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Status of witch flounder in NAFO Divisions 4RST

by

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ABSTRACT

The provisional landings of witch flounder in NAFO Divisions 4RST totalled 901 t in 1993. These are the lowest landings in the time series beginning in 1960. Minimum landings were recorded in 4S and 4T. Seine gear contribute the largest proportion of witch landings in 4RST. Research surveys of 4RST, conducted during summer and winter since 1983, indicate declining abundance and biomass. The distribution of witch flounder across NAFO boundaries was examined in relation to the issue of management units. Analyses of combined survey data from the Québec and Gulf regions of DFO indicate that witch prefer depths of 210-310 m in summer. In winter, witch seek deep channel water, coinciding with NAFO boundaries. Maps of the summer and winter distribution of witch flounder in the Gulf of St. Lawrence illustrate their distribution across NAFO boundaries. We conclude that 4RST is a more appropriate unit for the assessment of witch in the Gulf of St. Lawrence.

RÉSUMÉ

Selon les données provisoires, les débarquements de la plie grise dans les divisions 4RST de l'OPANO ont atteint 901 t en 1993. Les débarquements étaient à leur plus bas niveau parmi les données disponibles depuis 1960, comme c'était le cas dans les divisions 4R et 4T. Les seines ont contribué à la plus grande partie des prises de plie grise de 4RST. Les relevés scientifiques, effectués dans 4RST durant l'été et l'hiver depuis 1983, indiquent que l'abondance et la biomasse de la plie grise sont en déclin. La distribution de la plie grise a été examiné en fonction des divisions de l'OPANO et en rélation avec les unités de gestion. L'analyse des relevés scientifiques des régions du Québec de du Golfe du MPO indique qu'en été la plie grise préfère des profondeurs de 210 à 310 m. En hiver, la plie grise recherche l'eau profonde des chenaux, où l'on trouve les limites des divisions de l'OPANO. Des cartes saisonnières de la distribution de la plie grise dans le Golfe du St-Laurent démontrent que la plie grise se distribue à travers des divisions de l'OPANO. On constate que l'unité appropriée à l'évaluation de la plie grise dans le Golfe du St-Laurent serait les divisions 4RST.

INTRODUCTION

Witch flounder (*Glyptocephalus cynoglossus*) occur in the western North Atlantic from southern Labrador in the north, as far south as the Gulf of Maine and North Carolina (Scott and Scott 1988). They are frequently associated with mud and mud-sand bottoms, at depths of 180-366 m and temperatures ranging from 2-6°C (Powles and Kohler 1970, Bowering 1976).

Development of the witch flounder commercial fishery coincided with the introduction of otter trawling to Newfoundland in the 1940s. The fishery began to exploit Gulf of St. Lawrence stocks in the 1950s when declining catches by Danish seiners in Fortune Bay, Newfoundland (NAFO Division 3Ps) caused the fleet to move to St. George's Bay (4R) (Bowering 1979). A small directed fishery for witch developed in St. George's Bay during the summer, while in the winter, witch became a bycatch of cod and redfish-directed fisheries. The witch flounder fishery expanded in the Gulf from St. George's Bay during the 1970s to the Esquiman Channel and the northern shores of Cape Breton Island.

Witch flounder fisheries came under international quota regulation in 1974; at the same time, stock unit areas were defined on the basis of available biological information. In 1977, a precautionary quota of 3,500 t was set for Division 4RS, based on catch statistics. The first analytical assessment of 4RS witch was conducted in 1978 (Bowering 1978). Research data on this stock were analysed yearly up to 1981 (Bowering and Brodie 1980, Bowering 1981) and have not been examined in detail since then. Although the Groundfish Subcommittee of CAFSAC continued to review the status of the stock yearly, the first detailed report of the status of 4RS witch was made in 1991 (Tallman and Forest-Gallant 1991).

The last report of the status of 4RS witch flounder (Morin and Forest-Gallant 1993) resulted in the recommendation that an examination be made of the distribution of witch with respect to 4RST boundaries. Stock identity and the adequacy of management units have been longstanding issues for witch flounder in the Gulf of St. Lawrence. Ideally, management units should circumscribe the stock, defined by Larkin (1972) as a population sharing a common gene pool, sufficiently discrete to be considered as a self-perpetuating system that can be managed. We address the ecological component, that of discreteness, by predicting that with appropriate management units, witch should concentrate within the unit boundaries. We also expect that witch should prefer depths that are found within the borders of the current Gulf management units.

Description of the fishery

Landings of witch flounder in 4RS since 1991 are near their lowest level since 1960 (Tables 1, 2, 3). Landings in 4R in 1993 (436 t) increased from the 1992 level, but were considerably than the average since 1960 of 1,456 t (Table 1). The 1993 witch landings of 15 t in 4S are the lowest on record (Table 2). For the whole of the Gulf (4RST), witch landings declined marginally in 1993 from values recorded over the previous three years; however, the 1993 landings were the lowest on record (Table 4). More witch flounder continue to be landed in 4T than in 4RS (Figure 1), a pattern that has persisted since 1984.

In NAFO Division 4R, otter trawls contributed most of the annual witch landings during the late 1970s; however, since 1981 seining gear has increasingly dominated witch landings in 4R (Table 1). Otter trawls continue to contribute the majority of witch landings in 4S (Table 2). In general, the 4RS witch fishery was concentrated between the months of April and August in

1993; in 4T, landings were concentrated in June and July.

Bowering (1978) described the 4RS witch stock as composed of numerous old (up to age 26 years), slow-growing fish. Many of these were landed in "jellied" condition, providing a poor market product. In 1979, the quota on the stock was raised from 3,500 t to 5,000 t in order to remove the slow-growing component of the stock and improve growth rates of younger witch. Between 1976 and 1981, the growth rates of male and female witch increased significantly, the life span decreased from 26 to 16 years, while stock biomass and size at maturity remained stable (reviewed by Bowering and Brodie 1984). Although the management plan succeeded in removing the large aged component of the population, landings of witch in 4RS peaked in 1976 and declined in following years (Table 3), failing to reach the TAC of 5,000 t. In 1982, the TAC was returned to 3,500 t and has not been changed since then.

Research survey data

Abundance indices

Seasonal research vessel surveys have been conducted in the northern Gulf since 1983 by the Quebec Region of DFO (Figure 2). Summer surveys were conducted from 1984 to 1989 with the *Lady Hammond*, replaced in 1990 by the *Alfred Needler*. Additional gear changes that were made at the same time render the data series not comparable between vessels.

Mean numbers per tow by stratum and weighted division means are presented in Table 5 for winter surveys of the *Gadus Atlantica*. In most years, including 1994, several strata were not sampled due to ice and weather conditions. The increase noted in the 1993 winter survey for 4RST may be an artifact of sample coverage and strong catches in stratum 803 (Table 5). The abundance index based on winter surveys has varied widely, partly due to survey coverage; however, it appears that the present level of abundance is lower than that observed from 1985-1987 (Figure 3). Similar data from summer surveys indicate declining mean catches in all divisions (Table 6, Figure 4).

Minimum stock biomass was calculated in 4R, 4S and 4T based on research vessel surveys for years with sufficient coverage. The results from summer surveys (Table 7) indicate declining biomass in all divisions. Abundance estimates from winter surveys in 4S varied widely over time and exhibited no clear trend; however, strata coverage was frequently limited during the winter surveys, contributing to the observed variability in catch.

Analysis of depth and spatial distribution

Data for these analyses originate from groundfish surveys conducted by the Quebec and Gulf Regions of the DFO. Survey designs have been described in detail by Koeller (1981), Schwab and Hurtubise (1987), and Hurlbut and Clay (1990). Since 1984, the Quebec Region has conducted annual surveys of 4RS in January and August. Groundfish surveys of the southern Gulf (4T) have been conducted every September since 1971. Most of the surveys were based on a stratified random survey design, with depth as the main stratifying variable. From 1985 to 1987, the Gulf Region surveyed 4T using a fixed station design with the stations initially selected randomly. Although every effort was made to maintain common sampling procedures in the surveys, some changes were required as research vessels were changed or when the survey objectives were modified to cover other resources such as redfish and shrimp.

To compare fish of similar size between summer and winter surveys, the mean length frequencies per stratum from each survey were multiplied by the number of trawlable units in that stratum. The length frequencies were then summed to represent the survey-wide length-frequency distribution. Since length frequencies varied between surveys, partly due to differences in vessels and gear, we did not establish common size groups for all years. We selected size groups yearly that were standardized between each August survey and the following January survey. This was done by interpolating between the corresponding size quartiles from the two surveys. Three size groups were established based on the first quartile, the second and third quartiles combined, and the fourth quartile.

The abundance of each size group in relation to depth was analyzed separately for each survey by regressing the catch per unit of effort (standard tow distance of 1.75 NM) on the mean depth (m) of each tow. The analysis was performed using a Poisson regression model, described by Swain (1993) in a similar analysis of cod abundance in relation to hydrographic variables. The model used was of the form

$$E[Y_i] = \mu_i = \exp(\beta_0 + \beta_1 X_i + \beta_2 X_i^2)$$

$$Var[Y_i] = \phi \mu_i$$

where Y_i is the number of fish of a given size group in tow *i* of a particular survey; X_i is the depth of tow *i*; β_o, β_1, β_2 are coefficients of the regression; and ϕ is a parameter for extra-Poisson variation. This probability model was chosen because the mean and variance tend to be positively related in survey data (Smith 1990, Swain 1993). The significance of effects of depth on the abundance of witch was tested by examining the change in scaled deviance in models with and without the tested depth terms (McCullagh and Nelder 1989). The overall effect of depth in the model was tested by removing both depth terms from the regression model. The X_i and X_i^2 terms were then removed sequentially from the full model to test the contribution of the linear and quadratic terms, respectively.

Regressions with significant linear and quadratic terms ($P<0.05$) were then examined to determine the depth at which maximum abundance of fish occurs for that particular size group and survey. The depth of maximum CPUE was calculated from the derivative of the regression model set to zero ($f' = 0 = -\beta_1/2\beta_2$).

We describe the geographic distribution of witch in the Gulf of St. Lawrence at two distinct times of the year: during summer (combining August and September surveys) and during winter (January surveys). For comparability, the analysis of summer surveys was limited to 10 missions (5 Gulf Region:5 Quebec Region) conducted between 1985-89 aboard the *Lady Hammond* with a Western IIA survey trawl. Catches from three fixed-station (Gulf Region) surveys were incorporated in this analysis in order to include all of the available information on distribution. The analysis of winter surveys was limited to 5 missions conducted by the Quebec Region between 1986-90, aboard the *Gadus Atlantica*. For these missions, a Western IIA survey trawl was used for the years 1986-88 and an Engels-145 survey trawl was used for the years 1989-90.

Plots of the geographical distribution of witch were made with ACON software (Version 7.14, Black 1993). The catches at individual stations on the distributional plots were represented with expanding circles, indicating the catch in kilograms per standard tow. The expanding circle plots for each species were scaled identically for all surveys, based on quartiles of grouped catch data.

Results of analyses

Mean catches of witch flounder in summer and winter surveys relative to depth (Figure 5) indicate a marked difference in the seasonal distribution. In August surveys, witch of all size groups occupied intermediate depths, usually 150-300 m. Witch of the first two size groups, but particularly the smallest group of <30 cm length, tended to peak in abundance in a second depth range, usually >400 m (years 1988-91, Figure 5). In winter, witch of the two larger size groups (>30 cm length) increased sharply in abundance with increasing depth (Figure 5).

Poisson regressions of witch CPUE for August surveys accounted for less of the total deviance than in January surveys. Of the 15 regressions conducted on witch in August surveys, three regressions were not significant (P>0.05), four regressions produced significant negative linear relations, and the remaining eight regressions were significant quadratic models (Table 8). Regressions based on January surveys of witch accounted for a larger part of the deviance. All of these regressions were significant; 10 of the 15 regressions conducted on January surveys accounted for >60% of the total deviance and nine regressions were linear relations. The strength of the quadratic term varied across the August surveys, tending to dominate in the latter three years (1990-92) of the surveys that we examined (Table 9). The linear term clearly accounted for the largest part of the total deviance in all but one of the regressions conducted on the January survey data (Table 9).

Witch flounder tended to occupy deeper water in winter than in summer. The August surveys resulted in some regressions with significant quadratic terms. These indicate a depth of maximum abundance roughly between 210 and 310 m (Table 10); however, four of the 15 regressions resulted in significant linear models with negative slopes. The winter surveys for witch indicated a clear preference for the deepest available water, evidenced by the number of significant linear models with positive slope (Table 10).

Distribution maps of witch flounder during summer surveys indicate concentrations in 4S west of Anticosti Island, in western 4T and throughout the Laurentian Channel, north and west of Cape Breton, and in northern 4R (Figure 6). Some of these areas of concentration are centred within NAFO divisions; however, the distribution maps generally indicate that the summer distribution of witch is dispersed across the boundaries of management units. The summer surveys also suggest that witch in 4T are at a similar magnitude of abundance to witch in the 4RS management unit. During winter surveys, witch exhibit a tendency to occupy channel waters coincident with the 4RST boundaries (Figure 7). Witch appear to be distributed uniformly into 3Pn in winter and the January 1994 survey (Figure 8) suggests that witch may be found continuously on both sides of the channel, extending into 4Vn.

Discussion of depth and spatial distribution

The results of this analysis indicate that the Gulf management units do not circumscribe the distributions of witch flounder. Witch appear to occupy the deeper, eastern portion of the Gulf in winter and their distributions appear to be continuous with divisions outside of the Gulf, including 3Pn and 4Vn. By selecting deep waters in the Gulf of St. Lawrence, their centers of distribution correspond with the NAFO boundaries which were drawn along the axes of the main Gulf channels.

Our analyses of the seasonal distribution of witch flounder in the Gulf of St. Lawrence partly confirm other studies. Powles and Kohler (1970) noted significant movements of witch from their summer distribution on the Scotian Shelf to wintering sites located offshore in slope waters. Although they considered that most witch in the Gulf of St. Lawrence wintered in nearby channels, they also suggested possible overwintering movements outside of the

Gulf. Bowering and Brodie (1984) reviewed data from surveys between 1976 and 1981 in the Gulf of St. Lawrence. They observed winter concentrations of witch flounder in the lower Esquiman Channel and the eastern Laurentian Channel, but discounted the possibility of movements outside of the Gulf, as reported by Powles and Kohler (1970), due to the effects of seasonal changes in availability.

Powles and Kohler (1970) proposed a model of the life cycle of witch flounder with spatially segregated life stages. Juvenile witch (10-30 cm) were proposed to occupy deeper waters than adult stages during the summer. This pattern was supported elsewhere by Markle (1975); however, Walsh (1987) suggested that the pattern observed by Powles and Kohler (1970) was biased due to gear selectivity and the depth of sampling. Our results suggest that the smallest size group of witch (<30 cm) tended to peak at greater depths than larger size groups during summer surveys (Figure 5).

Overwintering witch in Division 4RS have been described by Bowering and Brodie (1984) as pre-spawning concentrations. Biochemical analyses of the witch stocks (Fairbairn 1981) indicate considerable differentiation, including separation between 4RS and 3Pn witch collected during winter surveys. Similar stock differentiation has been found based on meristic characters (Bowering and Misra 1982). Distributional data are useful in defining management units; however, they should be used in concert with results from biological data, including the analysis of heretible traits. Further analyses are required that incorporate the distribution of juvenile and maturing life stages, stock components, as well as fleet dynamics.

Prognosis

Biological information on 4RS witch, including age, growth and maturity, has not been brought up to date since the early 1980s. However, it appears from both commercial catches and survey data that the abundance of witch in 4RS is in decline. The current TAC of 3,500 t is high in relation to catches since 1981. Witch flounder in the Gulf of St. Lawrence are distributed across 4RST boundaries and 4RST would be a more appropriate unit for assessment of this resource.

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Table 1. Yearly landings of witch flounder in NAFO Division 4R by major gear types. Gear codes: OTB=otter trawls (unspecified), OTB1=otter trawl side, OTB2=otter trawl stern, SNU=seines, GNS=gillnets, LLS=longlines, LH=handlines.

YEAR	GEAR								TOTAL
	OTB	OTB1	OTB2	SNU	GNS	LLS	LH	OTHER	
1960	250	0	0	764	0	0	0	26	1040
1961	129	0	0	1409	0	0	0	14	1552
1962	114	0	0	1433	0	0	0	5	1552
1963	49	0	0	2047	0	0	0	0	2096
1964	304	0	0	1413	0	0	0	0	1717
1965	156	0	0	1464	0	0	0	0	1620
1966	0	184	4	1083	0	0	0	0	1271
1967	1	240	19	786	0	0	0	0	1046
1968	0	286	84	861	0	0	0	0	1231
1969	0	639	175	2427	0	1	0	0	3242
1970	0	576	341	2298	0	0	0	0	3215
1971	17	251	139	1604	2	0	0	0	2013
1972	23	243	207	68	2	0	0	7	550
1973	47	86	35	559	7	9	0	8	751
1974	0	218	720	1259	3	0	0	8	2208
1975	0	288	227	1134	6	4	0	5	1664
1976	0	839	2583	101	9	0	0	91	3623
1977	0	496	858	605	4	0	0	5	1968
1978	0	346	2247	787	2	3	0	44	3429
1979	0	485	1564	1007	20	4	0	7	3087
1980	1	208	1149	797	31	0	0	0	2186
1981	15	44	74	729	15	0	0	0	877
1982	22	52	101	733	17	0	0	0	925
1983	40	6	48	577	10	9	0	0	690
1984	20	8	36	0	15	0	0	0	79
1985	21	6	87	539	0	6	0	0	659
1986	30	4	36	480	3	1	0	0	554
1987	46	0	45	757	0	0	0	0	848
1988	43	2	36	946	31	1	0	2	1061
1989	29	0	54	951	46	0	0	0	1080
1990	0	7	60	436	15	8	0	3	529
1991*	0	0	28	314	27	2	0	3	374
1992*	0	0	31	285	11	2	0	3	332
1993*	0	0	56	276	10	0	0	95	436
MEAN	40	162	325	910	8	1	0	10	1456

* Provisional data

Table 2. Yearly landings of witch flounder in NAFO Division 4S by major gear types. Gear codes as in Table 1.

YEAR	GEAR								TOTAL
	OTB	OTB1	OTB2	SNU	GN	LL	LHP	OTHER	
1960	44	0	0	0	0	3	0	0	47
1961	58	0	0	0	0	16	1	0	75
1962	37	0	0	1	0	22	0	0	60
1963	236	0	0	5	0	21	4	0	266
1964	182	0	0	0	0	86	0	195	463
1965	333	0	0	0	0	36	0	0	369
1966	0	242	5	0	0	3	0	3	253
1967	0	179	1	0	3	4	1	0	188
1968	0	301	3	0	10	13	0	0	327
1969	3	219	96	0	0	0	0	0	318
1970	11	274	102	0	0	0	0	0	387
1971	0	381	7	0	9	40	0	0	437
1972	7	378	10	0	0	7	0	0	402
1973	19	116	1	0	0	0	0	0	136
1974	0	148	154	0	10	0	0	0	312
1975	61	116	90	0	0	0	0	14	281
1976	98	334	1262	0	0	0	0	24	1718
1977	96	171	359	1	0	0	0	1	628
1978	3	238	510	0	45	0	0	70	866
1979	61	340	219	0	74	7	0	0	701
1980	41	235	465	0	19	27	0	0	787
1981	72	92	158	2	0	18	0	0	342
1982	50	32	19	0	0	2	0	0	103
1983	30	39	4	0	0	1	0	0	74
1984	19	68	8	0	3	11	0	0	109
1985	5	5	6	0	1	0	0	21	38
1986	7	3	2	152	0	0	0	9	173
1987	12	6	31	0	0	2	0	5	56
1988	9	37	13	0	0	0	0	13	72
1989	9	30	66	0	0	0	0	0	105
1990	12	16	48	1	1	0	0	2	80
1991*	0	1	58	1	9	0	0	10	79
1992*	0	2	32	0	0	0	0	11	45
1993*	0	0	13	0	0	0	0	2	15
MEAN	45	118	110	5	5	9	0	11	303

* Provisional data

Table 3. Yearly landings of witch flounder in NAFO Division 4RS by major gear types. Gear codes as in Table 1.

YEAR	GEAR								TOTAL
	OTB	OTB1	OTB2	SNU	GN	LL	LHP	OTHER	
1960	294	0	0	764	0	3	0	26	1087
1961	187	0	0	1409	0	16	1	14	1627
1962	151	0	0	1434	0	22	0	5	1612
1963	355	0	0	2052	0	21	4	0	2432
1964	486	0	0	1413	0	86	0	195	2180
1965	489	0	0	1464	0	36	0	0	1989
1966	0	426	9	1083	0	3	0	3	1524
1967	1	419	20	786	3	4	1	0	1234
1968	0	587	87	861	10	13	0	0	1558
1969	3	858	271	2427	0	1	0	0	3560
1970	11	850	443	2298	0	0	0	0	3602
1971	17	632	146	1604	11	40	0	0	2450
1972	30	621	217	68	8	7	0	0	951
1973	66	202	36	559	7	9	0	0	879
1974	0	366	874	1259	13	0	0	8	2520
1975	61	404	317	1134	6	4	0	19	1945
1976	98	1173	3845	101	9	0	0	115	5341
1977	96	667	1217	606	4	0	0	6	2596
1978	3	584	2757	787	47	3	0	114	4295
1979	61	825	1783	1007	94	11	0	7	3788
1980	42	443	1614	797	50	27	0	0	2973
1981	87	136	232	7	15	18	0	724	1219
1982	72	84	120	0	17	2	0	733	1028
1983	70	45	52	0	10	10	0	577	764
1984	39	76	44	0	18	11	0	0	188
1985	26	11	93	539	1	6	0	21	697
1986	37	7	38	632	3	1	0	9	727
1987	58	6	76	757	2	0	0	5	904
1988	52	39	49	946	31	1	0	15	1133
1989	38	30	120	951	46	0	0	0	1185
1990	12	23	108	437	16	8	0	5	609
1991*	0	1	87	316	36	2	0	13	455
1992*	0	2	63	285	11	2	0	14	377
1993*	0	0	68	276	10	0	0	97	451
MEAN	87	280	435	855	14	11	0	80	1761

* Provisional data

Table 4. Yearly landings of witch flounder in NAFO divisions 4RST by major gear types. Gear codes as in table 1.

	GEAR							
YEAR	OTB	OTB1	OTB2	SNU	GNS	LLS	OTHER	TOTAL
1960	1912	0	0	1309	0	72	45	3338
1961	1428	0	0	1907	7	19	135	3496
1962	1342	0	0	2012	0	28	5	3387
1963	1561	0	0	2612	37	25	15	4250
1964	1377	0	0	1657	0	86	230	3350
1965	1137	0	0	2389	1	67	14	3608
1966	0	1620	39	1845	93	5	110	3712
1967	1	964	33	1647	36	23	10	2714
1968	0	1227	102	1995	46	13	7	3390
1969	3	1286	294	3179	0	1	0	4763
1970	12	1203	504	3078	8	0	0	4805
1971	17	1108	183	2352	11	137	13	3821
1972	30	968	329	636	2	7	29	2001
1973	68	613	56	1330	39	12	106	2224
1974	0	707	946	1569	15	0	10	3247
1975	82	771	371	1449	25	4	20	2722
1976	111	1606	4303	730	9	0	116	6875
1977	99	962	1248	715	4	0	8	3036
1978	3	616	2767	938	69	3	114	4510
1979	62	1065	1970	1309	120	14	21	4561
1980	106	548	1618	1100	98	30	27	3527
1981	108	446	267	1032	24	33	2	1912
1982	93	105	122	934	24	4	0	1282
1983	137	116	52	829	27	10	6	1177
1984	75	110	314	536	51	19	2	1107
1985	27	89	161	1127	28	7	221	1660
1986	49	63	79	1216	6	2	408	1823
1987	58	157	212	1671	7	0	504	2609
1988	56	177	177	1835	34	1	250	2530
1989	45	199	358	1698	47	0	0	2347
1990	12	120	236	873	16	8	7	1272
1991*	0	5	180	752	37	2	17	993
1992*	0	4	137	809	11	0	18	979
1993*	0	0	103	691	11	0	96	901
MEAN	294	496	505	1464	28	19	75	2880

* Provisional data

Table 5. Mean number per tow by stratum estimated from winter surveys of the *Gadus Atlantica* with division mean numbers per tow weighted by stratum size. Strata 401-408 are in NAFO Division 4T. "." indicates no fishing.

STRATUM	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
401	4.00	1.67	.	1.00	.	0.00	.	.	0.67	.	0.67	.
402	2.00	0.00	.	.	.	.	.	.	.	.	.	.
404	2.00	2.33	.	4.33	.	1.75	.	.	0.75	.	0.67	.
405	1.00	0.33	.	.	0.25	1.50	.	.	.	.	.	.
407	30.50	10.50	.	21.33	.	48.29	.	64.50	49.00	.	62.20	.
408	13.00	14.14	.	.	8.00	33.75	0.67	.	.	.	6.50	.
801	13.67	86.50	153.67	40.33	56.50	37.00	.	.	33.50	6.00	10.75	12.50
802	34.57	9.40	96.00	53.00	195.33	146.33	136.33	35.50	76.83	118.31	51.28	105.79
803	21.45	31.59	113.40	64.26	53.94	49.44	57.50	52.79	26.00	.	82.50	.
804	12.00	19.00	25.00	.	11.60	.	.	.	.	.	8.00	.
805	9.33	.	.	.	.	.	.	.	.	.	.	.
806	0.50	.	.	.	.	.	.	.	.	.	.	.
807	4.00	1.83	5.17	1.00	5.02	0.67	0.00	1.33	.	.	1.25	.
808	30.13	22.00	43.00	91.10	37.63	5.50	10.17	9.75	.	22.75	8.40	.
809	38.00	67.00	34.13	109.57	62.50	14.00	19.56	6.00	8.25	4.50	5.20	18.25
810	7.00	47.00	115.00	15.71	10.25	5.00	2.67	1.67	1.57	1.60	1.83	18.67
811	2.57	6.43	4.43	7.25	6.50	1.00	2.50	0.43	0.50	0.75	0.43	1.40
812	13.50	10.56	4.71	10.40	2.60	3.46	4.65	1.13	4.00	0.80	0.75	1.20
813	10.04	18.40	9.30	36.90	1.50	2.88	5.17	1.50	0.00	0.75	1.25	1.25
814	1.33	5.33	5.20	0.00	3.00	0.67	.	.	0.00	0.00	1.00	1.00
815	4.00	11.13	18.90	3.50	7.56	6.91	3.17	4.83	.	0.00	.	8.50
816	5.10	18.50	11.25	.	.	4.77	6.00	.	.	0.00	.	.
817	3.33	.	.	.	.	.	.	.	.	0.00	.	.
818	2.67	.	.	.	.	.	.	.	.	0.00	.	.
819	0.00	1.75	4.43	4.20	3.00	2.67	0.40	1.00	.	0.00	0.75	.
820	0.86	3.80	1.60	4.13	2.80	0.00	1.33	0.17	0.00	.	0.00	0.00
821	0.43	0.40	0.60	0.11	0.33	0.00	0.00	0.83	0.14	.	0.00	1.00
822	1.90	0.38	4.50	2.56	0.88	0.25	0.13	0.00	0.00	.	0.00	0.00
823	17.00	26.25	20.33	5.67	.	.	0.50	0.33	.	.	0.00	.
824	1.00	1.33	0.00	0.50	.	0.00	.	.	.	.	.	0.00
825	1.50	.	.	.	.	.	.	.	.	.	.	.
826	0.00	.	.	.	.	.	.	.	.	.	.	.
827	0.00	0.40	0.00	0.00	.	0.20	.	.	.	.	.	.
828	0.00	.	.	.	.	.	.	.	.	.	.	.
829	0.00	0.50	.	.	0.50	0.14	0.00	.	.	.	.	.
830	0.00	0.25	0.20	0.00	0.00	0.00	0.00	0.00	.	.	.	.
832	0.00	.	.	.	.	.	.	.	.	.	.	.
833	0.00	0.33	0.67	.	.	0.00	.	.	.	.	.	.
835	0.00	.	.	.	.	0.80	0.00	0.00	.	.	.	.
836	0.00	.	.	.	.	0.00	.	.	.	.	.	.
MEANS												
4R	11.84	19.17	26.47	25.32	24.03	14.79	14.49	3.94	9.22	9.11	5.22	10.60
4S	5.87	13.73	33.60	27.36	20.56	11.20	15.18	17.78	19.15	9.51	33.07	5.85
4T	12.94	7.55	.	14.65	5.28	26.46	0.67	64.5	31.42	.	25.58	.
4RST	8.10	14.58	30.94	25.59	20.61	14.13	14.18	14.55	14.62	9.20	19.89	9.39

Table 6. Mean numbers per tow by stratum of witch flounder from summer surveys of the *Lady Hammond* (1984-1989) and the *Alfred Needler*(since 1990). Strata 401-408 are in NAFO Division 4T. "." indicates no fishing effort.

STRATUM	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
401	0.00	2.20	.	.	5.27	2.38	3.26	0.50	0.50	0.00
402	.	8.70	3.01	7.00	5.44	5.32	17.55	11.09	0.86	0.00
403	.	51.72	56.76	3.71	39.53	6.00	2.67	2.89	0.56	1.98
404	2.54	3.25	3.85	8.15	2.67	1.71	0.30	0.00	0.33	0.21
405	2.29	2.25	1.71	6.00	3.45	1.04	0.44	0.00	0.00	0.00
406	.	5.00	5.82	2.69	4.06	0.80	2.02	0.62	0.30	0.00
407	3.15	3.16	4.44	6.05	11.10	7.91	2.31	0.89	0.69	0.00
408	2.22	3.40	11.38	4.80	3.73	1.97	1.42	2.44	0.53	0.21
409	.	.	.	42.65	28.99	13.42	19.48	14.44	14.00	1.22
410	.	.	19.55	.	9.86	6.33	1.33	16.00	0.53	0.48
411	.	.	.	41.29	15.78	.	15.97	27.56	34.93	5.49
412	.	.	.	64.50	18.35	.	18.74	36.24	41.43	23.68
413	.	.	.	48.20	21.75	.	19.00	13.44	34.20	1.36
414	.	.	.	4.00	22.22	.	15.41	11.82	8.67	1.12
801	38.38	7.08	12.00	2.00	5.59	4.54	7.48	6.89	1.19	0.00
802	8.54	6.06	13.33	8.24	14.18	6.65	6.59	1.87	0.00	0.00
803	7.50	5.27	11.41	5.18	7.31	9.19	1.70	8.61	0.00	0.00
804	8.44	3.18	9.57	6.45	6.35	2.68	0.18	1.07	0.63	0.21
805	9.29	27.31	14.80	8.70	6.97	1.73	3.12	7.28	4.40	1.45
806	11.25	0.98	9.84	5.62	6.50	0.33	1.22	0.67	0.30	0.22
807	1.14	3.26	10.09	3.05	4.18	1.24	1.19	1.07	0.08	0.18
808	3.48	1.56	3.65	4.08	5.87	2.91	1.92	0.38	0.15	0.92
809	2.76	7.27	.	7.00	4.01	2.00	3.38	1.65	0.38	0.00
810	4.31	17.25	5.04	11.11	6.63	3.00	1.67	0.44	0.80	0.78
811	1.50	10.56	8.49	5.15	1.73	1.67	3.26	0.85	2.06	0.00
812	0.45	1.96	4.41	3.94	2.94	1.77	3.98	5.97	1.79	0.44
813	.	6.45	24.66	7.39	3.14	3.16	0.48	1.07	0.00	0.75
814	.	1.02	.	5.21	6.33	2.33	1.00	2.22	0.67	0.00
815	.	4.82	3.82	3.47	2.07	1.59	0.59	0.42	0.34	0.56
816	15.13	7.82	15.67	5.78	7.45	4.29	8.70	5.22	1.54	0.57
817	5.84	14.39	17.19	16.84	9.74	6.26	3.56	13.27	12.57	0.60
818	14.54	2.81	24.96	19.46	5.53	6.42	1.96	1.42	0.86	0.30
819	.	3.39	6.80	4.66	4.22	0.67	0.30	1.49	1.01	0.37
820	0.00	2.48	4.95	10.06	19.04	0.33	0.89	2.15	6.11	0.00
821	1.00	0.69	7.04	1.00	1.32	4.00	1.05	0.80	0.30	0.00
822	5.70	0.74	3.27	4.83	5.69	3.37	2.81	0.67	0.33	1.23
823	15.69	7.58	9.84	54.00	30.71	26.00	0.00	1.16	0.33	0.00
824	6.86	2.29	4.00	46.11	5.81	2.35	1.39	.	0.00	.
825	.	50.65	4.68	.	0.00	.	0.00	.	.	.
827	.	8.55	1.76	3.41	4.51	.	2.43	.	.	.
828	.	2.00	1.06	0.50	8.32	10.93	3.26	1.82	0.00	0.00
829	.	2.23	12.00	0.00	6.21	4.23	0.89	.	0.53	0.00
830	1.59	0.67	5.16	0.25	3.50	1.00	19.00	0.29	1.48	0.00
831	.	1.96	0.45	10.00	14.56	8.11	0.00	.	1.33	0.00
832	.	40.39	506.19	30.40	39.78	45.91	.	12.82	0.00	3.06
833	.	.	.	0.47	1.06	0.32	.	.	0.00	0.00
MEANS										
4R	5.75	4.18	9.88	7.41	5.66	2.93	2.86	2.68	1.02	0.50
4S	8.24	12.45	42.41	8.19	8.16	7.47	3.65	4.00	1.36	0.46
4T	2.39	8.45	12.13	17.18	11.78	4.30	6.65	9.13	8.48	2.41
4RST	6.83	10.14	31.35	9.65	8.70	5.92	4.10	4.74	2.54	0.81

Table 7. Total biomass (t) in strata corresponding to NAFO Divisions, based on summer surveys of the *Lady Hammond* (1984-1989) and the *Alfred Needler* (since 1990). "-" indicates inadequate coverage for biomass estimate.

YEAR	4R	4S	4T
1984	943	-	-
1985	1629	3860	-
1986	1459	23779	-
1987	1212	3872	2743
1988	1116	3652	1787
1989	420	2287	-
1990	414	2176	1036
1991	334	1051	1685
1992	225	351	940
1993	137	75	190

Table 8. Coefficients of Poisson regression models, and corresponding standard errors, relating witch CPUE to depth (m). Regression models include intercept (β_o), linear (β_1) and quadratic (β_2) terms, with percent of total deviance accounted for by the model. Witch from August surveys and corresponding following January survey were divided into length intervals (cm) as indicated. NS indicates non-significance.

	Size	August survey				January survey			
Year	Interval	β_o	β_1	β_2	% Dev	β_o	β_1	β_2	% Dev
1988-89	<33	NS	NS	NS		-1.267 0.4051	0.0068 0.0011	NS	23
	33-41	2.232 0.2318	-0.0039 0.0009	NS	8	-3.363 0.4699	0.0138 0.0011	NS	62
	>41	1.200 0.2643	-0.0042 0.0011	NS	7	-5.096 0.5692	0.0168 0.0013	NS	67
1989-90	<33	NS	NS	NS		-1.891 0.4408	-0.0081 0.0011	NS	33
	33-41	1.627 0.3088	-0.0035 0.0012	NS	5	-6.710 1.8390	0.0322 0.0097	-2.542e-05 1.246e-05	70
	>41	0.971 0.3738	-0.0054 0.0016	NS	7	-4.454 0.5457	0.0146 0.0012	NS	66
1990-91	<26	-5.577 1.8370	0.0486 0.0125	-7.887e-05 2.073e-05	12	-6.938 2.7240	0.0405 0.0166	-5.687e-05 2.426e-05	8
	26-38	NS	NS	NS		-2.878 0.5182	0.0124 0.0012	NS	61
	>38	-1.295 1.165	0.0157 0.0093	-3.719e-05 1.805e-05	6	-4.919 0.0169	0.0169 0.0014	NS	72
1991-92	<28	-2.379 1.1460	0.0343 0.0090	-6.469e-05 1.739e-05	10	-8.040 2.4560	0.0407 0.0137	-5.072e-05 1.856e-05	18
	28-37	-4.295 1.3910	0.0421 0.0108	-7.972e-05 2.080e-05	11	-10.210 3.167	0.0471 0.0151	-4.139e-05 1.781e-05	66
	>37	-3.749 1.1670	0.0346 0.0093	-6.674e-05 1.812e-05	9	-9.250 3.2550	0.0425 0.0153	-3.346e-05 1.789e-05	69
1992-93	<28	-9.485 2.7750	0.0753 0.0193	-1.233e-04 3.315e-05	19	-6.285 2.0990	0.0295 0.0119	-3.227e-05 1.626e-05	19
	28-38	-4.010 1.1990	0.0435 0.0106	-9.486e-05 2.307e-05	11	-5.026 0.4773	0.0162 0.0011	NS	76
	>38	-12.830 4.3870	0.1050 0.0331	-1.959e-04 6.185e-05	12	-6.939 0.6451	0.0201 0.0014	NS	75

Table 9. Percent of total deviance explained by linear and quadratic terms in Poisson regressions of witch CPUE on depth. Size groups correspond to length intervals shown in Table 2.

	Size	August survey		January survey	
Year	Group	Linear	Quadratic	Linear	Quadratic
1988-89	1	1.2	0.2	23.3	4.3
	2	8.2	1.4	62.0	0.4
	3	7.4	0.2	66.5	0.8
1989-90	1	0.2	0.5	33.2	1.9
	2	5.2	2.1	65.6	1.3
	3	7.4	0.0	66.0	0.8
1990-91	1	1.1	10.5	2.0	5.8
	2	1.3	0.6	61.4	0.2
	3	2.9	2.7	71.7	0.0
1991-92	1	0.8	8.7	10.3	7.8
	2	0.8	10.1	63.1	2.3
	3	0.6	8.7	68.1	1.3
1992-93	1	6.7	11.8	16.8	2.6
	2	0.1	10.9	75.5	0.0
	3	1.4	11.0	75.1	0.0

Table 10. Depth of maximum predicted CPUE, based on significant Poisson regressions. NS indicates non-significant relation of CPUE to depth; "+/-" indicates the sign of the slope in significant linear relations of CPUE with depth.

	Size	Witch	
Year	Group	August	January
1988-89	1	NS	+
	2	-	+
	3	-	+
1989-90	1	NS	-
	2	-	634
	3	-	+
1990-91	1	308	356
	2	NS	+
	3	212	+
1991-92	1	265	402
	2	264	569
	3	259	636
1992-93	1	305	458
	2	229	+
	3	268	+

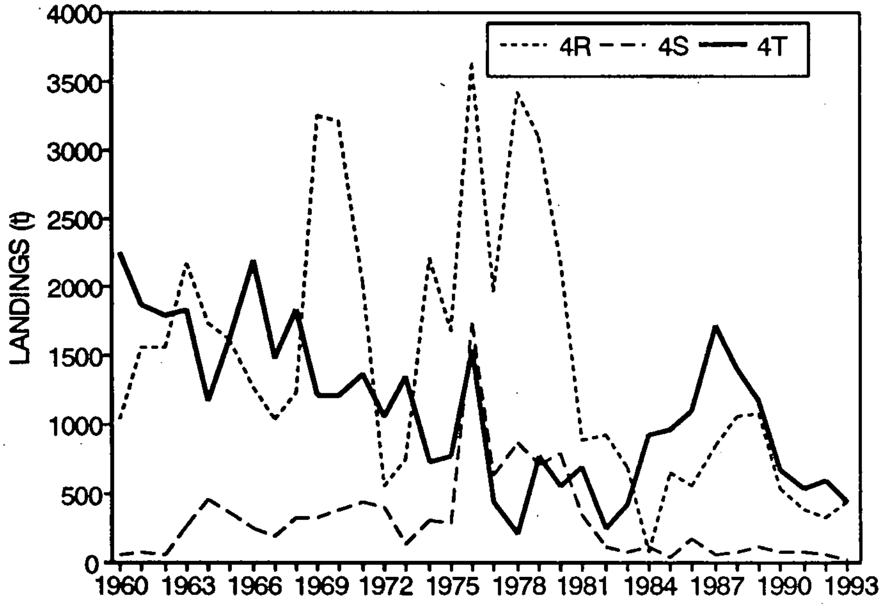

Figure 1. Nominal landings of witch flounder in NAFO divisions 4RST.

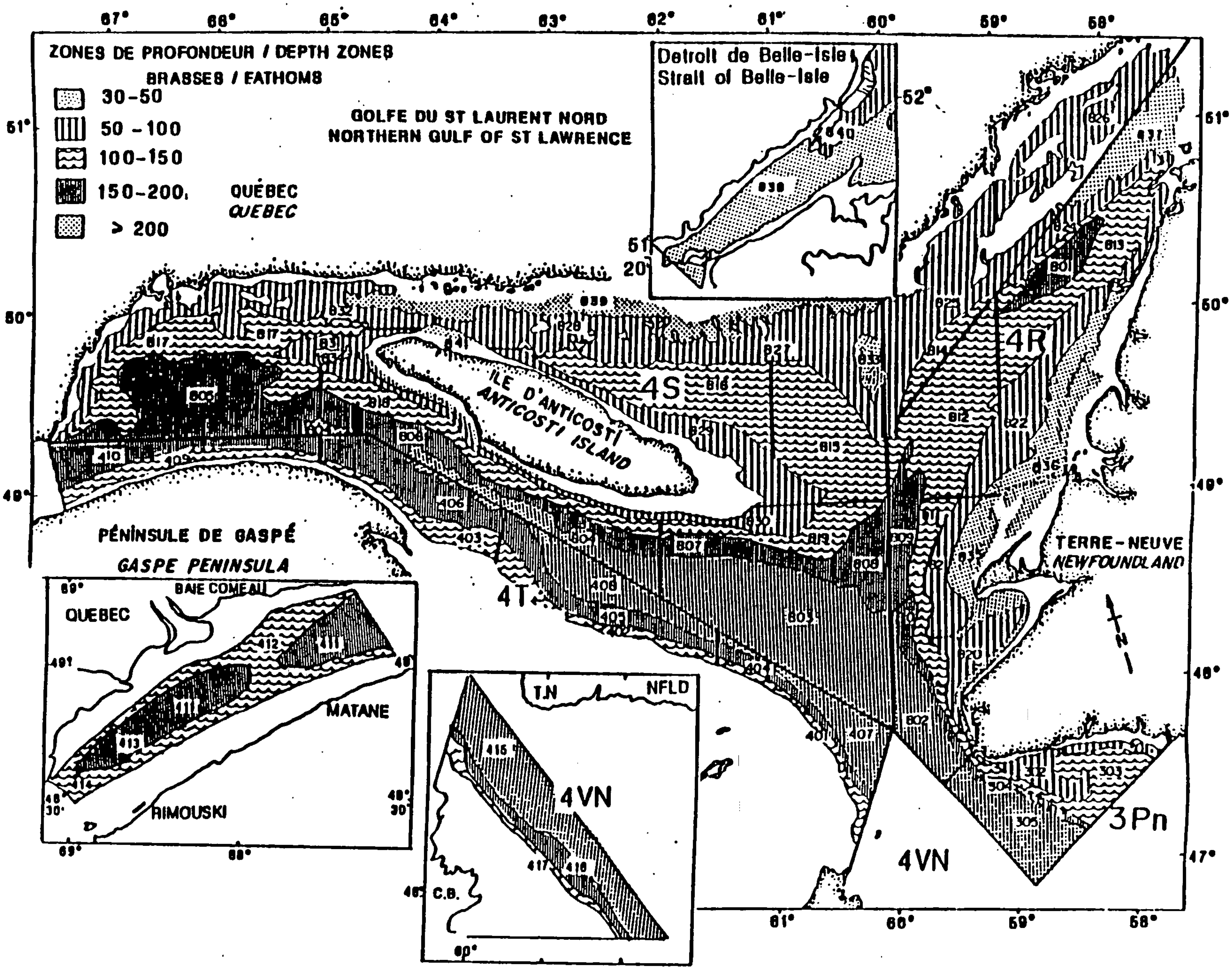

Figure 2. Strata boundaries in research surveys of 4RST, conducted by the Québec Region of DFO.

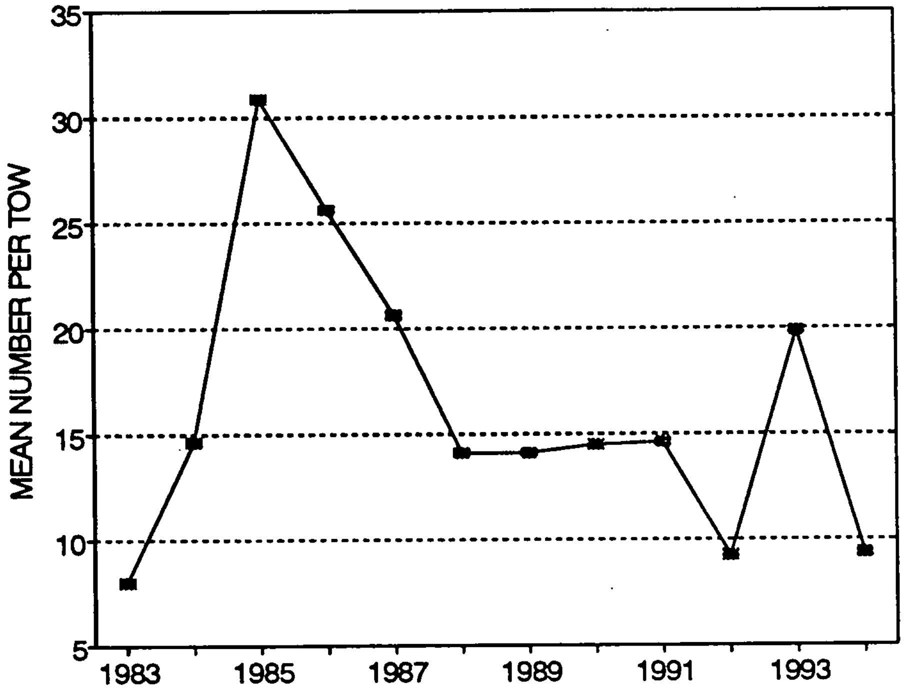

Figure 3. Catch rates of witch flounder in winter research surveys of 4RST.

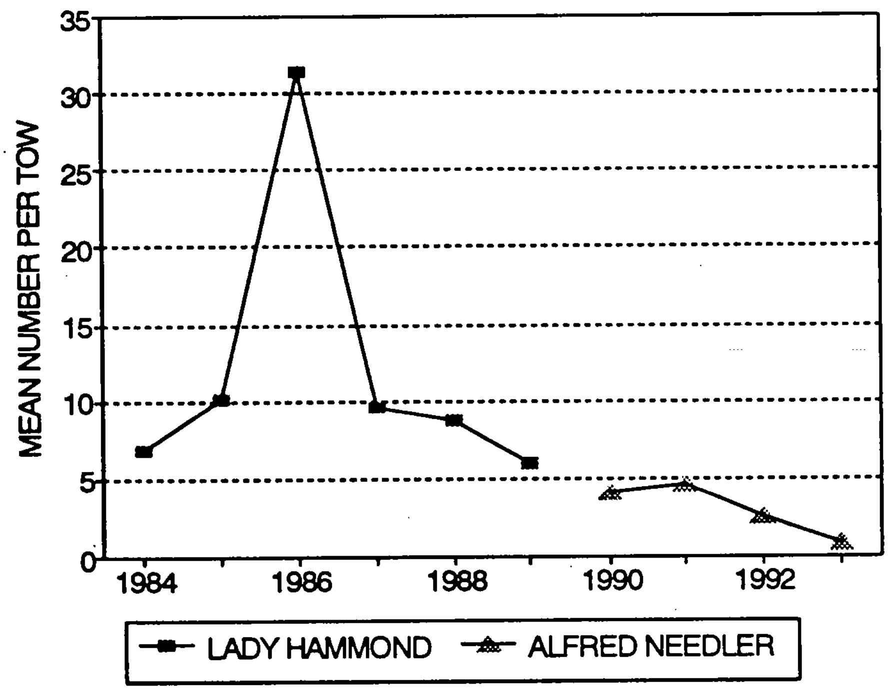

Figure 4. Catch rates of witch flounder from summer research surveys of 4RST.

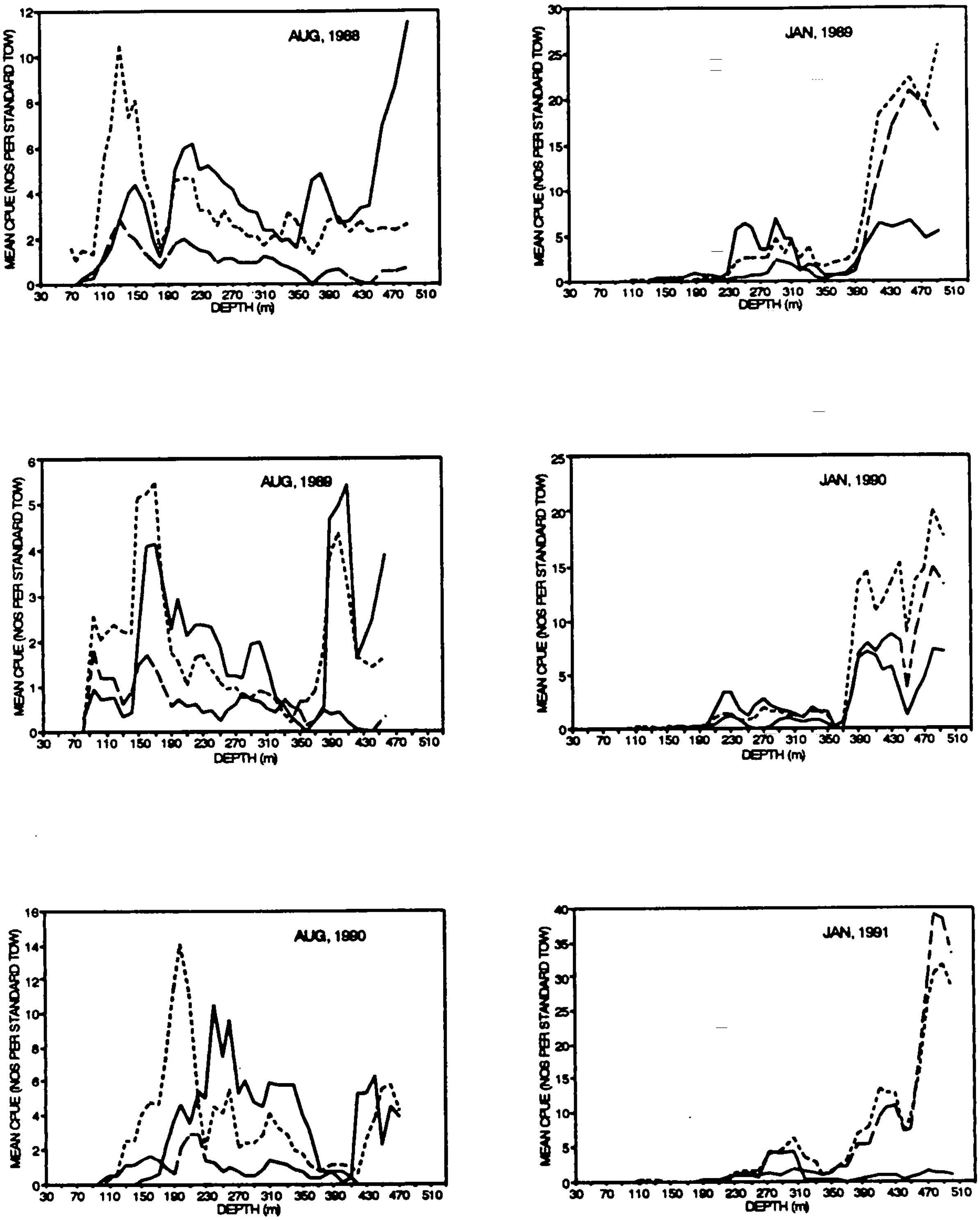

Figure 5. Continued next page.

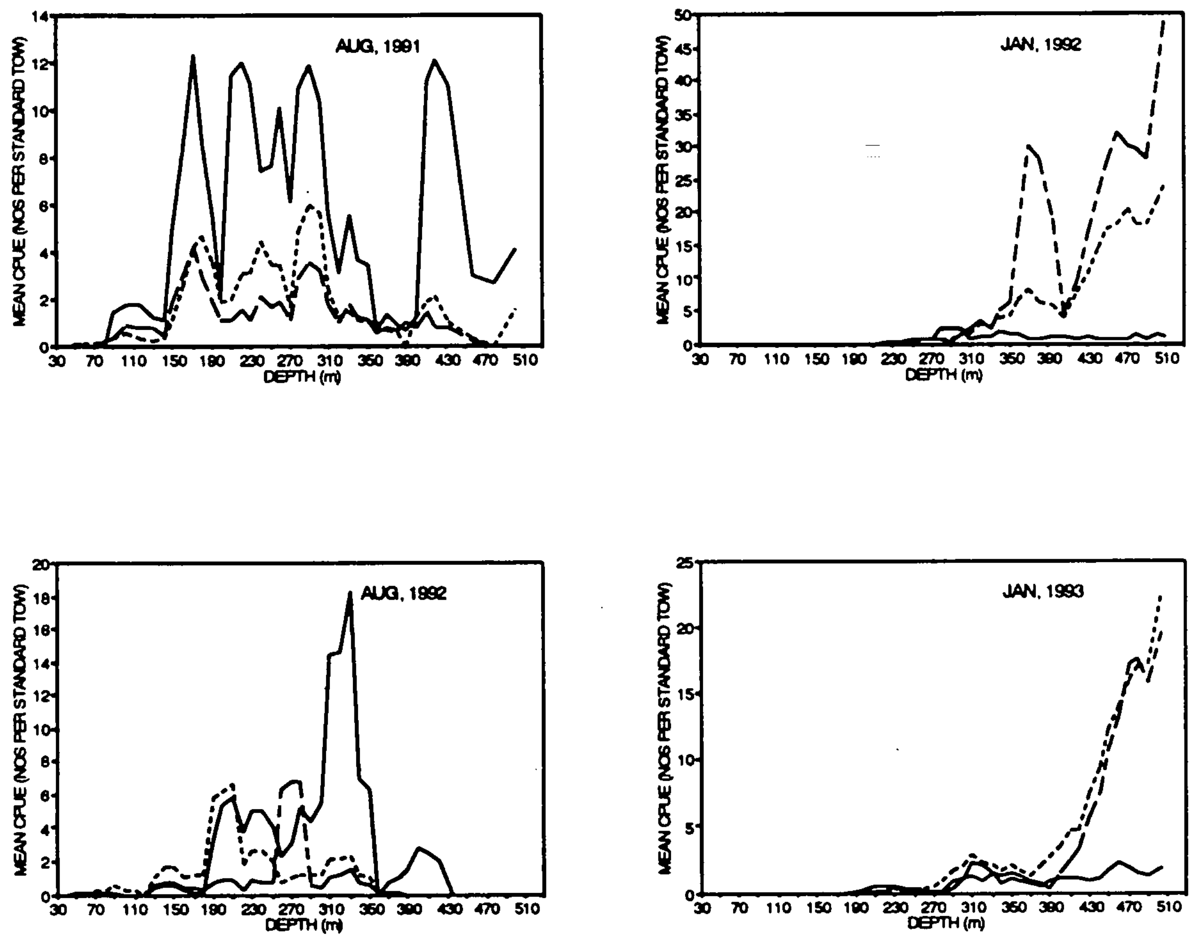

Figure 5. Mean catch of witch flounder in 10-m depth intervals, smoothed by a running average of three. Catch data are presented by size categories corresponding to the first quartile of length frequencies (solid line), second and third quartiles (dotted line), and fourth quartile (dashed line). Length intervals are equivalent for corresponding August and January surveys (intervals are listed in Table 8).

WITCH CATCH (kg)
Gulf/Quebec LADY HAMMOND Surveys - Aug./Sept.

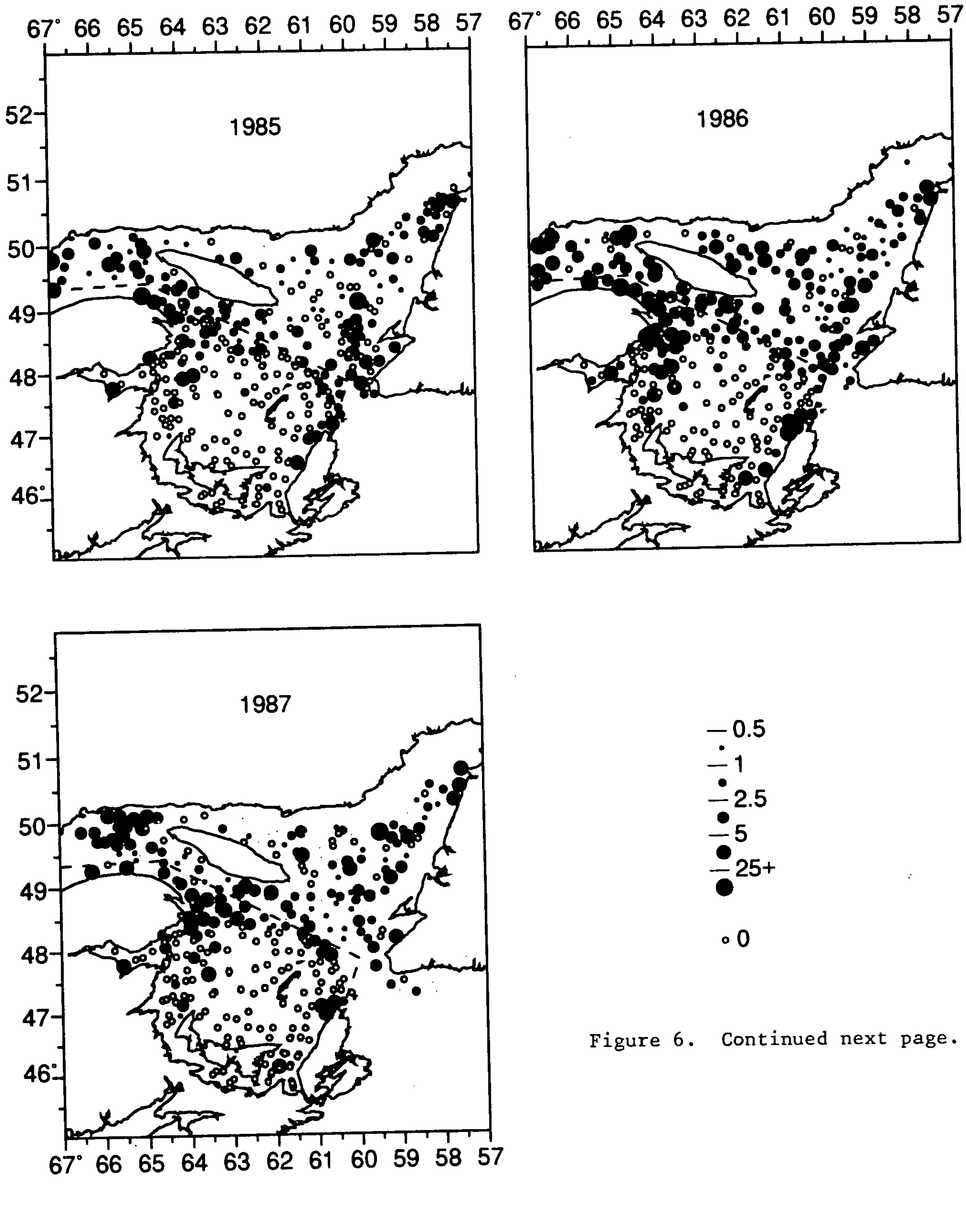

Figure 6. Continued next page.

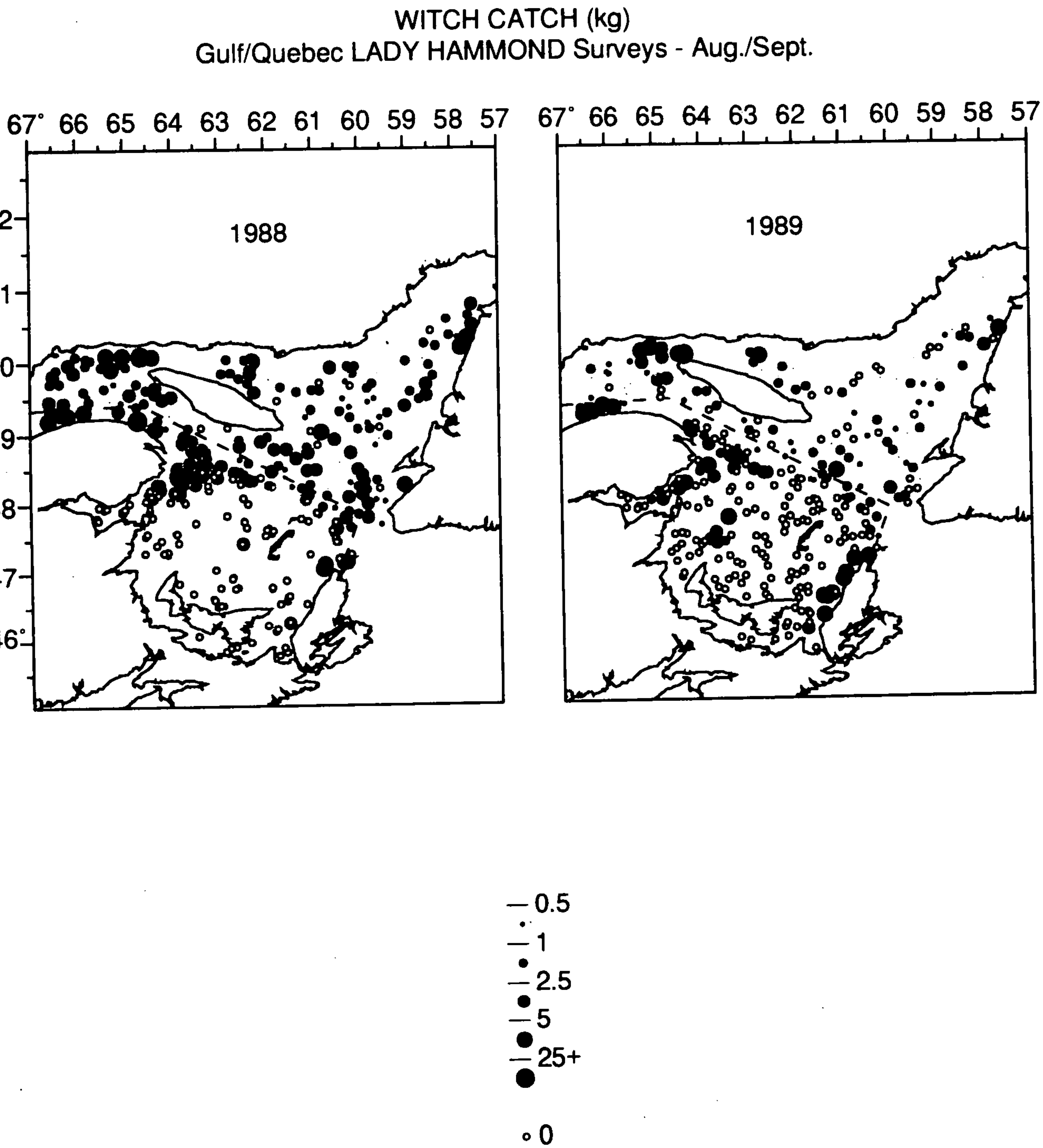

Figure 6. Witch flounder catch as kg/standard tow in research surveys of the Lady Hammond during August and September groundfish surveys, 1985-1989.

WITCH CATCH (kg)
Quebec GADUS ATLANTICA Surveys - Jan.

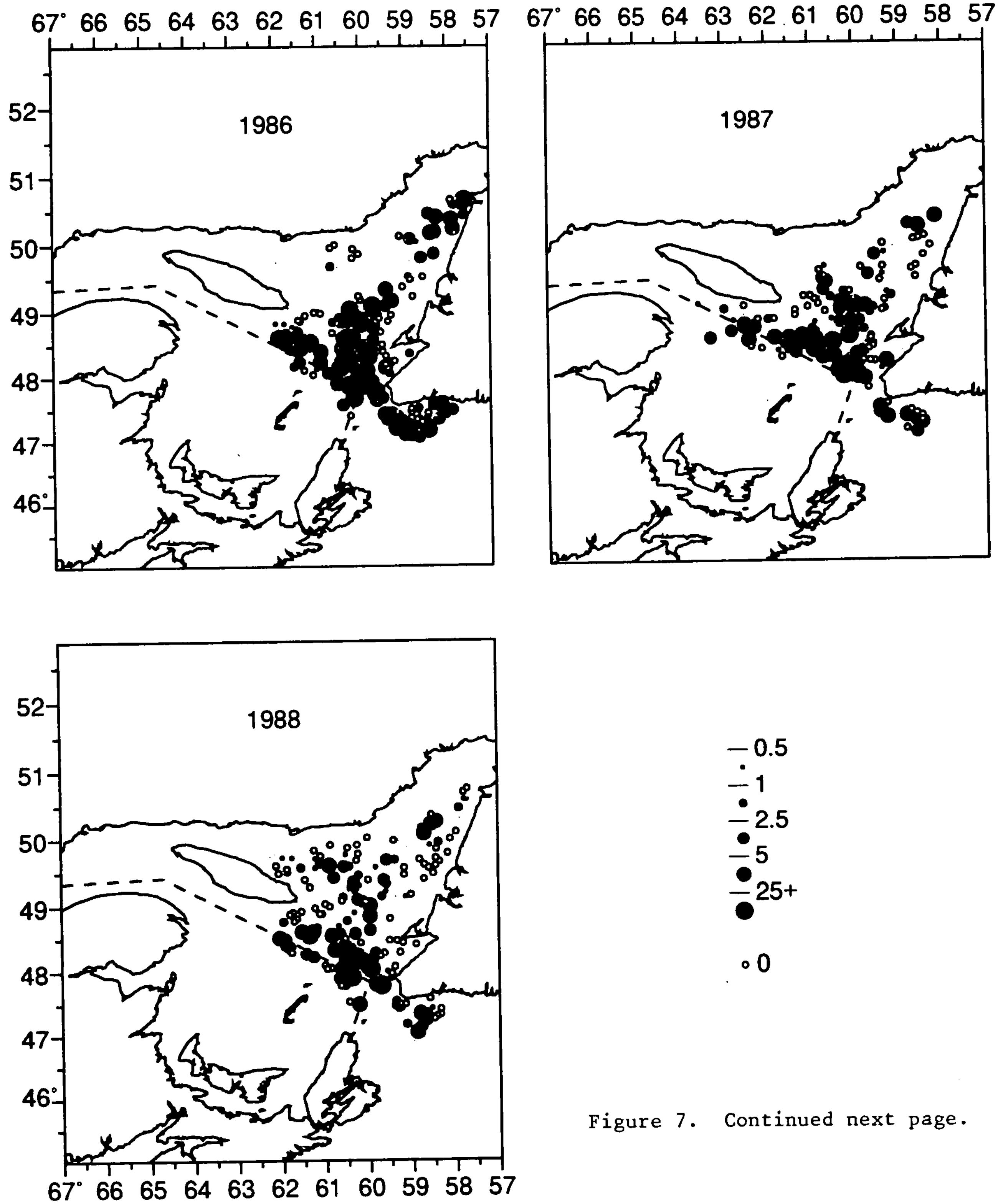

Figure 7. Continued next page.

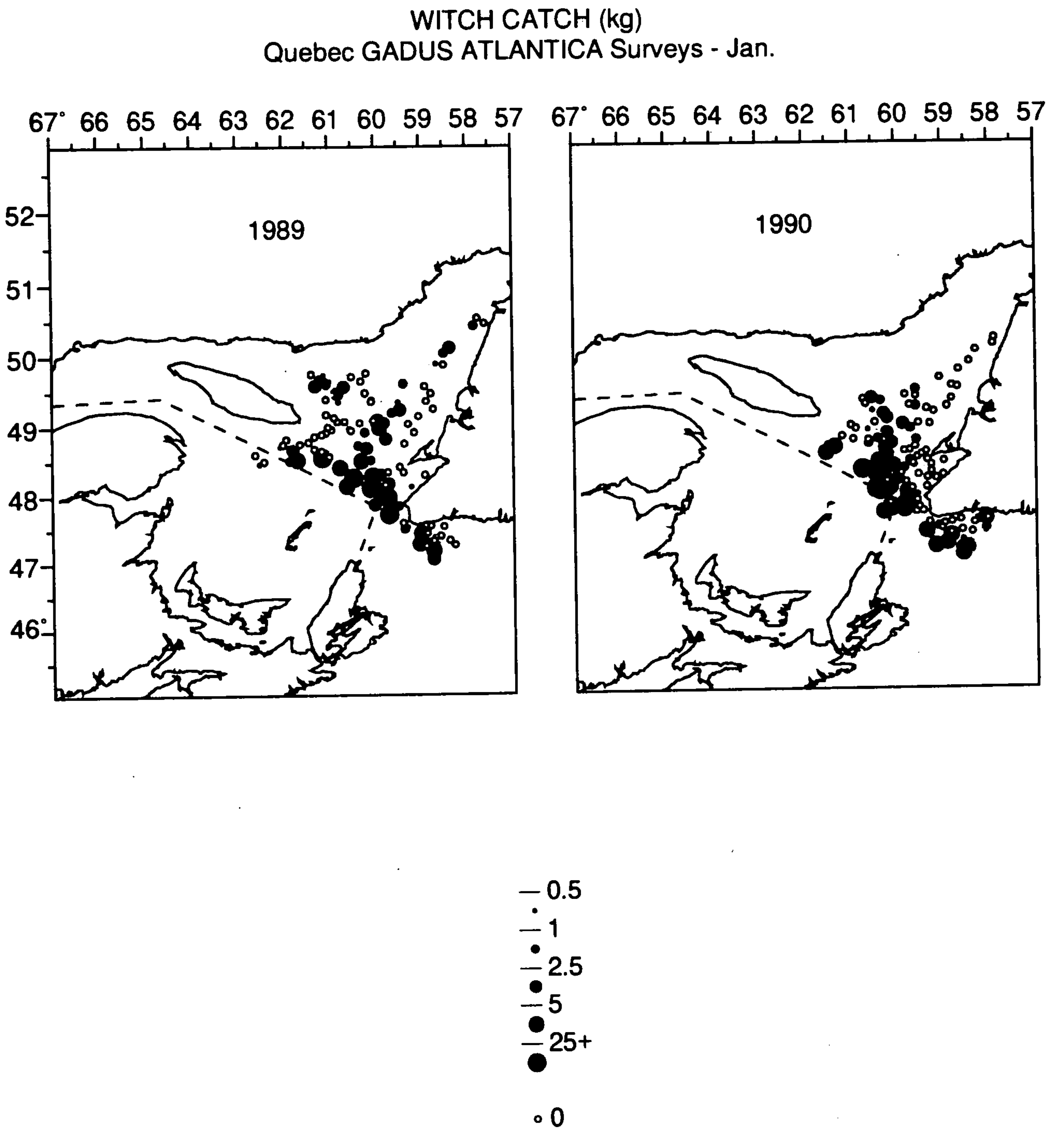

Figure 7. Witch flounder catch as kg/standard tow in research surveys of the <u>Gadus Atlantica</u> during January, 1986-1990.

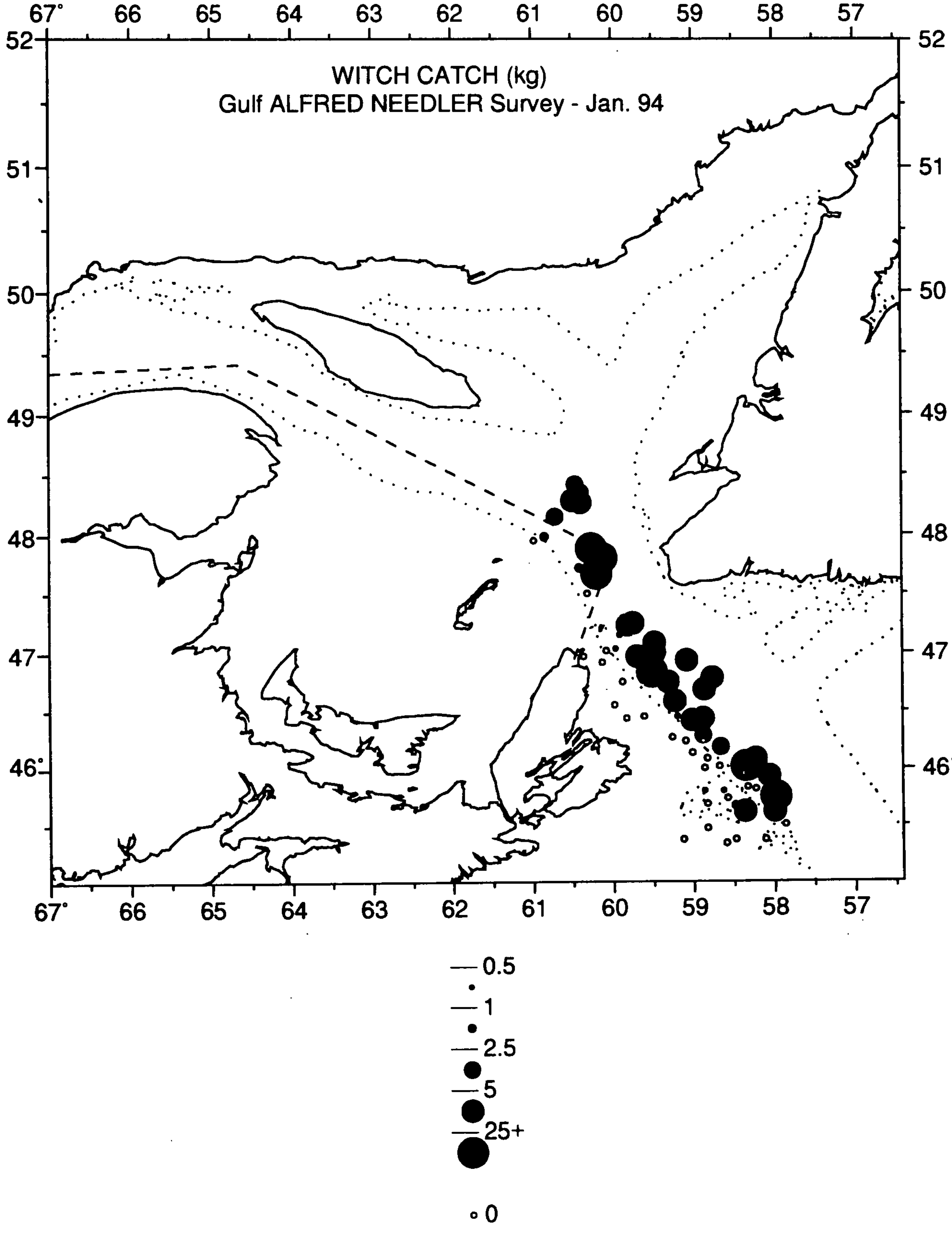

Figure 8. Witch flounder catch as kg/standard tow in the research survey of the Alfred Needler in January 1994.