Northwest Atlantic Fisheries Organization

Serial No. N2739 NAFO SCR Doc. 96/63

SCIENTIFIC COUNCIL MEETING - JUNE 1996

Should Closed Areas be Considered as a Management Measure in Future Fisheries for Cod and Flatfish on the Southern Grand Bank

by

W. B. Brodie

Science Branch, Dept. of Fisheries and Oceans
P. O. Box 5667, St. John's, Newfoundland, Canada A1C 5X1

INTRODUCTION

On the southern Grand Bank, NAFO Divisions 3NO, cod, American plaice, and yellowtail flounder comprised the bulk of the Canadian trawler catches in the 1970's and 1980's. Catches from these three groundfish stocks also made up the majority of catches by other fleets fishing in the Regulatory Area on the Tail of the Bank (Fig. 1). Fleets from Spain and Portugal, which traditionally fished for cod to salt, were joined by freezer trawlers of these nations, and by fleets from South Korea, U.S.A., and various 'flags of convenience' such as Panama and Caymen Islands. As a result, catches increased substantially in the mid 1980's (Fig. 2), then fell dramatically in the early 1990's as stocks collapsed and moratoria were imposed (NAFO S.C. Rep. 1994). Fisheries for these three stocks remain closed through 1996, with little or no evidence of improvement in stock status, particularly for cod and plaice.

From a biological perspective, yellowtail, cod, and American plaice share some common features. One of these is the presence of relatively large areas on the southern Grand Bank where substantial percentages of the juvenile fish in the populations can be found. These locations, commonly referred to as oceanic nursery areas, have been discussed extensively in much of the literature on groundfish distribution on the Grand Bank, particularly for the flatfish species (Walsh 1991, Walsh et al. 1995a). On the Tail of the Bank, these nursery areas extend on both sides of the Canadian 200 mile limit and overlap much of the adult distributions, exposing the juveniles to fishing pressure from fleets on both sides of the line. In fisheries for all three species, catches of small, immature fish were prevalent at various times, and were identified many times as a problem in managing the stocks effectively (Walsh et al. 1995a, NAFO S.C. Rep. 1990, 1992).

In this paper, data from the Canadian commercial fishery in Div. 3NO was examined and related to the distributions of groundfish observed in research vessel surveys in this area. The focus was on yellowtail flounder, as this species is limited mainly to the Southeast Shoal (areas labelled 375 and 376 in Fig.1) and surrounding region, and has a single nursery area for the entire stock. The ultimate goal of this work is to determine if one or more areas on the Grand Bank can be defined where catches of juvenile flatfish and cod could be eliminated when commercial fisheries are reopened. The more modest goal of this paper is to present some information to Scientific Council to stimulate discussion on the usefullness of closed areas as a management tool in the cod and flounder fisheries in Div. 3NO, and to determine if and how fishery and survey data can be used jointly in the definition of such areas.

METHODS AND MATERIALS

To obtain a sample of the Canadian commercial trawler fleet which fished in Divisions 3NO, 15 stern trawlers belonging to Fishery Products International (FPI) Ltd. were selected (Table 1).

PLEASE NOTE: IN SOME CASES, THE GREY-SCALE SHADING IN THE SPANS MAPS LOST SOME CLARITY WHEN THE ORIGINAL FIGURES WERE REPRODUCED.

Vessels from this company fished on the southern Grand Bank since the 1950's, and FPI possessed more than 85% of the flatfish quotas available to Canadian companies under enterprise allocations in most years. The boats chosen were ranked 1 to 15 in cumulative catch of yellowtail in Div. 3NO from 1985 to 1993, and were consistently among the high-liners in catches of American plaice and cod. These vessels also fished extensively in Div. 3L, but only the data for Div. 3NO were examined, as this study is limited to the southern Grand Bank area.

A typical vessel in this sample was about 45-50 meters in length, about 550-650 GRT, between 1300 and 1600 HP, and fished with a commercial otter trawl. Fishing trips were usually 10 days long, with catches being iced in the hold and processed on land after the vessel returned to port. Catches from a trip often consisted of a mixture of groundfish species, mainly the three species examined in this paper, but also including witch flounder, redfish, haddock and by-catches of many other species, such as skates, hakes, and wolffishes.

Data on catch and effort, which were completed by ship's officers on a set by set basis, were obtained from the vessel's fishing logs from 1985 to 1993, the last year the cod and flatfish fisheries in Div. 3NO were open to these vessels. Prior to 1985, logbook data were collected in a different format, and set by set information was not readily available. An entry in the log for a fishing set included the date, position, duration, depth, codend mesh size, main species sought, as well as catch and discard estimates, by species. The logbook data were compiled and various maps of catch and effort were generated using potential mapping techniques with SPANS software (Anon 1993). A description of the mapping techniques used is contained in Appendix 1.

Results for 1986-94, from research vessel surveys directed at juvenile flatfish and cod on the Grand Bank, were mapped to compare the distributions of these species with the location of the commercial fishery in the same area. These survey data have been used extensively in the past to map the distribution of juvenile fish on the southern Grand Bank in particular, most recently by Walsh et al. (1995a).

RESULTS AND DISCUSSION

Canadian fishery. Nearly 50,000 tows were made during 1985-93 by the 15 vessels selected, split almost evenly between Div. 3N and 3O (Table 2, Fig. 3a). These tows represented over 146,000 hours of fishing and accounted for 29% of the total Canadian catch of yellowtail in Div. 3NO from 1985-93. The mean tow duration was around 3 hours, with no real trend from 1986 to 1992, although the low and high points in the series were in 1985 and 1993 respectively. When compared to the actual main species in the catch, the main species recorded in the log was generally in agreement from 1985-91 (87% for cod, 64% for plaice, and 76% for yellowtail). In 1992-93, there were few tows logged with main species sought as cod or yellowtail, and only 32% of those directed at plaice actually had plaice as the main species in the catch (37% had yellowtail).

Categorized by main species sought, the data show a clear progression of effort from Div 3N to Div. 3O over the time period studied (Fig. 3b), as the Canadian offshore fishery gradually moved toward the southwest part of the Grand Bank. This is reflected in the divisional breakdown of the Canadian nominal catches of yellowtail by the trawler fleet in total (Fig. 4). The fishery in Div. 3L (which was not sampled in this study), exceeded 2500 tons in several years, and peaked at 5300 tons in 1984, before declining to negligible levels in 1992-93.

As seen in Fig 3b, the majority of sets in most years was directed at American plaice, often with desired by-catches of cod and yellowtail. With the rapid and severe decline in the stock of A. plaice on the Grand Bank, a greater proportion of the remaining plaice population was found on the southern Grand Bank, south of 45 degrees North latitude (Fig.5), resulting in a change in fleet behavior. Declining quotas for all three species also brought on more restrictive trip limits for individual species, resulting in further modifications in the fishing patterns.

Fig. 6 shows the difference in the location of yellowtail catches in 1985 and in 1993, from the vessels sampled. In 1985, yellowtail catches were concentrated on or near the Southeast Shoal, in Div. 3N, and in an area near the 3L/3N border. In 1993 however, the bulk of the yellowtail catch was taken in Div. 3O, with lesser catches occurring near the 3O/3N border, in areas removed from the highest densities of yellowtail. Catches were small on the Southeast Shoal and in the northern part of Div. 3N, in contrast to 1985. The catch data for 1985 and 1993 for plaice and cod (Figs. 7 and 8 respectively), also reflect the shift in effort to Div. 3O. Thus in 1993, the fleet had moved to an area where plaice could be fished while maintaining an acceptable level of by-catch of the other two species. Such shifts have confounded the interpretation of catch rates in these fisheries in past assessments (eg. Brodie et al 1993).

As can be seen in Figs. 6-8, there was some catch taken outside the 200-mile limit by these vessels in 1985, the last year in which there was a substantial amount of Canadian effort in that area. Brodie (1992) showed that the densities of flounders and cod in the mid 1980's were generally lower just outside the 200-mile limit compared to the area just inside the limit. Canadian trawler captains also claimed during this period that their catch rates usually declined substantially if they fished as little as a kilometer outside the 200-mile limit. Thus the effort by this fleet in the Regulatory Area was minimal during the period of this study, and precludes any comparisons of fishery data from inside and outside the 200 mile limit.

To get an overall picture of catch and effort in the Canadian trawler fleet from 1985-93, data from the sampled vessels were pooled for the whole period. The data were divided into categories by main species sought and the resulting maps of effort, catch, catch rate and by-catch are contained in Appendix 2.

Research Vessel Surveys. Yellowtail catches from the juvenile groundfish surveys of 1986-94 in Div. 3NO are shown in Fig. 9. The distribution of yellowtail is centered around the Southeast Shoal, as has been noted in previous studies on distribution of this stock (Walsh et al. 1995b). The reason for the wider distribution of large catch weights compared to numbers can be seen in Fig. 10, which shows the predominance of young yellowtail in the area just south of the 200-mile limit. Brodie et al. (1993), based on these survey data, showed that as much as 70-80% of yellowtail population numbers at age 3 are consistently contained in this region, and that the fish spread in a northwest direction as they get older. This is supported by Fig 10, which shows the broader distribution of older yellowtail, including overlap with the juveniles.

Information on American plaice and cod distribution from these surveys was presented in Walsh et al. (1995a), and Walsh and Murphy (1994) and has not been updated here. Young American plaice are more widely distributed over the Grand Bank than yellowtail (Fig. 11), with the highest densities on the southern Grand Bank occurring in the Regulatory Area in Div. 3N, and in Whale Deep in Div. 3O (area 339 in Fig. 1). On the northern Grand Bank, juveniles of this species occur over a broad area on the northeast slope in Div. 3L. Juvenile cod are distributed over much of the southern Grand Bank, with highest densities often found in and around the Southeast Shoal area (Fig. 12). For both plaice and cod, there is substantial overlap of the adult and juvenile components of the population, as measured by these surveys.

Although there is considerable overlap in the nursery areas for the three species examined here, it is clear that there are also distinct areas for each species. The distribution of juveniles of the two flounder species on the southern Grand Bank shows that the Tail of the Bank is important for both species, even though the distributions of young fish do not coincide over all of this area.

Catches of Juvenile Groundfish in Fisheries in Div. 3NO. The overlap of the adult and juvenile portions of all three populations in certain areas was one contributing factor to high fishing mortality on juvenile cod and flatfish on the Grand Bank for many years. However, it was not the only factor. Throughout the late 1980's and early 1990's, NAFO Scientific Council Reports contained numerous references to excessive catches of juveniles of all three species, with recommendations that these catches be eliminated. Catch at age data from some fleets indicated that the trawl mesh size used was considerably smaller than the 120-130 mm regulated size, and ship-board inspections revealed that the use of small-mesh liners in codends was not uncommon. There was also a considerable amount of catch taken by non-NAFO member fleets, some of whom ignored NAFO-imposed quotas and fishing regulations on the Grand Bank. Cod were being caught in large numbers at ages 1 and 2, as were flounders at ages 2-4, well before the age of maturity for any of these species. These problems continued right up to the closure of directed fisheries for these stocks in 1994. This measure, followed by a moratorium on fishing these stocks in 1995 and 1996, has resulted in severe reductions in catches of all three species in Div. 3NO.

Closed Areas as a Management Tool. Closed areas have been defined for many fisheries, often as a means to protect spawning (eg. Brown's Bank haddock) or juvenile (eg. North Sea plaice) fish. The potential benefits of such closed areas are obvious - they allow adult fish to spawn or they allow juveniles to grow to adult stage, before they are caught in either instance. As pointed out by Kenchington (1995), such closures are only of use to a fishery if they produce an increase in the fishable resource somewhere outside the boundaries of the closed area. Yellowtail flounder on the Grand Bank offers an excellent example, where most of the juveniles of a cohort are confined to a smaller area than the subsequent distribution of adults from that cohort. Clearly, protection of the yellowtail juveniles in the nursery area should lead to an increase in the outflow of adults ultimately available to the fishery. Other measures, such as restrictions on fishing mortality through catch limits, gear restrictions, mesh size regulations, etc. would obviously be required in the fishery, but these have been almost impossible to enforce and without question have not been successful in controlling this fishery in the recent past.

There are many arguments in favor of closed, or protected, areas as a management measure on the southern Grand Bank, and few against, particularly in the context of the current fishery moratorium. The existence of such an area could serve as a precautionary measure against overexploitation, or "hedge against uncertainty" (Kenchington, 1995), given that levels of uncertainty in fisheries science, and hence management, are often extremely high. Many fishermen are generally in favor of the concept of closed areas, as they understand the destructive nature of landing or discarding juvenile fish and have seen for themselves the areas where juveniles are most abundant in their catches. To define a closed area during a time when entire fisheries are closed is also more reasonable than defining such an area when it is actively being fished, as no vessels would have to be displaced suddenly.

Major practical considerations with closed areas include definition and enforcement. If the idea of closed areas is to be pursued further, it will obviously require considerable thought on the boundaries - what species are to be protected and what other fisheries will be affected. Data presented here showed that Canadian fisheries on the southern Grand Bank were quite dynamic in the period 1985 to 1993, as species abundance and distribution changed along with quotas. At present, there is a substantial amount of Canadian fishery data (mainly from inside the 200-mile limit), as well as survey data, which could be used. Information from fisheries which operated outside 200 miles on the Tail of the Bank during this period would also be useful, if it can be acquired.

To require that the benefits of a closed area, such as the expected improvement in recruitment, first be demonstrated statistically beyond any doubt would doom the idea to failure; the data required to predict changes in seasonal distribution, spawning success, survival rates, migration patterns, predator/prey interactions, and other ecosystem elements will likely never be available to allow such calculations to be done with sufficient confidence. The rationale for a closed area must therefore be along the lines of reducing uncertainty by improving chances for good recruitment to the fishery, improving yield per recruit, protecting juvenile habitat, providing a refuge for fish, etc. At a time when most stocks are at historic lows and fisheries are closed, the potential benefits of defining a closed area to implement when fisheries reopen would seem to far outweigh the drawbacks.

Acknowledgments

The author wishes to thank several people who made valuable contributions to the work contained here. Carla Barnes, Bill Smith, and Gabe Gregory of FPI Ltd. were very helpful in acquiring the trawler data. Lloyd George, Barb Greely, Heather Squires, and Darren Warford coded the information from the logbooks, and Charlene Peckham of Beothuk Data was responsible for the data entry. Wince Legge, Ann Marie Russell, and Darlene Gillett of DFO were all instrumental in establishing the trawler database. John McClintock of Seaborne Information Technologies did much of the tabulation and background analysis of the fishery data. Neil Ollerhead produced many maps from the data, a few of which are contained here, and provided documentation (and numerous explanations to the author) on the SPANS mapping techniques. The project was supported within DFO by the Oceans Science Programs Fund.

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Table 1. List of 15 vessels from Fishery Products International Ltd. from which logbook data were used in this study.

Atlantic Beatrice	*Grand Baron*	*Newfoundland Eagle*
Atlantic Carol	*Grand Count*	*Newfoundland Kestrel*
Atlantic Elizabeth	*Grand Knight*	*Zebulon*
Atlantic Jane	*Grand Prince*	*Zinder*
Atlantic Peggy	*Fermeuse*	*Zori*

Table 2. Summary of tow information from 15 FPI vessels sampled in this study.

Year	3N # tows	3O # tows	Total # tows	3N duration(h)	3O duration (h)	Total Dur.	Mean Dur.
85	4011	2170	6181	10843	5574	16417	2.66
86	5560	2250	7810	15869	6202	22070	2.83
87	4217	2159	6376	12090	6618	18708	2.93
88	3590	2118	5708	11068	6477	17545	3.07
89	2670	2461	5131	8404	7152	15555	3.03
90	2027	2057	4084	6017	5663	11680	2.86
91	1386	3577	4963	4126	10362	14488	2.92
92	382	4532	4914	1105	13741	14846	3.02
93	685	4055	4740	2074	13236	15310	3.23
total	**24528**	**25379**	**49907**	**71596**	**75024**	**146619**	
mean	*2725*	*2820*	*5545*	*7955*	*8336*	*16291*	*2.94*

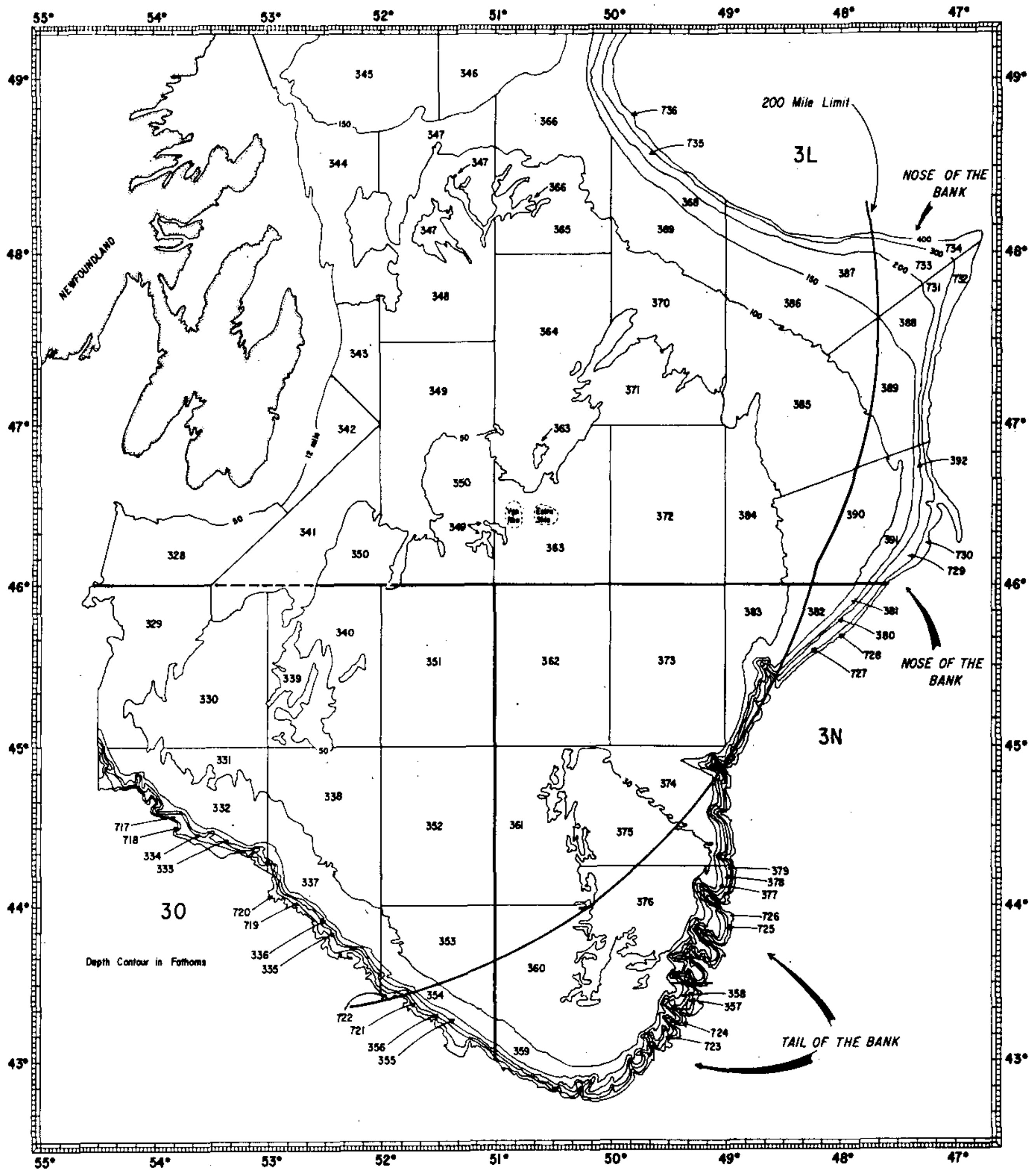


Fig.1. Grand Banks, NAFO Div. 3LNO, showing the Canadian 200 mile limit in relation to the Nose and Tail of the Bank as well as the stratification scheme used in Canadian groundfish surveys.

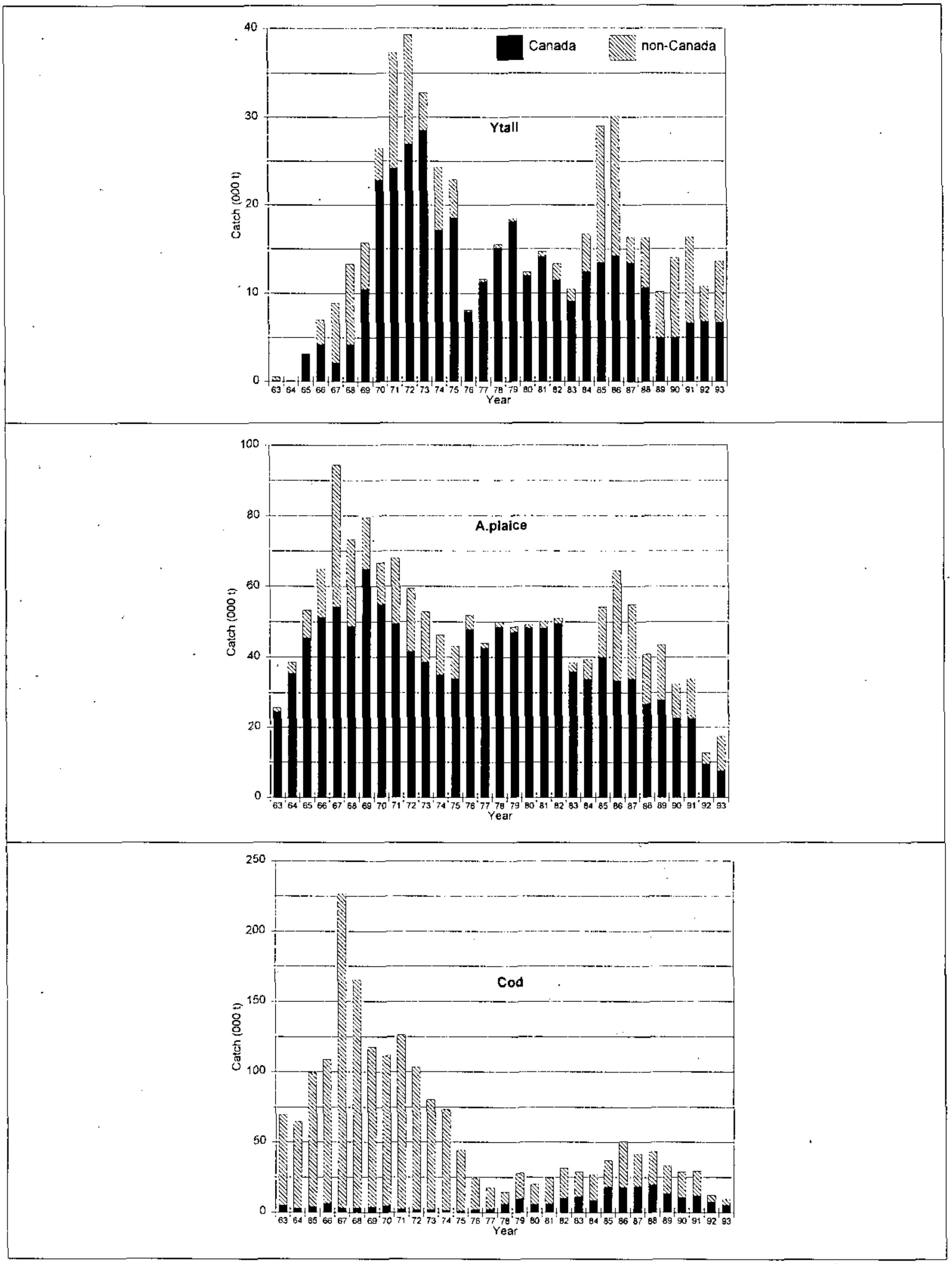


Fig. 2. Nominal catches of cod (Div. 3NO); and American plaice and yellowtail flounder (Div. 3LNO).

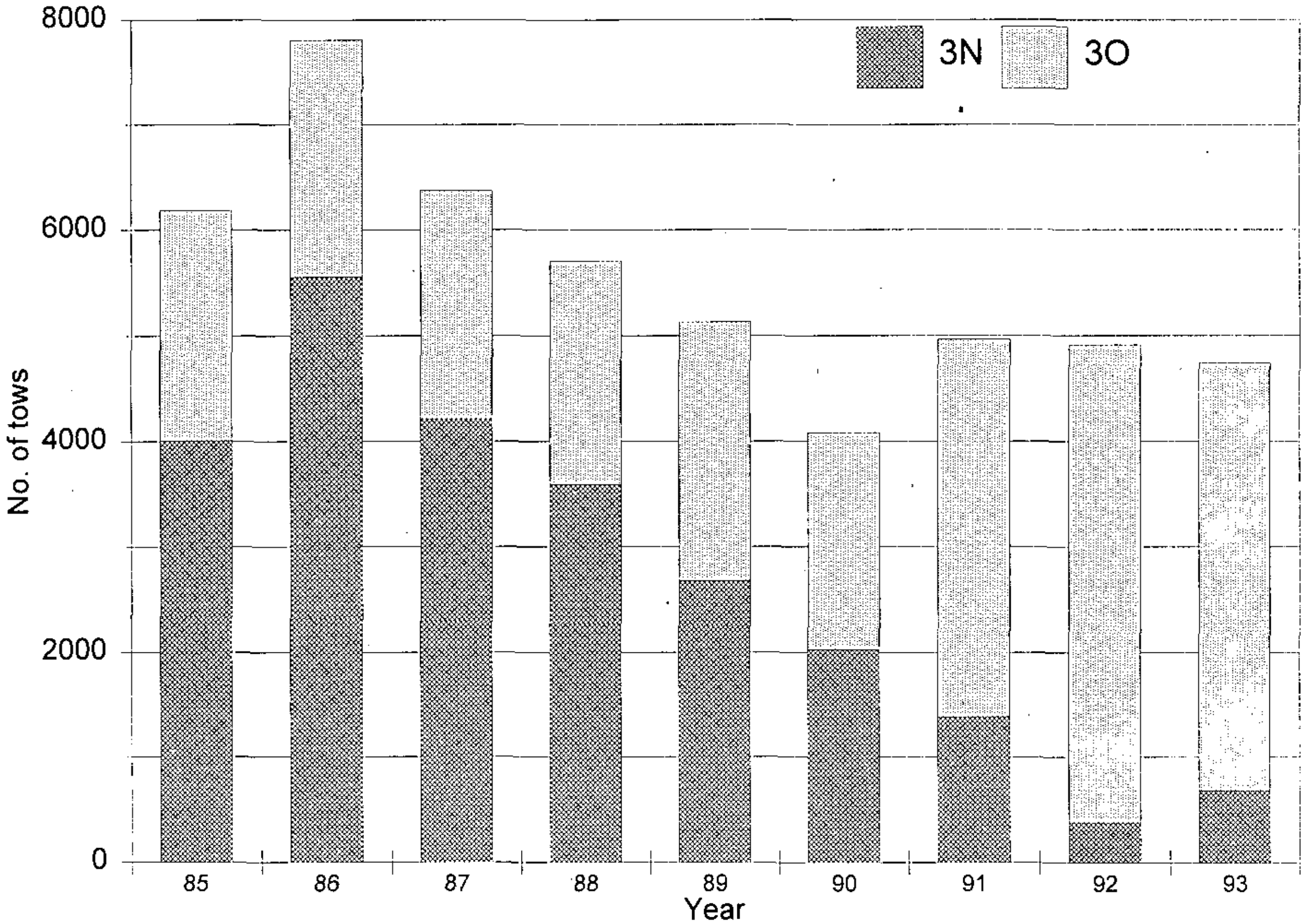


Fig. 3a. Number of tows made by 15
sampled vessels from 1985-93, Div. 3NO

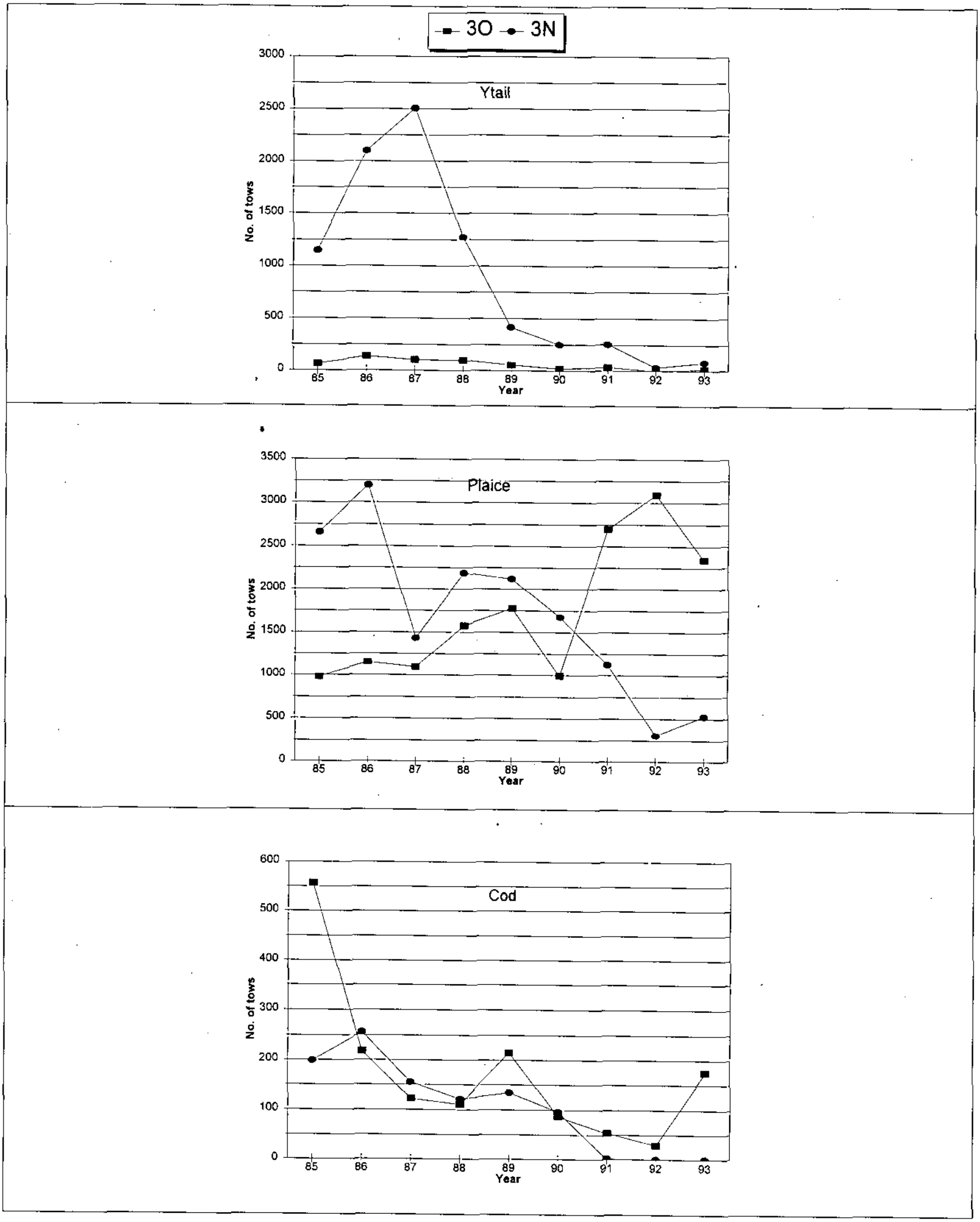


Fig. 3b. Number of tows, by Division and main species sought, from the 15 sampled vessels.

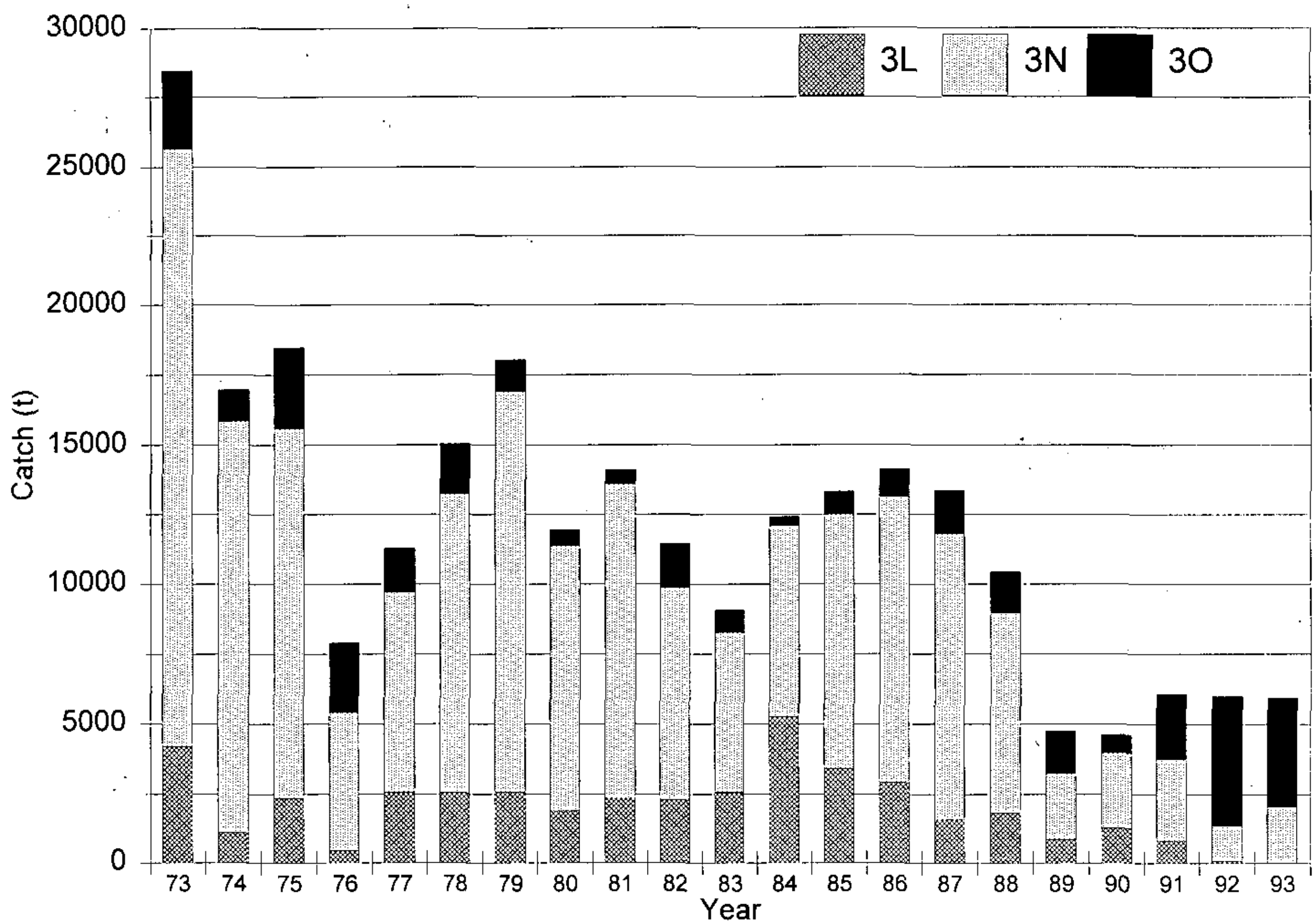


Fig. 4. Nominal catch of yellowtail, by Canada, from 1973-93.

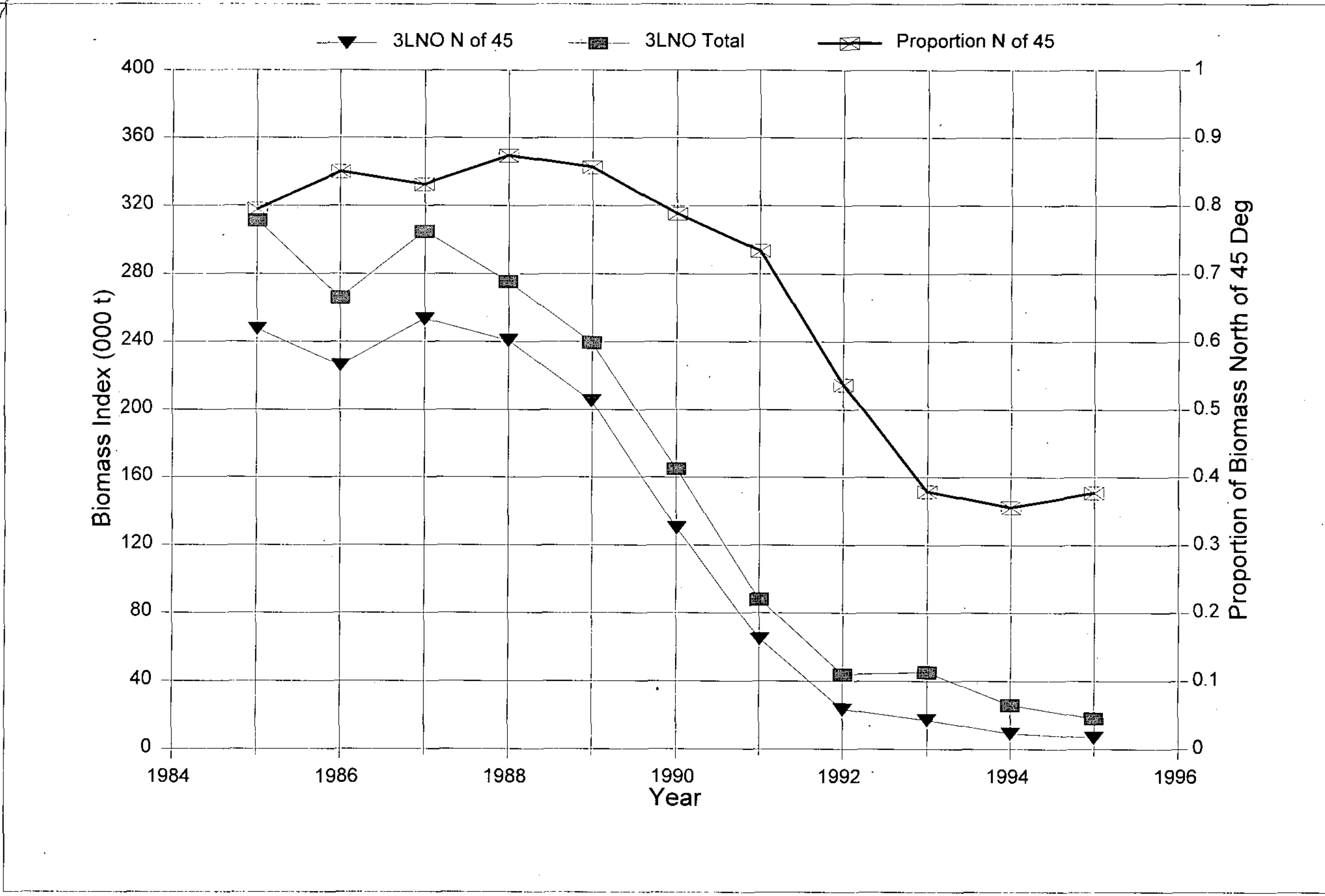
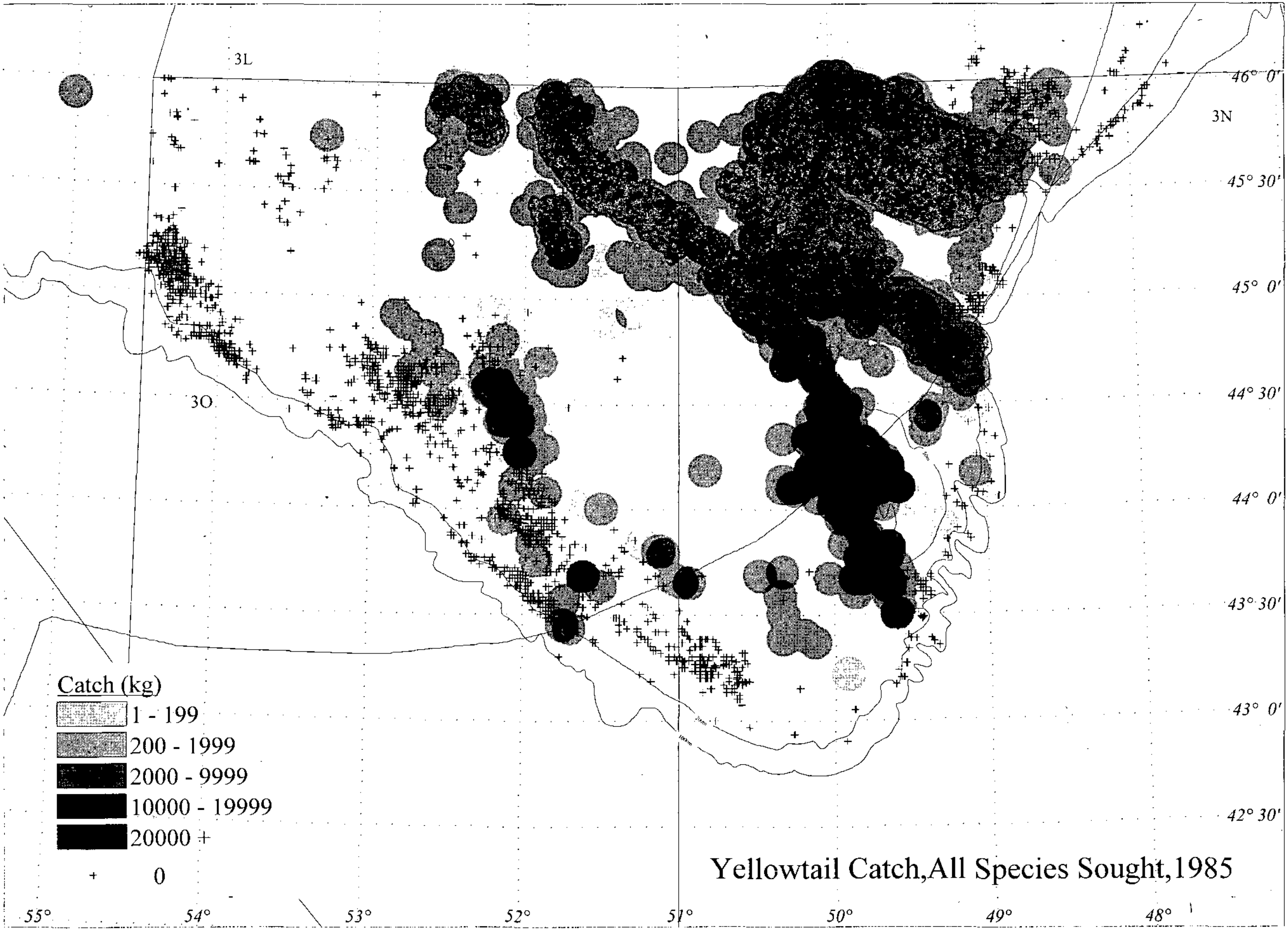


Fig. 5. Proportion of the American plaice stock found north of 45 degrees, as measured by RV surveys.

Fig. 6. Comparison of the fishery for yellowtail in 1985 with the same fishery in 1993.



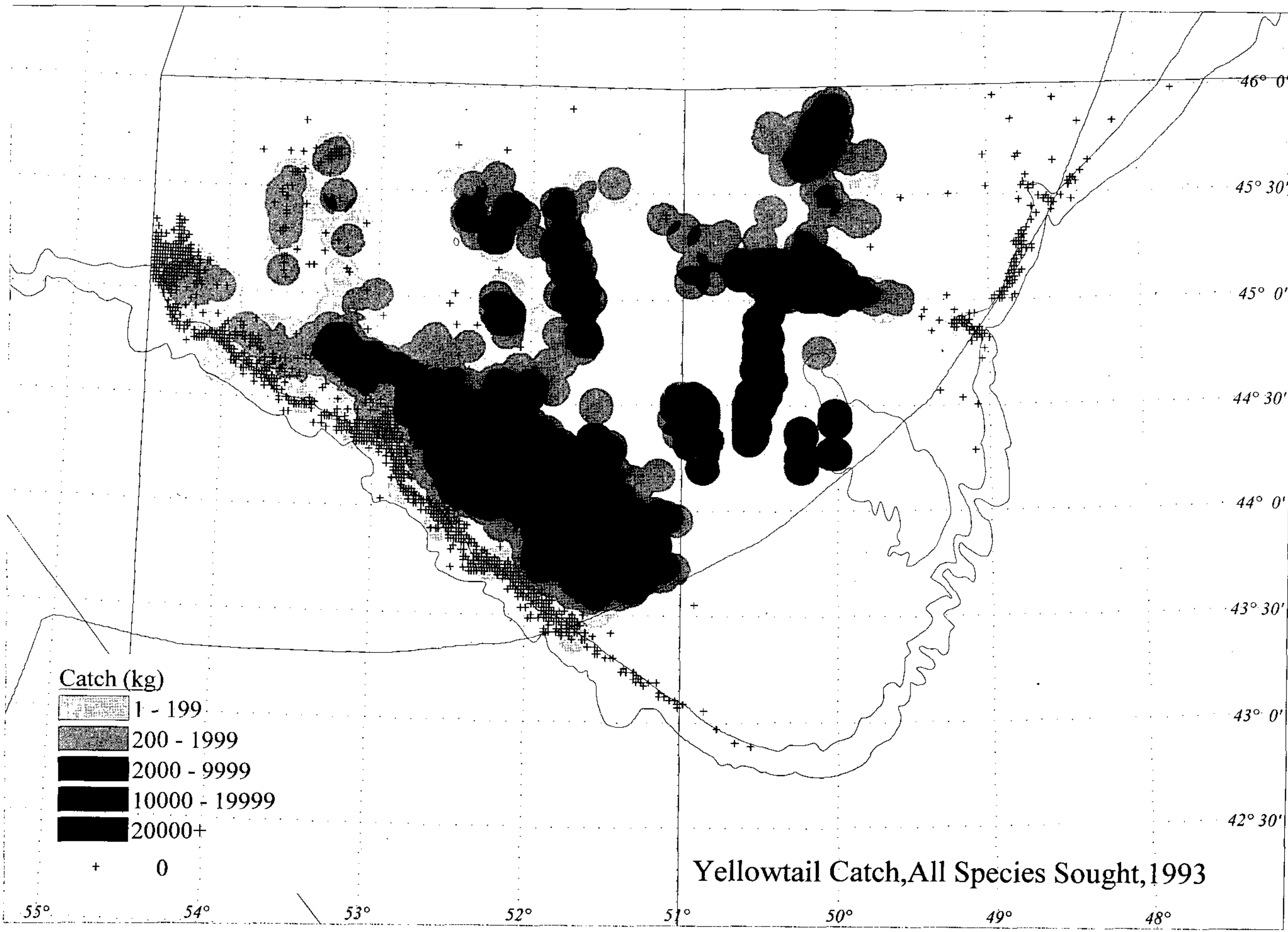
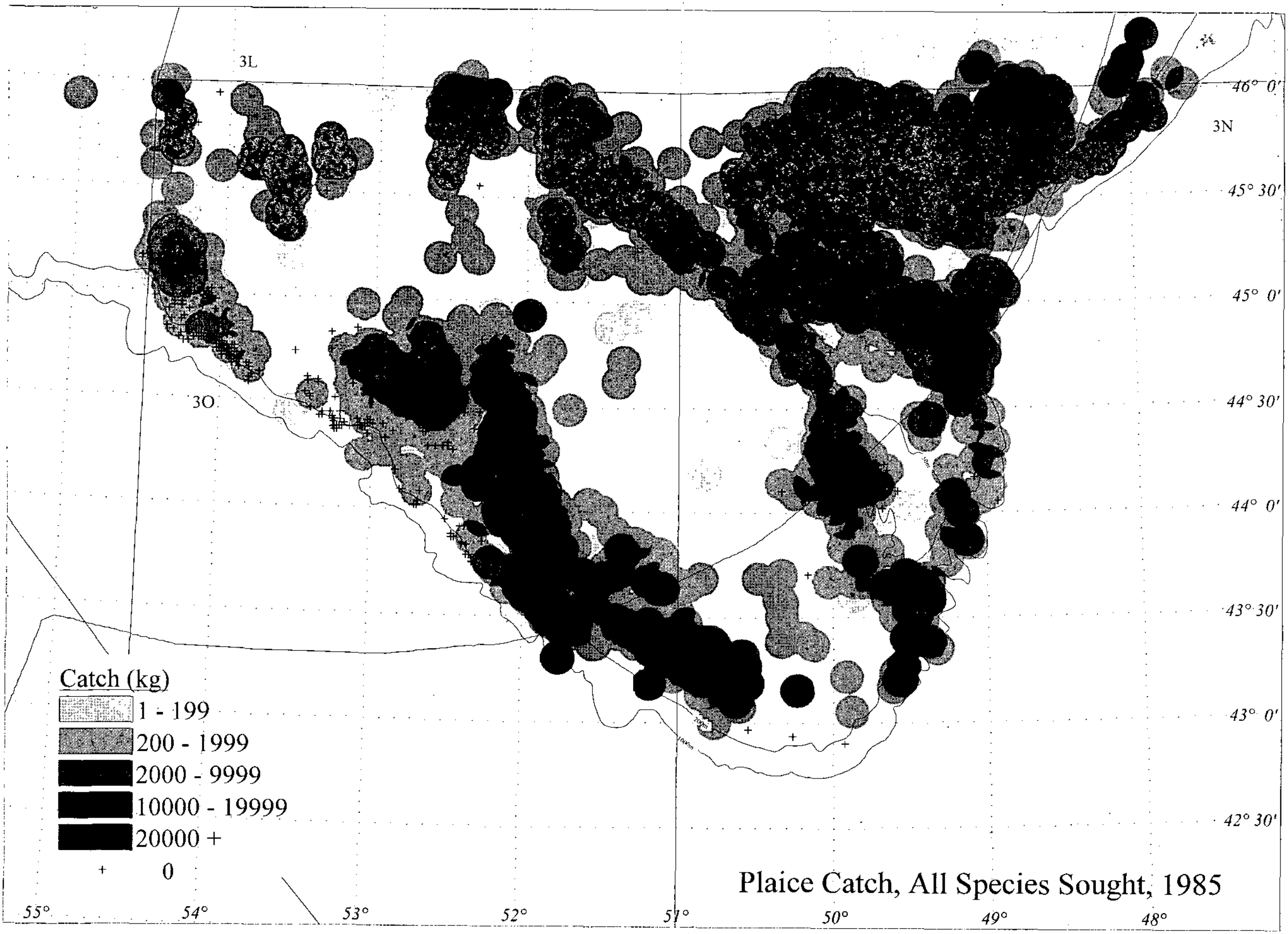
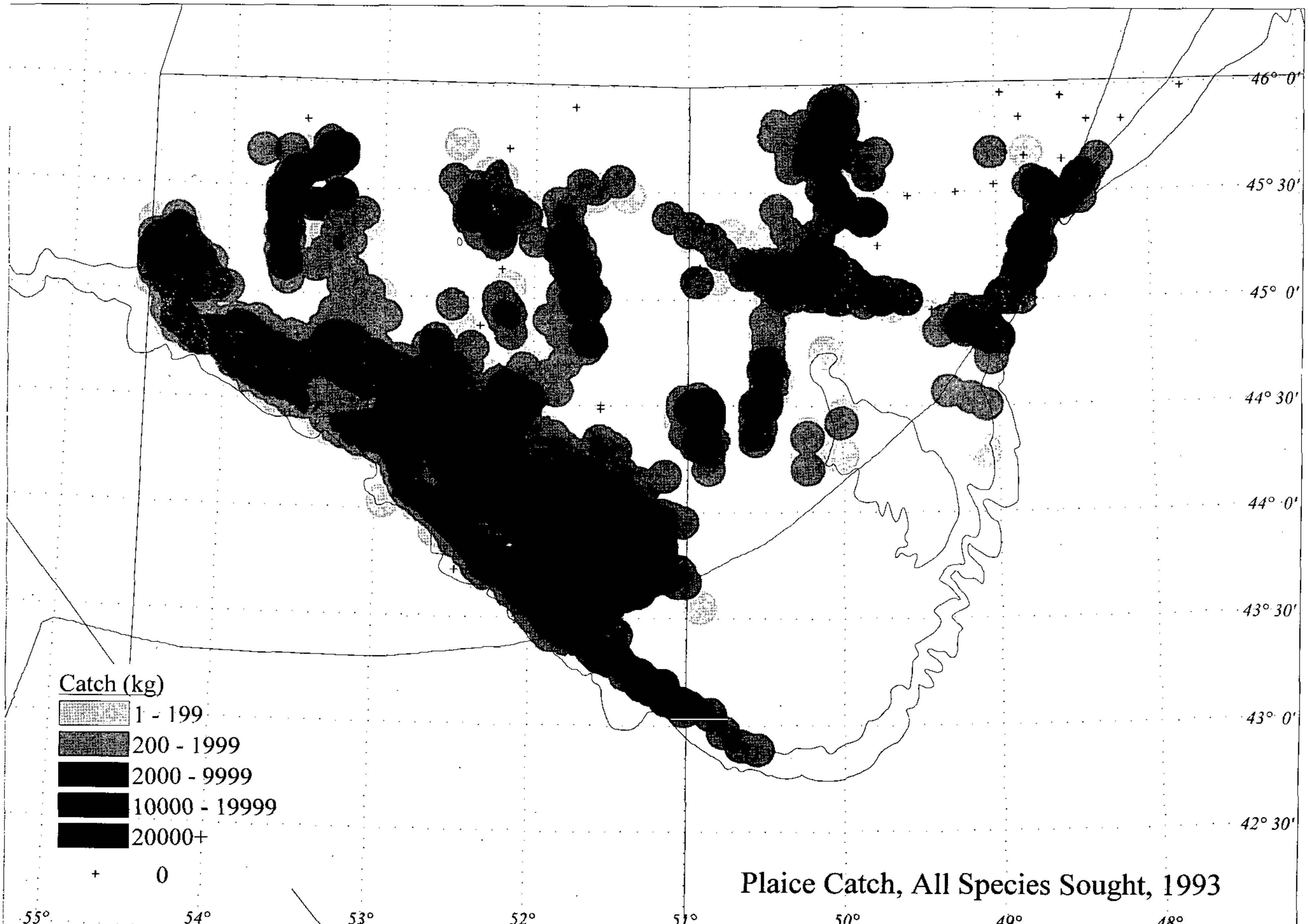

Yellowtail Catch,All Species Sought,1993
Catch (kg)
1 - 199
200 - 1999
2000 - 9999
10000 - 19999
20000+
0
46° 0'
45° 30'
45° 0'
44° 30'
44° 0'
43° 30'
43° 0'
42° 30'
55°
54°
53°
52°
51°
50°
49°
48°

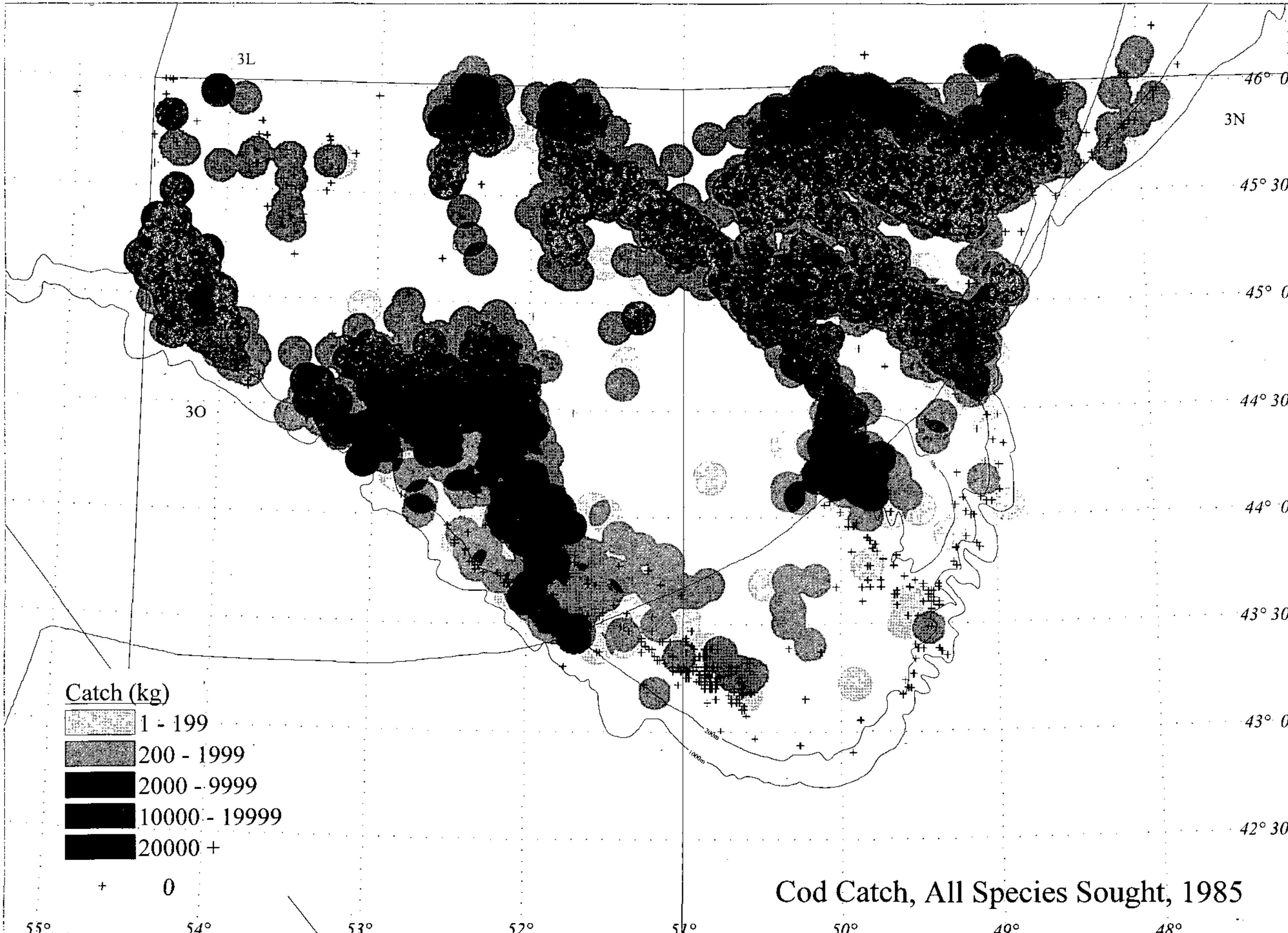
Fig. 7. Comparison of the fishery for A.plaice in 1985 with the same fishery in 1993.

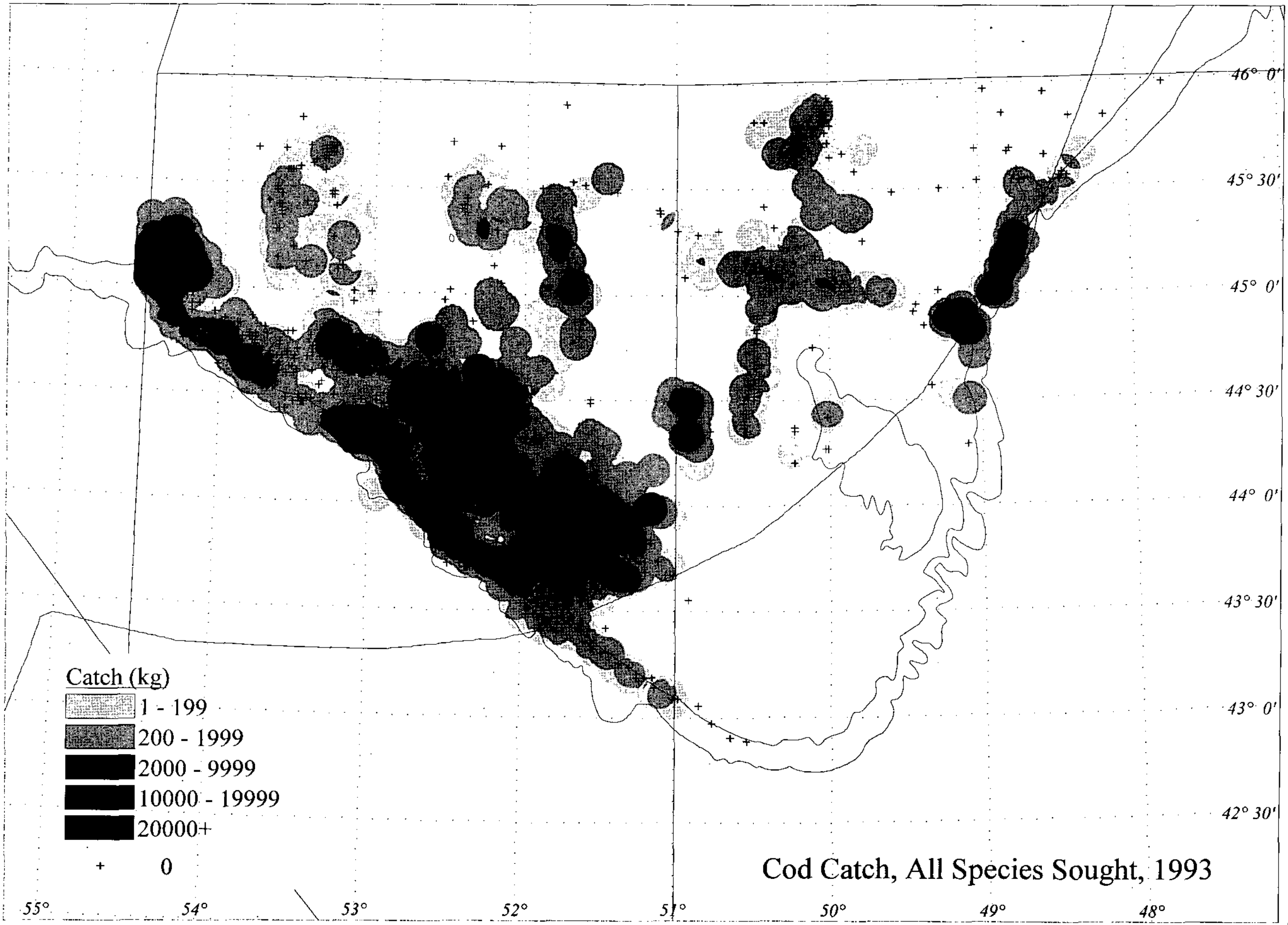




46° 0'
45° 30'
45° 0'
44° 30'
44° 0'
43° 30'
43° 0'
42° 30'
55°
54°
53°
52°
51°
50°
49°
48°
Catch (kg)
1 - 199
200 - 1999
2000 - 9999
10000 - 19999
20000+
0
Plaice Catch, All Species Sought, 1993

Fig. 8. Comparison of the fishery for cod in 1985 with the same fishery in 1993.




46° 0'
45° 30'
45° 0'
44° 30'
44° 0'
43° 30'
43° 0'
42° 30'
55°
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53°
52°
51°
50°
49°
48°
Catch (kg)
1 - 199
200 - 1999
2000 - 9999
10000 - 19999
20000+
0
Cod Catch, All Species Sought, 1993

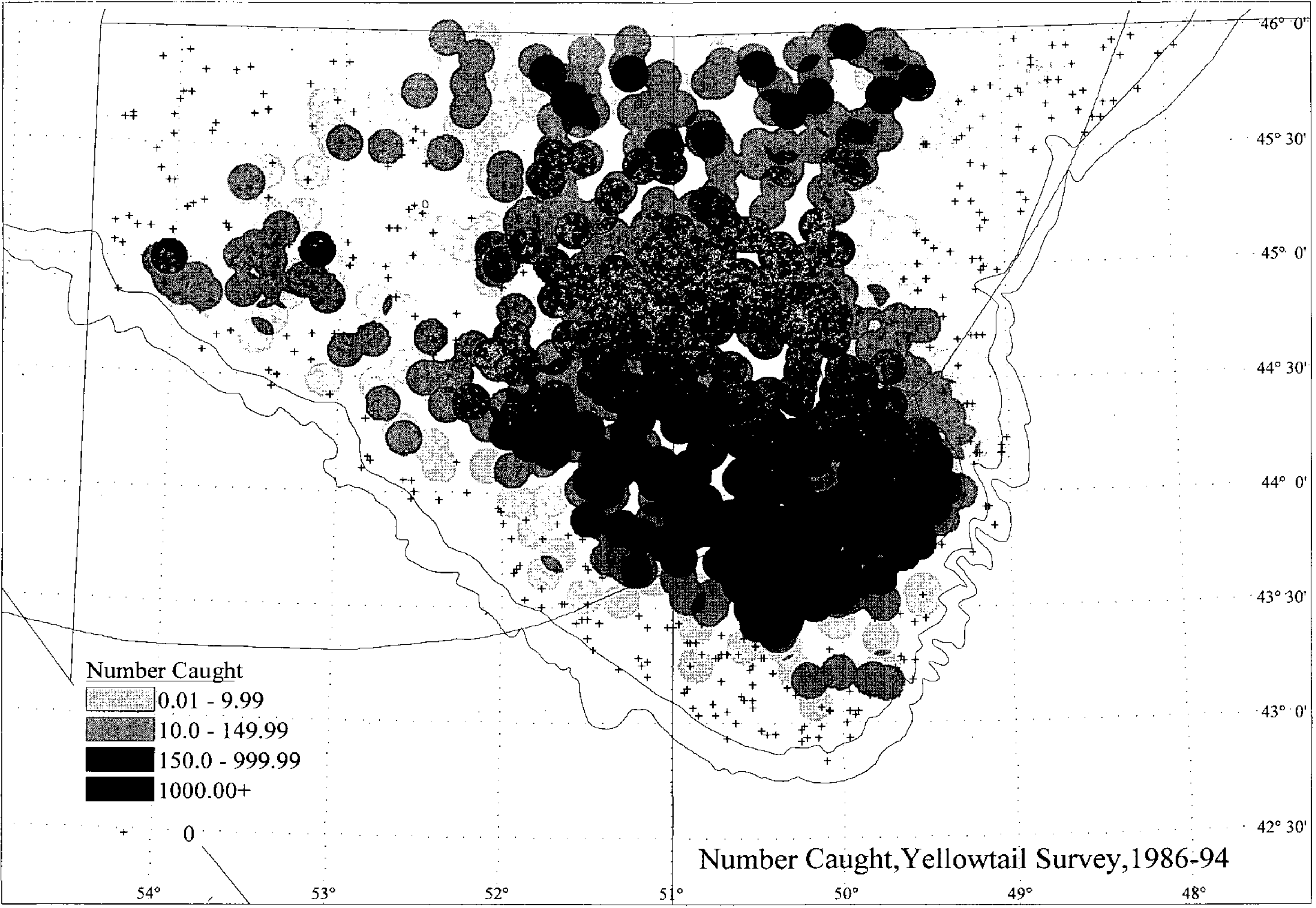
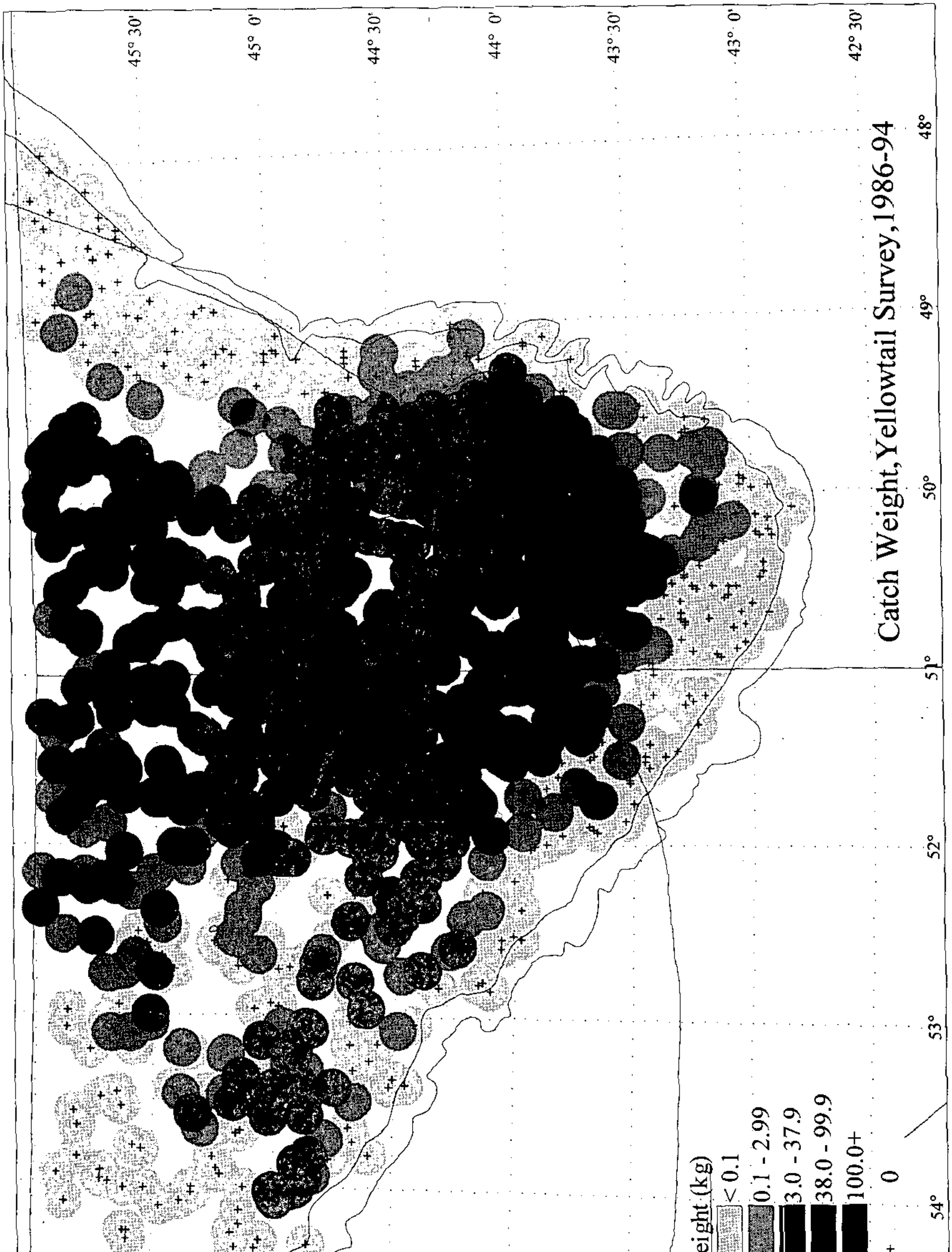


Fig. 9. Catch numbers and weights of yellowtail from juvenile groundfish surveys of 1986 to 1994 combined.



Catch Weight, Yellowtail Survey,1986-94

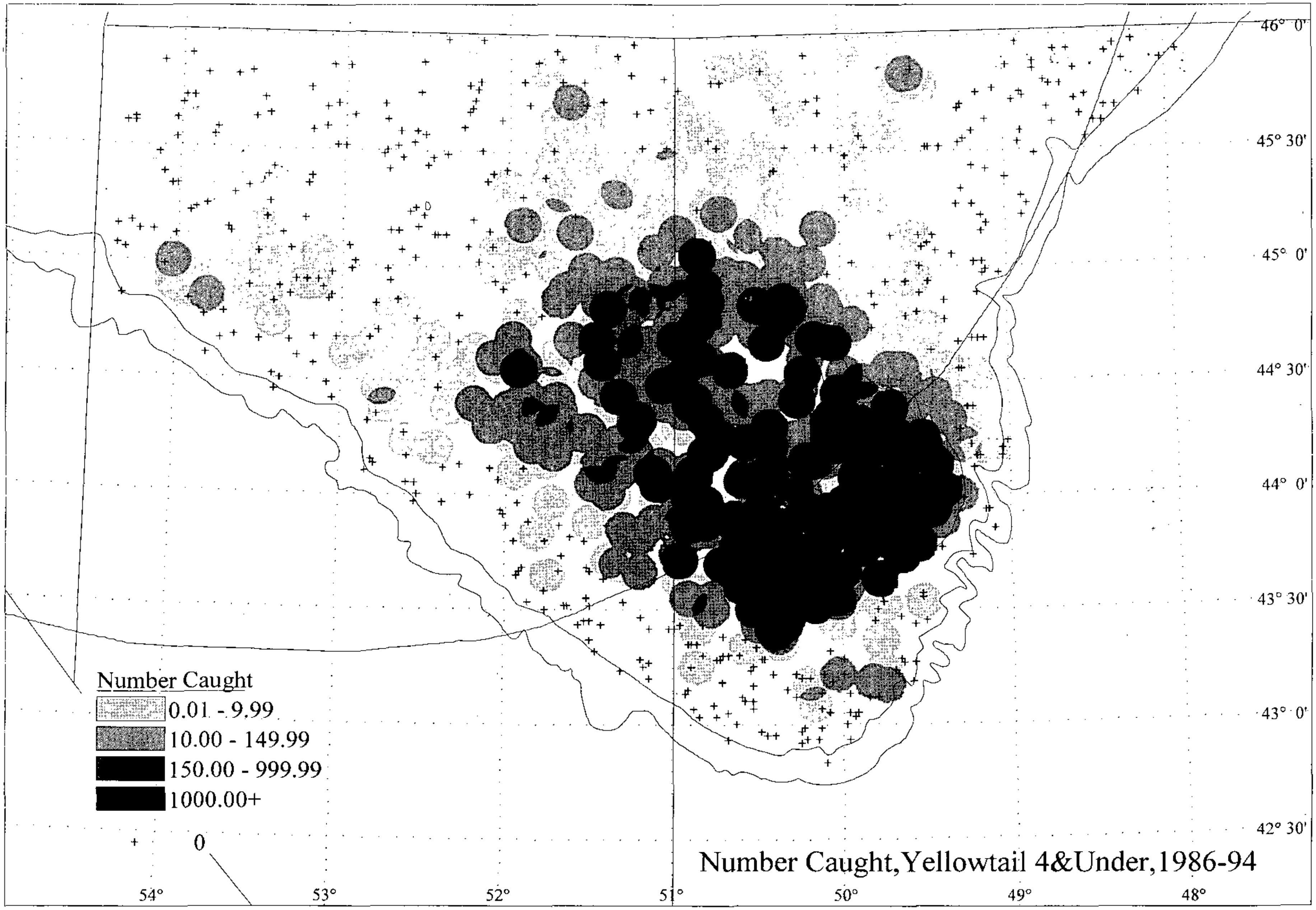
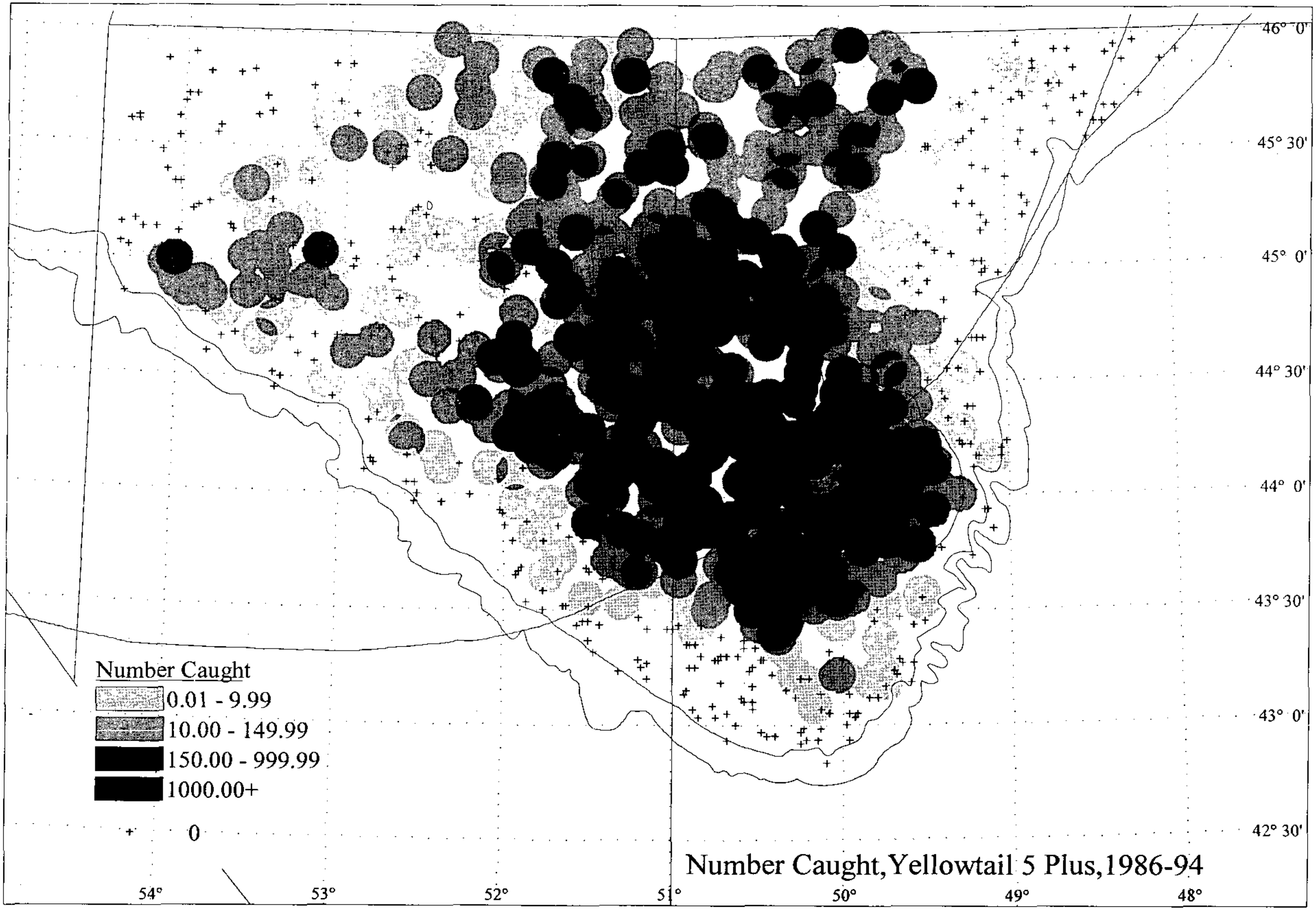


Fig. 10. Catch numbers of yellowtail from juvenile groundfish surveys of 1986-1994 combined, broken out by ages 1-4 and ages 5+.


Number Caught, Yellowtail 5 Plus, 1986-94
Number Caught
0.01 - 9.99
10.00 - 149.99
150.00 - 999.99
1000.00+
0
46° 0'
45° 30'
45° 0'
44° 30'
44° 0'
43° 30'
43° 0'
42° 30'
54°
53°
52°
51°
50°
49°
48°

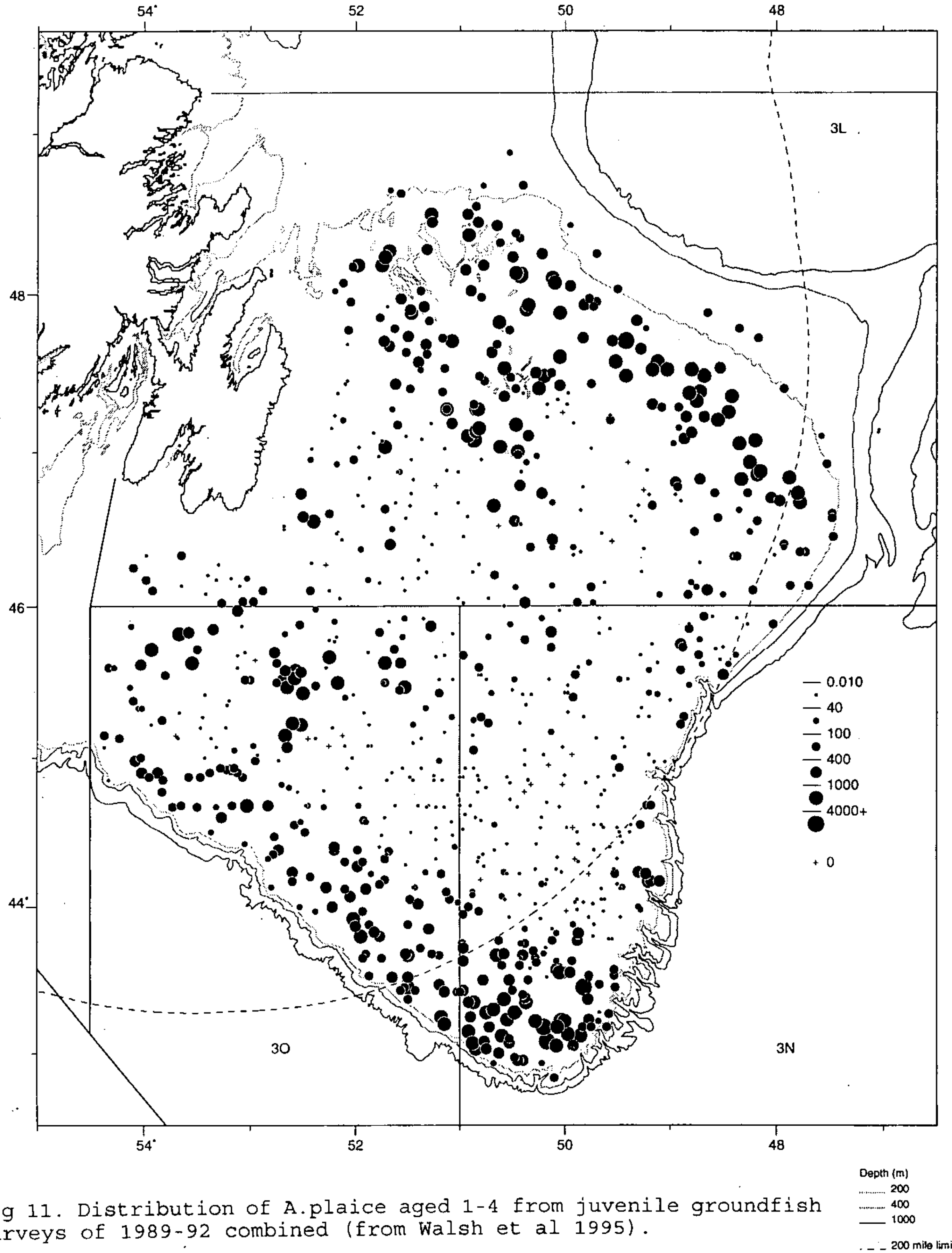


Fig 11. Distribution of A.plaice aged 1-4 from juvenile groundfish surveys of 1989-92 combined (from Walsh et al 1995).

AGE 1 COD

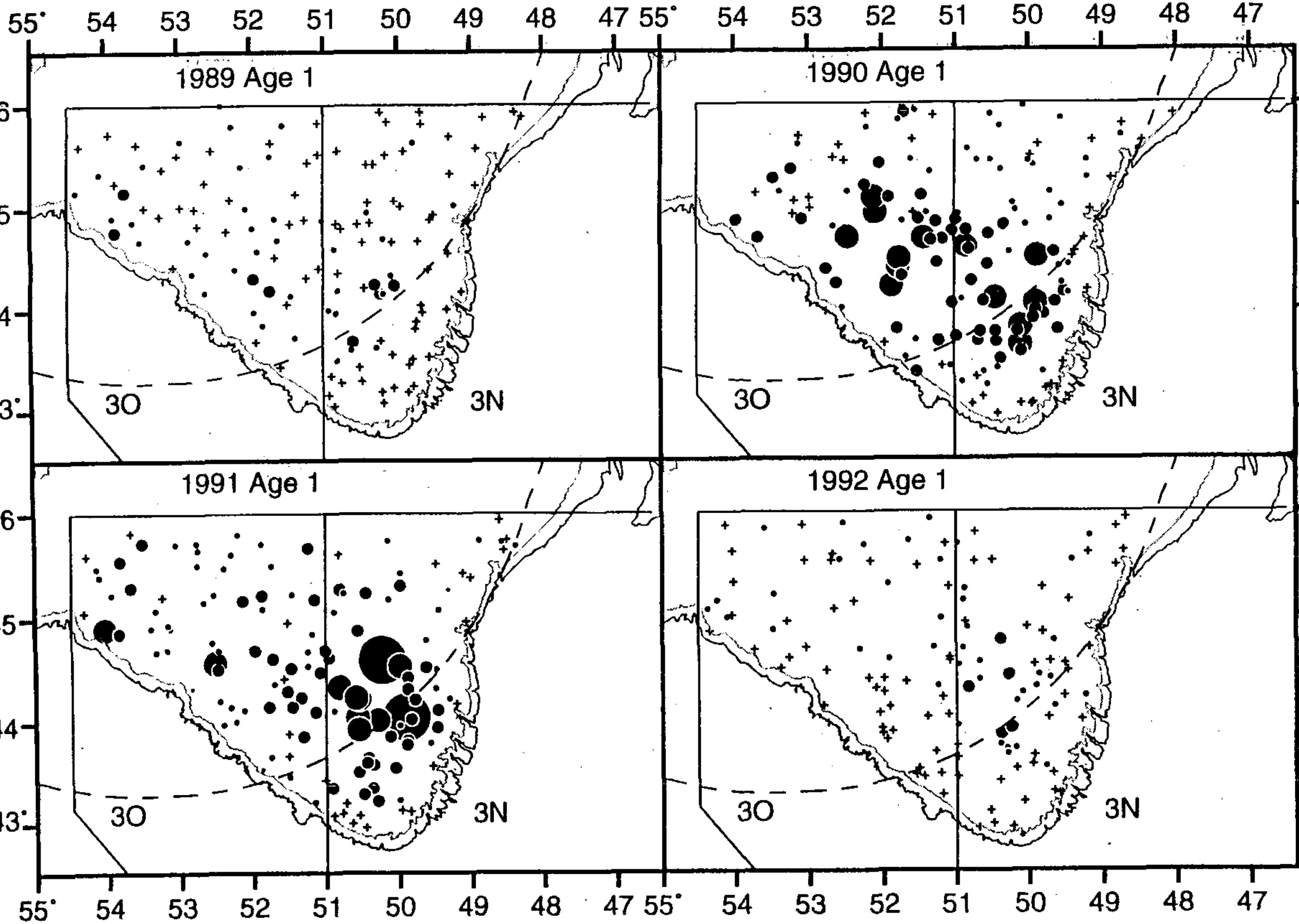


Fig 12. Distribution of age 1 cod from juvenile groundfish surveys of 1989-92

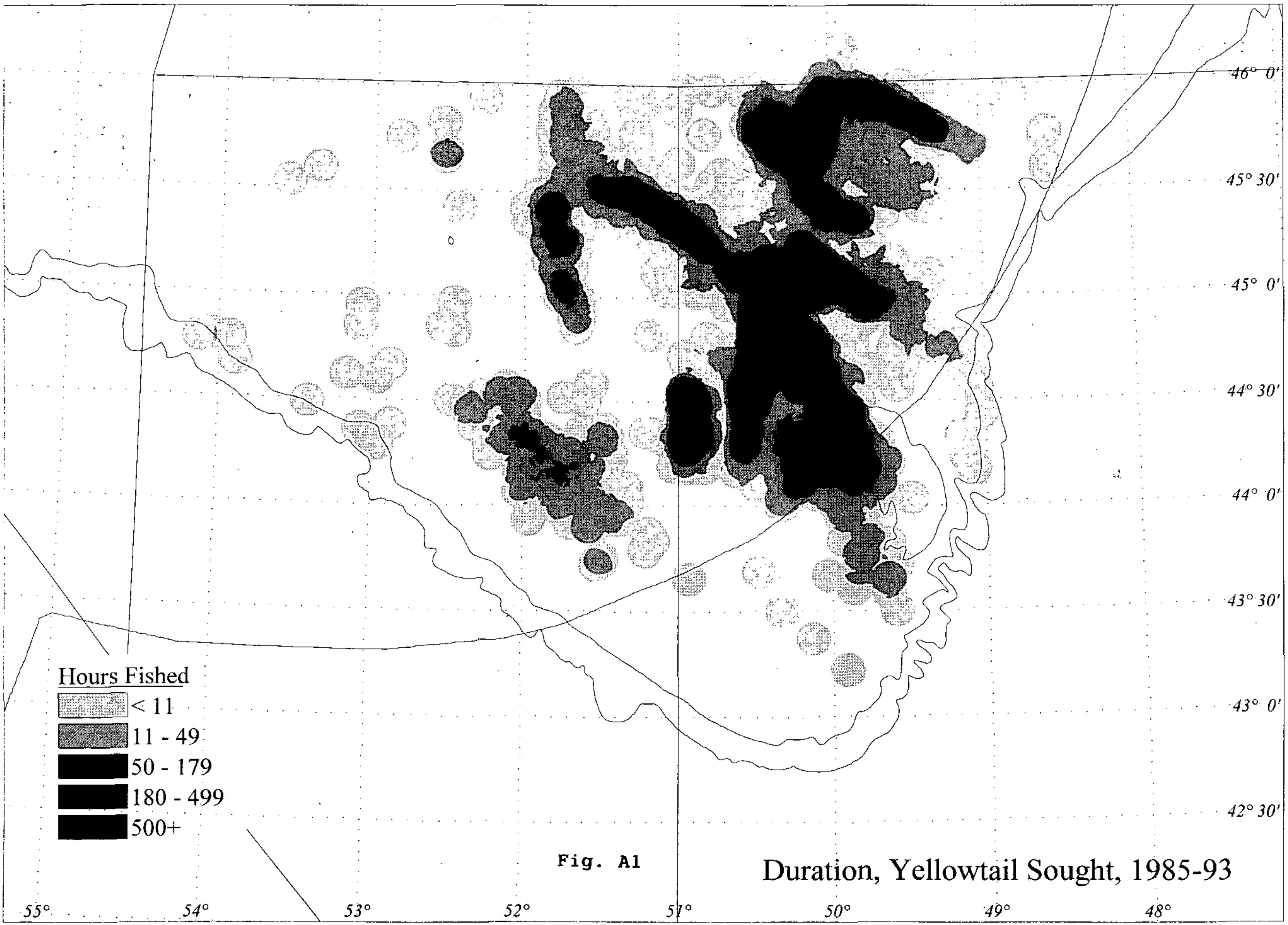


Fig. A1

Duration, Yellowtail Sought, 1985-93

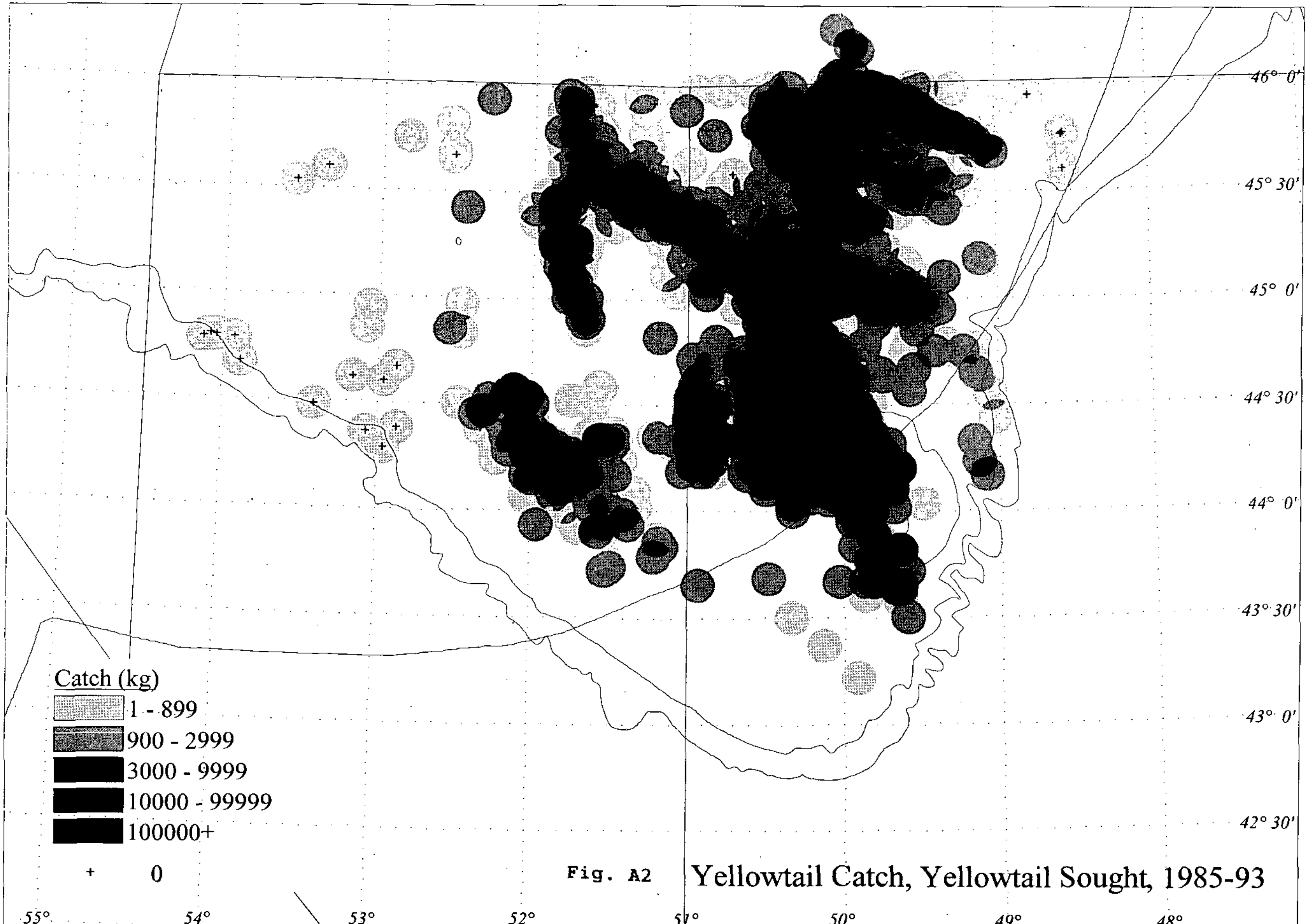


Fig. A2 Yellowtail Catch, Yellowtail Sought, 1985-93

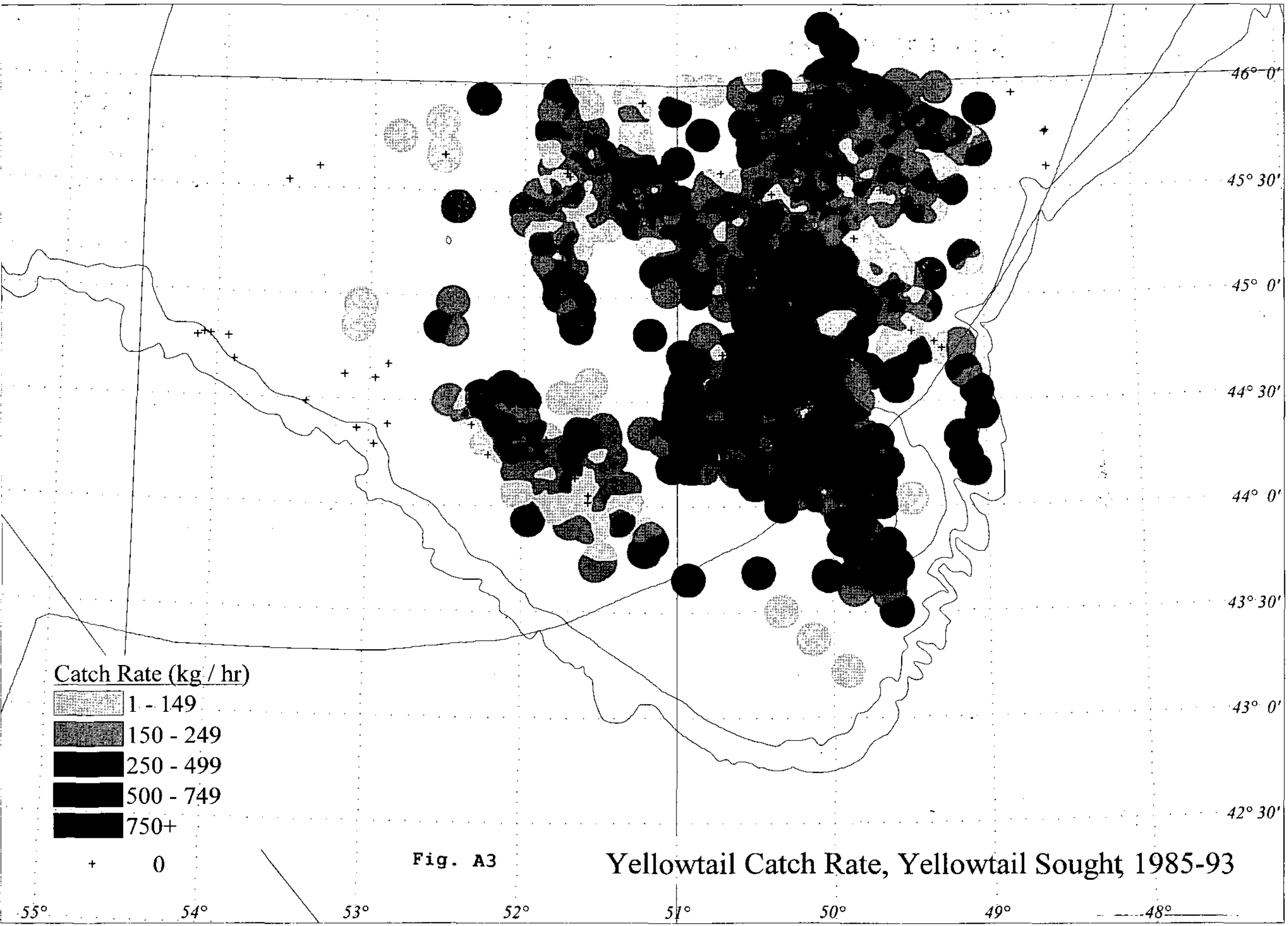


Fig. A3

Yellowtail Catch Rate, Yellowtail Sought, 1985-93

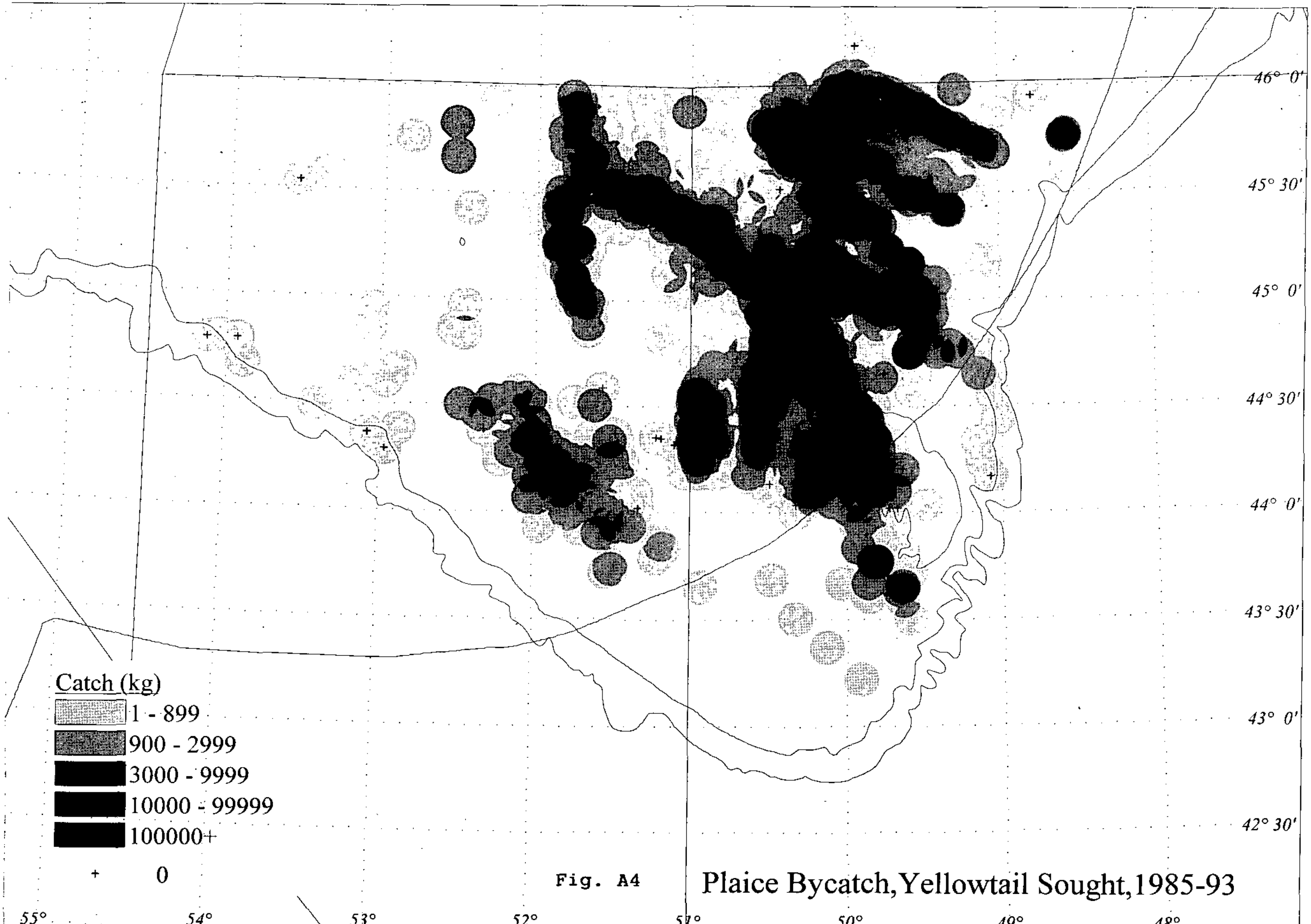


Fig. A4 Plaice Bycatch, Yellowtail Sought, 1985-93

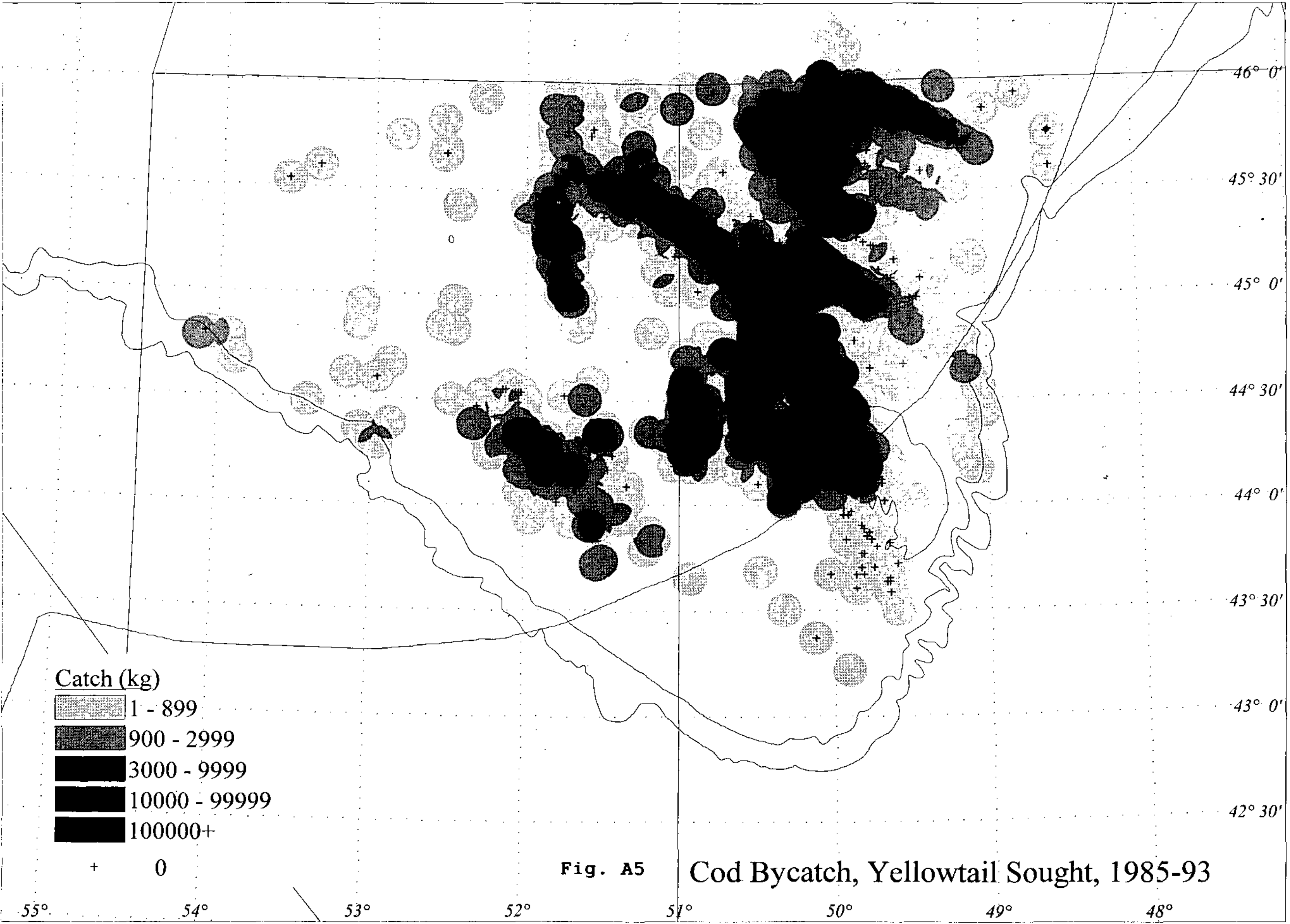


Fig. A5 Cod Bycatch, Yellowtail Sought, 1985-93

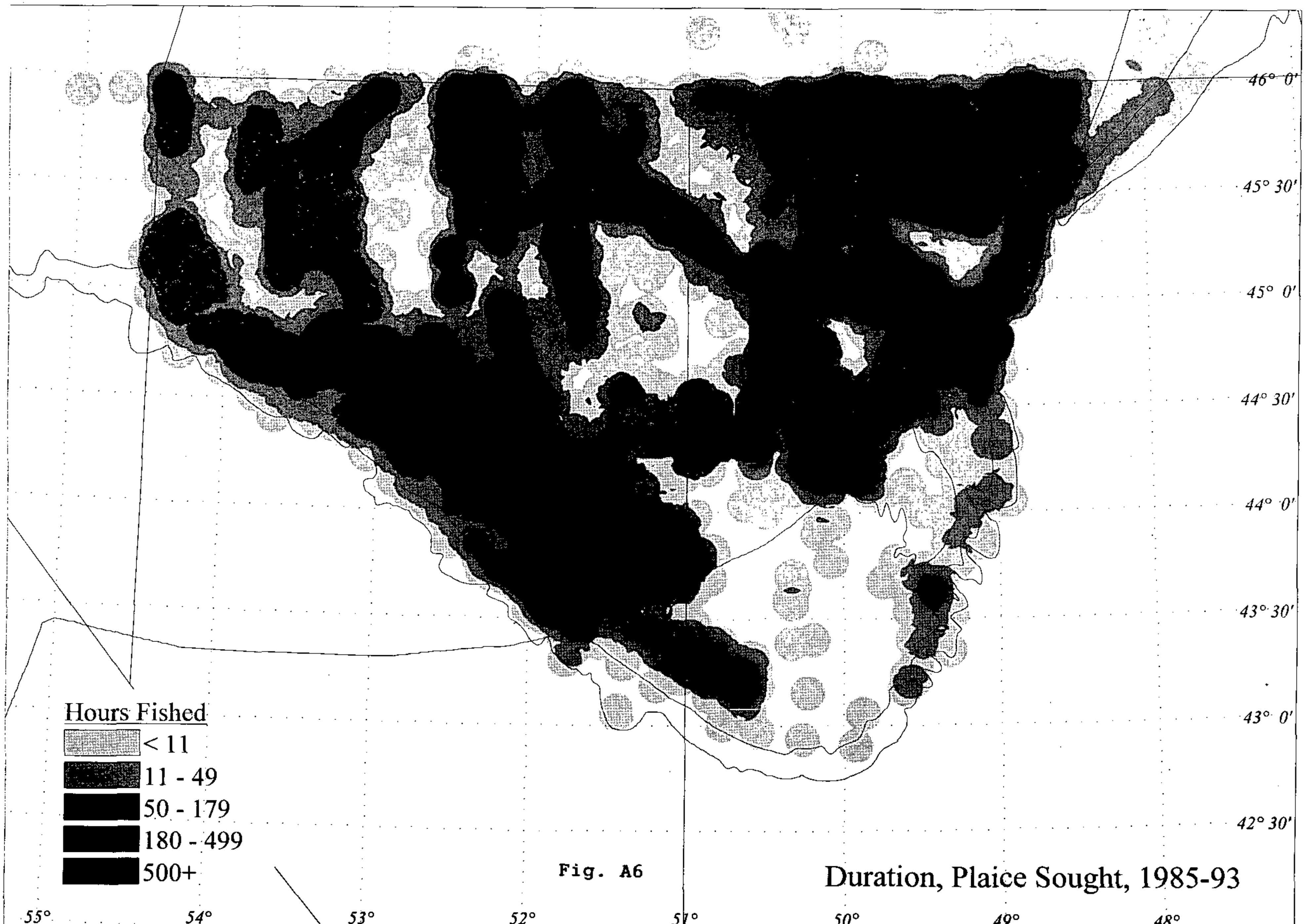

Hours Fished
< 11
11 - 49
50 - 179
180 - 499
500+
Duration, Plaice Sought, 1985-93
46° 0'
45° 30'
45° 0'
44° 30'
44° 0'
43° 30'
43° 0'
42° 30'
55°
54°
53°
52°
51°
50°
49°
48°

Fig. A6

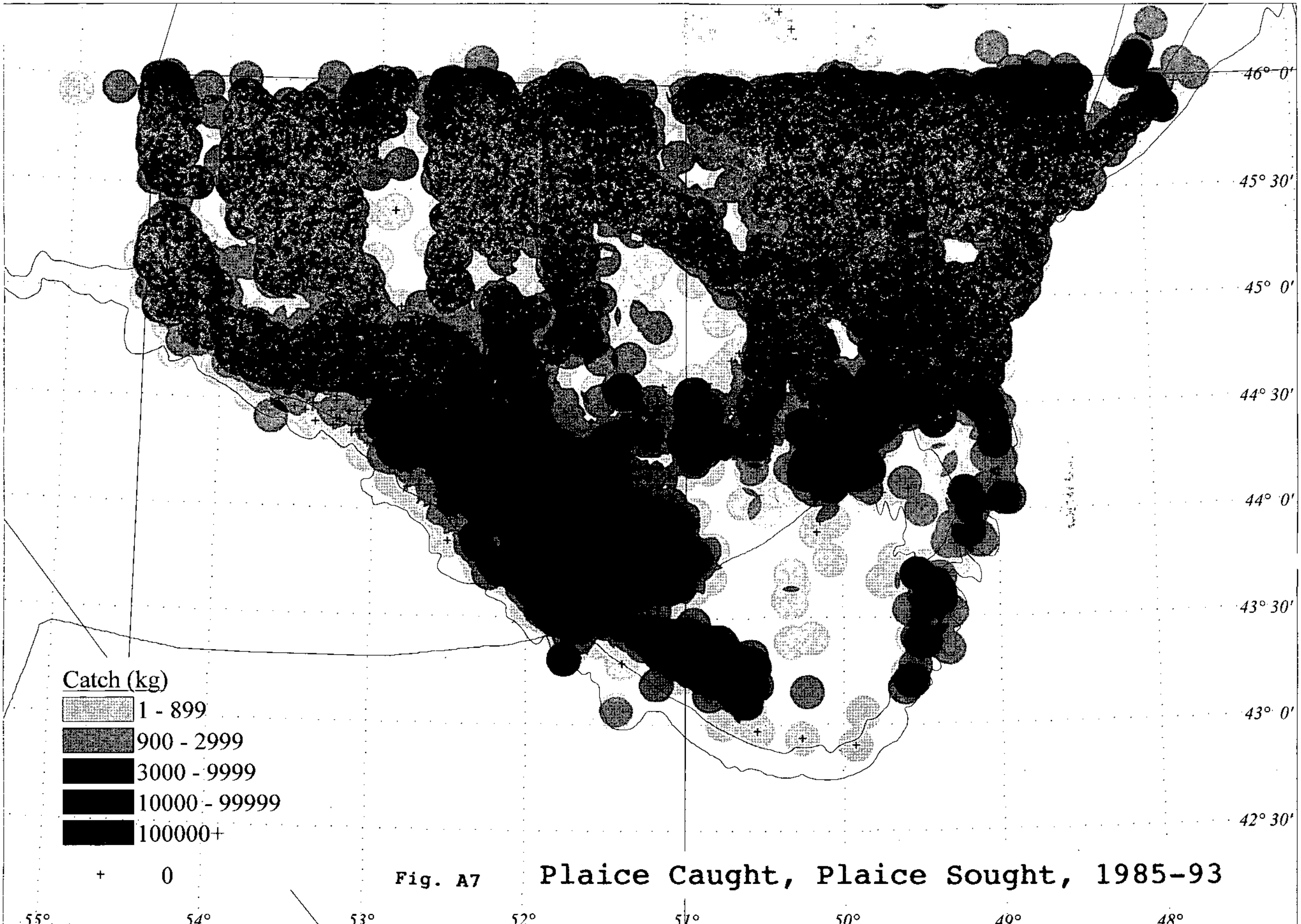


Fig. A7 Plaice Caught, Plaice Sought, 1985-93

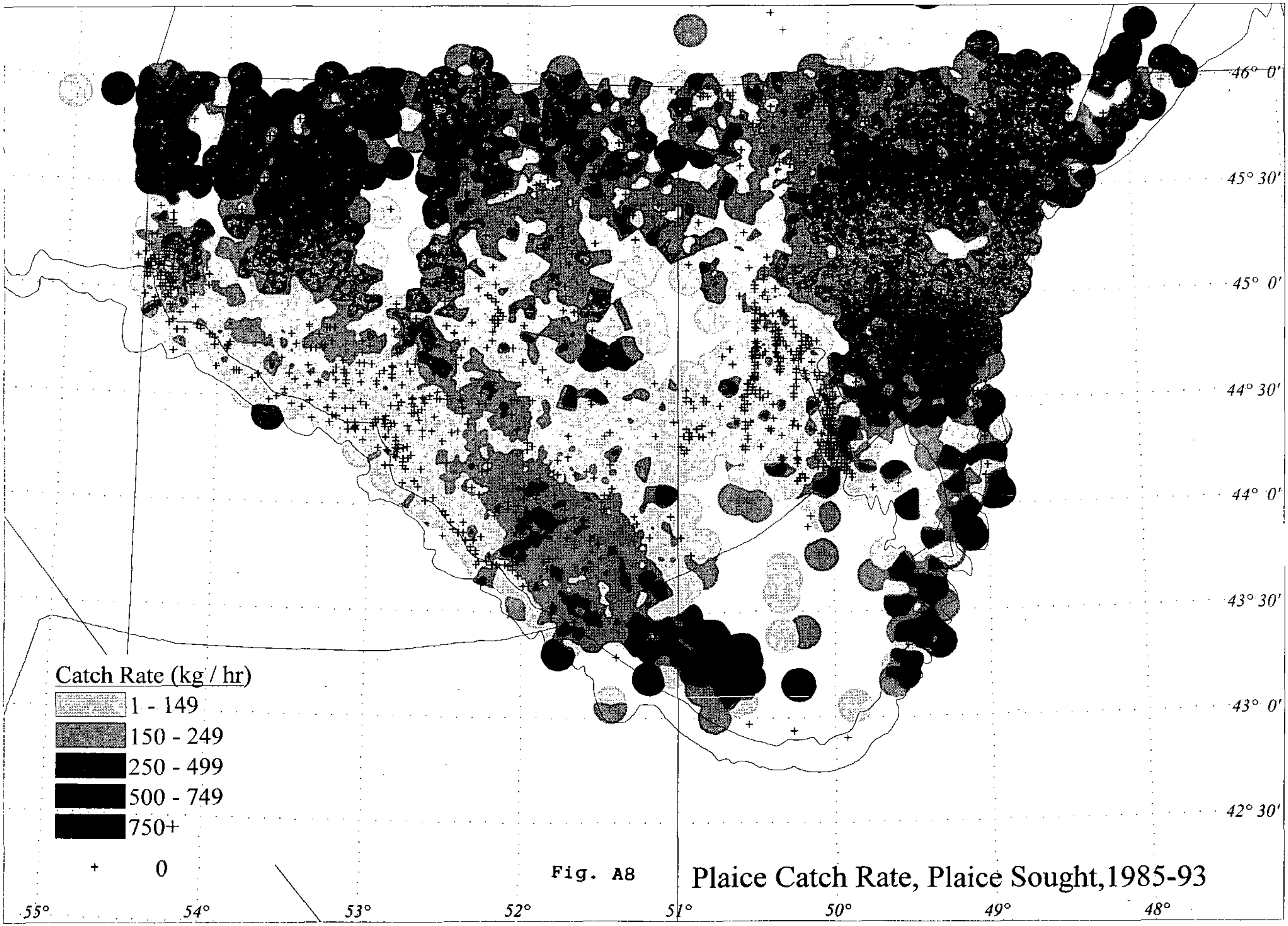


Fig. A8 Plaice Catch Rate, Plaice Sought, 1985-93

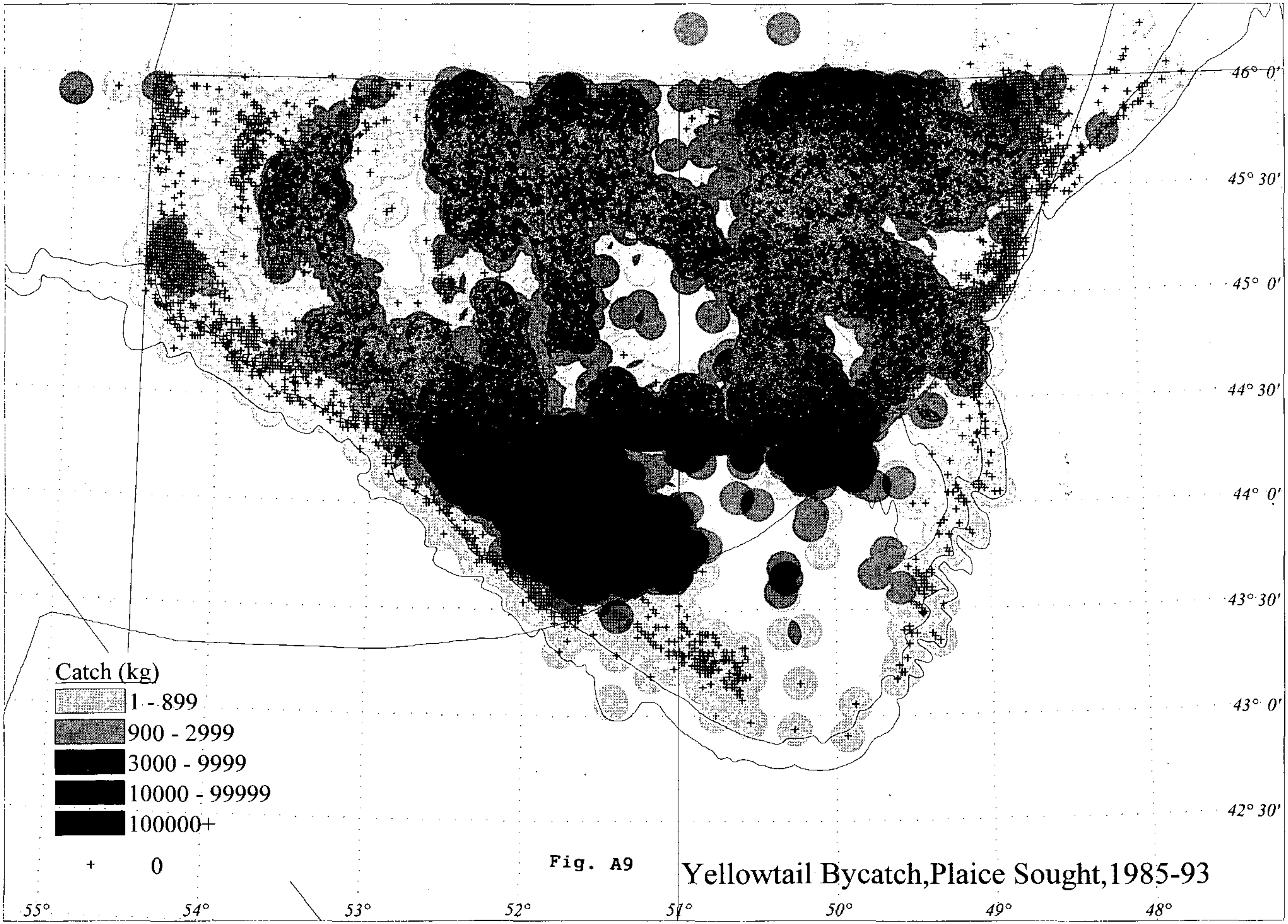


Fig. A9

Yellowtail Bycatch,Plaice Sought,1985-93

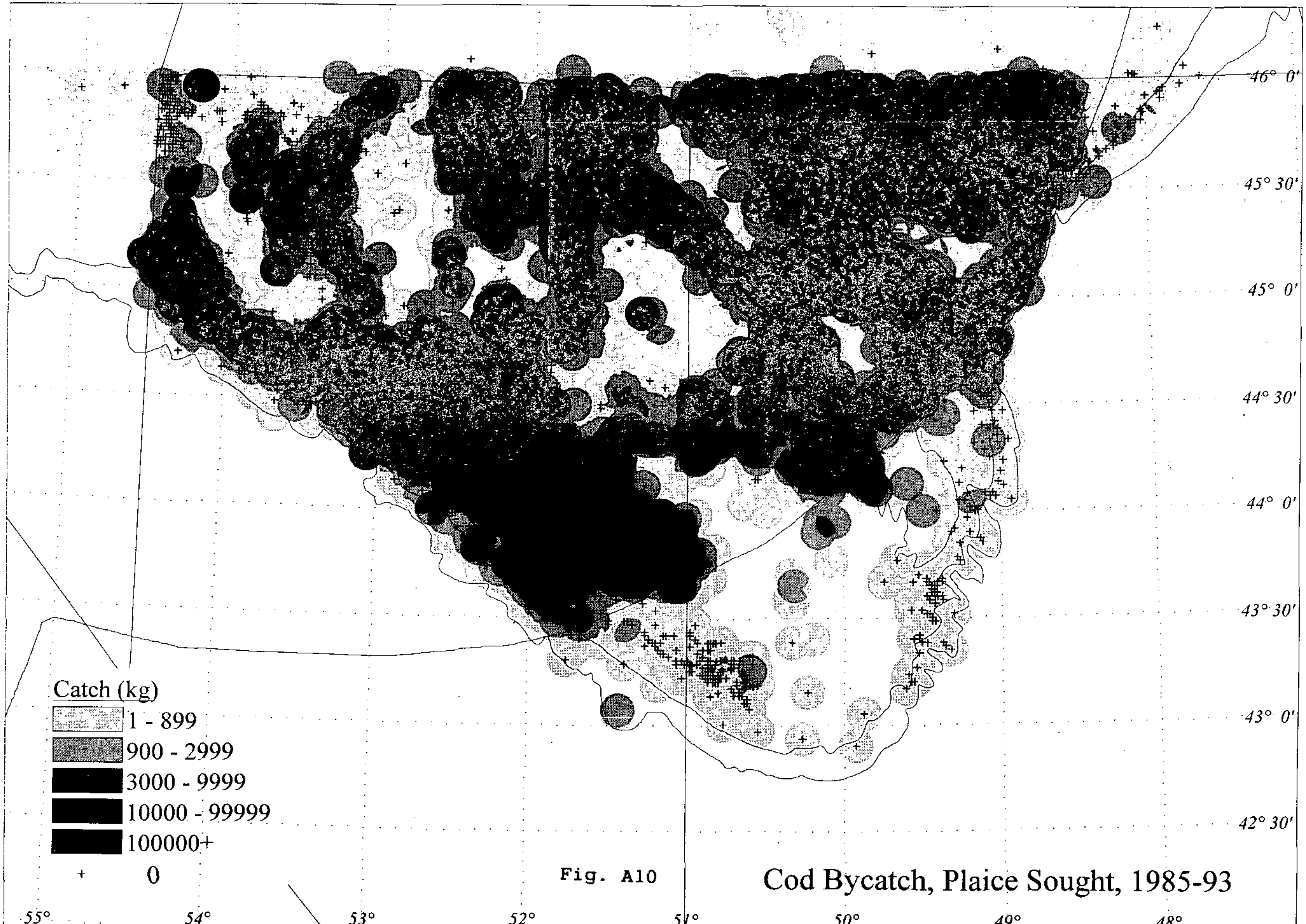

46° 0'
45° 30'
45° 0'
44° 30'
44° 0'
43° 30'
43° 0'
42° 30'
55°
54°
53°
52°
51°
50°
49°
48°
Catch (kg)
1 - 899
900 - 2999
3000 - 9999
10000 - 99999
100000+
0
Cod Bycatch, Plaice Sought, 1985-93

Fig. A10

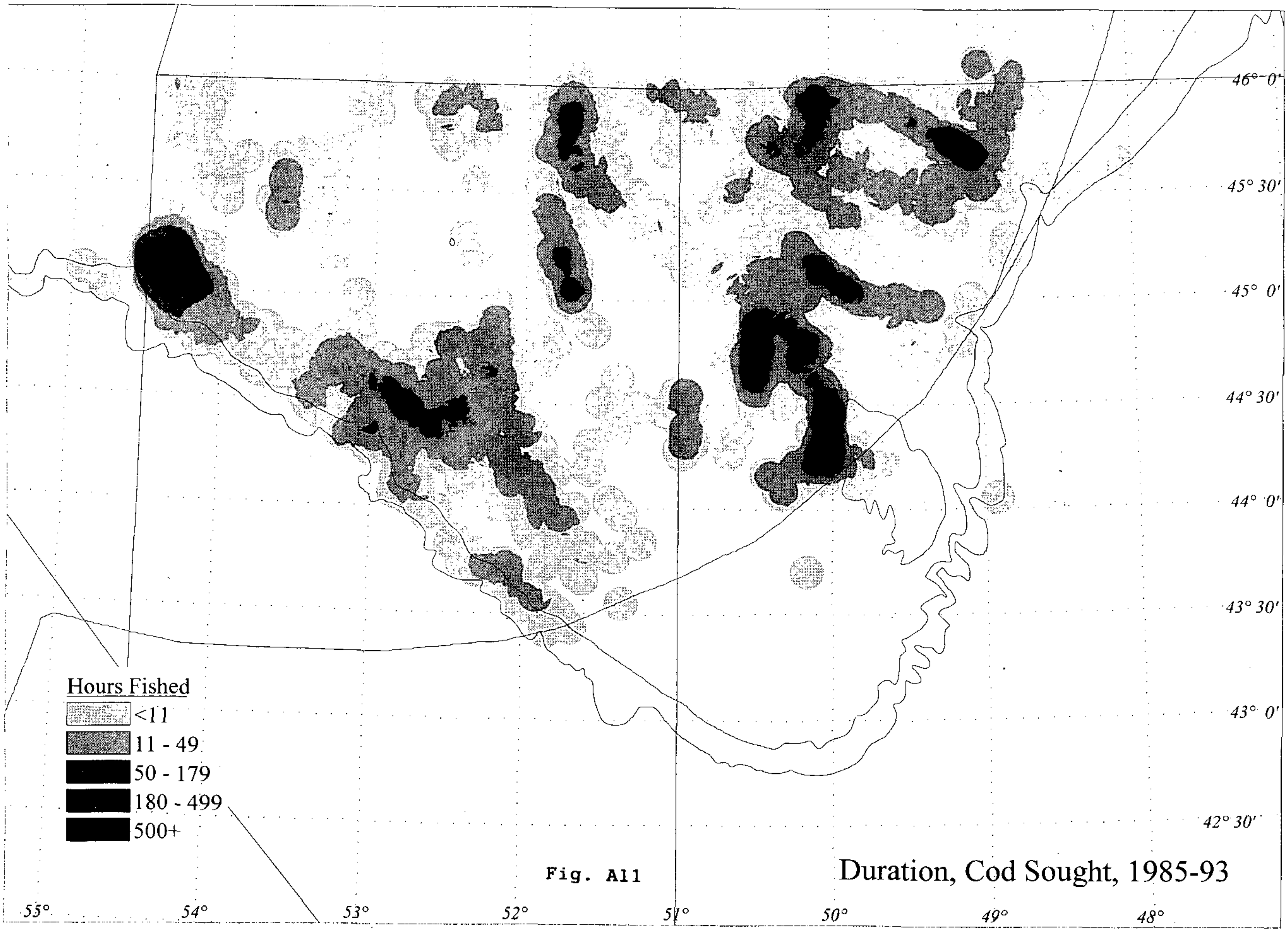


Fig. A11

Duration, Cod Sought, 1985-93

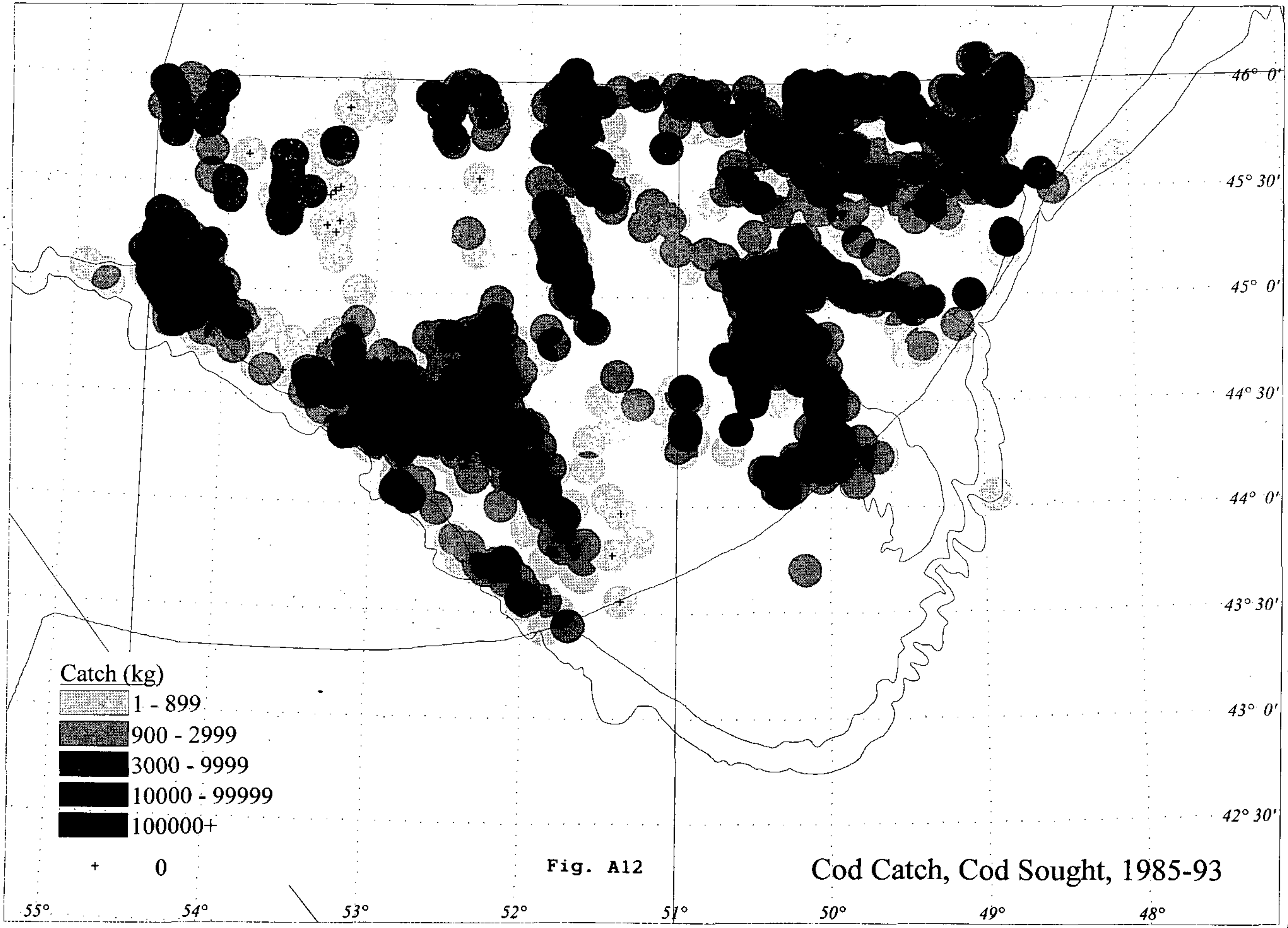

Cod Catch, Cod Sought, 1985-93
Catch (kg)
1 - 899
900 - 2999
3000 - 9999
10000 - 99999
100000+
+ 0
46° 0'
45° 30'
45° 0'
44° 30'
44° 0'
43° 30'
43° 0'
42° 30'
55°
54°
53°
52°
51°
50°
49°
48°

Fig. A12

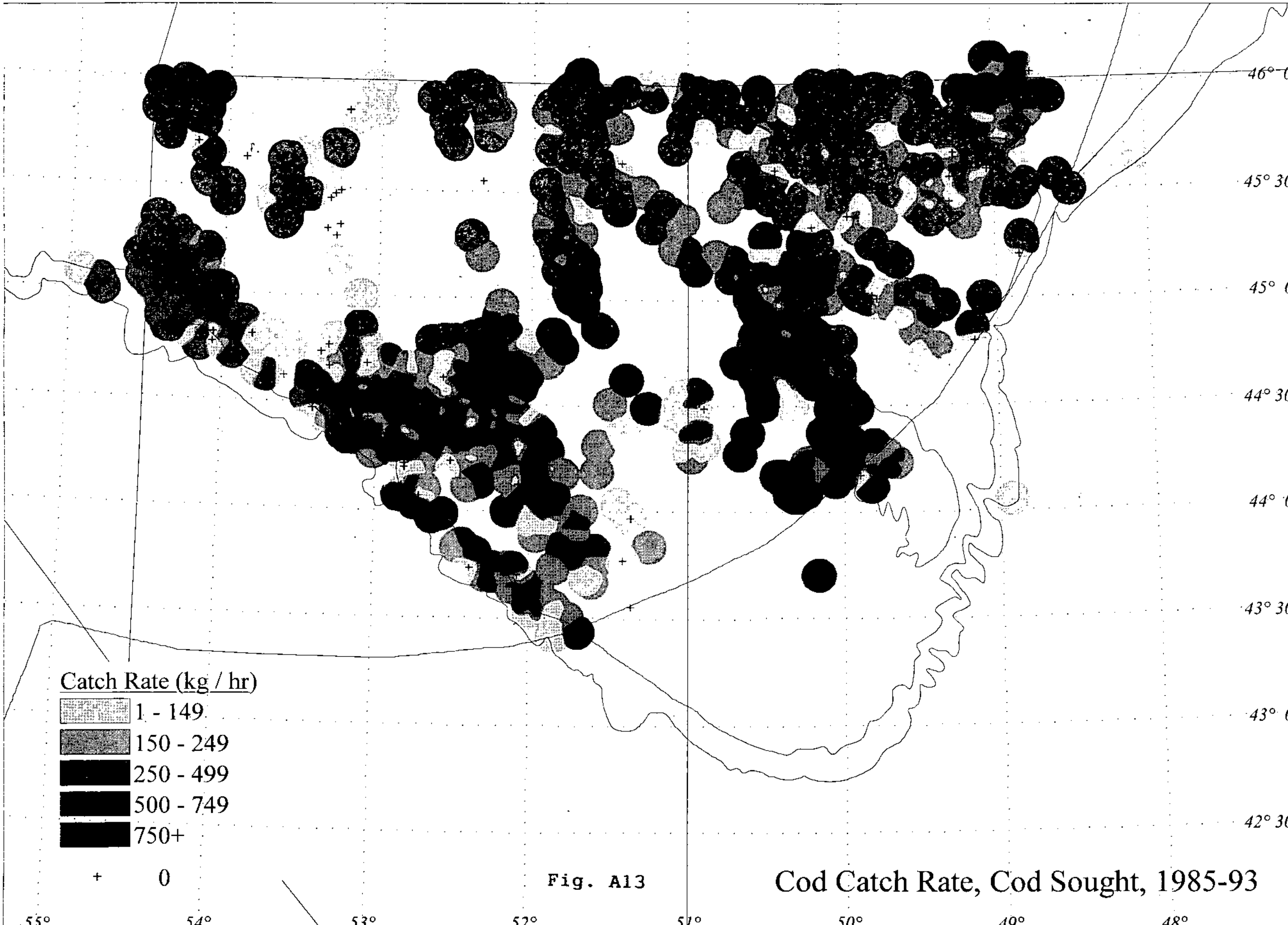


Fig. A13

Cod Catch Rate, Cod Sought, 1985-93

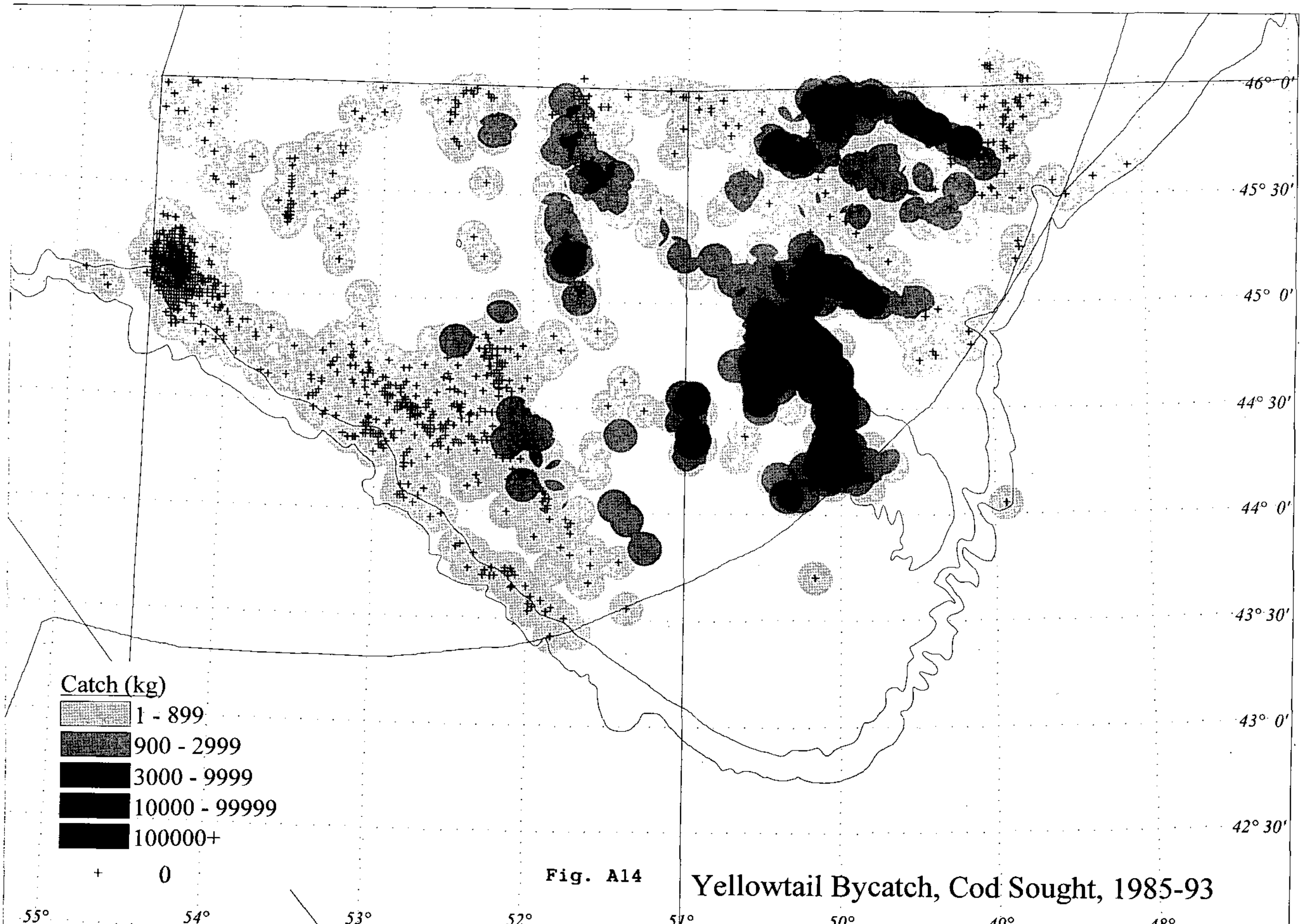


Fig. A14

Yellowtail Bycatch, Cod Sought, 1985-93

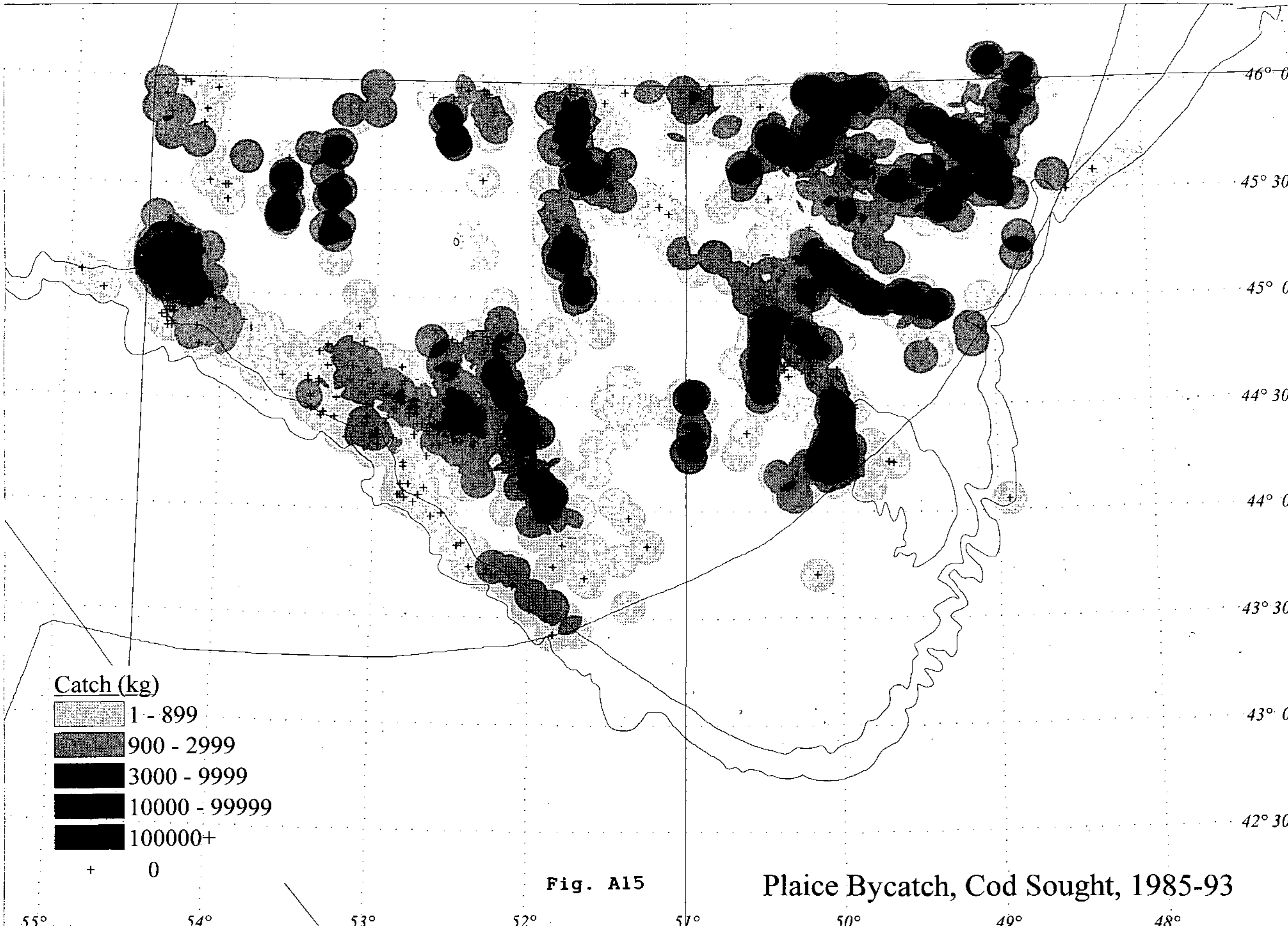


Fig. A15

Plaice Bycatch, Cod Sought, 1985-93

Appendix 1. Description of potential mapping techniques using SPANS

Potential mapping is a modelling technique used to create classified maps from point data. The procedure creates a circular area of influence around each point, and classifies overlapping areas based on the modelling function used and the values of the data which comprise the overlap. For example, if the surface is being generated to show a summation, the overlapping areas will be added together; these classified circular areas are then plotted to make the map.

The circle radius was chosen to represent the scale of the data and here the radius used was 9 kilometers, which corresponds to half the length of the average (3 hour) commercial tow. Although the research survey tows were of much shorter duration (30min.), the circle radius was kept at the same 9 km. value for ease of comparison with the fishery data. The classification schemes were developed after an examination of the data to determine their distribution properties. One classification scheme was maintained for each type of data modelled, again to allow comparisons between maps.

In this study, three types of information were modelled, catch (commercial and RV survey), fishing effort, and catch rate. The catch information was cumulative catch, in kilograms, by set. Fishing effort was computed two ways: as total number of tows and as tow density. The number of tows used a cumulative model, where each point was assigned a constant value of one, and any overlapping areas were added together to give the total number of sets fished. The tow density was calculated as the number of tows per square km., calculated using a density function (Anon, 1993). Catch rate, measured in kilograms per hour on a set-by set basis, used a distance-weighted model, where the overlapping areas were assigned an average of the points which comprised the overlap. These calculated overlapping values were then distance-weighted, that is the further a point was from the overlap, the less influence it had in the calculation.

The decay rate parameter, which determines the influence of a data point, extending from the actual point to the circle radius, was set to the maximum value for the catch and effort models, and to a minimal value for the catch rate models, which were distance-weighted anyway. The maximum neighbors parameter, which determines for any given point on the map surface how many points within the circle radius of the given point to consider, was set at 999, the maximum value allowed in SPANS GIS, to include as many sets as possible in the overlap. The projection used to produce the maps was the Lambert Conformal Conic, as it is well suited to depicting large regions which are primarily East-West in extent. The scale of the plotted maps was 1 : 2,500,000.

Appendix 2.

Figs. A1-A5. Data from the Canadian offshore trawler fishery for yellowtail in Div. 3NO, 1985-93 combined.

Figs. A6-A10. Data from the Canadian offshore trawler fishery for A. plaice in Div. 3NO, 1985-93 combined.

Figs. A11-A15. Data from the Canadian offshore trawler fishery for cod in Div. 3NO, 1985-93 combined.