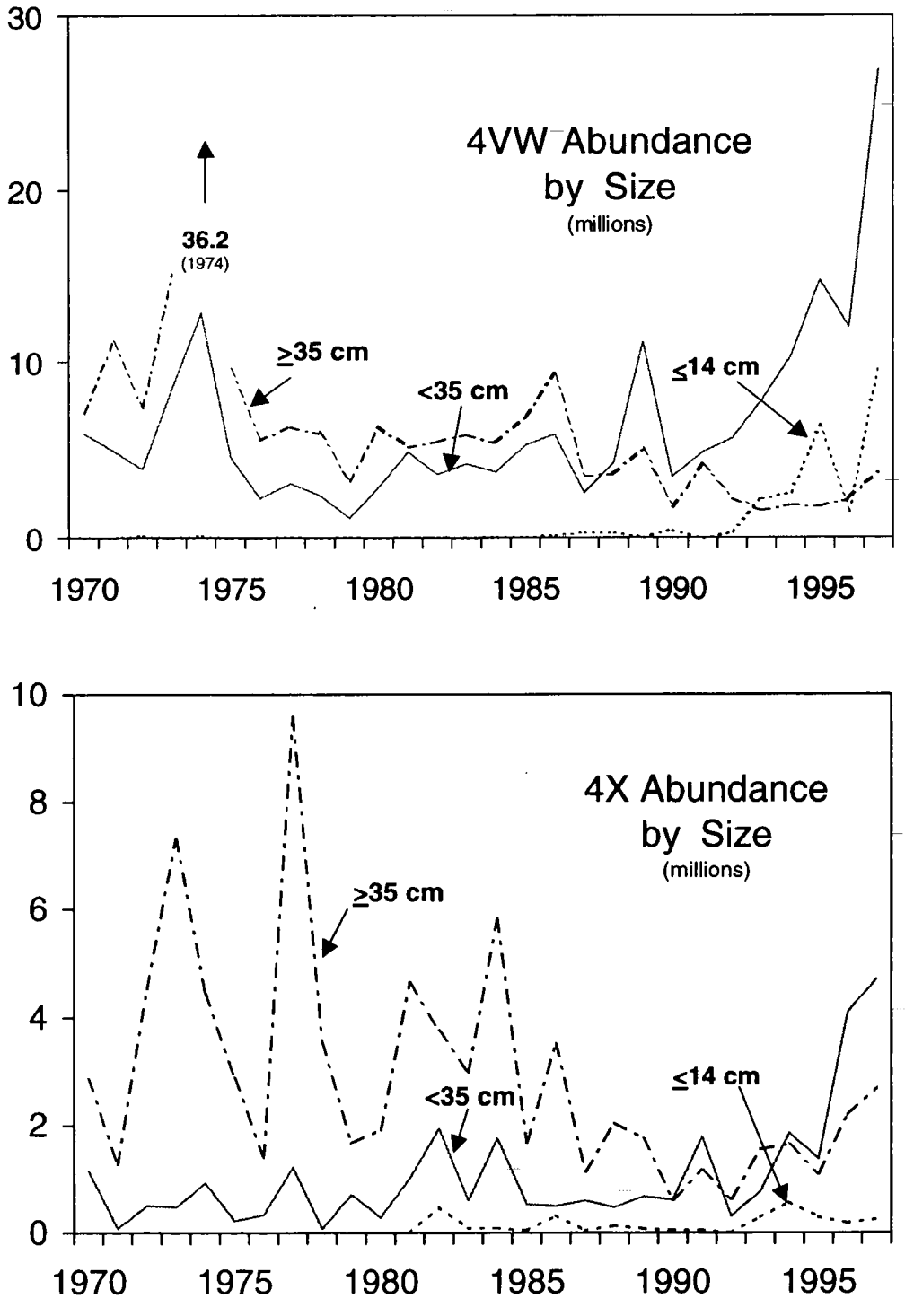

Fig. 14 Abundance of witch flounder in Div. 4VW and Div. 4X based on summer RV surveys, 1970-97, separately for recruited (>35 cm) and pre-recruited size groups (< or = 35 cm and < 15 cm shown).

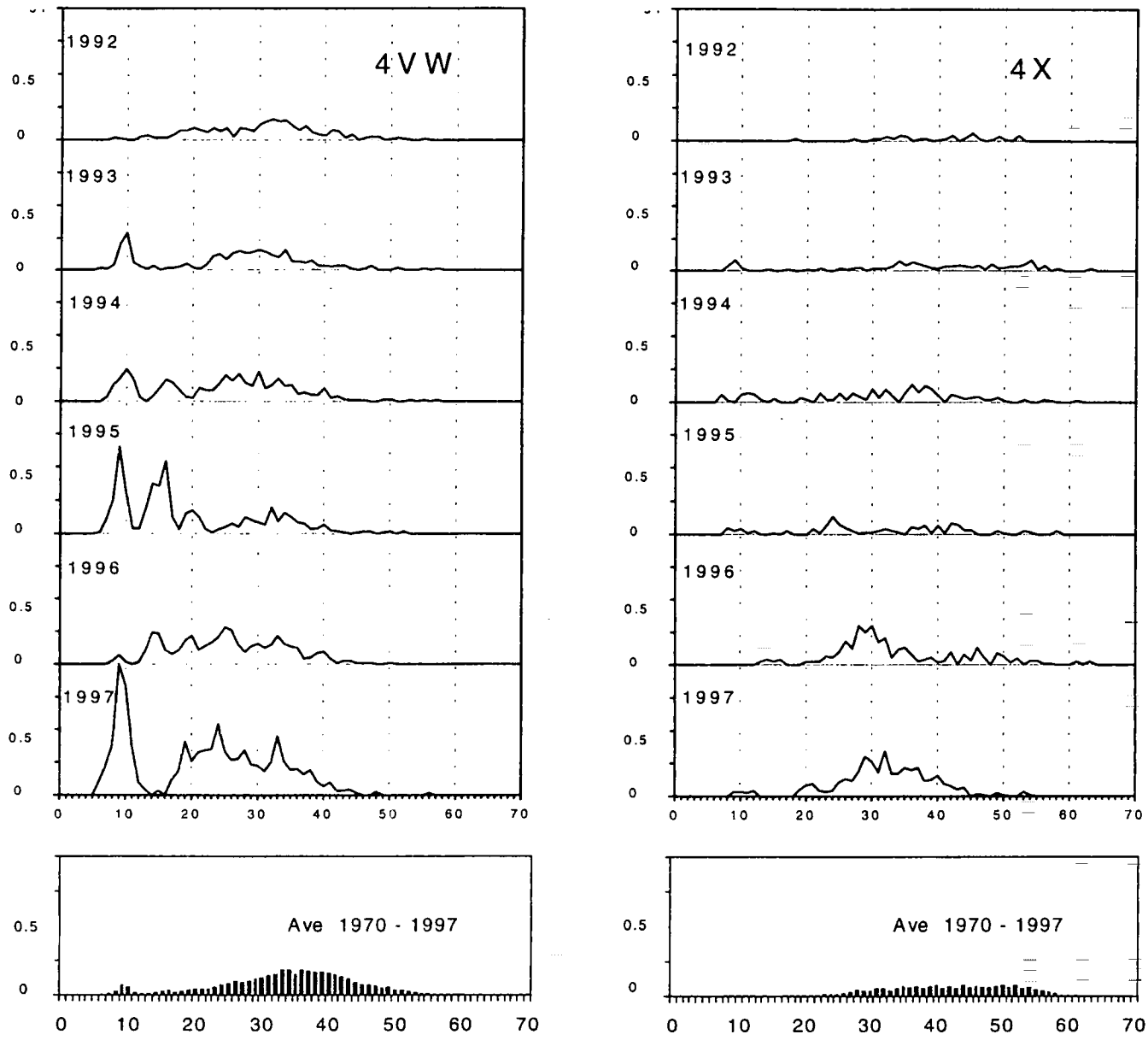

Fig. 15. The size composition of witch flounder in Div. 4VW and Div. 4X based on summer RV surveys, 1992-97, and combined for 1970-97

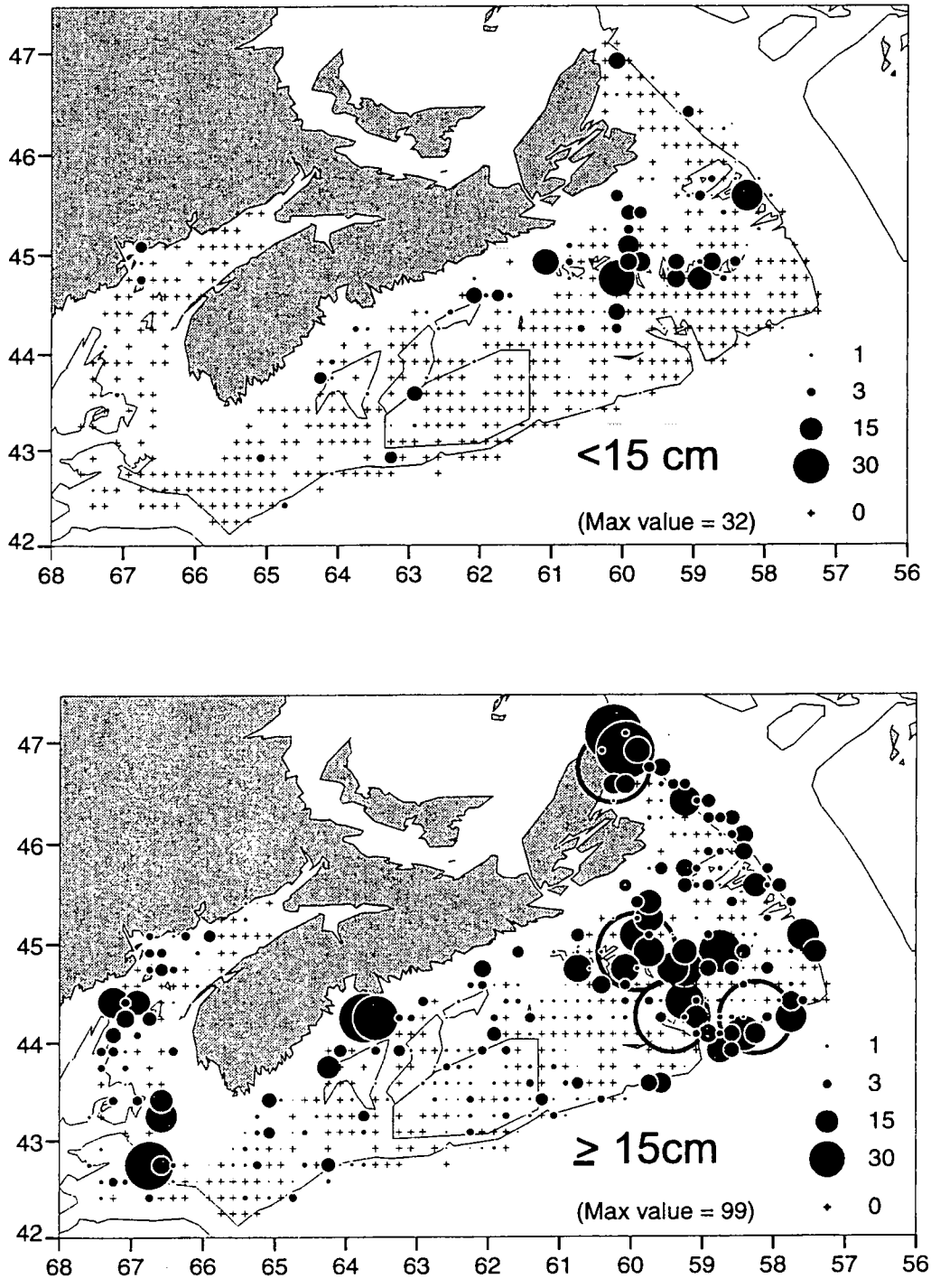

Fig. 16. The Distributionof witch flounder in Div. 4VWX (numbrs per tow) from summer RV surveys, 1993-97, separated by small fish (<15cm) and the larger fish (>15cm).

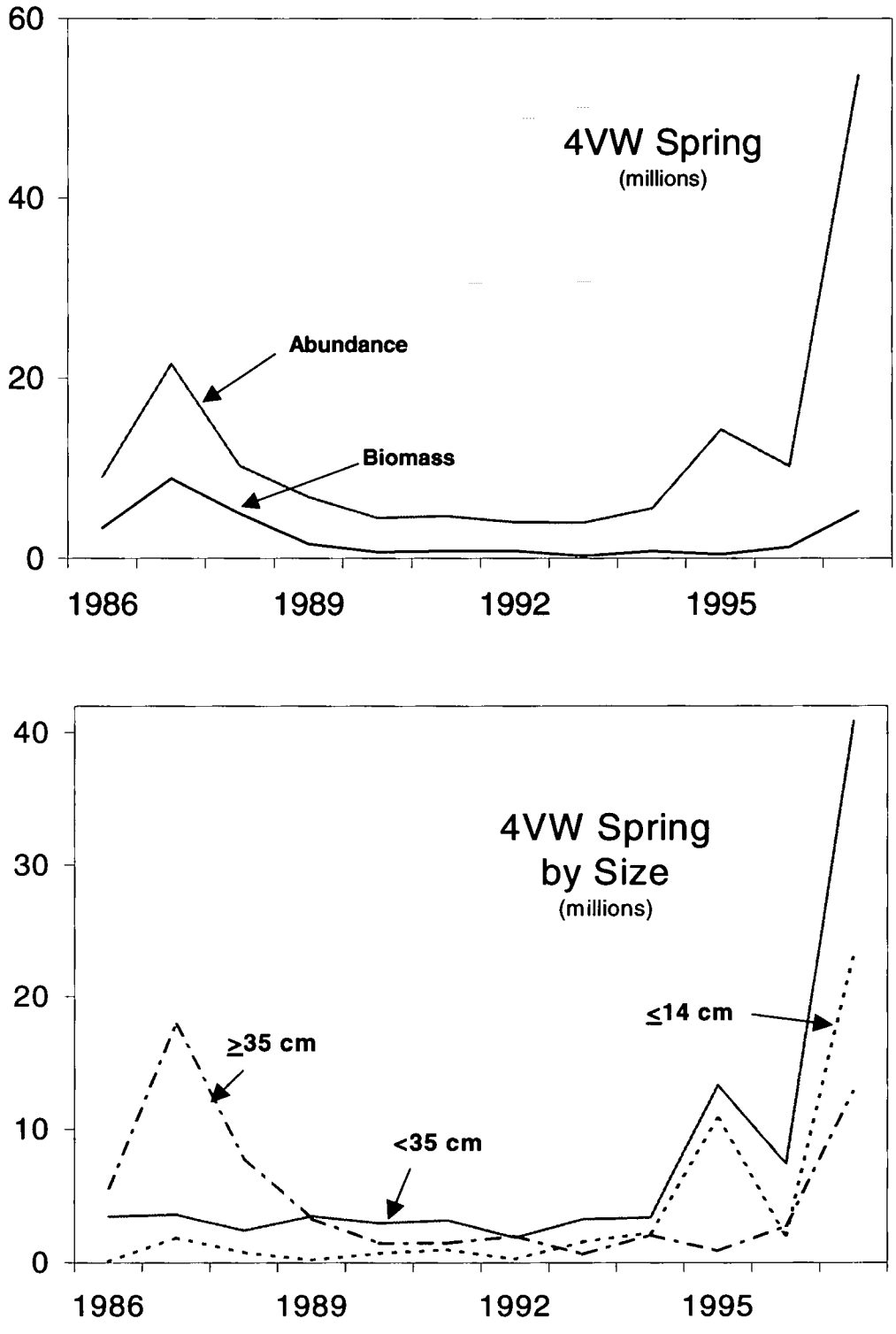

Fig. 17. Abundance and biomass of witch flounder in Div. 4VW based on spring RV surveys, 1986-97, and abundance separately for recruited (>35 cm) and pre-recruited size groups (< or = 35 cm and < 15 cm shown).

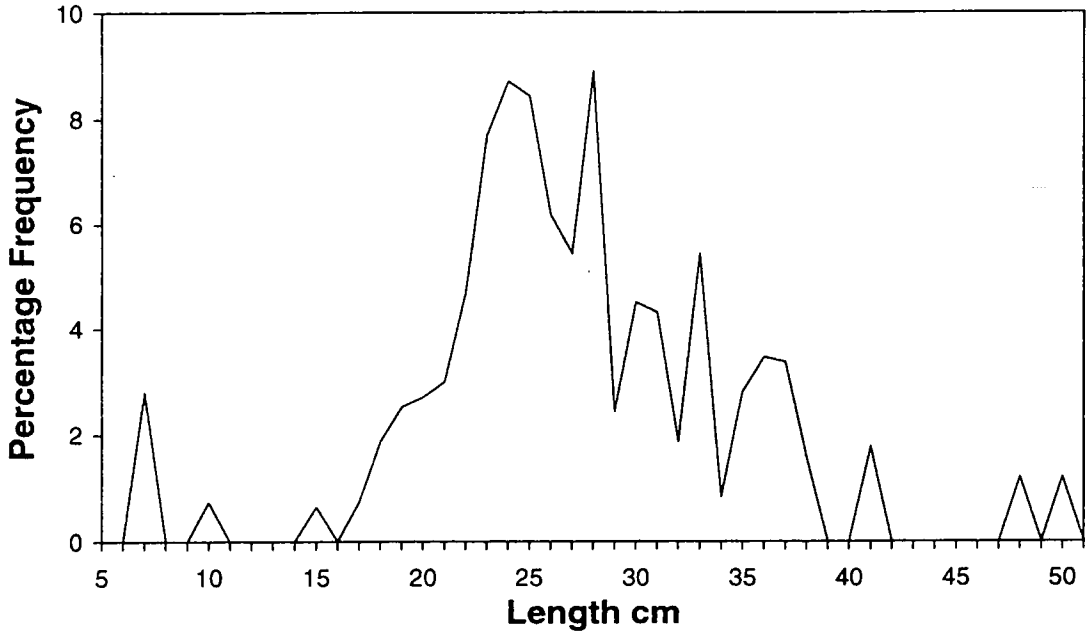

Fig. 18. Percentage length frequency of witch flounder in 201-400 fm depth strata in Div. 4VWX summer RV surveys, 1995-97.

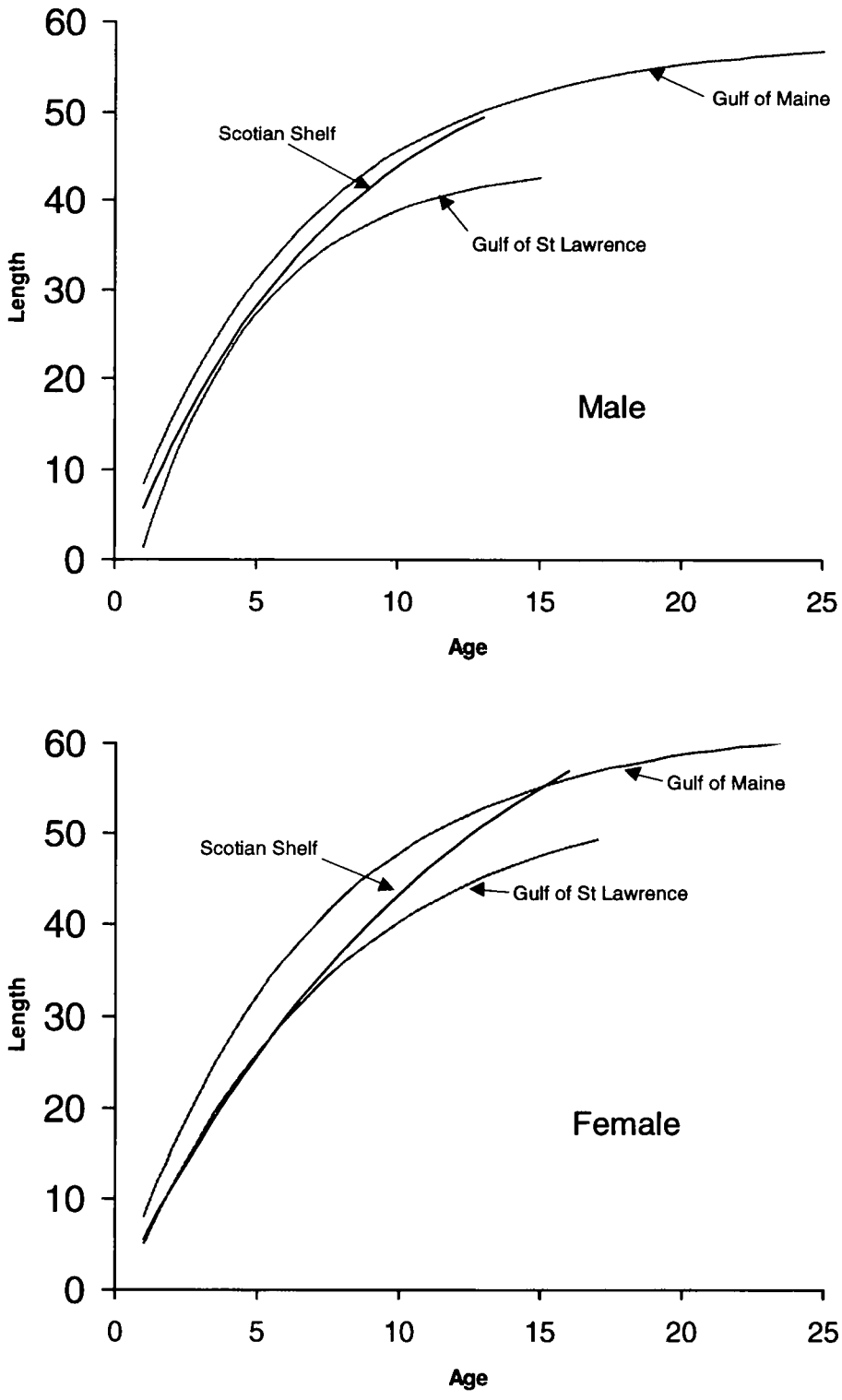

Fig. 19. Witch flounder growth curves for males and females for the Scotian Shelf, Gulf of Maine and the Gulf of St. Lawrence (see Table 10 for sources).

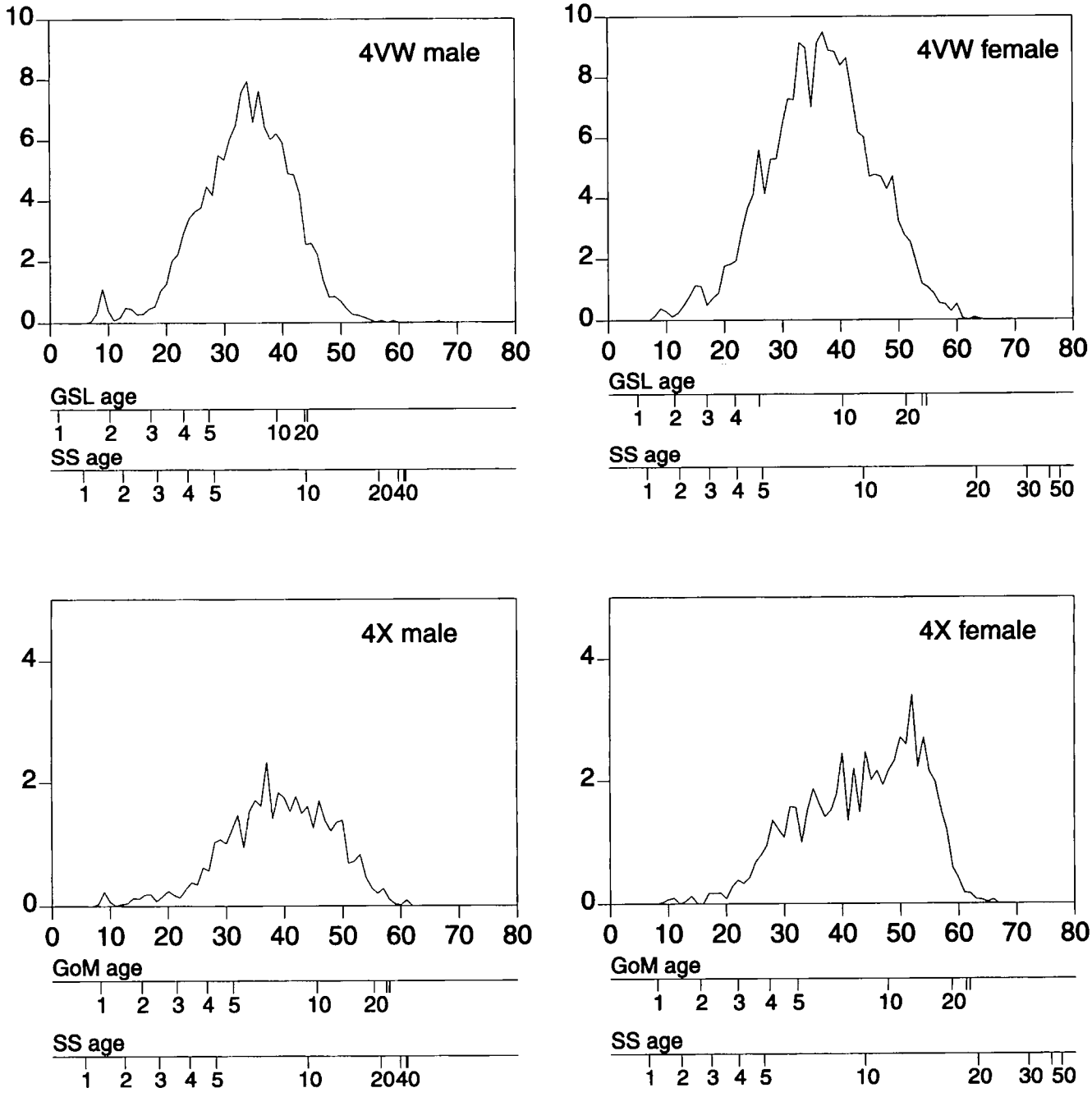

Fig. 20. Size composition of witch flounder for Div. 4VW and Div. 4X with age scales calculated using growth parameters from the Gulf of St Lawrence (GSL), Scotian Shelf (SS) and the Gulf of Maine (GoM).

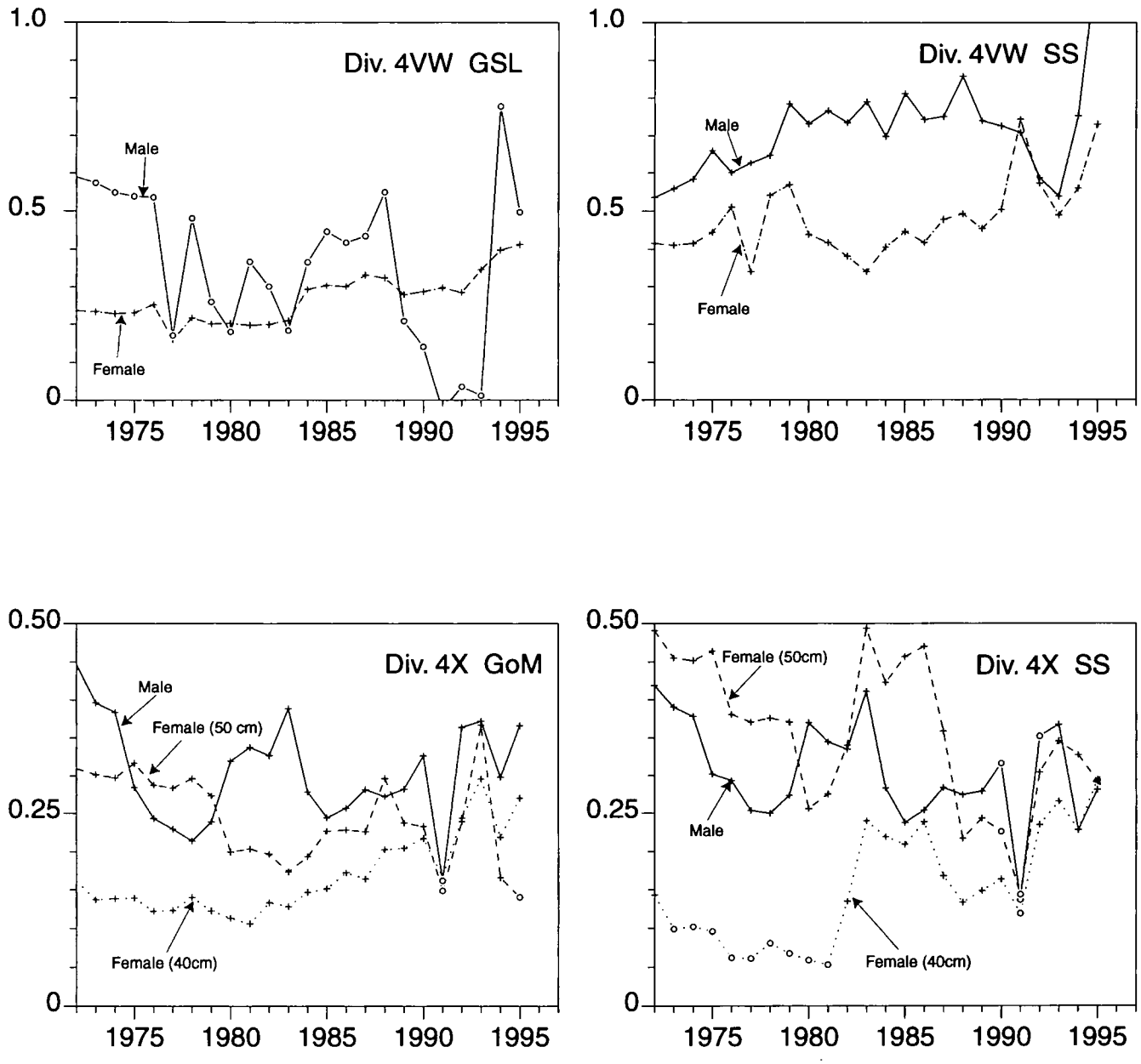

Fig21. Estimates of total mortality of witch flounder based on summer RV survey length frequencies and estimates of growth parameters for Gulf of St Lawrence (GSL), Scotian Shelf (SS) and Gulf of Maine (GoM) in Div. 4VW and Div. 4X.

(solid lines - males, dashed lines - females, + symbol - significant, ° symbol - non-significant)