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Distribution of Juvenile Yellowtail Flounder, American Plaice and Atlantic Cod on the Southern Grand Bank: a Discussion of Nursery Areas and Marine Protected Areas

by

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Abstract

The annual Canadian fall bottom trawl survey data from the southern Grand Bank, NAFO Div. 3NO were examined for the period 1985-1999 for the location of possible nursery areas for yellowtail flounder, American plaice and cod. Only the juvenile yellowtail flounder nursery area remained geographically localized throughout the time series with minimum temporal and spatial shifts. There was a large shift in the temporal and spatial pattern of juvenile plaice nursery areas in the southern Grand Bank, which may be related to a reduced overall stock size. This was also evident in the northern nursery area of Div. 3L. The temporal and spatial pattern of juvenile cod was also quite variable which may be related to changes in population size and bottom temperatures. The main nursery area for yellowtail flounder occupied the area of the southern portion of the Southeast Shoal together with area immediately to the west, i.e. in the NAFO Regulatory Area outside Canada's 360 km economic zone. This nursery is the only area for which a physical boundary can be defined in the context of establishing a Marine Protected Area. Two areas, a small and large box, were suggested that encompass, on average, 62% (small box) and 83% (large box) of all the juvenile yellowtail flounder on the southern Grand Bank. On average, 14% and 32% of all juvenile American plaice, respectively, and 13% and 44% of all juvenile cod, respectively, on the southern Grand Bank were found in these two boxes.

Introduction

Marine protected areas (MPAs) or closed areas are a fisheries management technical control measure for the reduction of fishing mortality on a seasonal or permanent basis. A MPA has been discussed as a technical measure for conservation of some groundfish stocks on the southern Grand Bank to hedge against uncertainty in stock abundance (Walsh 1992; Walsh *et al*. 1995a, 1999; Brodie 1996). The main goal of introducing spatial and temporal restrictions in a fishery is to protect either a particular life history stage of a species from exploitation, e.g. the permanent nursery closures in Pacific halibut, or protect the stock during seasons of high vulnerability, e.g. haddock spawning period on Georges Bank (Parsons, 1993). Such technical measures are generally thought to enhance stock recovery through the protection and subsequent enhancement of survival of juveniles in the nursery area. For example survivorship of juvenile haddock in the closed area on the Scotian Shelf (NAFO Div. 4W) was greater than that found in juveniles in the adjacent unprotected areas (Frank and Simon 1998).

Walsh (1992) and Walsh *et al*. (1995a) identified the area of the Southeast Shoal and the Tail of the southern Grand Bank as oceanic nursery sites for NAFO Div. 3LNO yellowtail flounder, one of the nursery sites for Div. 3LNO American plaice and Div. 3NO Atlantic cod. On these oceanic nursery grounds there is a large overlap in the spatial distribution of both adults and juveniles of each species and also the distribution of each species. The Southeast Shoal is an area of high primary productivity and contains the highest benthic biomass on the Grand Bank (Neiss 1965; Anderson and Gardner 1986). It's northern border is defined by 45^0 N and its western boundary by 50°

30[1] W. The shoal area is also considered important for critical life stages of capelin and sand lance (Anderson and Gardner 1986; Frank *et al*.1989), forage species that are often prey items for cod, plaice and, to a lesser extent, yellowtail flounder. A permanent closure of these juvenile nursery areas would effectively close a large segment of shallow water (inside the 100 m isobath) fisheries in the Regulatory Area of Div. 3NO and another large section inside the 200 Canadian territorial mile limit, i.e. from approximately 43°N to 45°N (Fig. 1). However, before an MPA to protect nursery areas on the southern Grand Bank can be established, the physical boundaries of the nursery areas have to be delineated. Defining the range and extent of each nursery is important for developing a comprehensive management strategy for implementation of a MPA.

Previous research has mapped plaice, yellowtail flounder and cod nursery grounds in the area of the Southeast Shoal and the Tail of the Bank, but not in sufficient quantitative detail to define the physical boundaries of each specific nursery area (Walsh *et al*. 1995a). Knowledge of the spatial and temporal variation in juvenile abundance of the target species in the nursery area is important in refining this boundary. This data can be derived using annual research vessel catch data, however, the quantitative definition of a continuous area from trawl station samples is problematic. Previously, through a combination of spatial statistics, we established a preliminary spatial boundary for the juvenile yellowtail flounder nursery area on the southern Grand Bank using the annual fall DFO groundfish surveys (Walsh *et al*. 1999). In this paper, we extend that work and also include American plaice and Atlantic cod on the southern Grand Bank. The objective is to re-examine the nursery areas of the three species and define their physical boundaries using a variety of geostatistics.

Materials and Methods

Data Sources:

Spatial information was gathered from the analyses of catch-at-age data from the annual fall stratified-random bottom trawl surveys of NAFO Division 3NO, 1985-1999. The stratification scheme is presented in Fig. 1. These annual surveys were conducted by the 50 m *FRV Wilfred Templeman* using a Yankee 41 shrimp trawl during juvenile groundfish surveys in the fall of 1985 to 1994 (Walsh *et al*. 1995b). From 1995 to 1999, the fall surveys were carried out by the same vessel using a Campelen 1800 shrimp trawl (see McCallum and Walsh 1996 for details). There is no trawl derived conversion for these two data sets to make them continuous, although Walsh and McCallum (1998) noted that there was very little differences in trawl efficiency between both shrimp trawls for yellowtail flounder and similar results are expected for plaice.

Since male plaice and yellowtail flounder are maturing by age 4, juvenile flatfish are classified here as age 0 to 3 yr. Juvenile cod were defined as age 0 and 1yr. fish.

Geostatistics:

<u>Expanding symbol plots</u>

Exploratory analysis of spatial distribution began with visual inspection using ACON expanding symbol plot software (Black 1993). For each species the standardized catch-at-age per fishing set was plotted using the following time series for which data was available: a) 1985-1998 for the plaice, b) 1985-1999 for yellowtail flounder and c) 1989-93, 1995-99 for cod. Noteworthy is that the surveys in 1985 and 1987 have the poorest coverage in the time series, however, they contain some information to show catch distribution and have been used only for graphical representation.

<u>Swept area estimates</u>

Following the preliminary examination of the ACON plots, a stratum abundance estimate was calculated for the juveniles of each species/year using the existing groundfish survey strata (Fig. 1). For each stratum, a standard swept area model was used to calculate the abundance, i.e., mean stratum catch per unit area multiplied by the stratum area. This simple estimate assumes that each stratum is homogeneous. Further calculations included the stratum-specific estimation of abundance expressed as a percent of the Div. 3NO abundance for each species, and the relative importance of strata 375/376 (Southeast Shoal), strata 361/360 (immediately adjacent to the west of the shoal). Stratum 360 comprises much of the Tail of the Bank inside the 100 m contour.

Contours

We further analysed the annual distribution using contour plots based on Delaunay triangles using the ACON software (Black 1999). Contour plots were calculated based on a triangulated surface that subdivides the data field to interpolate the response surface.

Kriging statistics

To refine the distribution of abundance contours, we used kriging, a linear interpolation method using the semivariance of log transformed trawl catches employing S-plus, Surfer, and GS+ software. Semi-variance analysis uses a measure of the spatial autocorrelation between points, the semi-variogram. The semi-variogram is half the expected value of the squared difference between two points a distance 'h' apart. The data was log transformed. This analysis was followed by point kriging, which uses the known covariance structure from the semi-variogram to weight the observations taken over the region to obtain a spatially interpolated estimate of abundance at unsampled points in the region. Variogram models were selected based on the least squares method to minimize the sum of the square of the error. Deviations from isotropy were minimal in all models, therefore anisotropy was disregarded. Kriging interpolates values for unsampled points using the spatial relationships in the data set derived from the semivariogram.

Generalized additive models

Generalized additive models (GAM) were used to model variation in the catch of juvenile yellowtail flounder, American plaice and Atlantic cod and to study the influence of environmental variables and density on distribution. GAMs model additive non-linear relationships between the predictors and the response functions. Additive models assume only that the response is affected by each predictor in a smooth way. Using S-Plus, a step-wise GAM analysis was conducted using year, bottom temperature and depth as covariates with latitude and longitude. Zero catches were included. Initially, we used a stepwise GAM (AIC test statistic) to determine the best smooth function, i.e. the best fitted model, which was a cubic spline. We applied the GAM to the catch of juveniles of each species in an exploratory fashion to look at spatial trends in distribution and to determine if these trends were influenced by location (latitude and longitude), depth, temperature and year. The effect of depth and temperature on abundance was determined by running the models without the spatial variable (location). Comparison of the level of contribution for each environmental parameter was evaluated using the pseudo coefficient of determination, R^2 (1-minus the deviance of the model to the deviance of the full model) from the model output (Swartzman *et al*. 1992).

Results

Yellowtail flounder

The largest abundance of juvenile yellowtail flounder were found in Div. 3N (Fig. 2). Since 1995 the amount of juveniles in Div 30 had been increasing, but remained below 25%. The expanding symbol plots of standardized catches of juveniles showed that the largest catches were taken primarily in the area on and around the Southeast Shoal in Div. 3N (Fig. 3). In select years there has been a few large catches in Division 3O. The contour plots confirm that the highest densities were found on the Southeast Shoal and to the area immediately west of the shoal (Fig. 4). Analysis of strata specific abundance estimates revealed that, on average, 63% of the juveniles in the southern Grand Bank, Divisions 3NO, were concentrated, in strata 376 (Southeast Shoal southern stratum – see Fig. 1), and 360 (west of the shoal) (Table 1). In some years, stratum 375, the northern section of the shoal, and stratum 361 immediately to the west of stratum 375 contribute on average an additional 20 %. In Div 30, an average of 7 % of the juvenile catches were found in stratum 352, which is located on the western side of the 3N-3O border line and west of the shoals (Table 1). Together, these 5 strata contained an average of 90% of the juveniles during the time series. Inter-annual variations in the amount of juveniles found on the Shoal (strata 375 & 376) and the area adjacent to the west of the Shoals (strata 360 & 361) were evident (Table 1;Fig 5). In 1999, more juveniles were found in areas other than the key 4 strata of Div. 3N. Large catches of juveniles were taken further north in stratum 362 of Div. 3N and to the west in stratum 352 of Div. 3O (the *off* shoal category in Fig. 5) as evident in Figures 3 & 4 (see also Table 1).

Semi-variance analysis of the spatial autocorrelation between fishing sets was determined for juveniles using survey data from 1988-1999 and the variogram model parameters are shown in Table 2.. Spherical variogram models provided the best fit in each year. Greater than 84% of the sample variance of the trawl catches i.e. the proportion of the total variance that can be modelled as spatial dependence (see proportion column in Table 2), was explained by spatial structure variance in the range of 19.6 to 71.1 n.mi (see range statistic, Table 2). On average from 1988 to 1999, autocorrelation in juvenile abundance extended over 44.4 n.mi. (S.D =18.3), i.e. the average distance within which the catches remained spatially correlated. In other words on average, the closer two sampling points are to each other the more likely their values will be similar. The variogram models the average degree of similarity between the values as a function of their separation distance. A small autocorrelation range is indicative of sampling points are closer together and similar, i.e. show spatial continuity in the data while a large range is indicative of more dispersion and reflect data that are farther apart and dissimilar, i.e. spatial discontinuity in the data.

Comparisons of the temporal patterns in spatial structure between years was carried out using correlation analysis and the results presented in Table 3. In general, the interpolated distribution of kriged juvenile abundance values was generally highly correlated between years. The spatial correlation also remained high with multi-year lags. This indicates that the integrity of the spatial patterns of juveniles has been consistent from year to year

Table 4 summarizes the results of the generalized additive models (GAM) for all years Year effects were included in all model formulations. In the full model, 59% (R^2) of the variation in juvenile yellowtail flounder distribution is explained by the model. The partial model results indicated that depth together with density has the most influence on distribution. Addition of temperature into the depth-year model increased the model R^2 by 12 % and the addition of location had only a 9% increased effect. These results indicate that temperature and location had little effect on distribution. GAM plots (not shown) of the catch numbers of juveniles showed the abundance was mainly concentrated on and around the Southeast Shoal in Division 3N in all years, similar to the other observed spatial results.

<u>American plaice</u>

In the early years of the time series up to 1989, most of juvenile American plaice were concentrated in Div. 3N. Then from 1990 onwards the largest abundance was found in Div. 30 (Fig. 6). Since 1996, less than 10% of the juveniles were found in Div. 3N. From 1986-92, the expanding symbol plots showed that the highest catches were mainly found in the NAFO Regulatory Area on the Tail of the Bank (Fig. 7). However, since 1993 there has been a decreasing trend in the catches of juveniles on the Tail of the Bank. The contour plots of juvenile catches give a more exacting picture of what has happened on the southern Grand Bank (Fig 8). In the beginning of the time series, the Tail of the Grand Bank had the highest densities, but due to poor coverage in 1985 and 1987, this can be misleading. Nevertheless, since 1988, the survey coverage was more consistent. From 1988 to 1992, the highest densities were found on the Tail of the Bank in Div. 3NO, on Whale Deep and Whale Bank in the western side of Div. 3O, and, to a lesser extent, along the southwest slope of Div 3O. From 1993 onward the highest densities, decreasing over time, were found in the Whale Deep-Whale Bank area and along the southwest slope.

Table 5 gives the analysis of strata specific estimates of abundance. On average 31% of the juvenile abundance in Div 3NO was found in stratum 360, Div. 3N, and stratum 353 (Div. 30) which make up most of the juvenile habitat on the Tail of the Bank (see Fig. 1). Beginning in 1988, when 66% of the juveniles in Div 3NO were found in this area there has been a downward trend in the density of juveniles on the Tail of the Bank, reaching the lowest estimate of 8% in 1997. In the Whale Deep and Whale Bank area of Div. 30, strata 329, 339 and 340, an average of 29% of the juveniles were found during the time series. Since 1992, when the decrease began on the Tail of the Bank, the amount of juveniles in the Whale Deep-Whale Bank area ranged from 21% to 47%. Of note is that less than 20% of the combined- 3NO juveniles were found on the Southeast Shoal in any single year, however, most of the juveniles were found in the adjacent strata, 360 and 361 (Fig. 9). Since 1993, there has been an increasing trend in the amount of juveniles found away from the Southeast Shoal (the *off shoal* category in Fig. 9) area corresponding to the increase proportion found in Div 3O.

Semi-variance analysis of the spatial autocorrelation between fishing sets was estimated using the 1988-1998 surveys. No one variogram models provided the best fit for all years so a combination of linear, exponential and spherical models was used. Greater than 70 % of the sample variance of the catch numbers of juveniles was explained by spatial structure variance in the range of 40.2 to 197.7 n.mi (see range statistic, Table 2). On average, autocorrelation in juvenile abundance extended over 109.4 n.mi. (S.D =56.2), i.e. the average distance within, which the catches remained spatially correlated. A large range is indicative of more dispersion and reflect data that are farther apart and dissimilar, i.e. spatial discontinuity in the data.

While the year to year correlation of kriged juvenile abundance values was relatively high in the late 1980s and early 1990's (Table 6), in later years the correlation in the spatial structure was reduced. As well, correlations were low between kriged values of abundance when multiple year lag times were considered reflecting a change in the distribution of juvenile American plaice. This corresponds to the results from the other spatial analysis of catches of juveniles.

Table 4 summarizes the GAM results using all available predictors: temperature, depth, location and year. The full model explained 45% of the variance in the spatial distribution of juveniles. Depth and year together explained 32%, while temperature and year only explained 27% of the variance. It appears that year together with depth and location were the most important variables affecting the distribution of juveniles. Temperature had a somewhat lesser effect.

Atlantic cod

During the time period 1989-1999, there was no definite trend in the distribution of juveniles in Div. 3NO, i.e., 50% of the time juveniles were either in Div. 3N or 50% in 3O (Fig 10). For those years, 1990, 1991 and to a lesser extent 1999, when the abundance of juveniles on the southern Grand Bank was the highest in the time series, the expanding symbol plots showed that juveniles were widely spread across both divisions (Fig 11). The contour plots of the time series showed that the highest densities were found around the Southeast Shoal area in Div 3N, in the area just southeast of Whale Deep and along the western side of the southwest slope of Div 3O (Fig. 12). Strata specific abundance estimates for the time series show that, on average, 45% (range 12 to 81%) of juvenile cod in Div. 3NO were located either on the Southeast Shoal (strata 375 and 376) or in the adjacent area (stratum 361) to the west of the northern section of the shoal, in Div. 3N (Table 7; Fig 13). An average of 55% (range 24 to 89%) of the juveniles were associated with other areas away from the shoal (the *off shoal* category in Fig 13).

Semi-variance analysis of the spatial autocorrelation between fishing sets was estimated for 1989-1999 surveys. Spherical variogram models provided the best fit for almost all years. Greater than 52 % of the sample variance of the trawl catches was explained by spatial structure variance in the range of 14.4 to 94.4 n.mi. (see range statistic, Table 2). On average, autocorrelation in juvenile abundance extended over 40.3 n.mi (SD=27.5), which is quite restricted. A small autocorrelation range is indicative of sampling points are closer together and similar, i.e. show spatial continuity in the data.

Comparisons of the temporal patterns in spatial structure between years was carried out using correlation analysis and the results presented in Table 8. In general, the interpolated distribution of kriged juvenile abundance values is poorly correlated in single and multi-year comparisons. This indicates that the integrity of the spatial patterns of juveniles are not consistent from year to year.

Table 4 summarizes the results of the generalized additive models (GAM) for all years: In the full model, 44% of the variation in juvenile cod abundance and distribution is explained by the model. The partial model results indicate that temperature and year are primary variables explaining 33% of the variation and had the most effect on distribution of juveniles. Both depth and location had a lesser effect.

Discussion

Walsh *et al*. (1995a) suggested that an area closure, i.e. a marine protected area, which included the Southeast Shoal and surrounding area to the Tail of the Grand Bank, of the yellowtail flounder, plaice and cod nursery areas on the southern Grand Bank would protect the juveniles from the excessive fishing mortality levels seen in the early 1990s and contribute to rebuilding of these stocks. By the mid-1990s, the NAFO Fisheries Commission had imposed a moratorium on directed fisheries in the Regulatory Area for all three species and this was supported by Canada and other NAFO member countries. In 1998, after a 4 year closure, the moratorium on yellowtail flounder was lifted and a small fishery of 4000 t was permitted. The rebuilding of the yellowtail flounder stock to the levels of the mid-1980s benefited from a cessation of fishing, which protected and rebuilt the spawning stock biomass. It also protected the year-classes spawned prior to and during the moratorium (Walsh *et al*. 2001). For reasons not yet understood, the rebuilding of plaice and cod stock did not occur and their moratoria has continued. However, because of other fisheries in the area, a by-catch mortality of juveniles and adult plaice and cod continues to rise (NAFO 20001) with an expected negative effect on stock rebuilding.

The analyses presented here corroborates the identification of the yellowtail flounder nursery area (Walsh 1992, Walsh *et al*. 1995a, 1999). Although there was some inter-annual variation in the size and extension of the nursery area, the main area is the Southeast Shoal and the two neighbouring strata, west of the shoal where an average of 82% of all the juveniles are found. More specifically, an average of 60% of the juveniles were concentrated in the southern section of the shoal (stratum 376) and stratum 360, the Tail of the Bank, which neighbours the shoal. Year and depth were identified as the primary variables influencing distribution of juveniles. Location and temperature had a lesser effect. Year may be a proxy for density and further exploration is needed to ascertain its significance. In addition, the analysis was carried out with data from two sets of surveys (1985-94 juvenile and regular the 1995-2000 groundfish surveys) for which no conversion factor exists and the assumption has been selectivity of both of the survey gears (both small mesh shrimp trawls with small footgear) was shown to be similar for yellowtail flounder (Walsh and McCallum 1998) and we have extended that assumption to plaice and cod.

Contrary to the pattern observed in yellowtail flounder, on average 71% of juvenile American plaice were found in Div. 3O. However this effect does not reflect the temporal variation in which, prior to 1990, Div. 3N (specifically stratum 360) contained greater than 50% of the abundance of juvenile American plaice on the Grand Bank. Since 1993, the highest densities, decreasing over time, were found in the Whale Deep-Whale Bank area and along the southwest slope of Div 3O. Spatial analysis has confirmed this new regime. Density together with depth and location were the most important variables influencing the distribution of juveniles on the southern Grand Bank. Temperature had a lesser effect.

The former high density nursery area for American plaice on the Tail of the Bank has disappeared since the mid-1990s coincidental with the disappearance of the high density area on the northern slope of the Grand Bank in Div. 3L. Walsh (1991) identified the northern slope, in the 100-200 m depth range as being a nursery area for Div 3L. In Figs. 1-4 of Appendix I, new information on the distribution of all juvenile plaice by age (0 –3) are presented from for the 1989-1999 time series. The observed decline in abundance of juveniles began in the early 1990s and was most noticeable in 1993. By 1995 there were very few of any age classes anywhere on the Grand Bank (see also Morgan *et al*. 2001). There doesn't appear to be good year-classes of juvenile plaice anywhere on the Grand Bank in recent years. The reasons for low abundance and absence from the traditional nursery areas in the north and the south are unknown. It is interestingly to note that during this time series the stock size declined to a very low level that the remnants of the stock biomass is mainly concentrated on the Tail of the Bank (Morgan *et al*. 2001).

In Atlantic cod, on average 49% (SD=23.4) of juveniles were found in Division 3N in particular the area of the northern section of the Southeast Shoal and the neighbouring strata to the west of the northern section of the shoal. This is similar to the results presented by Lilly *et al*. (2000). Walsh *et al*. (1995a) had suggested that the although distribution of juveniles was widespread across the southern Grand Bank the Southeast Shoal area was a nursery area. The analyses presented here using a longer time series corroborates the earlier observations that juvenile cod are widespread across the southern Grand Bank, however, an average of 45% of the abundance (range 12-81%) was associated with the Southeast Shoal and the 2 neighbouring strata to the west. This emphasizes the importance of the area for juveniles. The distribution of juveniles was shown to be influenced by density and temperature. Changes in the bottom temperatures resulted in a cold period from 1990-1994 and this was followed by a warm period from 1995 onward (Colbourne 2001). It is suspected that the wide distribution of juveniles may be the result of these temperature changes together with large changes in densities of juveniles. A simple explanation could be that there are several smaller nursery sites across the southern Grand Bank.

On the southern Grand Bank, only the juvenile yellowtail flounder nursery area remained geographically localized throughout the time series. The once dense nursery area for juvenile plaice on the Tail of the Bank, now contains few juveniles which may be related to poor success of year-class survival through most of the 1990s and not emigration. Should the stock of American plaice rebuild to levels seen in the mid 1980s then it is expected that the Tail of the Bank and the northern slope will once again be the major nursery areas on the Grand Bank. At present juveniles are dispersed along the southwest slope and Whale Bank-Whale Deep area of Div. 3O.

The yellowtail flounder nursery area is the only nursery area for which physical bounds can be defined with some certainty. If we want to protect an average of 61%[1] of the juvenile abundance (70% of Div 3N juveniles) on the southern Grand Bank, Div 3NO from exploitation then a closed area is proposed in Fig. 14 (Table 9). This area is based on the analysis of aggregated Voronoi polygons on percent abundance using ACON software to construct the polygons. This closed area covers an estimated 6351 n.mi^2 and includes most of strata 376, the southern portion of the Southeast Shoal and some of stratum 360 on the Tail of the Bank. The majority of this area is located in the NAFO Regulatory Area. In this closed area, an average of 14%[1] of Div 3NO juvenile plaice (34% of Div 3N juveniles) and 13%[1] of juvenile cod (20% of 3N juveniles) have been found during the analyses of the time series (Table 9). A much larger closed area is presented in Fig. 15, which includes the majority of the Southeast Shoal and the two neighbouring strata to the west, strata 360 and 361. This area encompasses an estimated 12,079 n.mi^2 and takes in most of the stratum 360 portion of the Tail of the Bank inside the 100 m contour. In this closed area, an average of 83%[1] of juvenile yellowtail flounder, 32%[1]of juvenile plaice and 45 %[1] juvenile cod have been found during the analyses of the time series (Table 9). In addition, of the juveniles in Div. 3N, 91% of yellowtail flounder, 73% of plaice and 65% of cod are in the proposed large area.

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[1] Since the presentation of the first draft at STACFIS meeting in June 2001 an error was detected in the analyses that has been corrected here. Estimates have changes slightly in particular plaice and cod.

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Table 1. Strata specific abundance estimates of juvenile yellowtail flounder, Age 0-3,
expressed as a percentage of total abundance in Div. 3NO.

Div	Stratum	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Average	Std.
3N	375	9.2	2.29	23.49	17.65	14.37	8.53	5.67	6.58	0.42	10.12	16.95	15.47	6.92	10.94	7.66	10.42	6.18
3N	376	34.03	8.52	50.61	37.83	44.46	54.84	65.19	40.19	29.97	57.76	30.01	37.91	55.15	23.71	14.63	38.99	39.32
3N	360	20.42	81.83	21.54	21.91	23.06	24.68	15.40	36.26	43.93	14.94	11.74	15.11	4.01	13.63	6.79	23.68	23.90
3N	361	7.28	4.32	1.27	11.57	9.81	8.94	7.75	7.49	11.16	10.52	12.15	14.41	4.06	22.39	13.54	9.78	9.94
3N	357											0.00	0.00	0.00	0.00	0.00	0.00	0.00
3N	358								0.00			0.00	0.00	0.00	0.00	0.00	0.00	0.00
3N	359					0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3N	362	11.63	0.07	0.07	0.43	0.40	0.16	2.19	0.17	0.14	0.80	21.01	4.11	11.13	3.61	35.11	6.07	5.70
3N	373	1.72	0.05		0	0.07	0.02	0.00	0.02	0.07	0.21	1.19	0.00	3.07	0.85	1.38	0.62	0.54
3N	374	2.19	0.1	0.05	0.03	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.19	0.62	0.23	0.10
3N	377									0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00
3N	378										0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3N	379											0.00	0.00	0.00	0.00	0.00	0.00	0.00
3N	380											0.00	0.00	0.00	0.00	0.00	0.00	0.00
3N	381											0.00	0.00	0.00	0.00	0.00	0.00	0.00
3N	382											0.00	0.00	0.00	0.00	0.00	0.00	0.00
3N	383											0.00	0.00	0.00	0.00	0.00	0.00	0.00
3N	723											0.00	0.00	0.00	0.00	0.00	0.00	0.00
3N	724											0.00	0.00	0.00	0.00	0.00	0.00	0.00
3N	725											0.00	0.00	0.00	0.00	0.00	0.00	0.00
3N	726											0.00	0.00	0.00	0.00	0.00	0.00	0.00
3N	727											0.00	0.00	0.00	0.00	0.00	0.00	0.00
3N	728											0.00	0.00	0.00	0.00	0.00	0.00	0.00
3O	329											0.00	0.00	0.00	0.00		0.00	0.00
3O	330				0	0.01	0.00	0.00	0.30	0.00	0.12	0.10	0.06	0.71	0.22		0.14	0.14
3O	331				0	0.00	0.02	0.00	0.03	0.00	0.00	0.03	0.00	0.06	0.00		0.01	0.01
3O	332					0.00	0.02	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.10		0.02	0.02
3O	333						0.23		0.00	0.00		0.00		0.00	0.00		0.04	0.04
3O	334											0.00		0.00	0.00		0.00	0.00
3O	335											0.00	0.00	0.00	0.00	0.00	0.00	0.00
3O	336											0.00	0.00	0.00	0.00	0.00	0.00	0.00
3O	337					0.00		0.01	0.06	0.00	0.00	0.00	0.11	0.00	0.09	0.00	0.03	0.03
3O	338		0.2		0.24	1.00	0.13	0.03	0.47	0.24	0.46	3.08	0.00	0.11	1.09	0.01	0.54	0.54
3O	339				0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00
3O	340		0		0	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.53	0.03		0.06	0.06
3O	351	13.52	0.25		1.96	0.05	0.21	0.05	0.50	0.80	0.17	0.13	1.42	3.83	12.23		2.70	1.87
3O	352	0	1.83	2.98	8.09	6.70	2.19	3.50	7.86	13.14	4.91	3.57	11.15	10.32	10.91	19.81	7.13	7.61
3O	353		0.54	0	0.29	0.08	0.00	0.17	0.07	0.00	0.00	0.03	0.00	0.08	0.00	0.45	0.12	0.12
3O	354											0.00	0.00	0.00	0.00	0.00	0.00	0.00
3O	355											0.00	0.00	0.00	0.00	0.00	0.00	0.00
3O	356											0.00	0.00	0.00	0.00	0.00	0.00	0.00
3O	717											0.00	0.00	0.00	0.00	0.00	0.00	0.00
3O	718											0.00	0.00	0.00	0.00	0.00	0.00	0.00
3O	719											0.00	0.00	0.00	0.00	0.00	0.00	0.00
3O	720											0.00	0.00	0.00	0.00	0.00	0.00	0.00
3O	721											0.00	0.00	0.00	0.00	0.00	0.00	0.00
3O	722											0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 2 Kriging statistics from variogram models for yellowtail flounder, American plaice and cod.

Yellowtail flounder

Year	Model	Nugget	Sill	Range	Proportion	R2	RSS	Active Lag	Interval
1999	S	0.01	1.00	67.60	0.99	0.30	1.40	195.37	19.55
1998	S	0.09	1.01	48.20	0.92	0.34	0.47	236.71	23.67
1997	S	0.09	0.98	21.90	0.91	0.04	0.30	227.95	22.80
1996	S	0.00	0.98	41.90	1.00	0.24	0.86	225.80	22.58
1995	S	0.09	1.02	55.30	0.91	0.48	0.34	223.21	22.32
1994	S	0.02	1.02	45.60	0.98	0.36	0.40	201.23	20.12
1993	S	0.02	0.96	32.10	0.96	0.19	0.42	215.09	21.51
1992	S	0.16	0.99	20.90	0.84	0.08	0.18	203.87	20.39
1991	S	0.10	1.06	65.50	0.90	0.71	0.17	200.87	20.09
1990	S	0.08	1.10	71.10	0.92	0.87	0.08	203.15	20.32
1989	S	0.14	1.00	42.50	0.86	0.54	0.16	206.52	20.65
1988	S	0.07	0.97	19.60	0.92	0.06	0.47	172.35	17.24
Mean					44.4				
SD					18.3				

American plaice

Year	Model	Nugget	Sill	Range	Proportion	R2	RSS	Active Lag	Interval
1998	E	5.93	19.99	97.80	0.70	0.96	0.15	236.71	23.67
1997	L	0.50	1.49	192.88	0.67	0.96	0.03	227.95	22.80
1996	E	0.44	1.19	197.70	0.63	0.84	0.05	225.80	22.58
1995	S	0.21	1.03	40.20	0.80	0.77	0.04	223.21	22.32
1994	S	0.11	1.02	48.70	0.90	0.69	0.13	201.23	20.12
1993	S	0.33	1.05	63.40	0.69	0.78	0.06	215.09	21.51
1992	S	0.19	1.05	72.50	0.82	0.74	0.13	203.87	20.39
1991	E	0.29	1.15	130.50	0.75	0.94	0.02	200.87	20.09
1990	S	0.21	1.12	95.40	0.82	0.97	0.02	203.15	20.32
1989	S	0.30	1.12	92.70	0.74	0.88	0.06	206.52	20.65
1988	E	0.24	1.29	171.30	0.82	0.93	0.05	172.35	17.24
Mean					109.4				
SD					56.2				

Atlantic cod

Year	Model	Nugget	Sill	Range	Proportion	R2	RSS	Active Lag	Interval
1999	S	0.52	1.08	94.40	0.52	0.84	0.04	223.31	22.33
1998	S	0.00	1.05	58.20	1.00	0.37	0.66	236.85	23.69
1997	S	0.00	0.97	14.60	1.00	0.00	1.26	227.90	22.79
1996	S	0.21	0.96	14.40	0.78	0.00	0.10	225.70	22.57
1995	S	0.00	1.01	14.70	1.00	0.00	0.94	223.43	22.34
1993	E	0.26	1.01	28.80	0.74	0.26	0.05	215.11	21.51
1992	S	0.12	1.00	26.30	0.88	0.27	0.16	203.86	20.39
1991	S	0.30	1.06	66.20	0.72	0.85	0.05	200.88	20.09
1990	S	0.14	10.28	59.20	0.86	0.69	0.15	203.16	20.32
1989	S	0.14	0.99	26.20	0.86	0.33	0.08	206.36	20.64
Mean					40.3				
SD					27.5				

Table 3 Correlation of kriging values between years for juvenile yellowtail flounder

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
1988	**1.00**										
1989	0.75	**1.00**									
1990	0.73	0.82	**1.00**								
1991	0.74	0.82	0.89	**1.00**							
1992	0.68	0.79	0.76	0.78	**1.00**						
1993	0.64	0.72	0.72	0.79	0.77	**1.00**					
1994	0.71	0.81	0.85	0.89	0.79	0.80	**1.00**				
1995	0.57	0.63	0.74	0.79	0.66	0.61	0.76	**1.00**			
1996	0.59	0.67	0.77	0.79	0.70	0.66	0.80	0.78	**1.00**		
1997	0.52	0.59	0.65	0.74	0.66	0.64	0.73	0.74	0.78	**1.00**	
1998	0.47	0.54	0.67	0.67	0.57	0.59	0.70	0.72	0.74	0.71	**1.00**
1999	0.43	0.44	0.57	0.69	0.51	0.59	0.64	0.74	0.71	0.71	0.68

Table 4 Comparison of GAM models based on pseudo R2

	R^2			
Model	Plaice	Yellowtail	Cod	
catchnum ~s(depth)+s(bottemp)+lat+lon+year	0.449319	0.591691	0.443448	FULL MODEL
catchnum ~s(depth)+s(bottemp)+year	0.33647	0.555608	0.396583	Partial Model
catchnum ~s(depth) +lat+lon+year	0.416991	0.532328	0.331997	Partial Model
catchnum ~s(bottemp) +lat+lon+year	0.412001	0.384407	0.339846	Partial Model
catchnum ~s(bottemp) +year	0.26913	0.254903	0.329175	Partial Model
catchnum ~s(depth) +year	0.316407	0.436746	0.263869	Partial Model

Table 5. Strata specific abundance estimates of juvenile American plaice, Age 0-3, expressed as a percentage of total abundance in Div. 3NO.

Div	Stratum	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Average	Std.
3N	375	0.07	0.02	0.09	0.37	0.04	0.09	0.06	0.04	0.56	0.91	0.11	0.07	0.08	0.09	0.19	0.26
3N	376	0.7	1.28	11.11	14.21	0.28	0.54	2.24	3.86	0.49	0.26	0.02	0.10	0.05	0.06	2.51	4.47
3N	360	63.27	77.39	63.67	55.83	52.76	34.45	31.03	8.86	6.10	21.82	7.35	0.58	5.38	3.22	30.84	26.99
3N	361	2	0.29	0.52	1.4	0.36	0.38	0.79	0.22	0.36	0.64	1.94	0.59	0.47	0.10	0.72	0.61
3N	357											0.01	0.00	0.00	0.00	0.00	0.01
3N	358								0.39			0.00	0.01	0.09	0.03	0.10	0.16
3N	359					5.54	3.22	5.80	0.86	1.27	0.23	0.07	0.01	0.05	0.27	1.73	2.29
3N	362	3.69	0.41	5.84	4.18	2.26	1.19	5.79	2.05	0.75	3.73	3.68	0.91	1.42	1.84	2.70	1.80
3N	373	12	0.39		0.32	0.53	0.99	0.92	0.29	1.88	6.68	0.82	0.05	0.20	0.11	1.94	3.49
3N	374	5.58	2.15	0.02	1.93	0.89	0.38	0.09	0.66	2.24	0.50	0.52	0.07	0.09	0.81	1.14	1.49
3N	377									0.44	0.29	0.41	0.07	0.04	0.07	0.22	0.18
3N	378										0.47	0.29	0.12	0.01	0.04	0.19	0.19
3N	379											0.00	0.14	0.00	0.00	0.04	0.07
3N	380											0.10	0.05	0.00	0.00	0.04	0.05
3N	381									1.04	0.32	0.20	0.11	0.11	0.10	0.31	0.37
3N	382					0.05	3.14	0.22	0.27	0.99	0.57	0.10	0.19	0.08	0.12	0.57	0.95
3N	383	7.17			0.61	0.56	1.65	2.23	2.26	0.22	0.19	0.04	0.02	0.01	0.17	1.26	2.04
3N	723											0.00	0.01	0.00	0.00	0.00	0.01
3N	724											0.00	0.02	0.00	0.00	0.01	0.01
3N	725											0.00	0.03	0.00	0.00	0.01	0.02
3N	726											0.00	0.03	0.00	0.00	0.01	0.02
3N	727											0.01	0.06	0.00	0.00	0.02	0.03
3N	728											0.00	0.24	0.00	0.00	0.06	0.12
3O	329					5.90		9.77	8.07	27.89	8.07	10.42	10.81	5.74	9.48	10.68	6.70
3O	330				0.02	3.28	0.24	1.66	1.46	4.47	3.28	0.46	0.76	6.08	3.91	2.33	2.00
3O	331				0.04	0.59	3.37	0.89	0.89	0.21	0.45	2.35	2.97	6.24	8.98	2.45	2.85
3O	332					2.53	5.11	5.49	7.91	6.02	5.75	6.26	6.78	5.19	15.51	6.66	3.40
3O	333								0.00	0.00		0.02		0.01	0.00	0.01	0.01
3O	334											0.00		0.00	0.00	0.00	0.00
3O	335											0.01	0.01	0.00	0.00	0.01	0.01
3O	336									0.00		0.03	0.16	0.02	0.32	0.11	0.14
3O	337					1.09	5.66	2.74	6.22	0.98	3.83	2.39	2.01	3.20	4.50	3.26	1.79
3O	338		0.41		2.54	3.25	1.79	4.24	7.35	2.36	8.57	14.73	27.00	12.25	9.51	7.83	7.52
3O	339				3.29	9.96	14.28	7.36	8.64	22.95	8.29	11.80	4.68	26.27	10.83	11.67	7.14
3O	340		0.12		0.5	0.19	0.34	3.35	12.28	0.75	10.67	27.25	2.13	17.71	1.87	6.43	8.76
3O	351	4.88	1.28		0.62	5.04	8.59	0.72	9.43	7.36	5.32	0.90	2.07	4.06	4.59	4.22	3.00
3O	352	0.61	1.61	12.91	3.54	1.41	1.58	1.01	5.36	4.07	2.90	3.69	18.91	1.84	5.82	4.66	5.16
3O	353		14.64	5.84	10.61	2.88	11.52	9.10	6.88	5.19	4.91	3.79	14.36	2.96	14.90	8.28	4.51
3O	354					0.61	1.50	4.49	5.77	1.40	1.32	0.24	3.77	0.29	1.92	2.13	1.90
3O	355										0.01	0.01	0.07	0.01	0.74	0.17	0.32
3O	356											0.00	0.00	0.00	0.02	0.01	0.01
3O	717											0.00		0.05	0.00	0.02	0.03
3O	718											0.00		0.00	0.00	0.00	0.00
3O	719											0.00	0.02	0.00	0.03	0.01	0.02
3O	720											0.00	0.00	0.00	0.00	0.00	0.00
3O	721											0.01	0.01	0.00	0.00	0.01	0.01
3O	722											0.00	0.00	0.00	0.00	0.00	0.00

Table 6 Correlation of kriging values between years for juvenile American plaice

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
1988	**1.00**										
1989	0.66	**1.00**									
1990	0.69	0.69	**1.00**								
1991	0.67	0.85	0.61	**1.00**							
1992	0.61	0.70	0.61	0.72	**1.00**						
1993	0.30	0.49	0.36	0.50	0.63	**1.00**					
1994	0.14	0.55	0.41	0.51	0.49	0.47	**1.00**				
1995	-0.14	0.04	-0.03	0.06	0.32	0.39	0.51	**1.00**			
1996	-0.38	0.01	0.02	-0.13	0.20	0.20	0.52	0.61	**1.00**		
1997	0.01	0.00	0.01	-0.01	0.00	0.00	-0.01	-0.01	0.00	**1.00**	
1998	0.00	0.13	0.13	0.14	0.40	0.31	0.36	0.64	0.50	-0.01	**1.00**

Table 7. Strata specific abundance estimates of juvenile Atlantic cod, Age 0 &1, expressed as a percentage of total abundance in Div. 3NO.

Div	Stratum	1989	1990	1991	1992	1993	1995	1996	1997	1998	1999	Avg.	St.Dev.
3N	375	2.58	3.64	30.34	23.63	0.00	40.33	0.00	0.00	1.78	28.27	13.06	15.72
3N	376	10.09	6.15	16.24	2.05	0.00	18.22	0.00	0.00	10.89	0.35	6.40	7.06
3N	360	11.64	2.07	5.20	20.55	0.00	1.81	0.00	0.00	0.79	1.01	4.31	6.74
3N	361	8.91	13.17	24.10	15.77	11.50	20.13	24.26	57.69	38.44	1.85	21.58	16.19
3N	357						0.00	0.00	0.00	0.00	0.00	0.00	0.00
3N	358				0.58		0.00	0.00	0.00	0.00	0.00	0.10	0.24
3N	359	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3N	362	0.00	0.46	1.85	1.58	0.00	0.80	0.00	0.00	5.72	10.40	2.08	3.41
3N	373	1.36	0.21	0.36	2.20	0.00	0.00	0.00	0.00	0.89	1.47	0.65	0.79
3N	374	0.00	0.00	0.06	1.11	0.00	0.00	0.00	0.00	0.65	0.61	0.24	0.40
3N	377					0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3N	378						0.00	0.00	0.00	0.00	0.02	0.00	0.01
3N	379						0.00	0.86	0.00	0.00	0.01	0.17	0.38
3N	380						0.00	0.00	0.00	0.00	0.00	0.00	0.00
3N	381					0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3N	382	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
3N	383	0.00	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.42	0.00	0.05	0.13
3N	723						0.00	0.00	0.00	0.00	0.00	0.00	0.00
3N	724						0.00	0.00	0.00	0.00	0.00	0.00	0.00
3N	725						0.00	0.00	0.00	0.00	0.00	0.00	0.00
3N	726						0.00	0.00	0.00	0.00	0.00	0.00	0.00
3N	727						0.00	5.88	0.00	0.00	0.00	1.18	2.63
3N	728						0.00	0.00	0.00	0.00	0.00	0.00	0.00
3O	329	4.81		0.21	7.19	1.35	0.84	3.14	0.00	1.58	0.32	2.16	2.45
3O	330	10.97	1.88	1.24	8.73	2.39	7.53	21.73	24.23	20.95	10.27	10.99	8.56
3O	331	0.49	0.20	0.01	0.96	0.00	1.61	0.00	0.00	0.48	1.73	0.55	0.67
3O	332	9.06	6.60	9.06	0.00	35.39	0.00	0.00	8.10	2.58	2.54	7.33	10.55
3O	333				0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00
3O	334						0.00		0.00	0.00	0.00	0.00	0.00
3O	335						0.00	0.00	0.00	0.00	0.00	0.00	0.00
3O	336					0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3O	337	4.10	2.00	0.12	0.00	11.36	0.00	0.00	0.00	0.00	0.00	1.76	3.64
3O	338	3.20	46.45	5.06	4.73	30.96	6.36	34.86	0.00	3.43	7.22	14.23	16.57
3O	339	0.00	0.02	0.07	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03
3O	340	5.57	4.29	1.53	2.98	0.09	0.00	3.13	0.00	7.07	13.46	3.81	4.17
3O	351	6.81	2.12	1.59	4.36	0.33	1.00	0.00	0.00	0.89	14.44	3.15	4.51
3O	352	11.16	9.72	2.73	3.52	6.10	1.38	4.70	9.98	3.45	5.27	5.80	3.38
3O	353	9.24	0.58	0.18	0.00	0.53	0.00	0.00	0.00	0.00	0.49	1.10	2.87
3O	354	0.00	0.42	0.01	0.00	0.00	0.00	1.44	0.00	0.00	0.05	0.19	0.46
3O	355						0.00	0.00	0.00	0.00	0.00	0.00	0.00
3O	356						0.00	0.00	0.00	0.00	0.00	0.00	0.00
3O	717						0.00		0.00	0.00	0.02	0.01	0.01
3O	718						0.00		0.00	0.00	0.00	0.00	0.00
3O	719						0.00	0.00	0.00	0.00	0.00	0.00	0.00
3O	720						0.00	0.00	0.00	0.00	0.00	0.00	0.00
3O	721						0.00	0.00	0.00	0.00	0.00	0.00	0.00
3O	722						0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 8 Correlation of kriging values between years for juvenile Atlantic cod

	1989	**1990**	**1991**	**1992**	**1993**	**1995**	**1996**	**1997**	**1998**	**1999**
1989	**1.00**									
1990	0.56	**1.00**								
1991	0.13	0.49	**1.00**							
1992	0.21	0.38	0.44	**1.00**						
1993	0.35	0.49	0.12	0.24	**1.00**					
1995	0.26	0.34	0.43	0.44	0.10	**1.00**				
1996	0.26	-0.19	0.19	0.06	-0.10	-0.03	**1.00**			
1997	0.03	0.08	0.18	0.13	0.04	0.10	0.02	**1.00**		
1998	0.15	0.31	0.54	0.42	0.06	0.47	0.07	0.28	**1.00**	
1999	0.03	0.11	0.19	0.02	-0.14	0.11	-0.03	0.27	0.46	**1.00**

Table 9. Percentage of Div. 3NO juveniles found in the two proposed closed areas. Small area encompasses 6,351 n.mi^2 and the large closed area encompasses 12, 079 n.mi^2

Yellowtail flounder

	3NO		3N	
Year	Small-MPA	Large-MPA	Small-MPA	Large-MPA
1988	64.39	90.28	76.69	97.20
1989	65.37	82.81	73.39	91.19
1990	77.22	92.59	83.17	96.46
1991	81.91	95.06	85.63	97.84
1992	61.86	89.58	69.44	95.44
1993	23.71	88.70	31.34	96.96
1994	39.04	86.01	47.44	92.77
1995	58.22	75.99	66.43	86.46
1996	76.60	84.20	84.51	92.76
1997	79.11	65.11	88.58	80.65
1998	59.89	78.51	73.44	91.49
1999	52.80	66.54	64.54	82.63
Mean	**61.68**	**82.95**	**70.38**	**91.82**
S.D.	**17.18**	**9.71**	**16.75**	**5.77**

American plaice

	3NO		3N	
Year	Small-MPA	Large-MPA	Small-MPA	Large-MPA
1988	51.43	72.00	67.00	88.30
1989	17.48	66.78	26.70	85.89
1990	11.16	48.06	23.28	80.30
1991	11.54	34.25	21.97	62.67
1992	9.07	23.75	38.02	78.03
1993	7.43	12.55	37.36	61.27
1994	28.80	45.09	58.23	84.70
1995	3.53	21.15	16.80	72.32
1996	0.63	2.32	9.04	35.20
1997	2.86	13.99	23.44	76.78
1998	6.38	14.00	54.97	84.34
Mean	**13.66**	**32.18**	**34.26**	**73.62**
S.D.	**14.78**	**23.10**	**18.67**	**15.58**

Atlantic cod

	3NO		3N	
Year	Small-MPA	Large-MPA	Small-MPA	Large-MPA
1989	5.81	62.84	11.18	88.45
1990	16.36	29.32	38.58	66.84
1991	33.32	62.89	41.44	77.20
1992	11.60	40.23	15.57	56.79
1993	17.52	32.84	29.61	57.79
1994	2.41	52.03	3.69	71.37
1995	27.86	79.41	36.32	90.32
1996	2.32	18.37	5.24	43.22
1997	7.62	24.92	13.28	47.50
1998	16.59	72.55	30.90	91.64
1999	1.79	10.03	3.39	23.42
Mean	**13.02**	**44.13**	**20.84**	**64.96**
S.D.	**10.55**	**23.18**	**14.75**	**21.73**

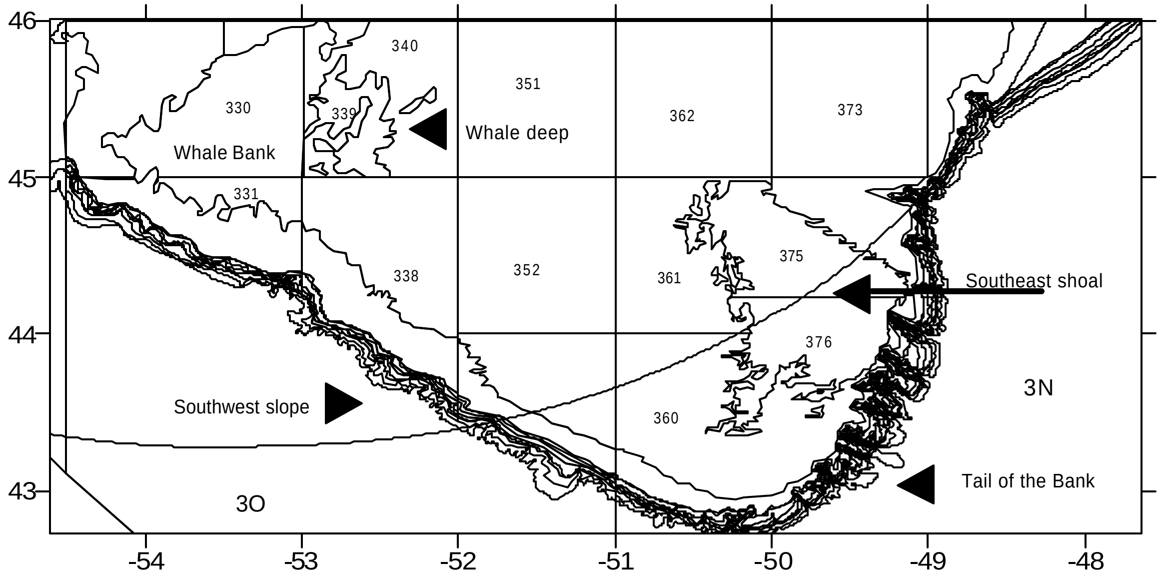


Fig. 1. Survey stratification scheme for the southern Grand Bank, Div. 3NO. Showing major strata.

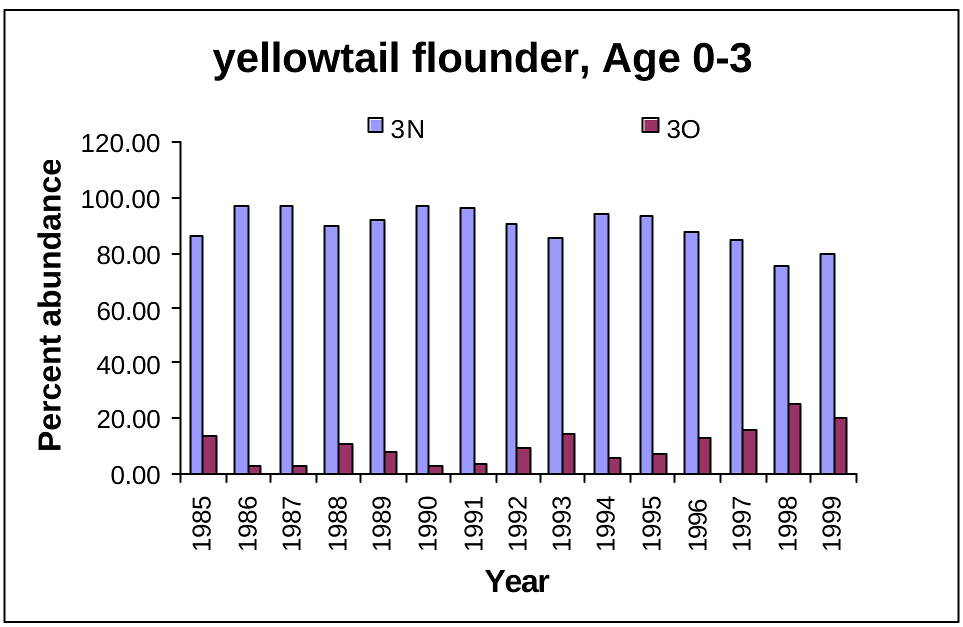


Fig. 2. Frequency of occurrence (percent abundance) of juvenile yellowtail flounder in Div. 3NO, 1985-1999.

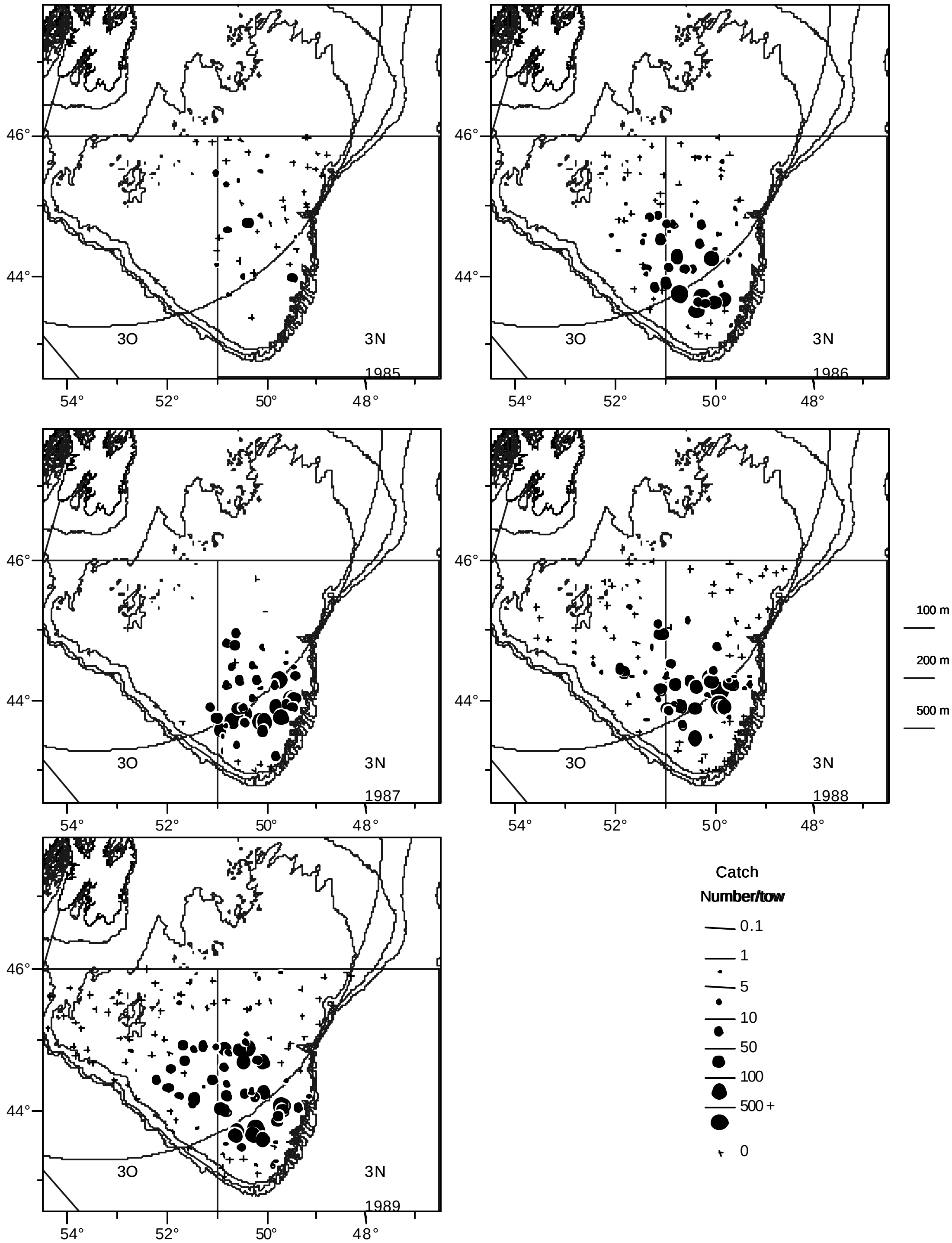


Fig. 3. ACON expanding symbol plots of standardized catches (numbers) of juvenile yellowtail flounder from annual fall surveys of Div. 3NO, 1985-1999

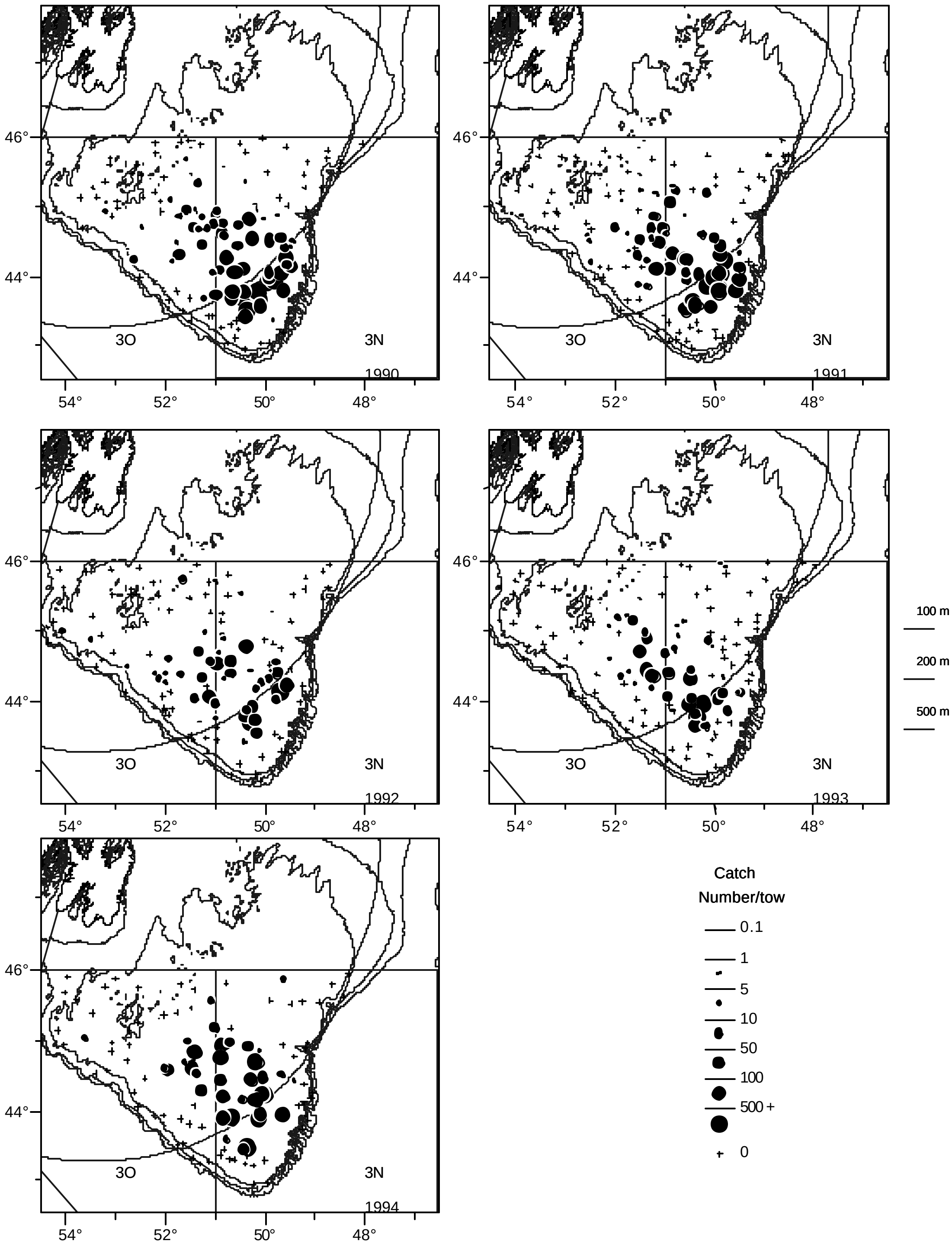

46°
44°
3O
3N
1990
1991
1992
1993
1994
54°
52°
50°
48°
100 m
200 m
500 m
Catch
Number/tow
0.1
1
5
10
50
100
500 +
0

Fig. 3. Cont'd

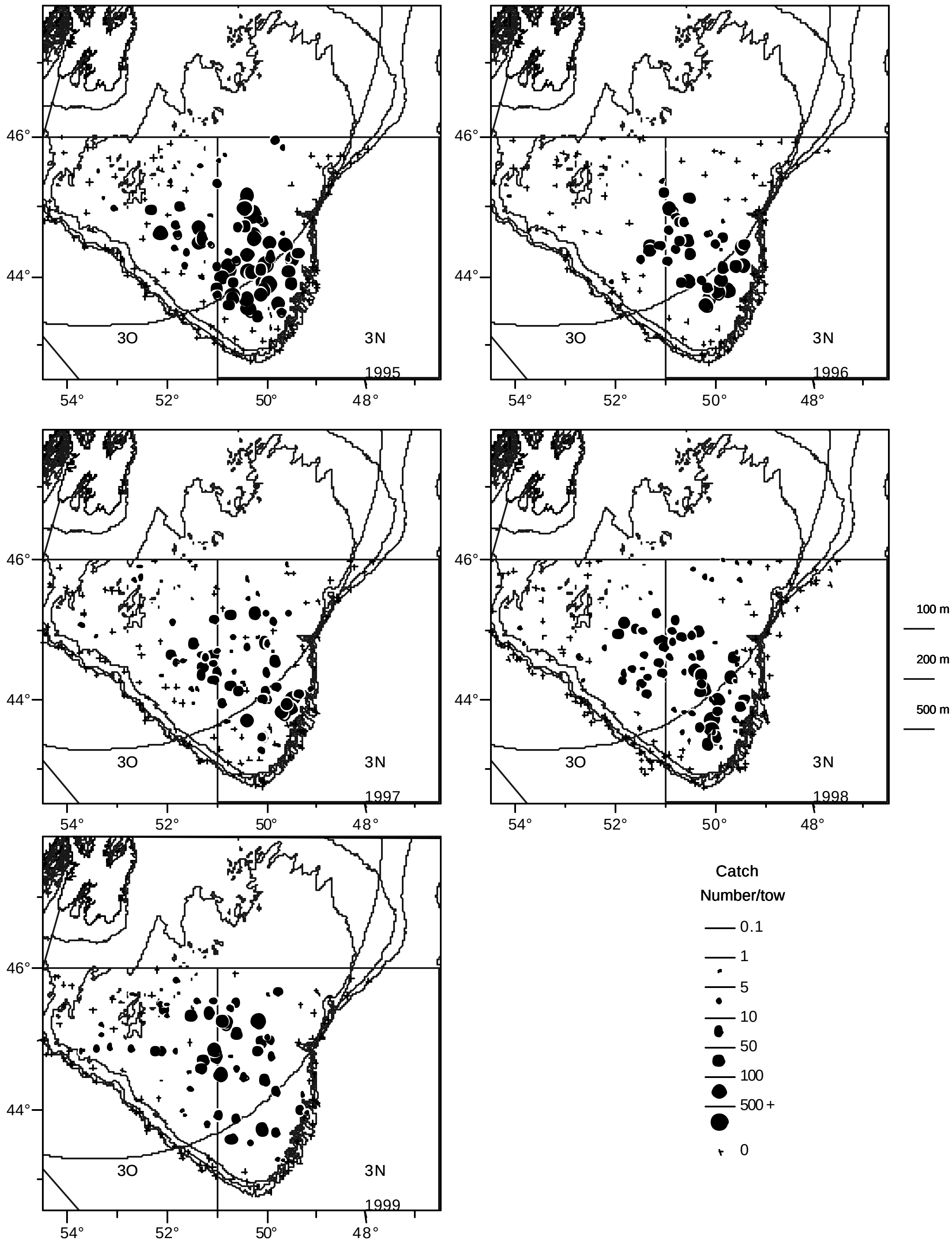

46°
44°
3O
3N
1995
1996
1997
1998
1999
54°
52°
50°
48°
100 m
200 m
500 m
Catch
Number/tow
0.1
1
5
10
50
100
500 +
0

Fig. 3. Cont'd.

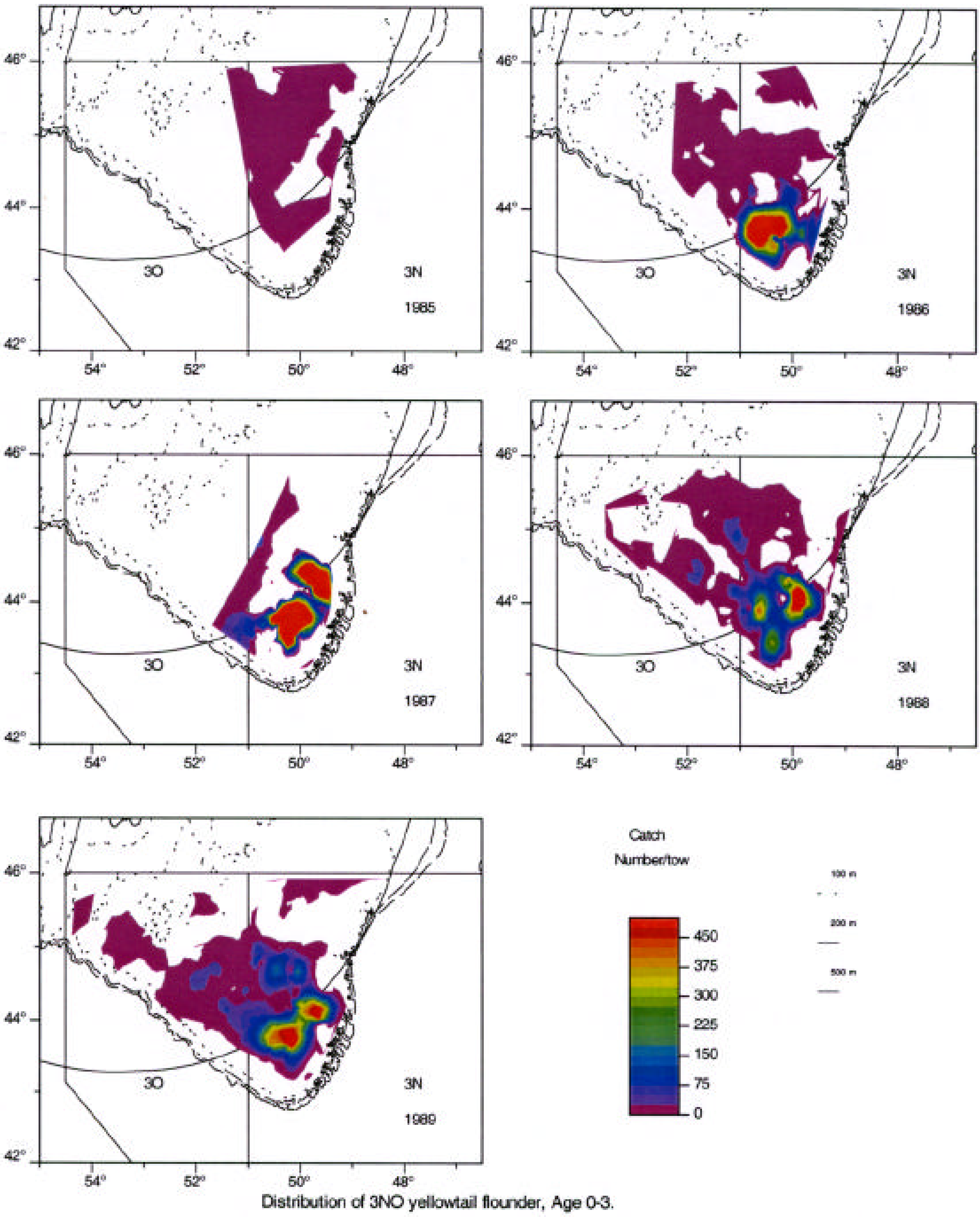


Fig. 4. ACON contour plots of standardized catches (numbers) of juvenile yellowtail flounder from annual fall surveys of Div. 3NO, 1985-1999.

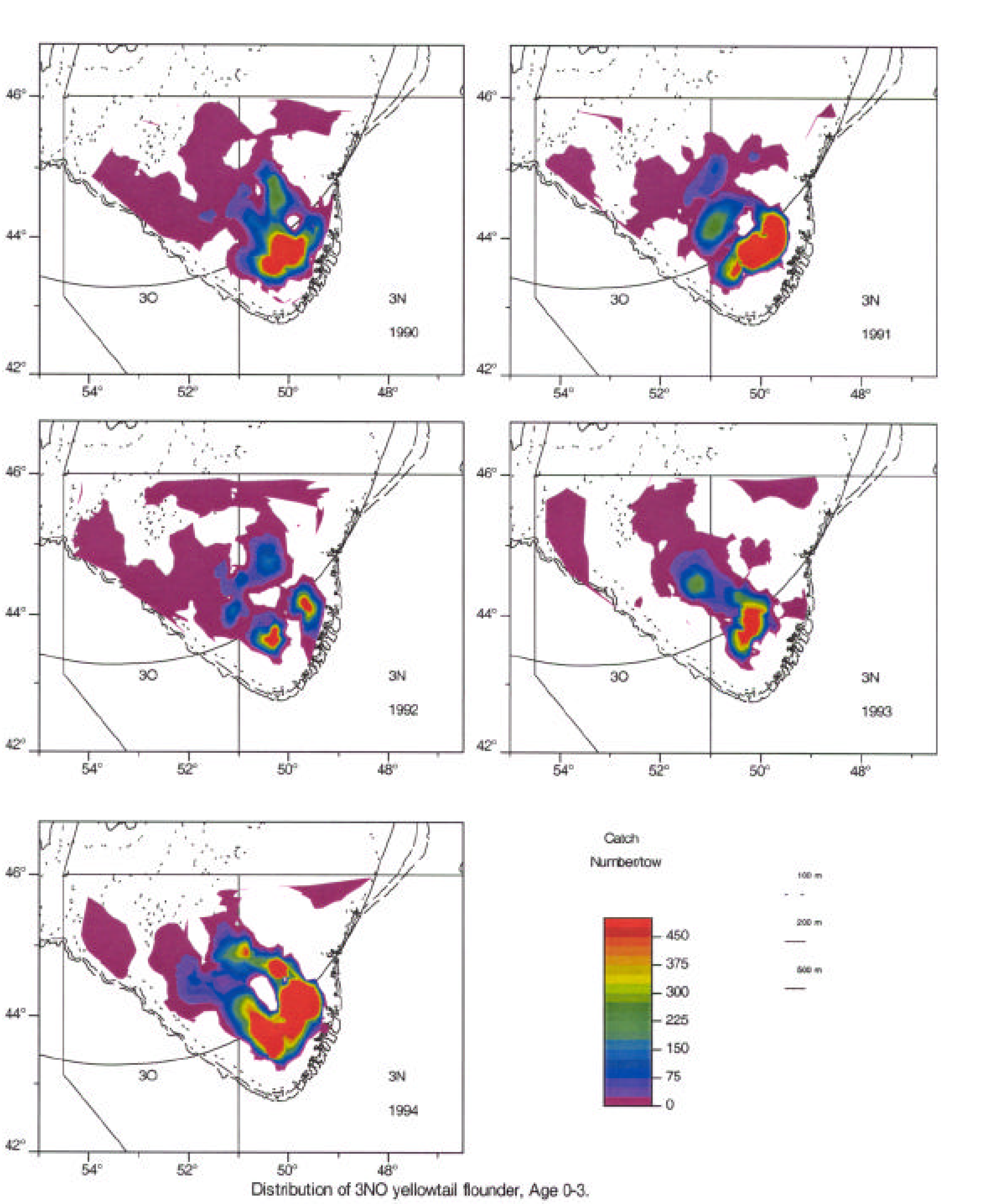

46°
44°
42°
54°
52°
50°
48°
3O
3N
1990
1991
1992
1993
1994
Catch
Numbertow
450
375
300
225
150
75
0
Distribution of 3NO yellowtail flounder, Age 0-3.

Fig. 4. Cont'd

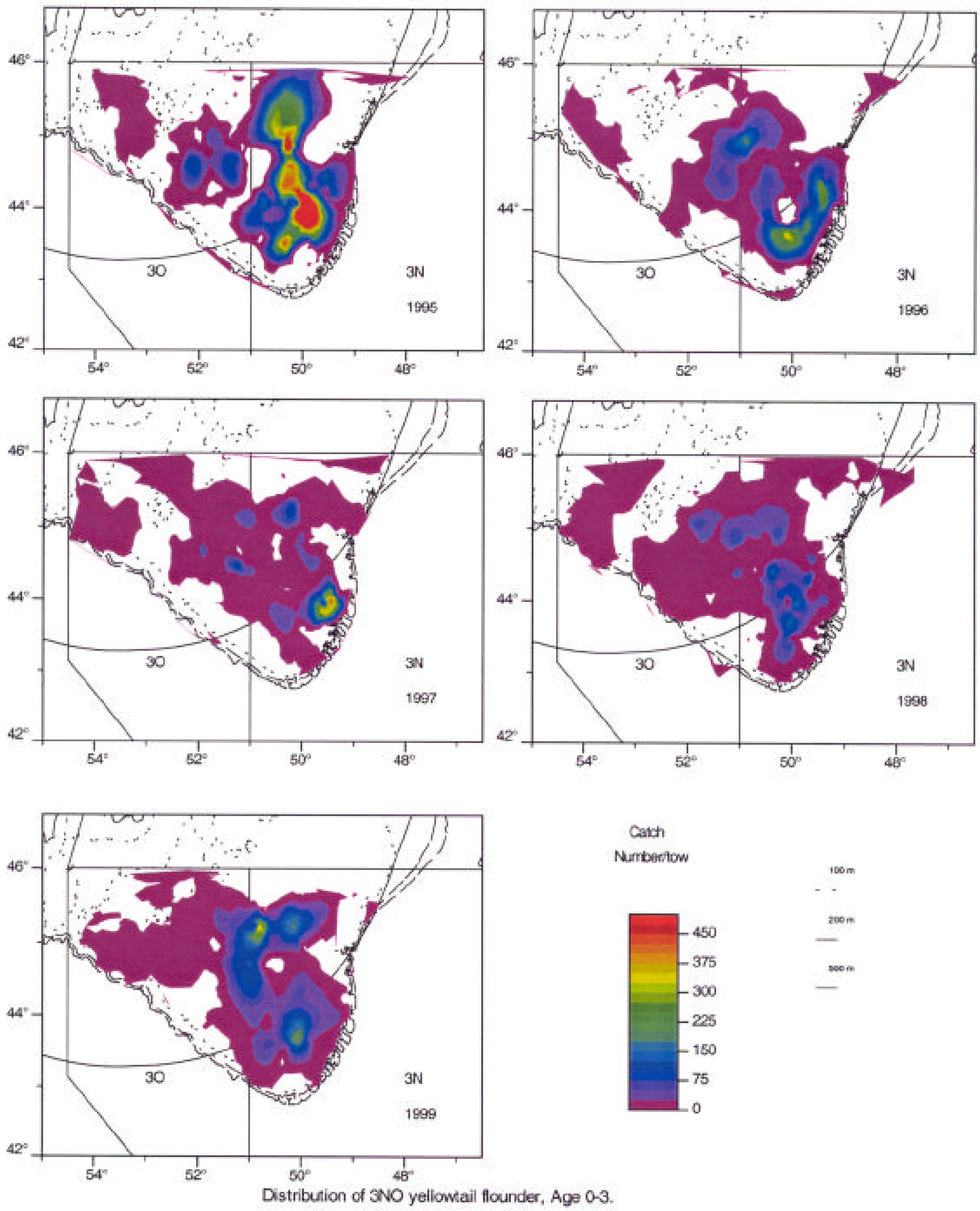

46°
44°
42°
54°
52°
50°
48°
3O
3N
1995
1996
1997
1998
1999
Catch
Number/tow
450
375
300
225
150
75
0
Distribution of 3NO yellowtail flounder, Age 0-3.

Fig. 4. Cont'd

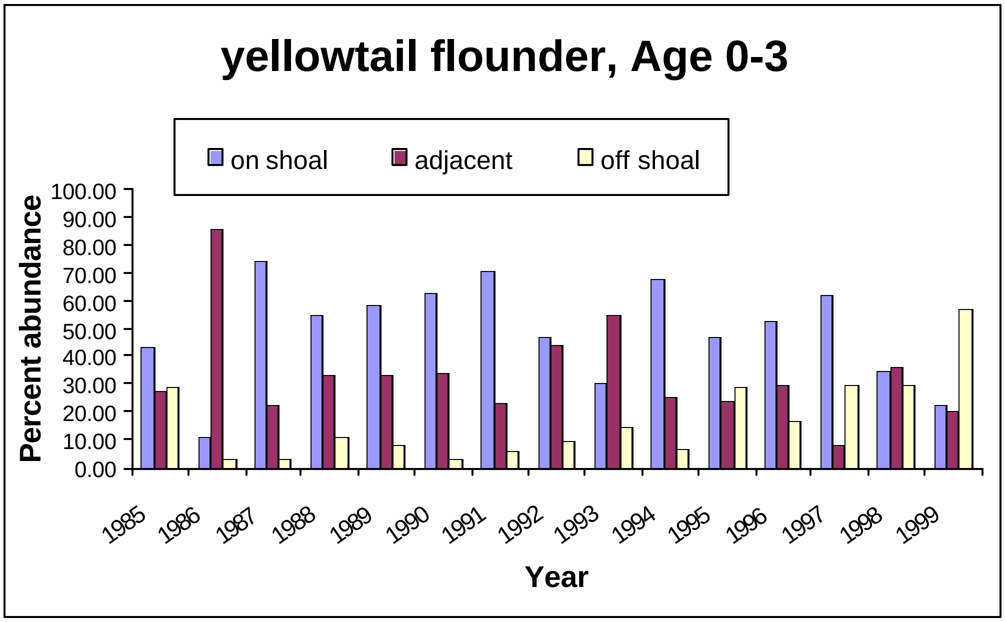


Fig. 5. Frequency of occurrence (percent abundance) of juvenile yellowtail flounder in Div. 3NO that are found on the Southeast Shoal (strata 375+376), adjacent to the shoal (strata 360+361) and off the shoal (all other strata in Div 3NO), 1985-1999.

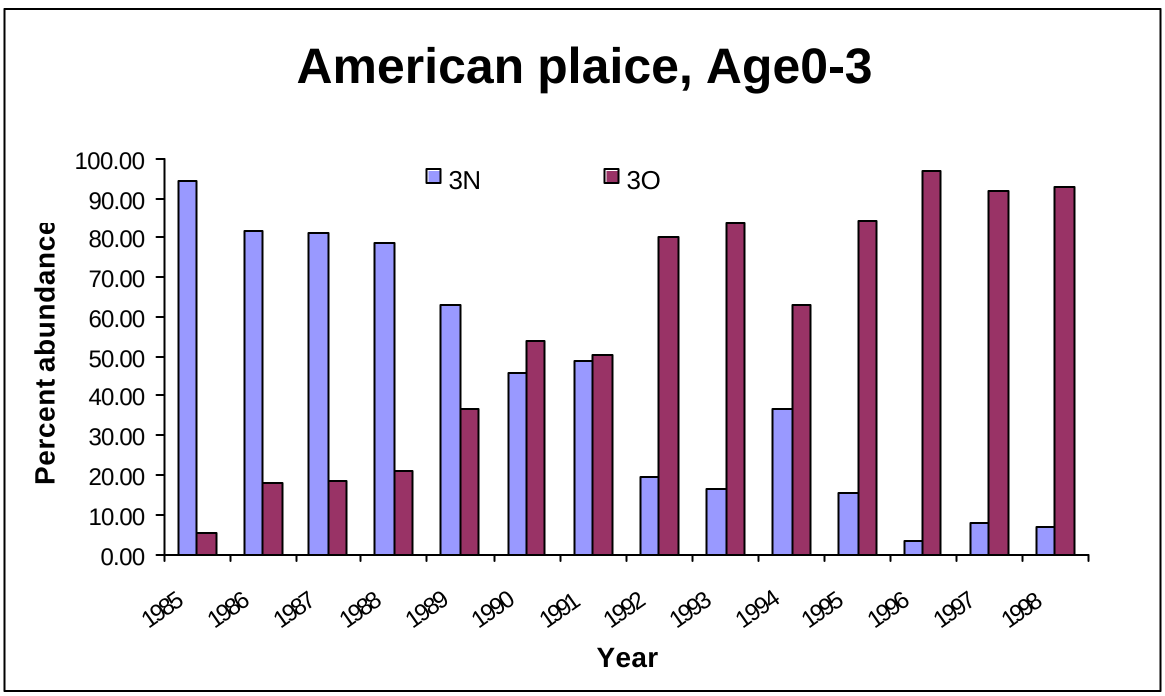


Fig. 6. Frequency of occurrence (percent abundance) of juvenile American plaice in Div. 3NO, 1985-1998.

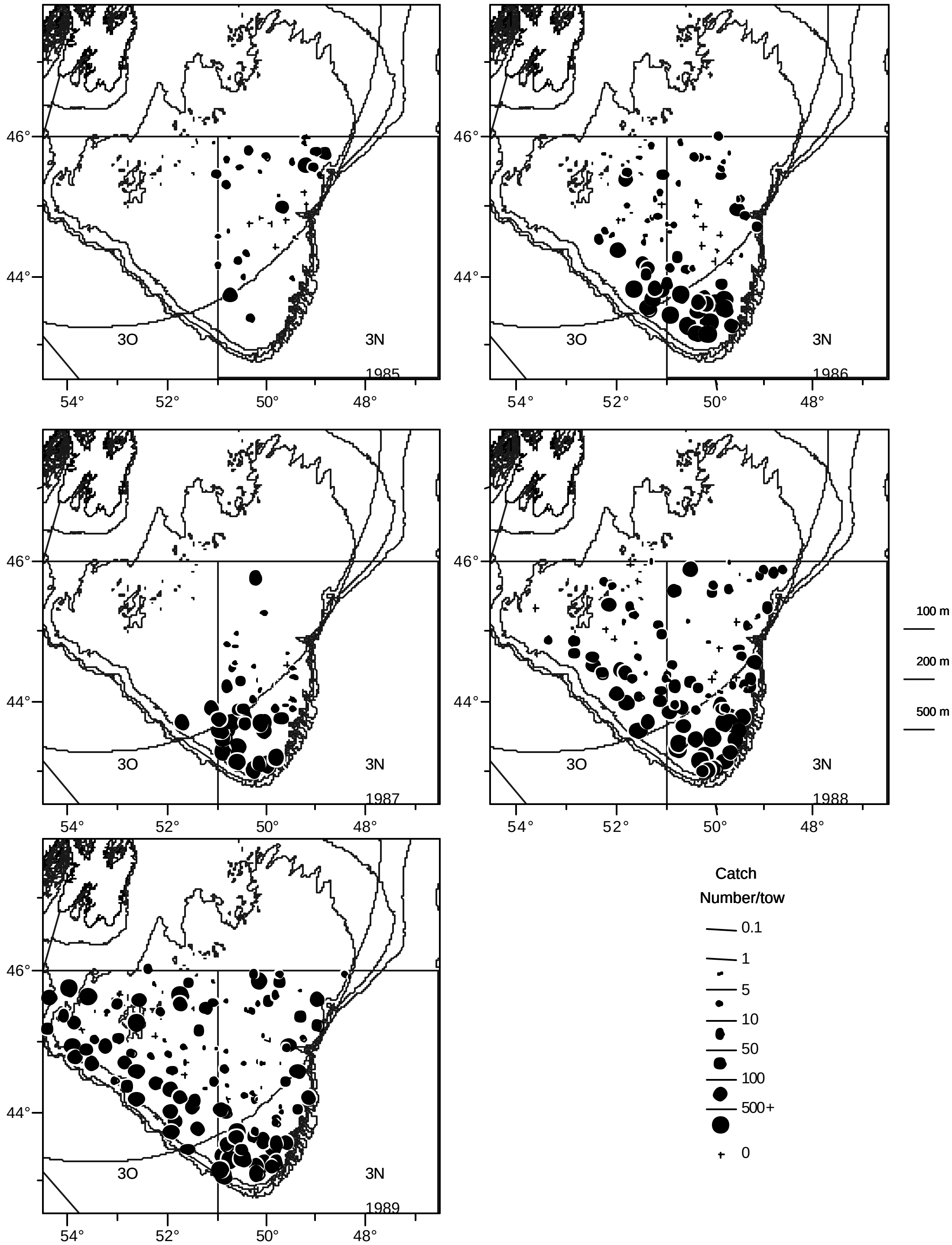
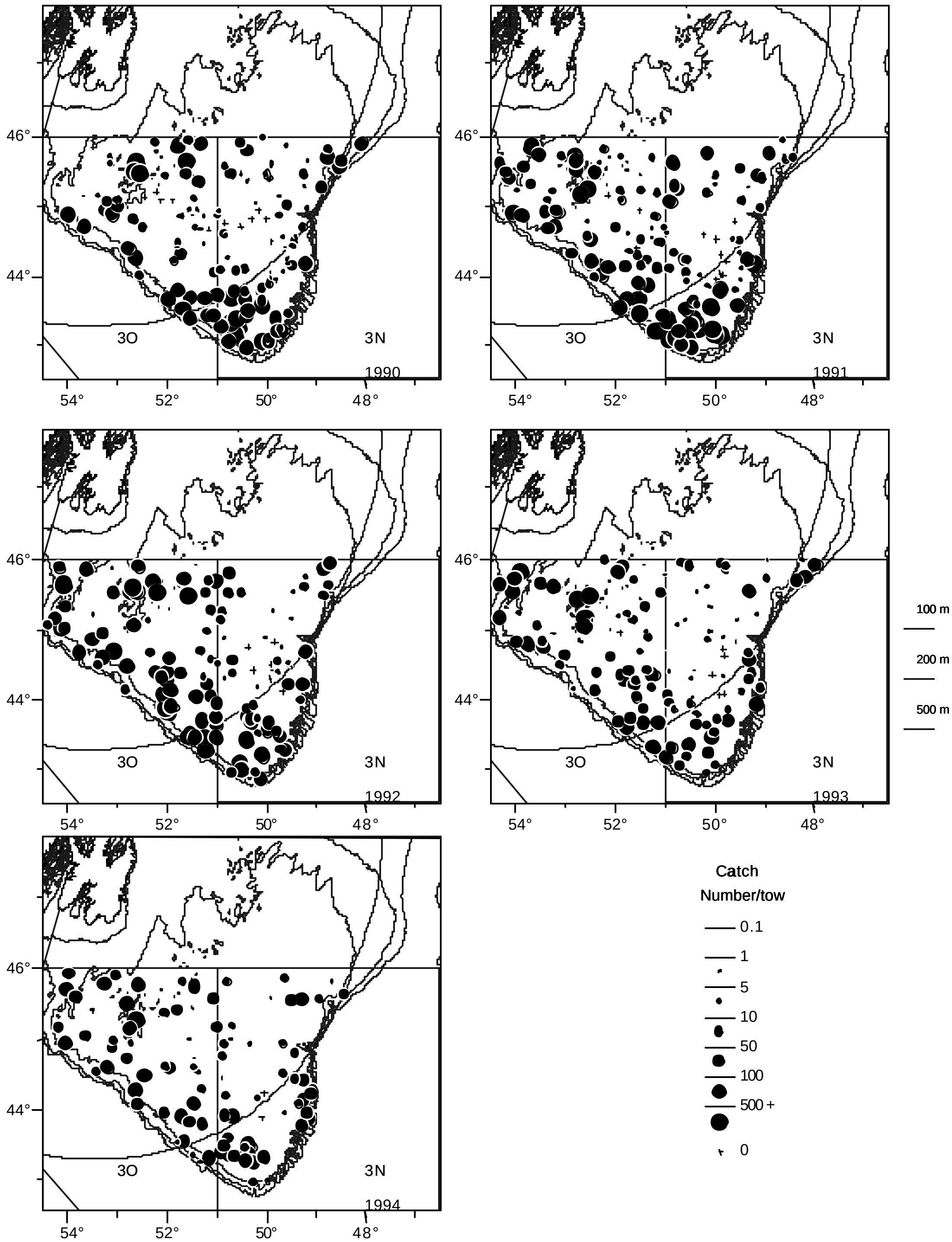


Fig. 7. ACON expanding symbol plots of standardized catches (numbers) of juvenile American plaice from annual fall surveys of Div. 3NO, 1985-1998



46°
44°
3O
3N
1990
54°
52°
50°
48°
1991
1992
1993
1994
100 m
200 m
500 m
Catch
Number/tow
0.1
1
5
10
50
100
500 +
0

Fig. 7. Cont'd

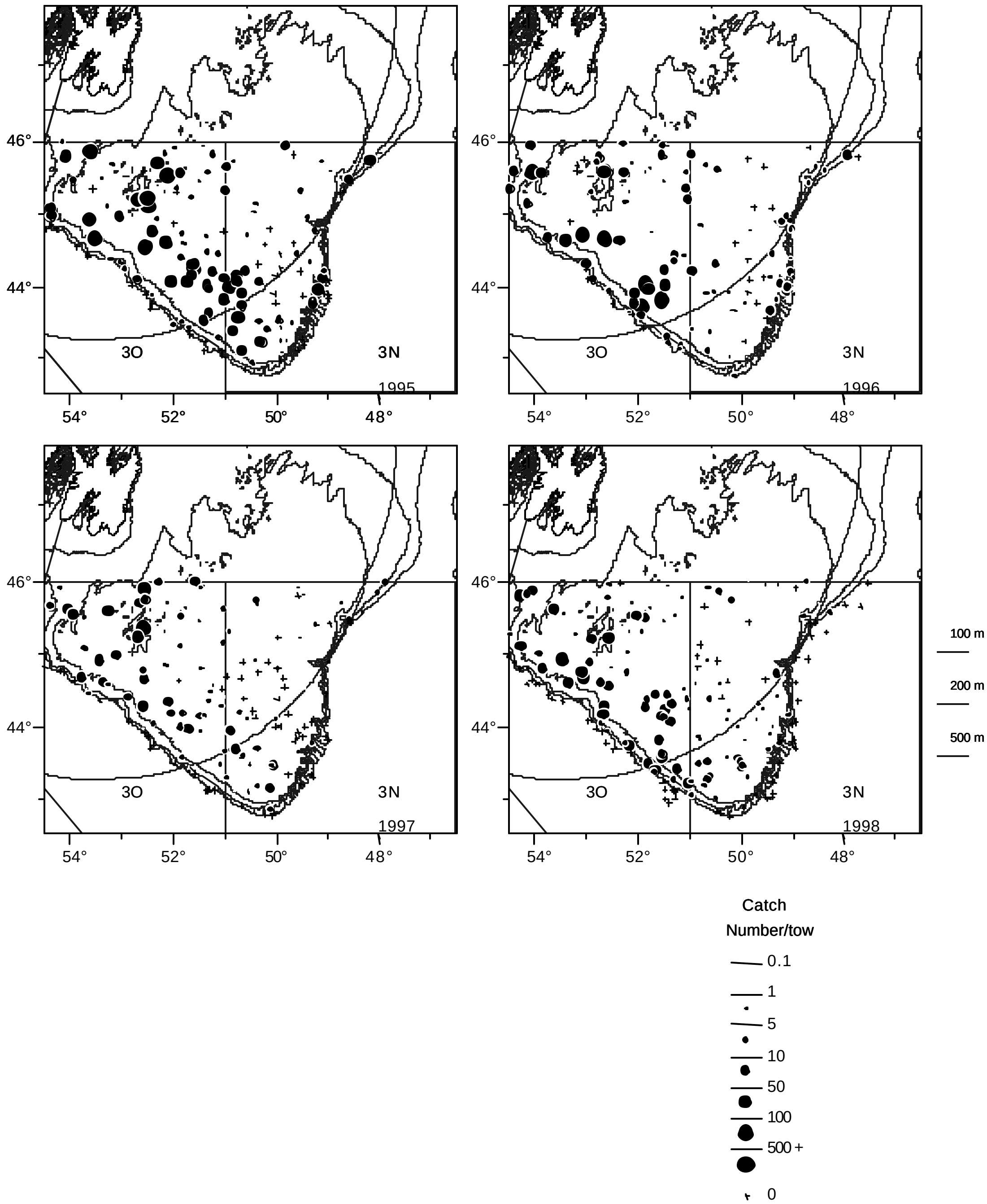

46°
44°
3O
3N
1995
54°
52°
50°
48°
1996
1997
1998
100 m
200 m
500 m
Catch
Number/tow
0.1
1
5
10
50
100
500 +
0

Fig. 7. Cont'd

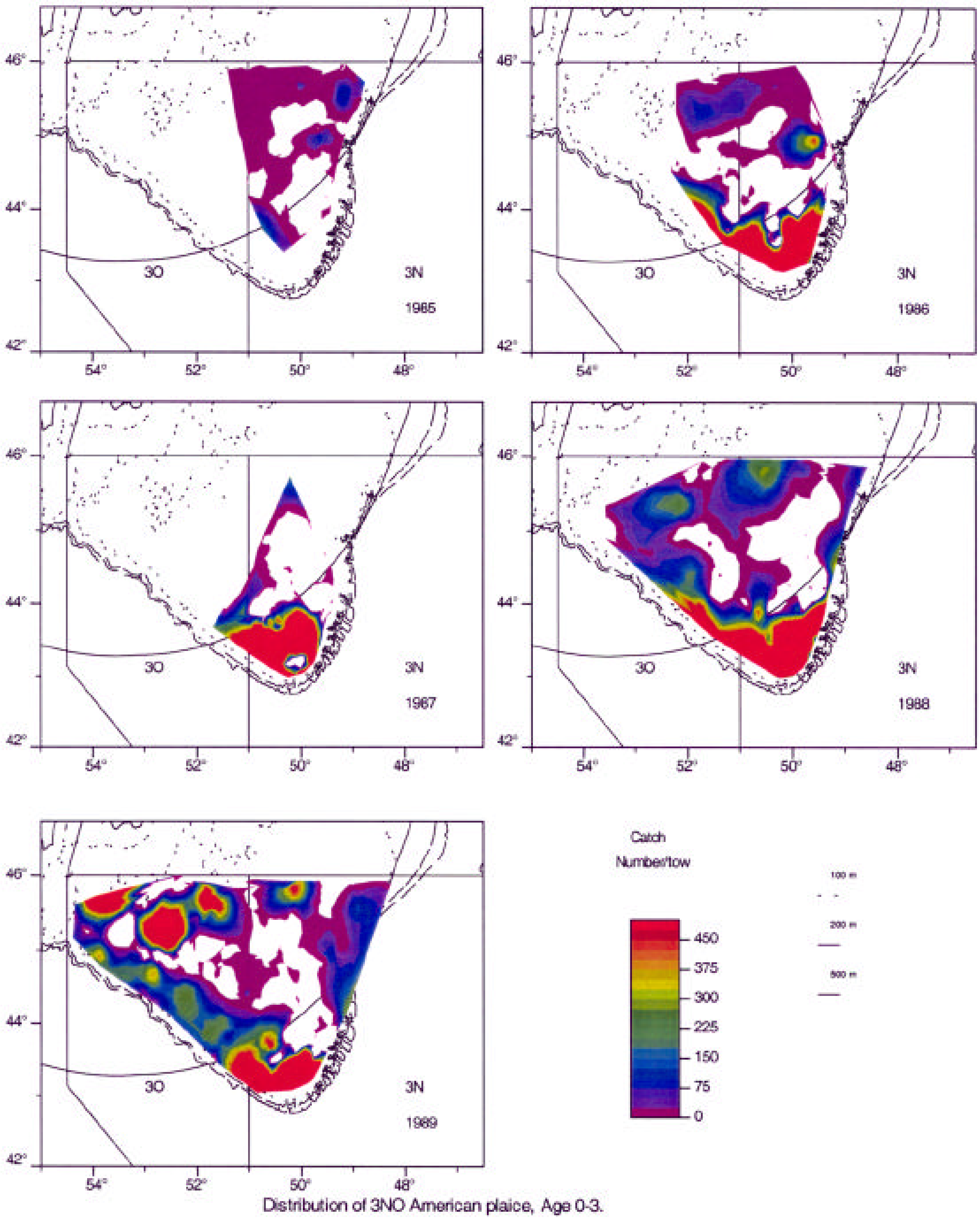
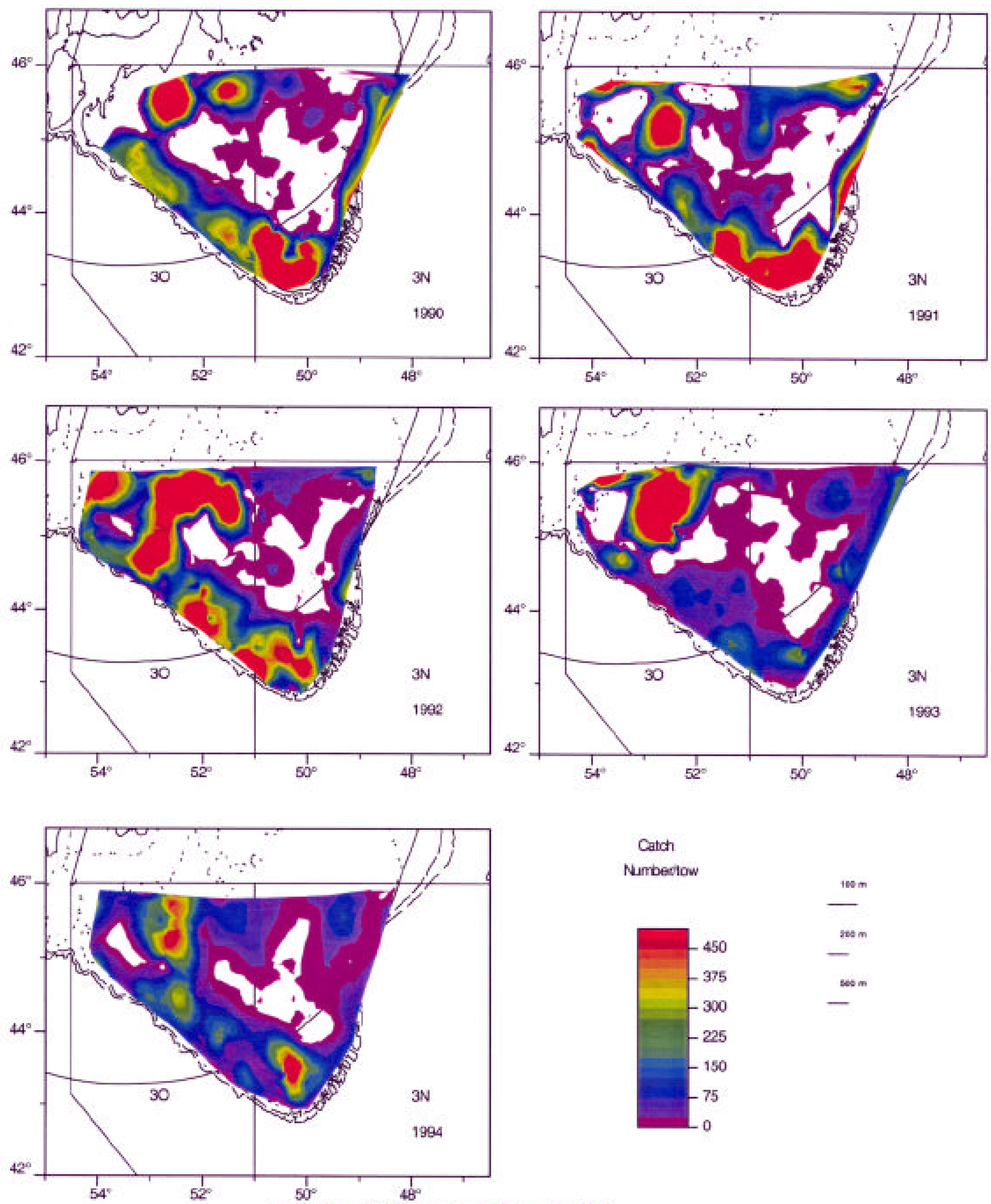


Fig. 8. ACON contour plots of standardized catches (in numbers) of juvenile American plaice from annual fall surveys of Div. 3NO, 1985-1998.



Distribution of 3NO American plaice, Age 0-3.

Fig. 8 Cont'd

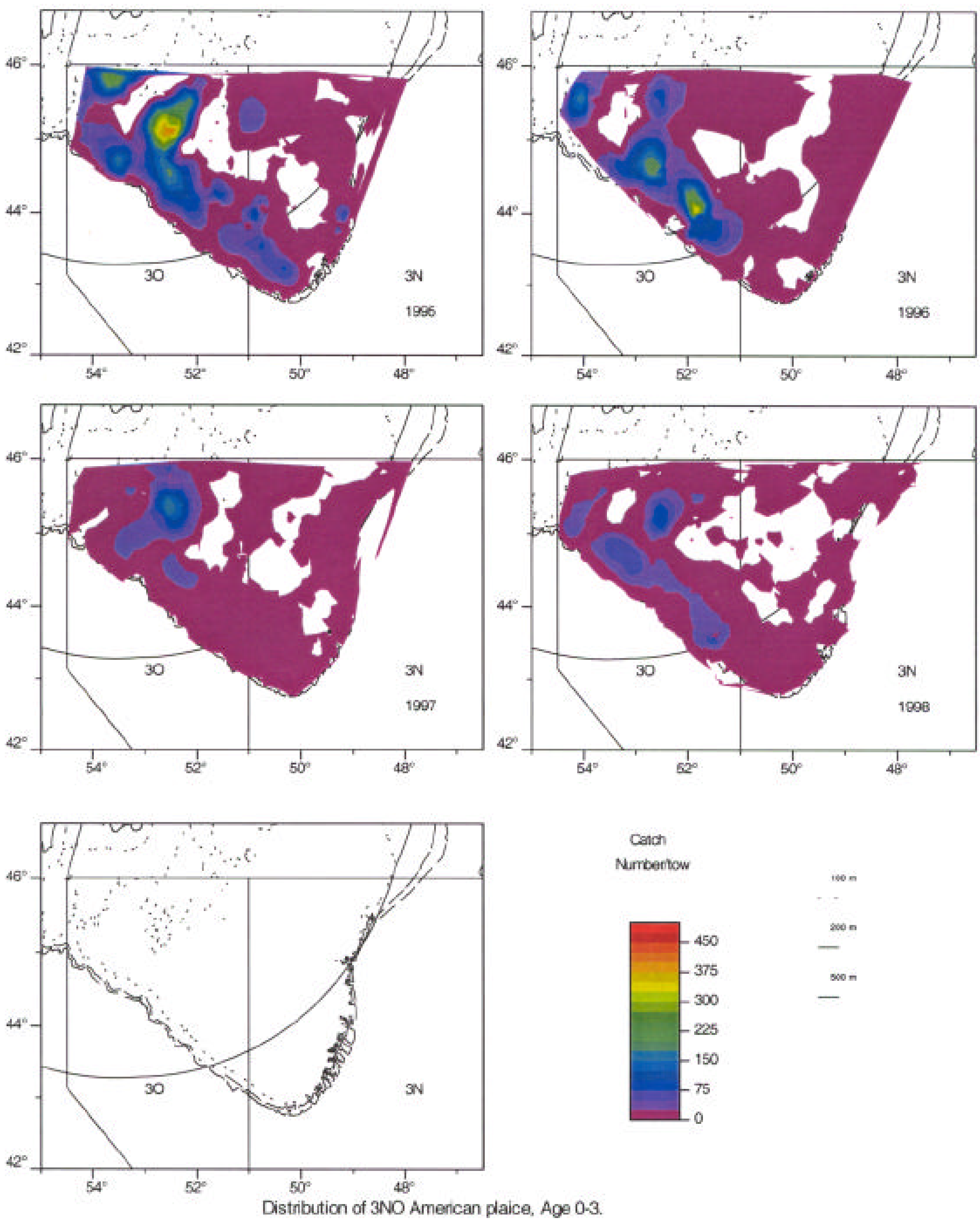


Fig. 8 Cont'd (no age data for 1999).

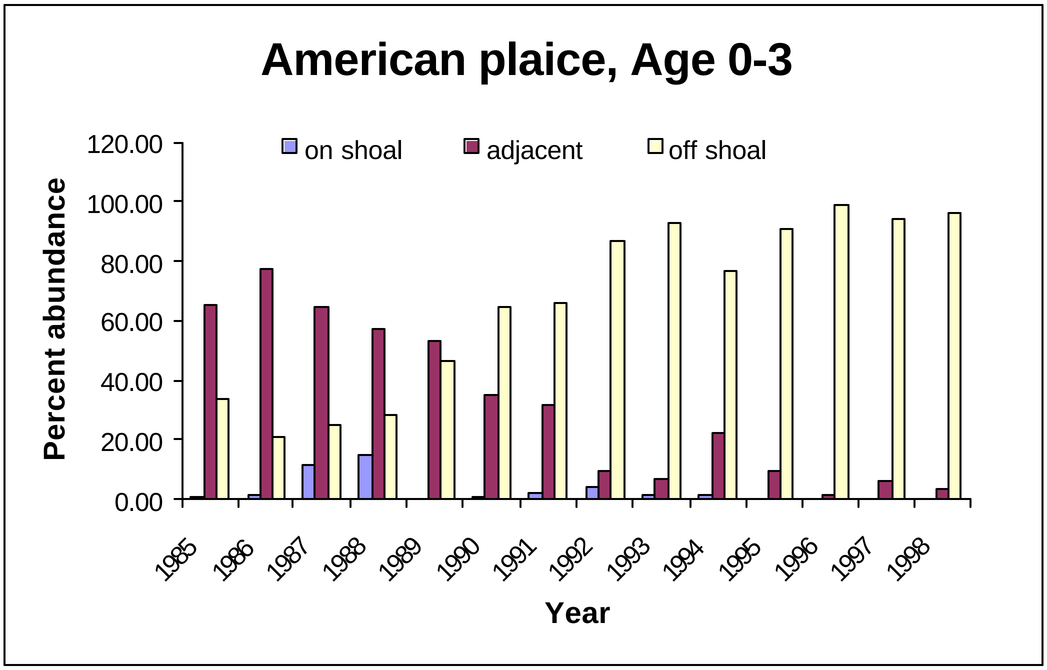


Fig. 9. Frequency of occurence (percent abundance) of juvenile American plaice in Div. 3NO that are found on the Southeast Shoal (strat 375+376), adjacent to the shoal (strata 360+361) and off the shoal (all other strata), 1985-1998.

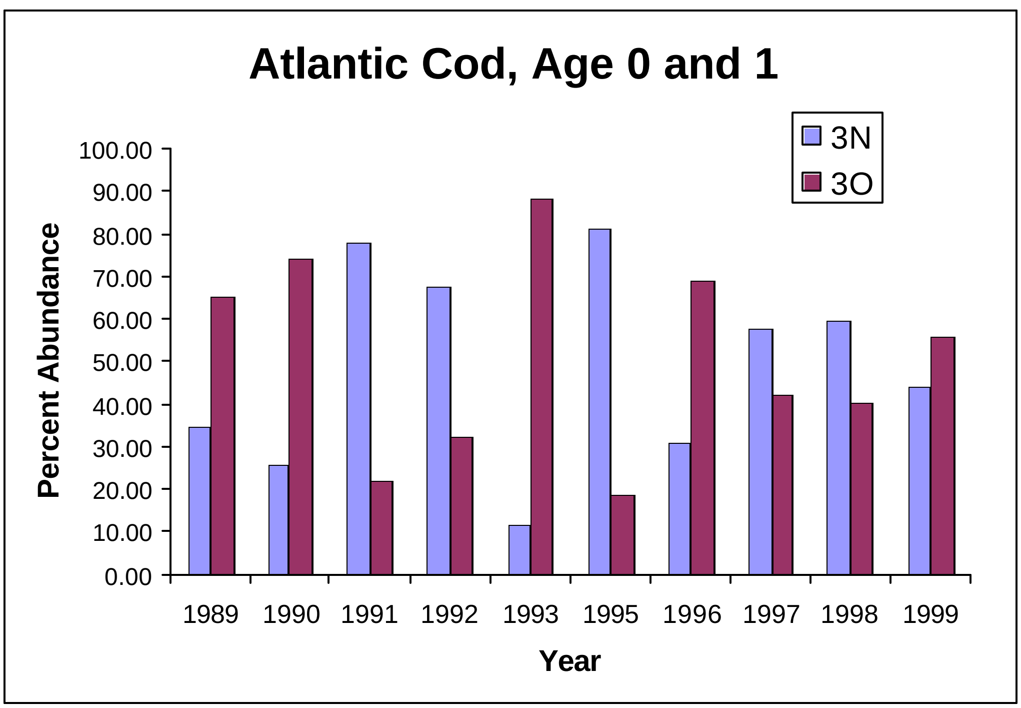


Fig. 10. Frequency of occurrence (percent abundance) of juvenile Atlantic cod in Div. 3NO, 1989-99.

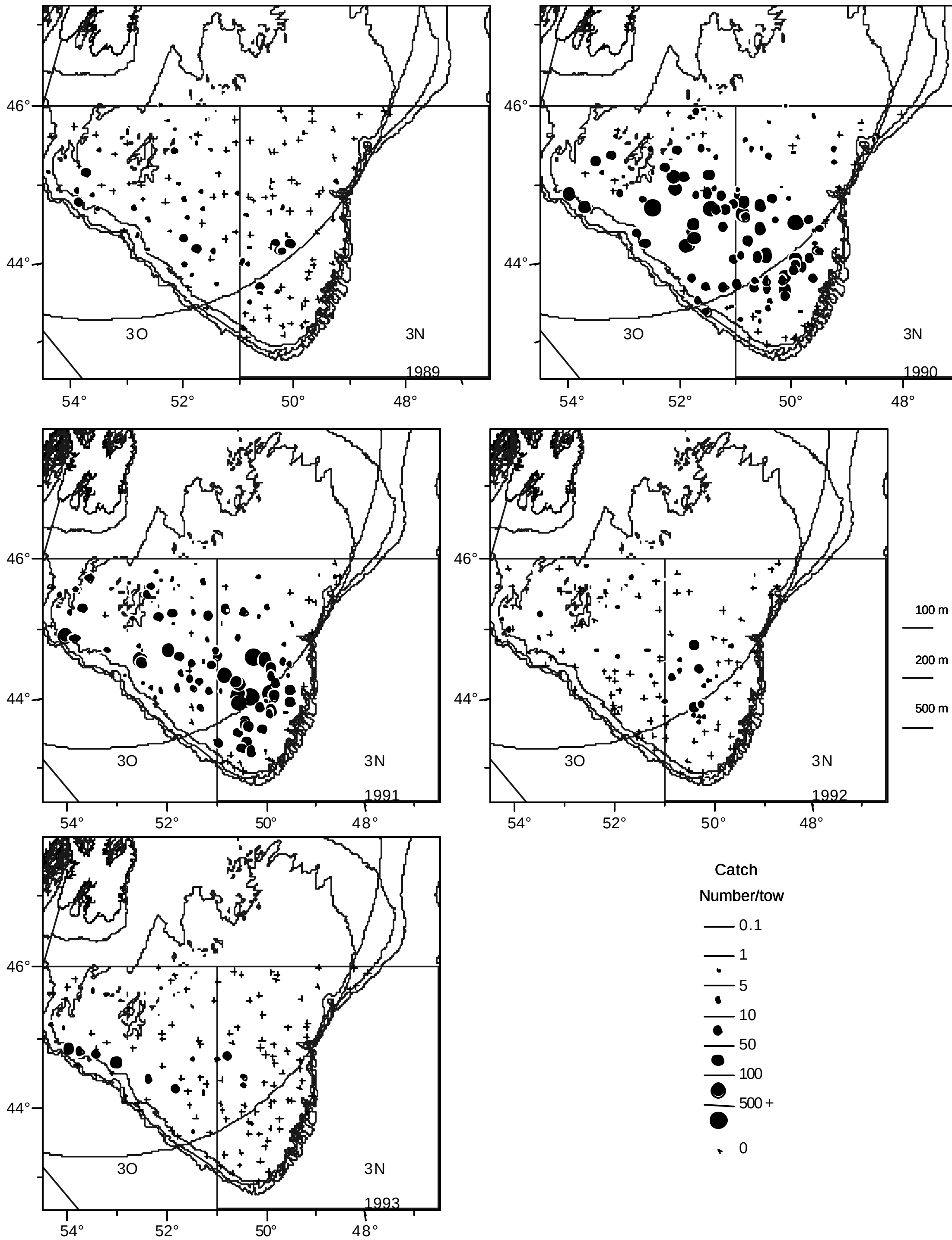


Fig. 11. Acon expanding symbol plots of standardized catches (numbers) of juvenile Atlantic cod from annual fall surveys of Div. 3NO, 1989-99 (no data available for 1994)

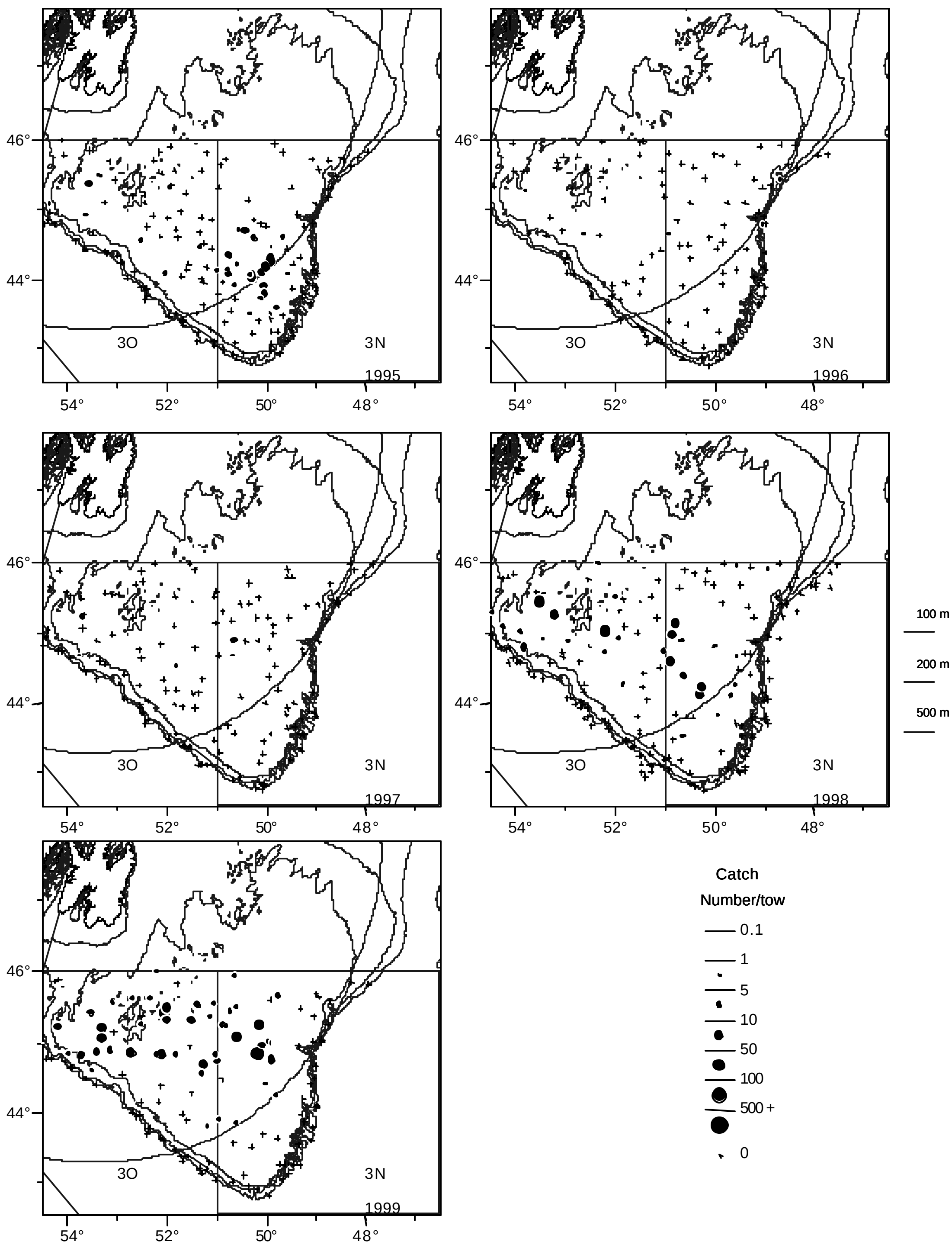

46°
44°
3O
3N
1995
1996
1997
1998
1999
54°
52°
50°
48°
100 m
200 m
500 m
Catch
Number/tow
0.1
1
5
10
50
100
500 +
0

Fig 11 Cont’d

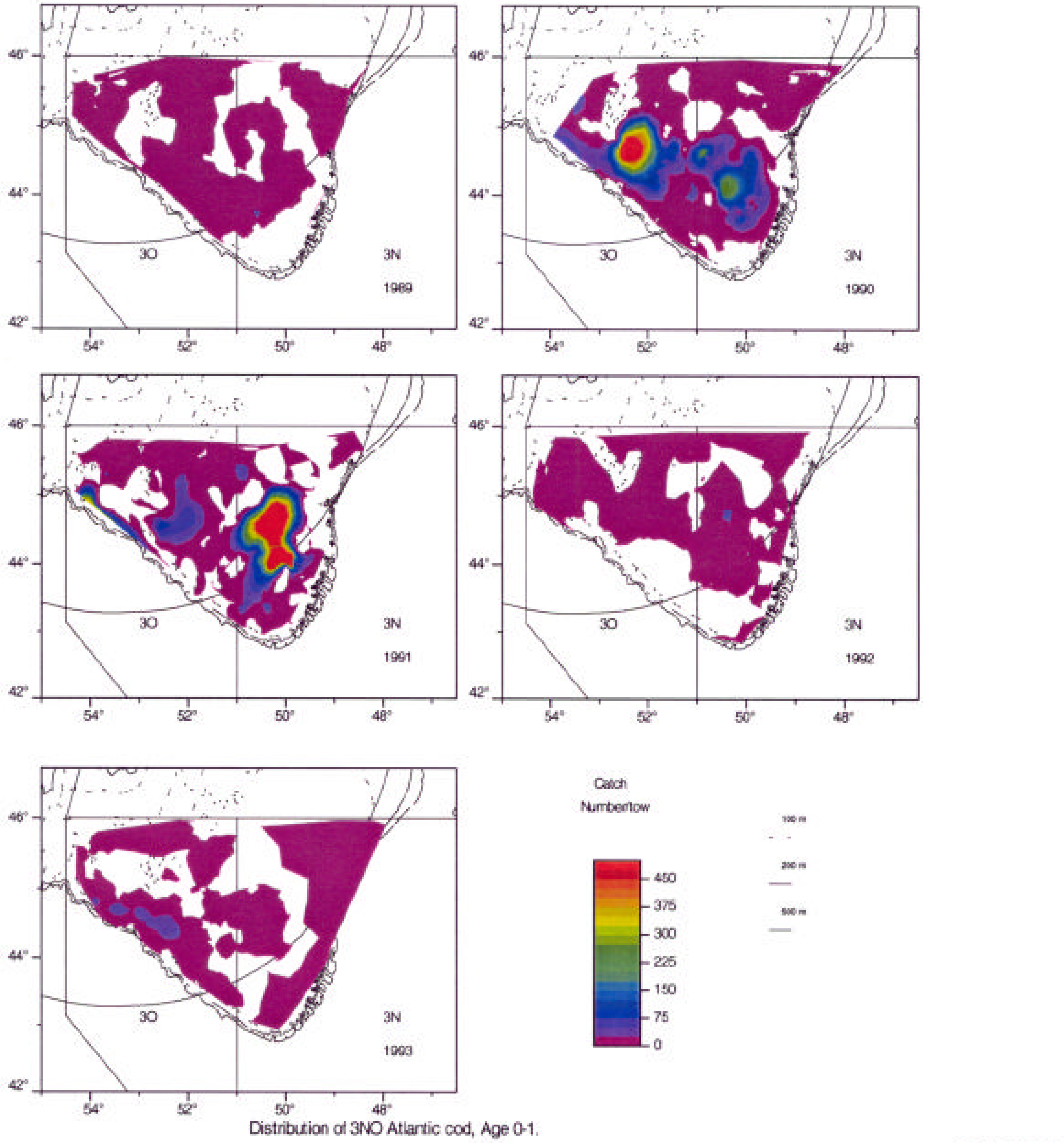


Fig. 12. ACON contour plots of standardized catches (numbers) of juvenile Atlantic cod from annual fall surveys of Div. 3NO, 1989-1999.

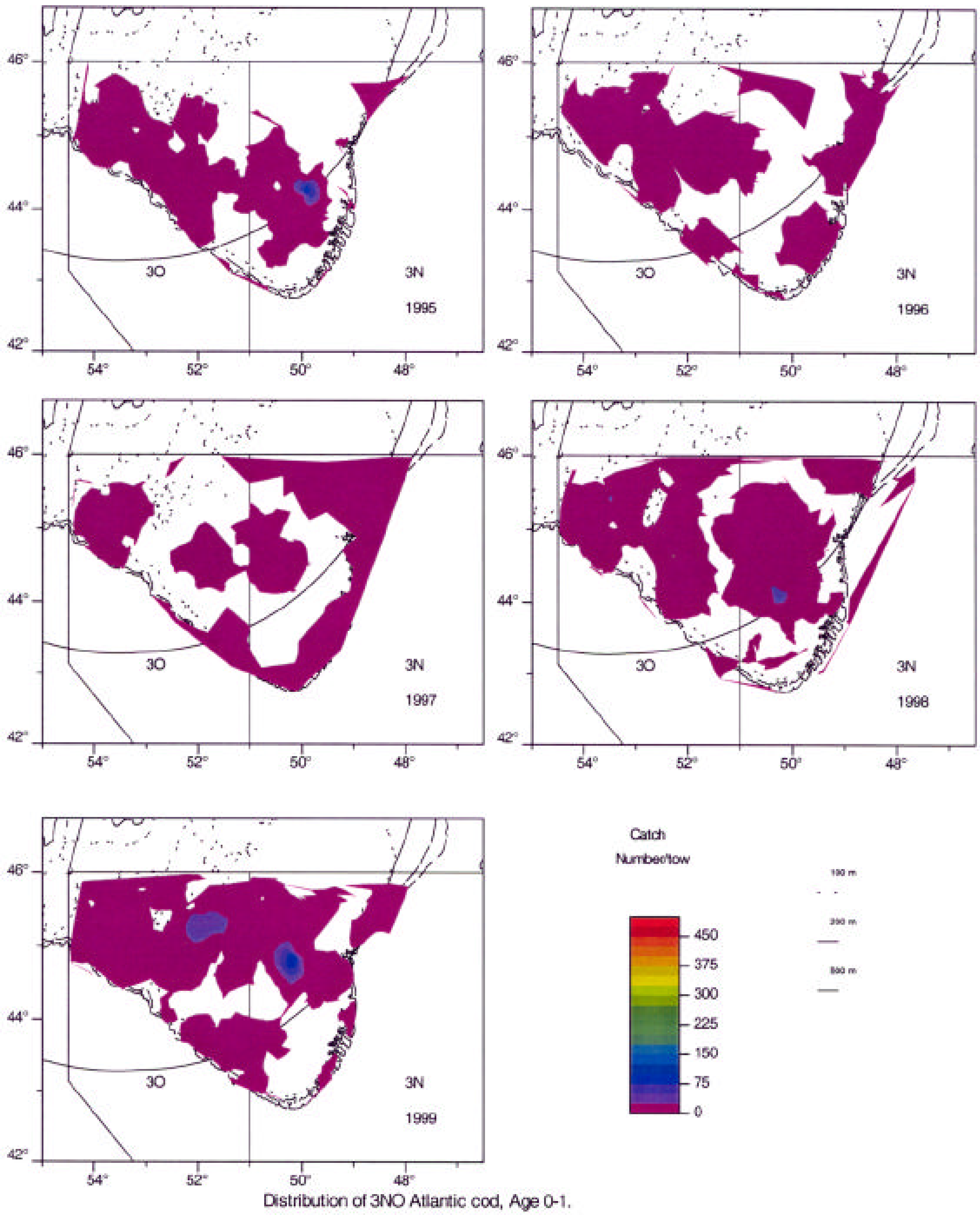

46°
44°
42°
54°
52°
50°
48°
3O
3N
1995
1996
1997
1998
1999
Catch
Number/tow
450
375
300
225
150
75
0
Distribution of 3NO Atlantic cod, Age 0-1.

Fig. 12. Cont'd

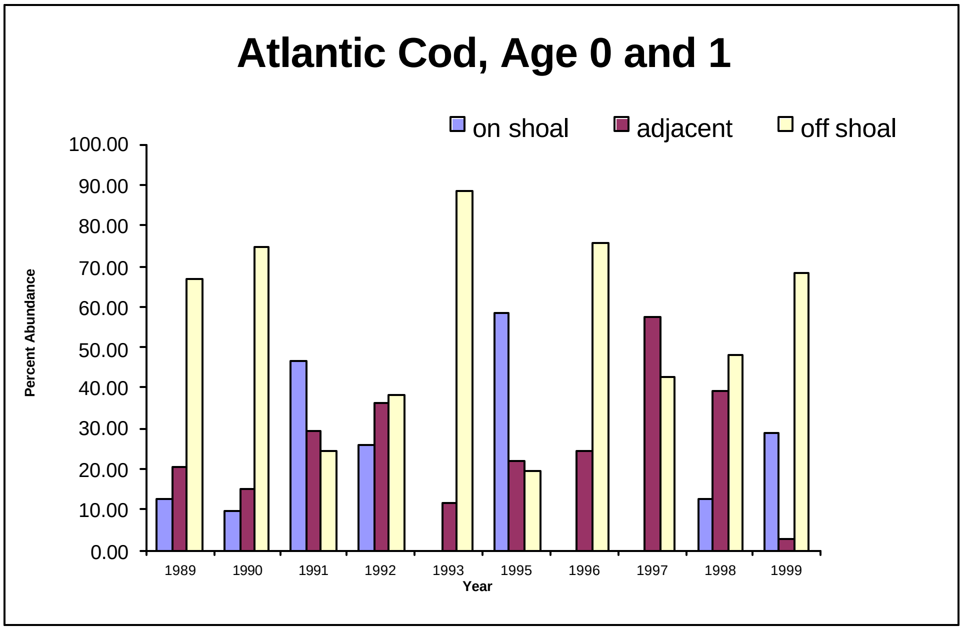


Fig. 13. Frequency of ovccurence (percent abundance) of juvenile Atlantic cod in Div. 3NO that are found on the Southeast Shoal (strata 375+376), adjacent to the shoal (strata 360+361) and off the shoal (all other strata), 1989-1999.

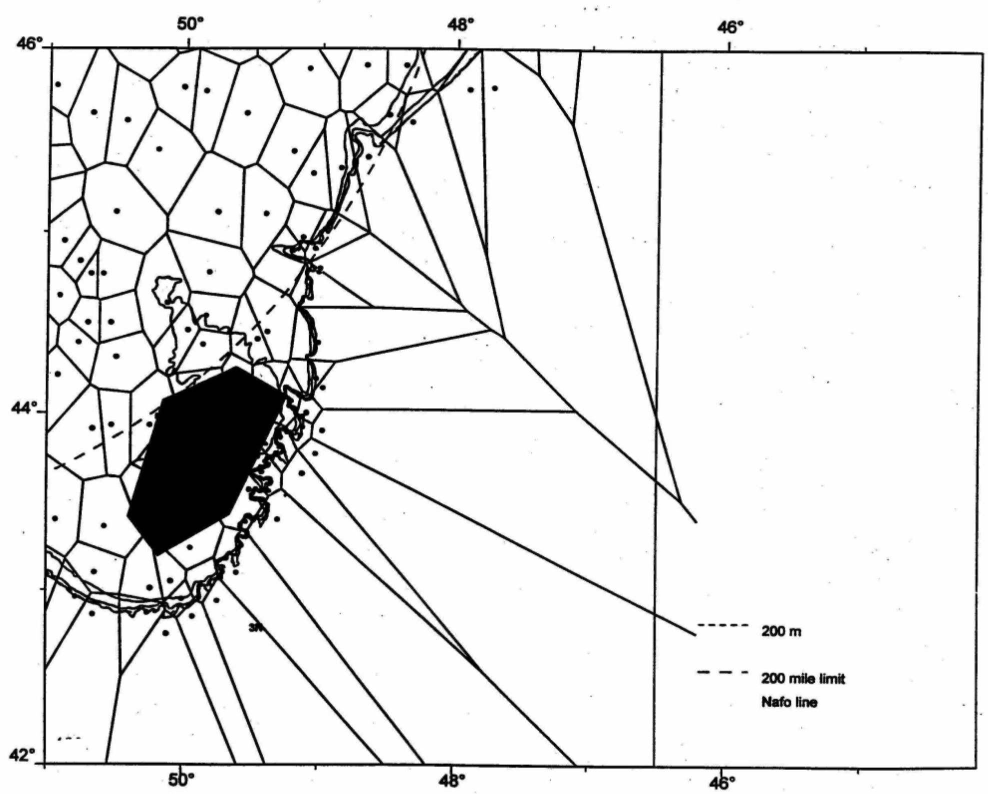


Fig. 14. Proposed cloased area (MPA) # 1 – shaded area (6,351 n.mi.^{2}) for juvenile yellowtail flounder on the southern Grand Bank based on aggregated Voronoi polygons using the percent abundance of jyveniles in Div. 3N data.

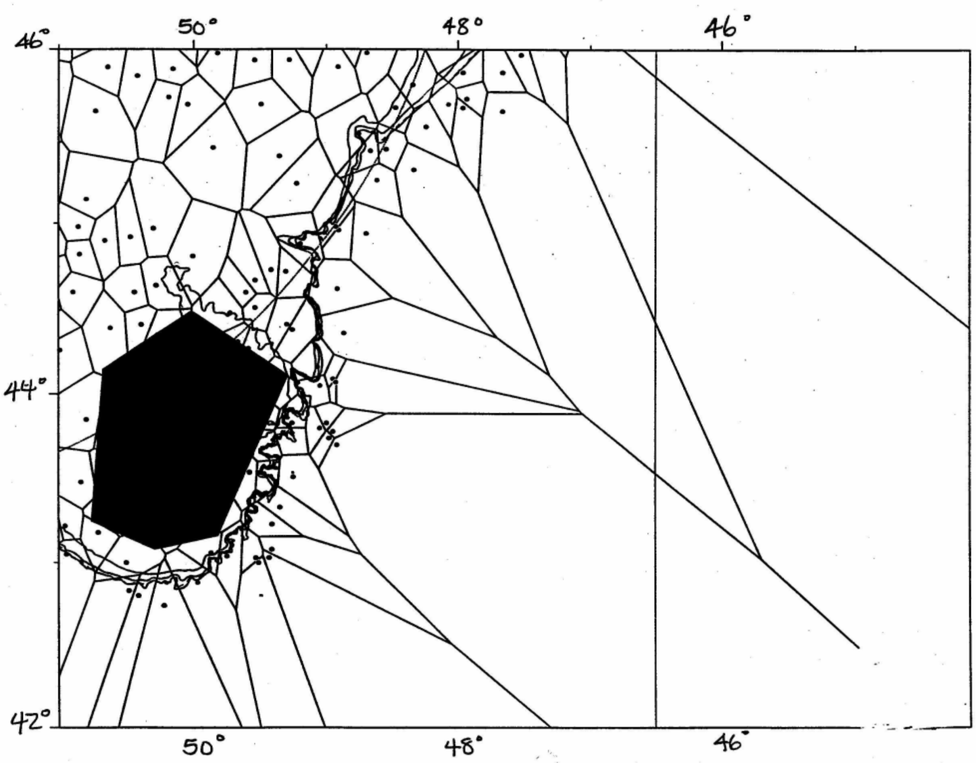


Fig. 15. Proposed cloased area (MPA) # 2 – shaded area (12,079 n.mi.^{2}) for juvenile yellowtail flounder on the southern Grand Bank based on aggregated Voronoi polygons using the percent abundance of jyveniles in Div. 3N data.

APPENDIX I

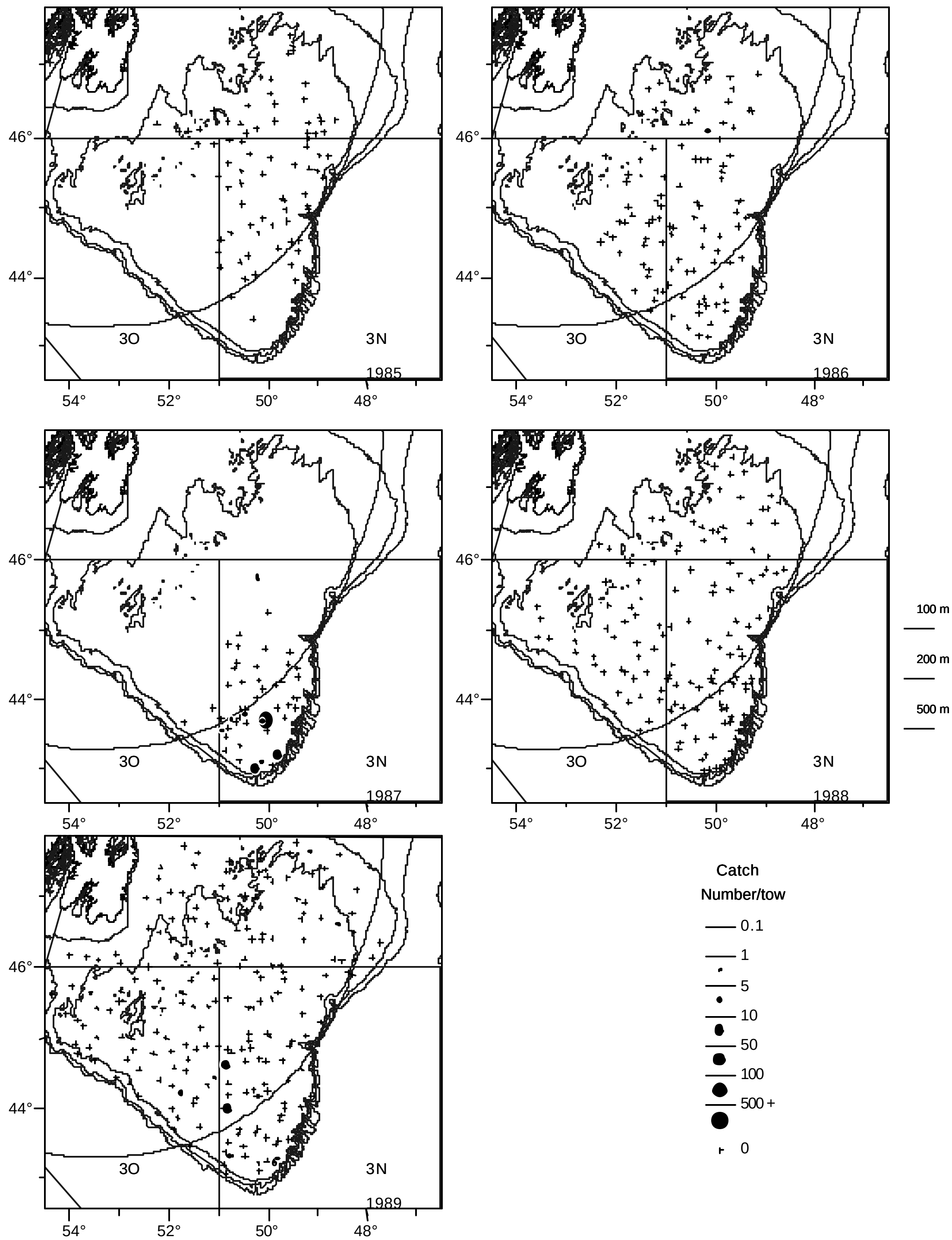


Fig. 1. ACON expanding symbol plots of standardized catches (numbers) of age 0 juvenile American plaice from annual fall surveys of Div. 3LNO, 1985-1998.

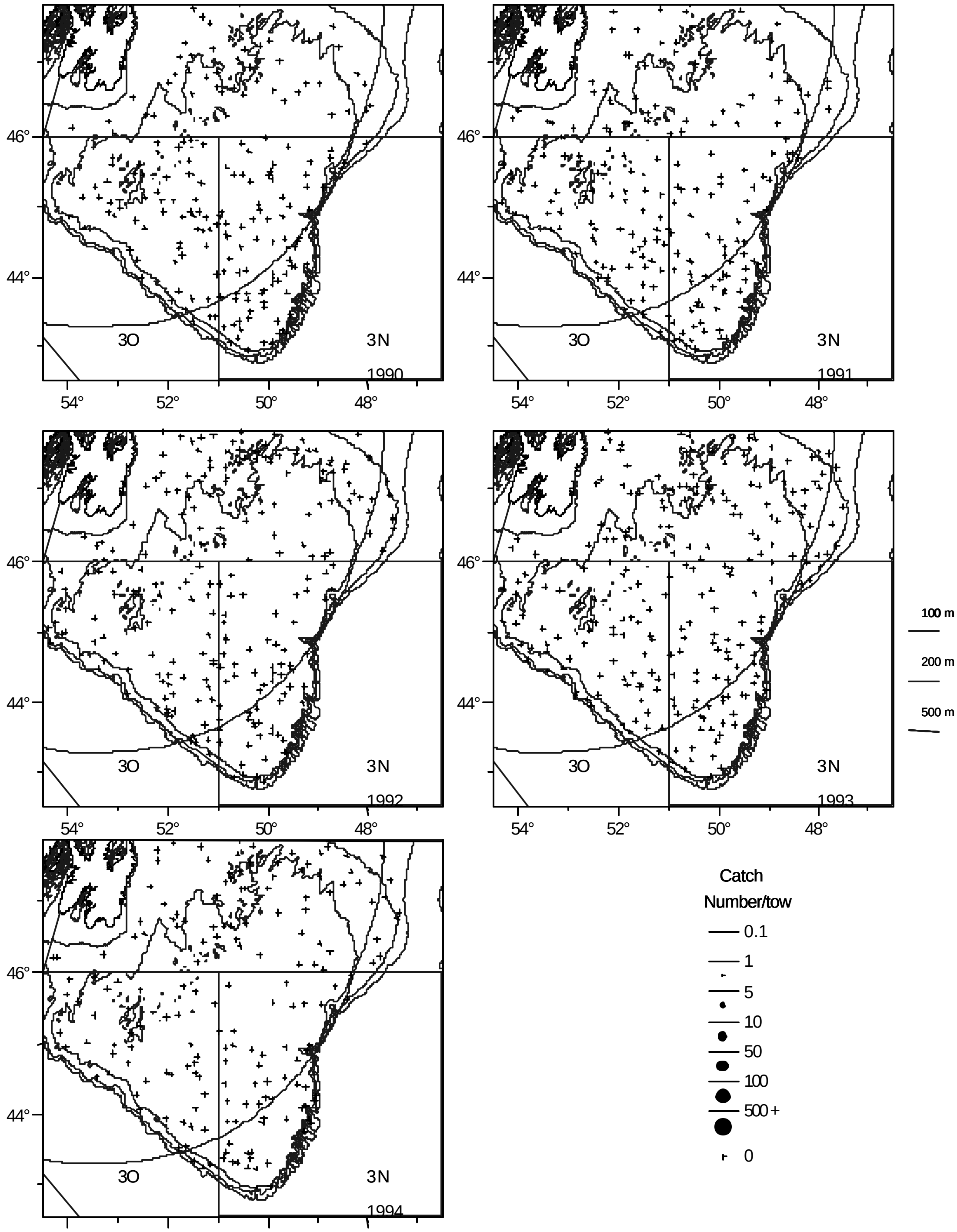

46°
44°
3O
3N
1990
54°
52°
50°
48°
1991
1992
1993
1994
100 m
200 m
500 m
Catch
Number/tow
0.1
1
5
10
50
100
500+
0

Fig. 1 Cont’d

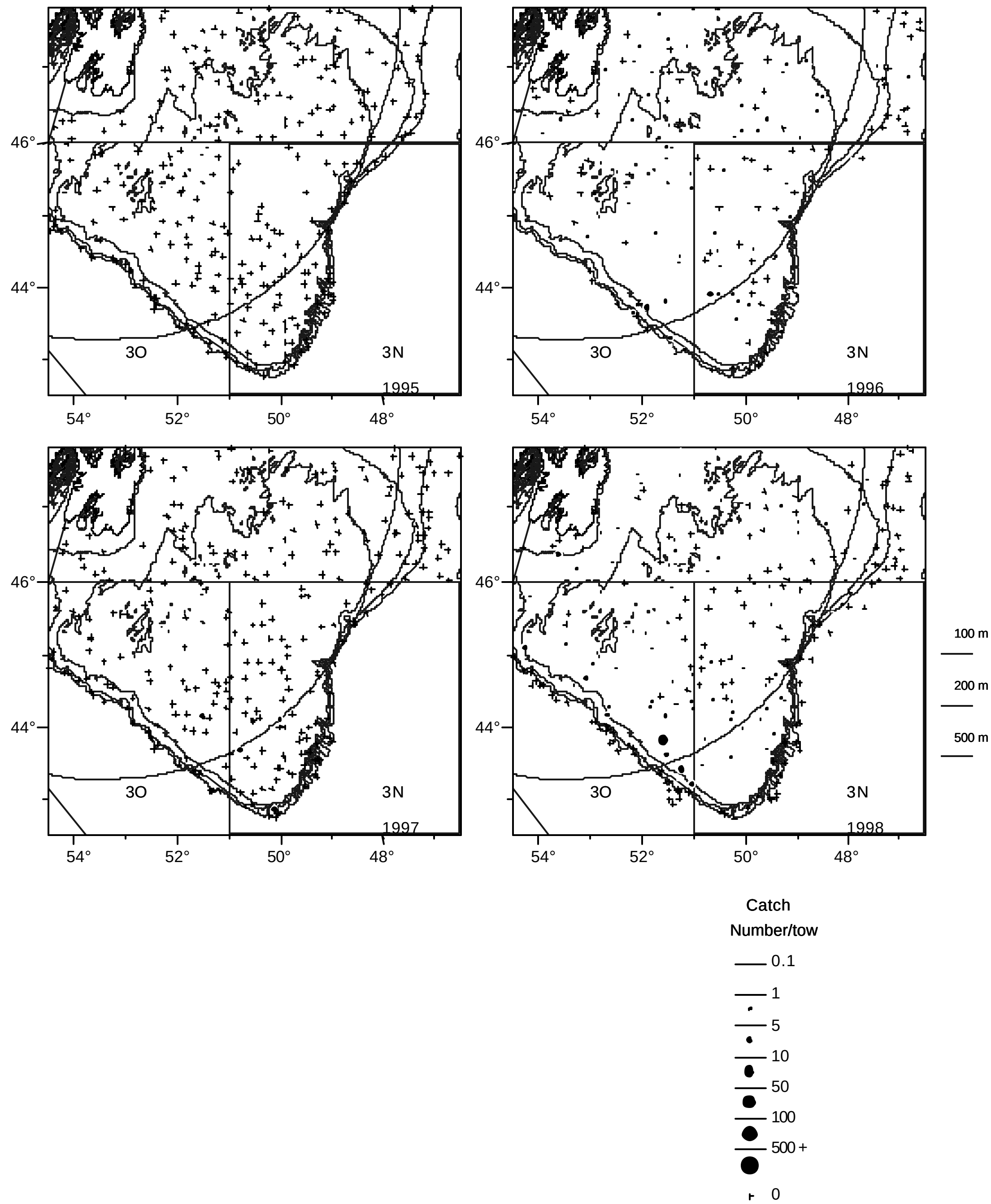

46°
44°
3O
3N
1995
1996
1997
1998
54°
52°
50°
48°
100 m
200 m
500 m
Catch
Number/tow
0.1
1
5
10
50
100
500 +
0

Fig. 1. Cont'd

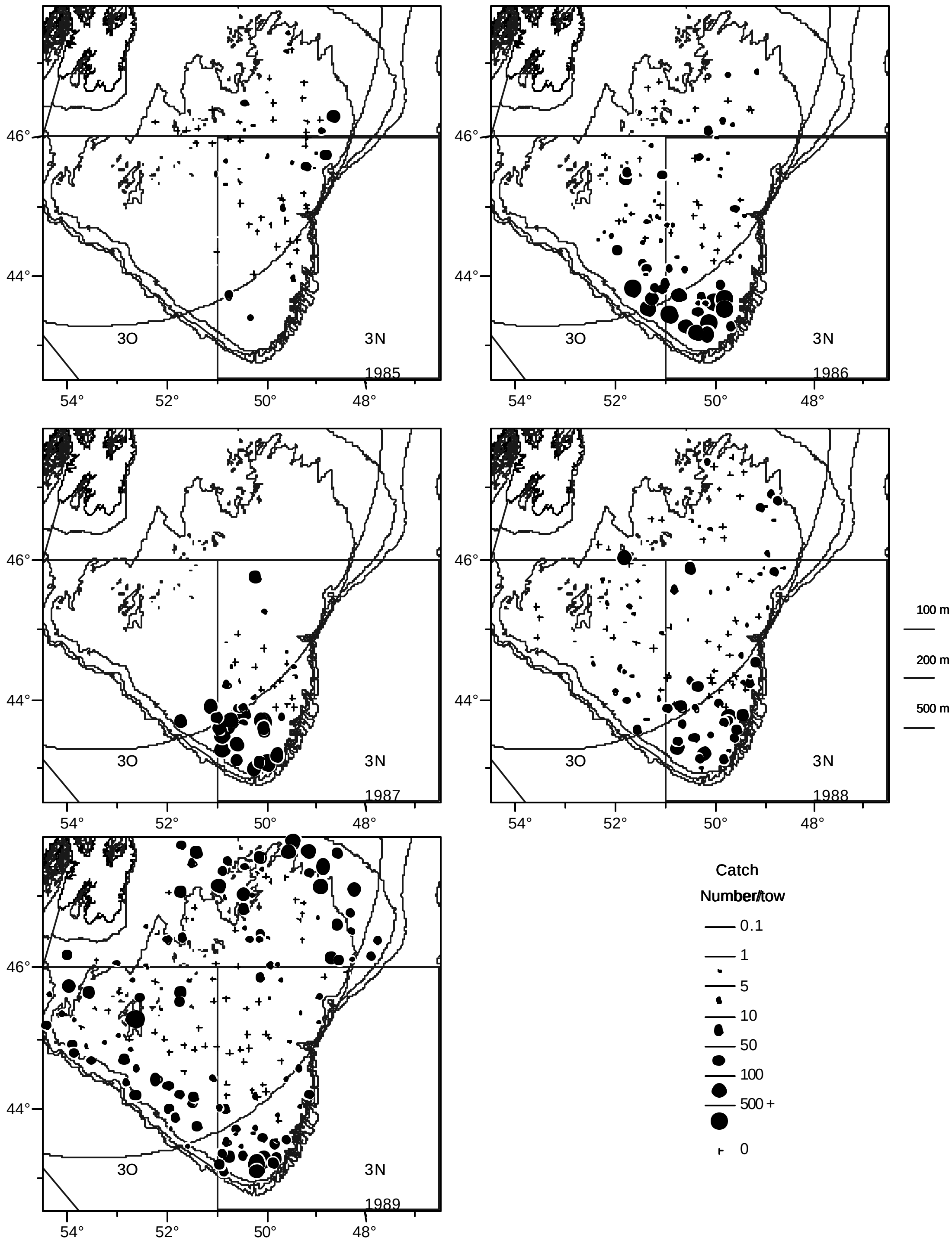


Fig. 2. ACON expanding symbol plots of standardized catches (numbers) of age 1 juvenile American plaice from annual fall surveys of Div. 3LNO, 1985-1998

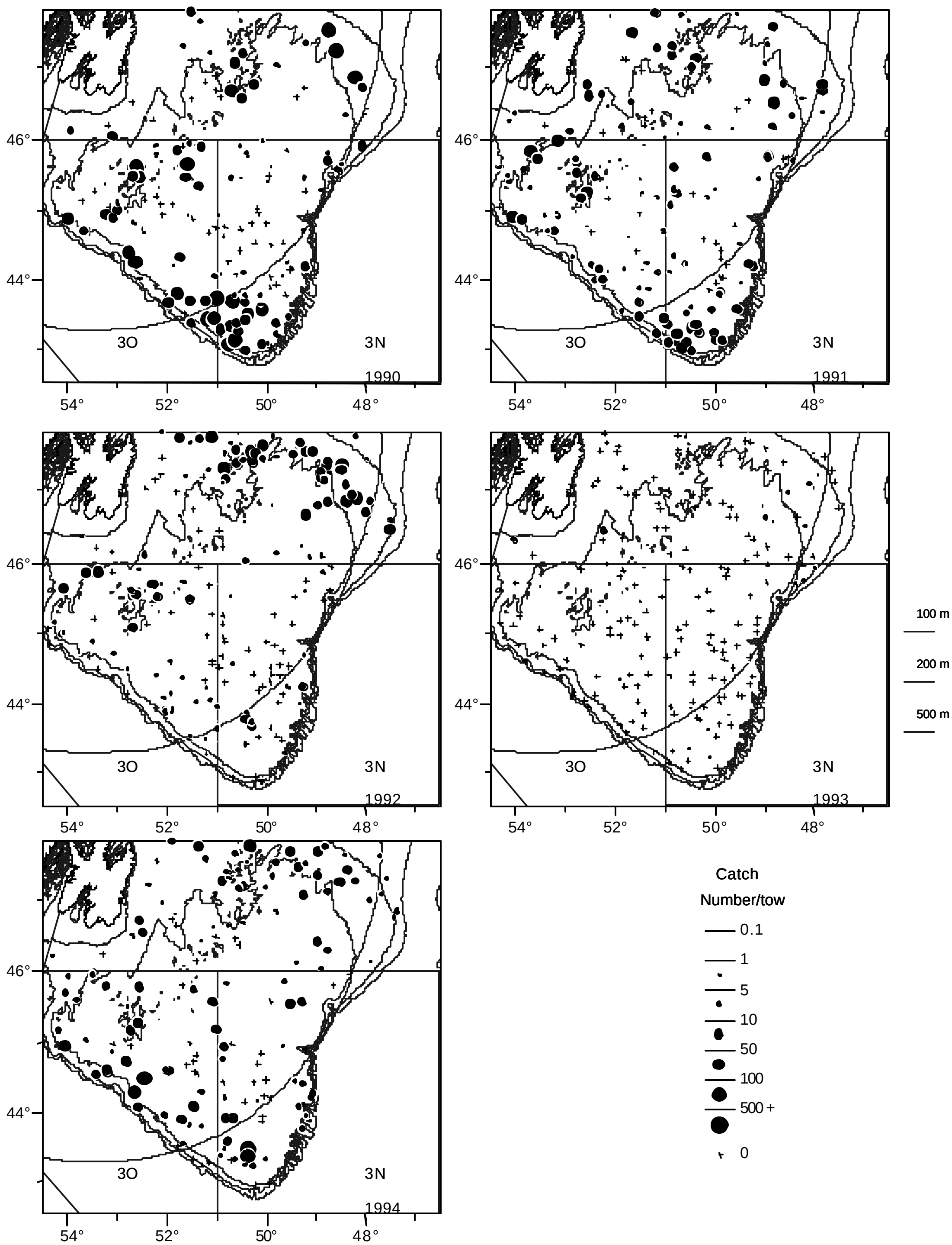

46°
44°
3O
3N
1990
1991
1992
1993
1994
54°
52°
50°
48°
100 m
200 m
500 m
Catch
Number/tow
0.1
1
5
10
50
100
500 +
0

Fig. 2. Cont’d

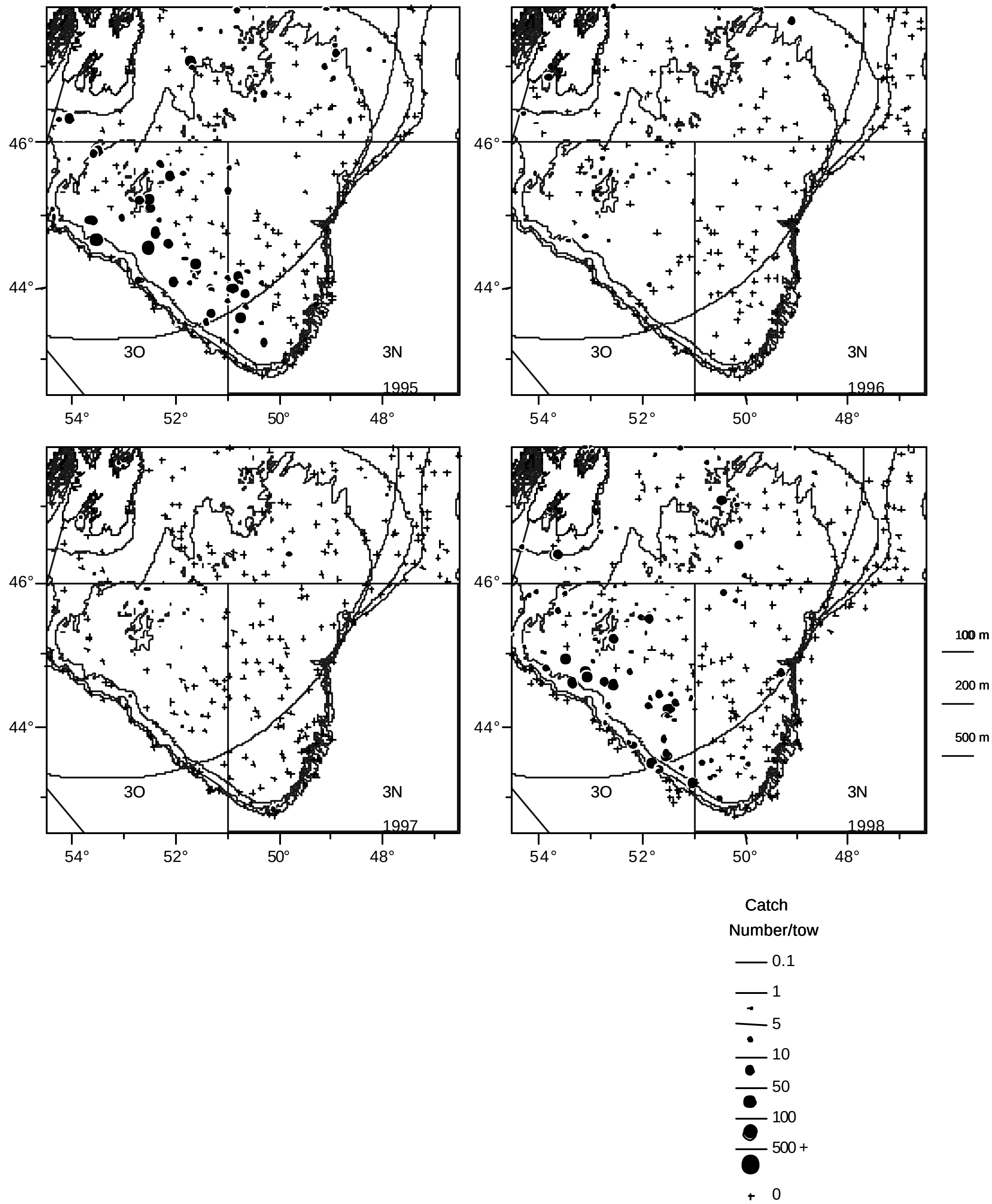

46°
44°
3O
3N
1995
54°
52°
50°
48°
1996
1997
1998
100 m
200 m
500 m
Catch
Number/tow
0.1
1
5
10
50
100
500 +
0

Fig. 2. Cont'd

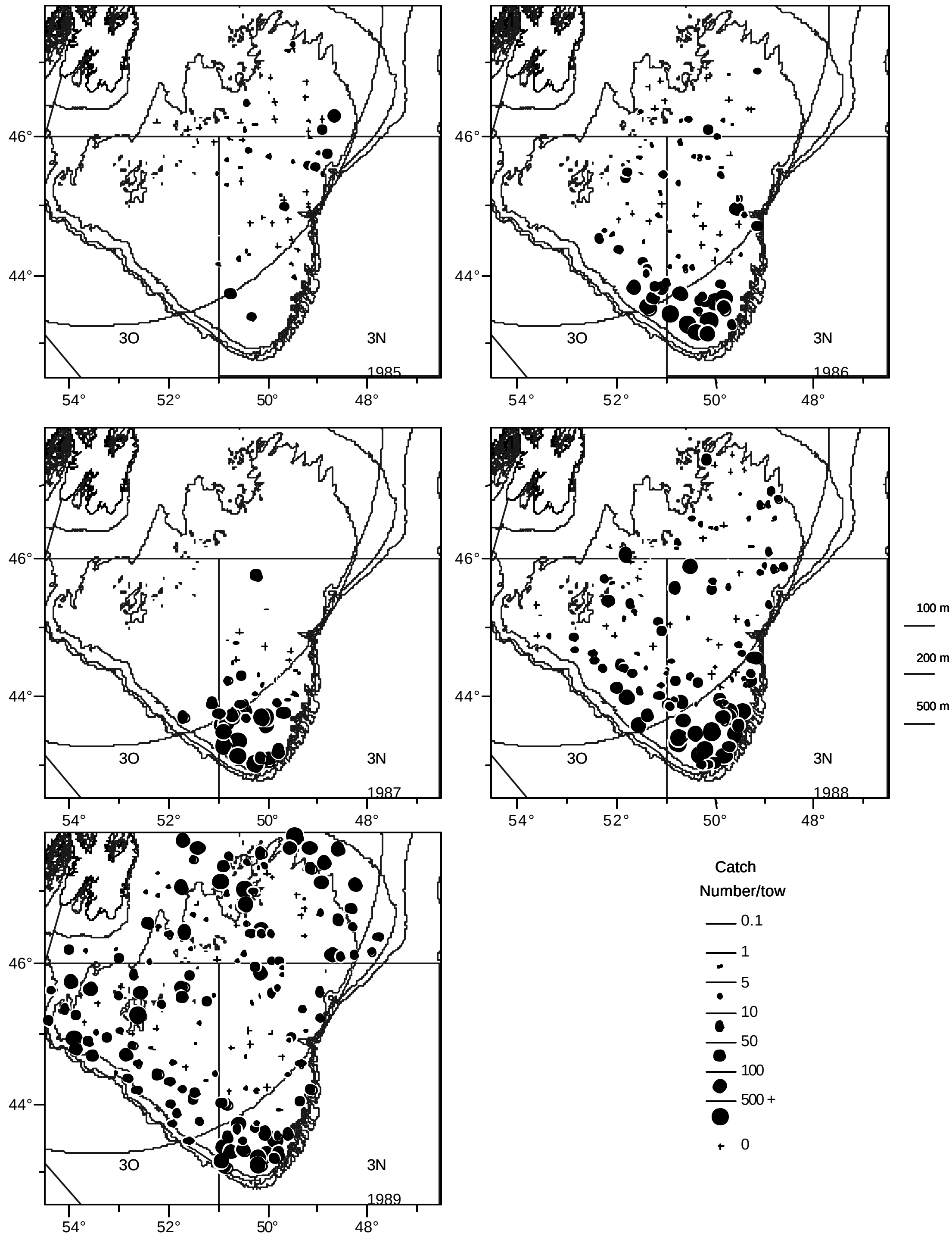


Fig. 3. ACON expanding symbol plots of standardized catches (numbers) of age 2 juvenile American plaice from annual fall surveys of Div. 3LNO, 1985-1998

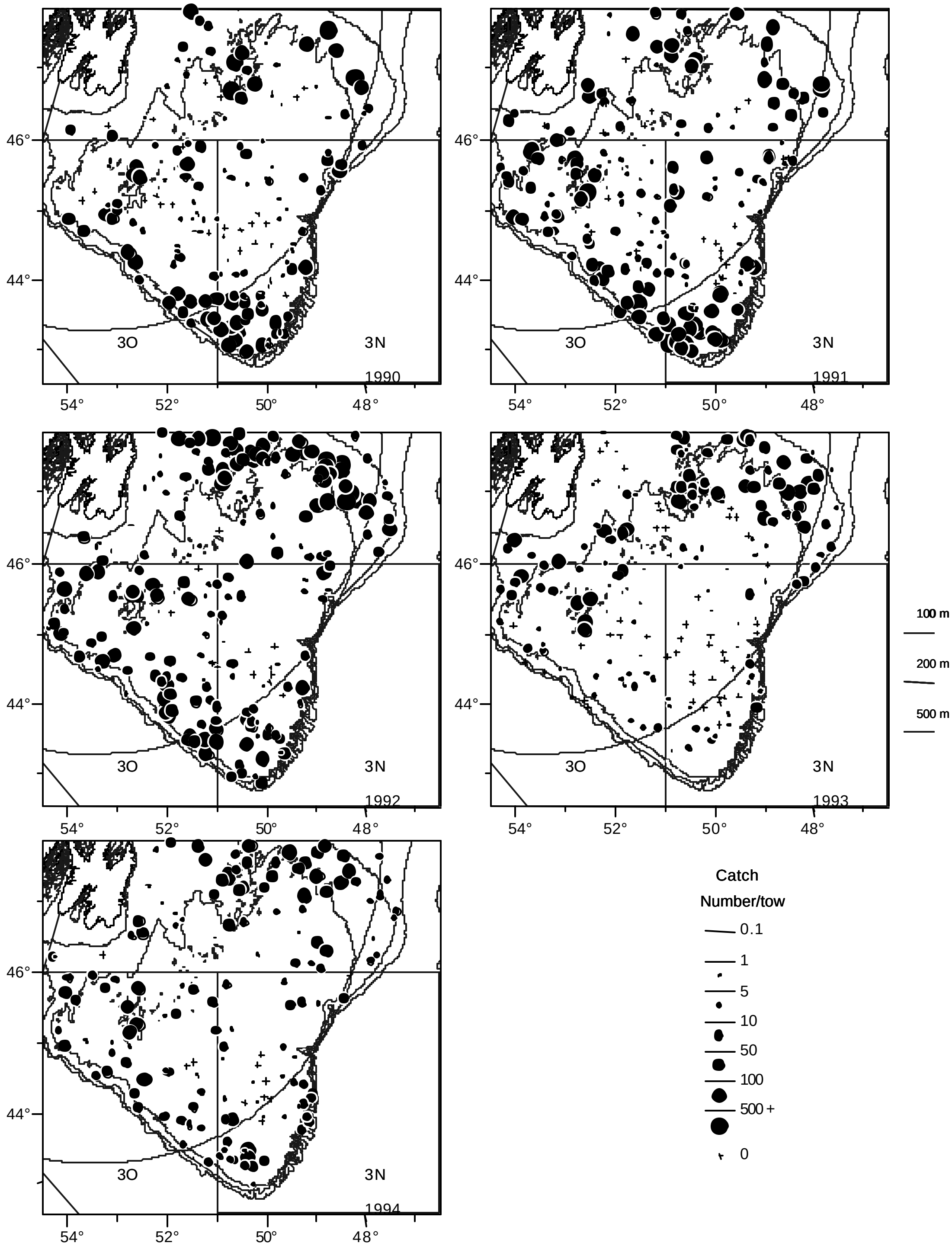

46°
44°
3O
3N
1990
54°
52°
50°
48°
1991
1992
1993
1994
100 m
200 m
500 m
Catch
Number/tow
0.1
1
5
10
50
100
500 +
0

Fig. 3. Cont'd

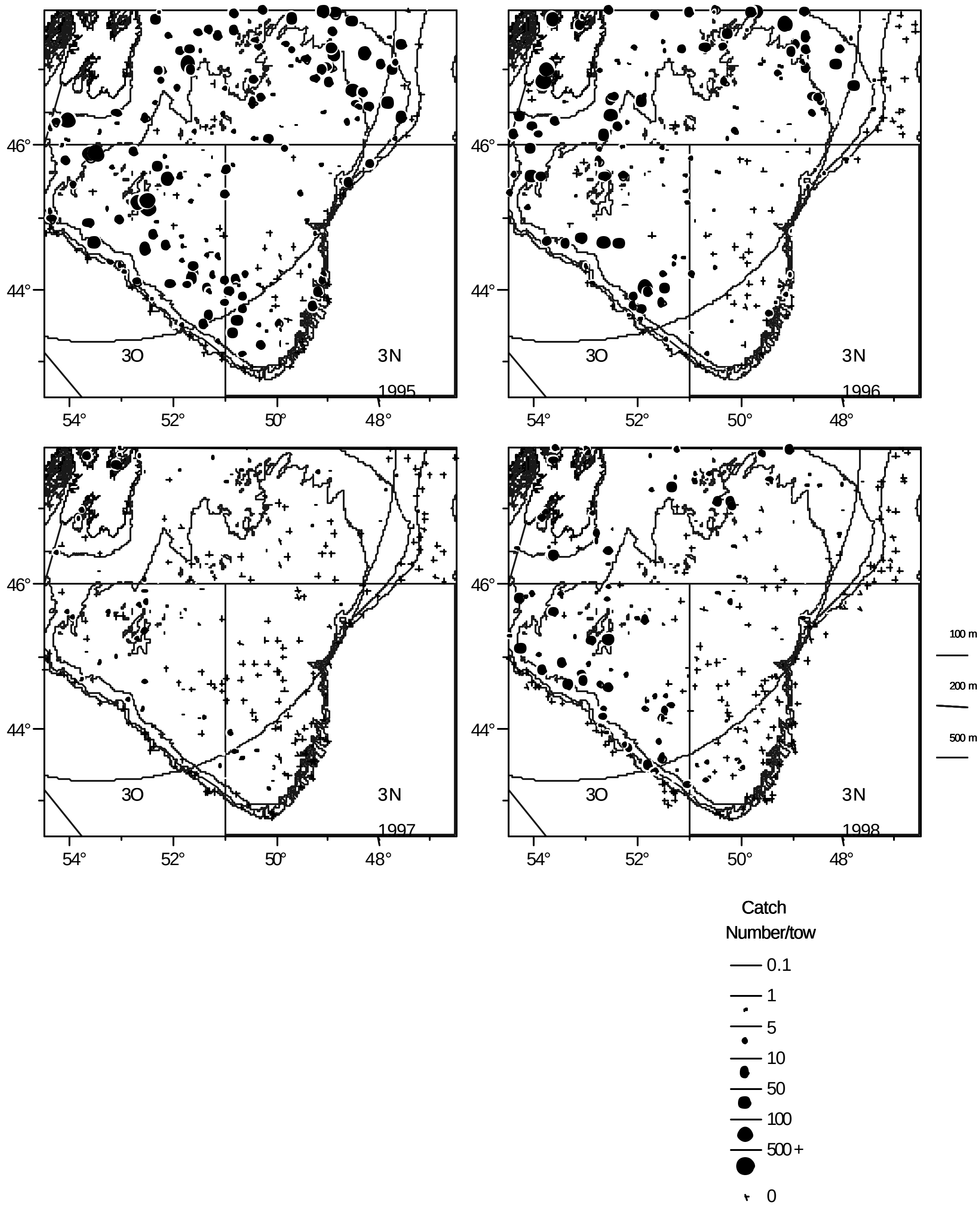

46°
44°
3O
3N
1995
54°
52°
50°
48°
1996
1997
1998
100 m
200 m
500 m
Catch
Number/tow
0.1
1
5
10
50
100
500+
0

Fig. 3. Cont'd

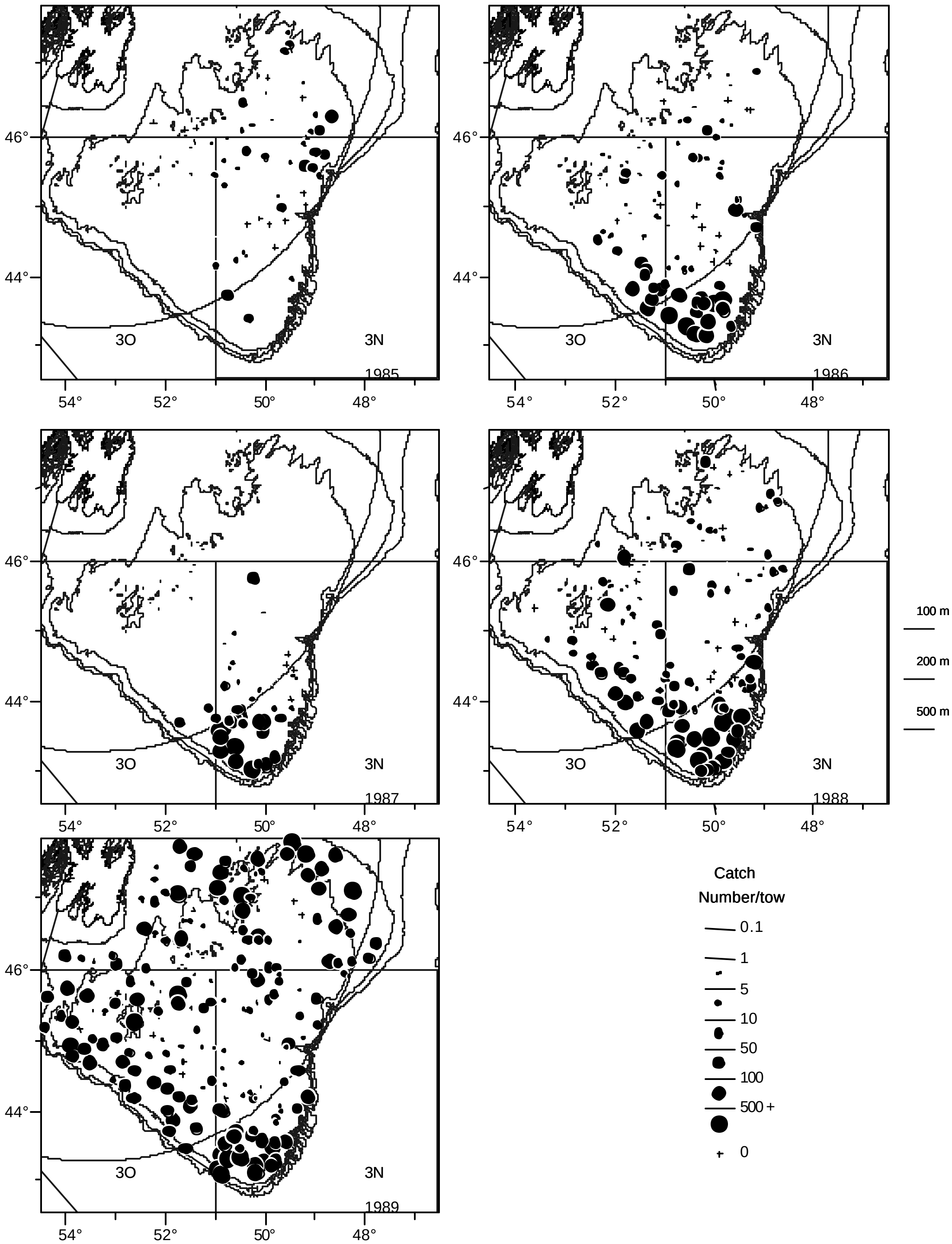
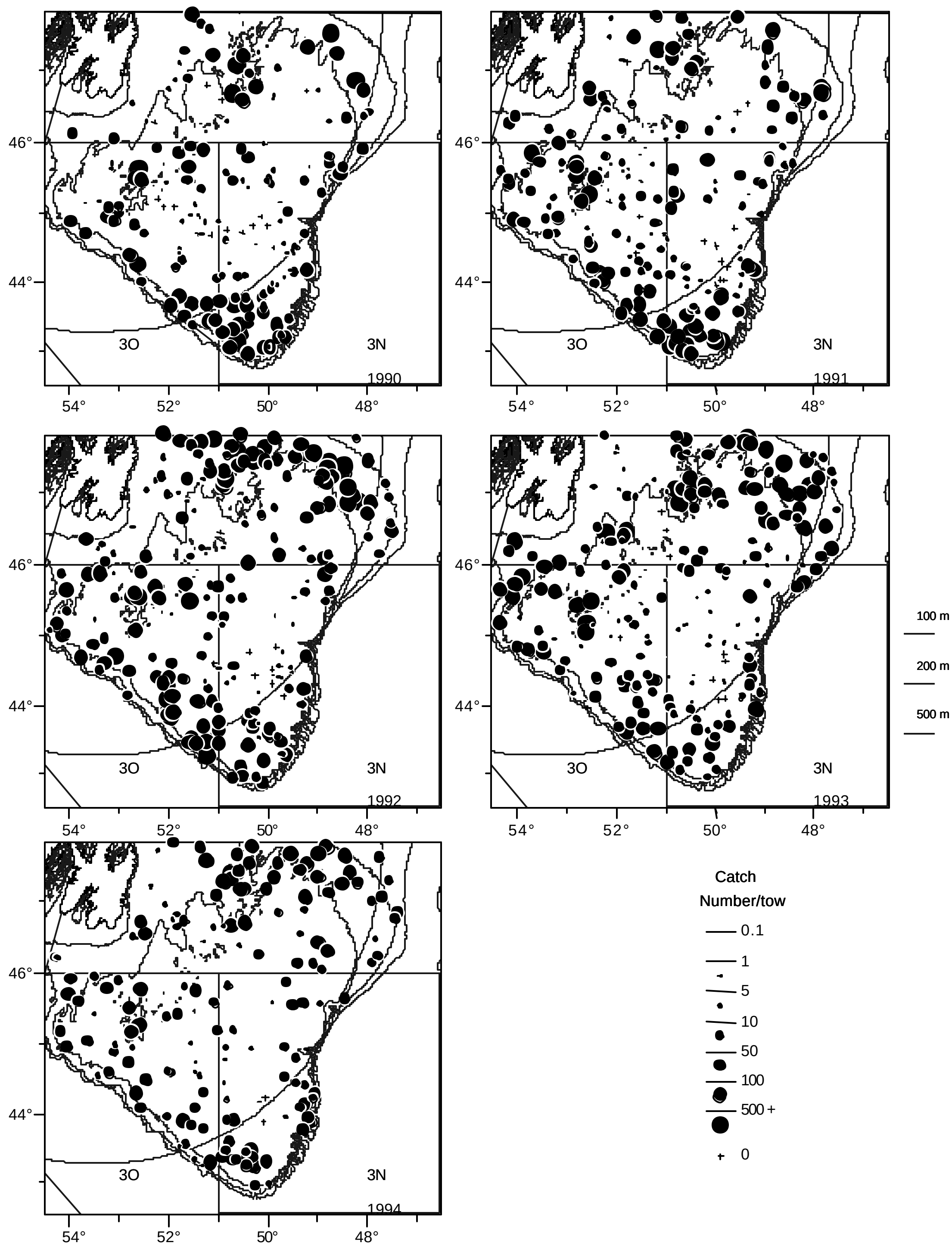


Fig. 4. ACON expanding symbol plots of standardized catches (numbers) of age 3 juvenile American plaice from annual fall surveys of Div. 3LNO, 1985-1998.



3O
3N
1990
1991
1992
1993
1994
46°
44°
54°
52°
50°
48°
100 m
200 m
500 m
Catch
Number/tow
0.1
1
5
10
50
100
500 +
0

Fig. 4. Cont’d

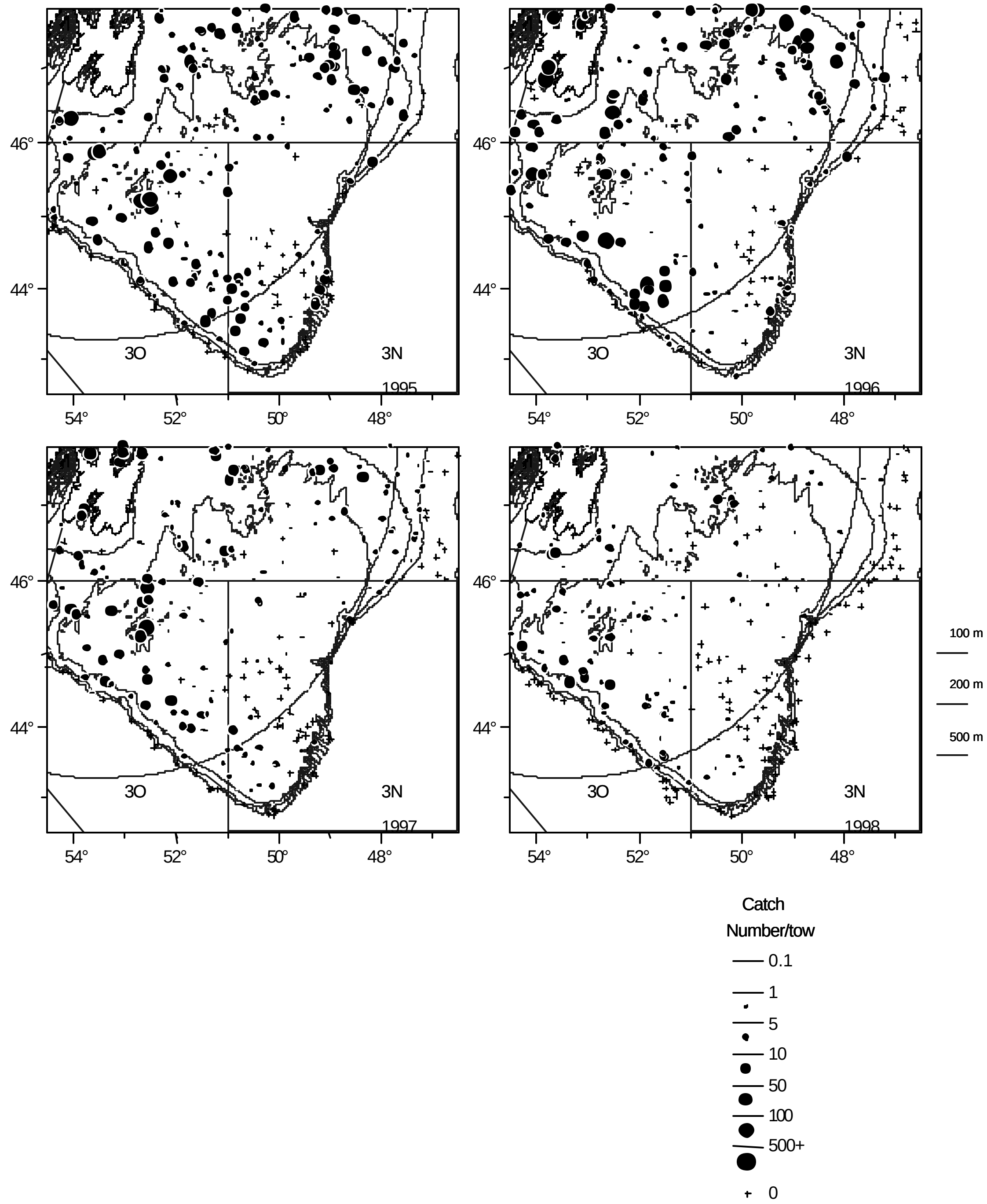

46°
44°
3O
3N
1995
54°
52°
50°
48°
1996
1997
1998
100 m
200 m
500 m
Catch
Number/tow
0.1
1
5
10
50
100
500+
0

Fig. 4. Cont'd.