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Preliminary Analysis of Spatial and Temporal Variation in the Distribution of Juvenile Yellowtail flounder on the Grand Bank: Investigating the Methodology

by

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Introduction

Marine protected areas (MPAs) or closed refuges are a fisheries management control measure for the reduction of fishing mortality on a seasonal or permanent basis. The main goal of introducing spatial and temporal restrictions in the fishery is either to protect 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.

Walsh *et al*. (1995) 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, Div. 3NO 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 each other. 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 the 45^0 N and its western boundary by the 50^0 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 91 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 43^0N to 45^0 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, but not quantitatively enough 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. In this paper, we use geostatistics to investigate the spatial and temporal variation in abundance and distribution of juvenile yellowtail flounder in the nursery area on the southern Grand Bank as a first step in delineating the physical boundary of the nursery area.

Material and Methods

Catch data from annual fall stratified-random surveys of the Grand Bank were analyzed for the period 1985 to 1997. 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 1998, the fall surveys were carried out using a Campelen 1800 shrimp trawl (see McCallum and Walsh, 1996, for details). Walsh and McCallum (1998) noted that there was very little differences in trawl efficiency between both shrimp trawls for yellowtail flounder. Nevertheless, data conversions for spatial analysis are not required.

Exploratory analysis of spatial distribution began with visual inspection of ACON expanding symbol plots (Black 1993) of the standardized number per tow of yellowtail flounder catches from trawl hauls in NAFO Div. 3LNO during annual surveys. Following the exploratory analysis of these point (catch) patterns we employed 1) a standard swept area model to calculate number of juveniles in each stratum; 2) Voronoi polygons (Black, 1993) to interpolate the distribution of juveniles; and 3) semi-variance analysis and kriging to examine the temporal and spatial variability in distribution and to map the juvenile densities.

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. All semivariance and kriging analysis were conducted using GS+ software.

Since male yellowtail are maturing at age 4, juveniles are classified here as age 0 to 3 yrs.

Results and Discussion

Geographic distribution

ACON plots of survey aggregated catch data from 1985 to 1997 for both juvenile and adult yellowtail flounder are shown in Figures 2-4. Yellowtail flounder catches were located mainly in Divisions 3N and 3O in all years (see also Walsh, 1992a, 1992b; Walsh *et al* 1995a,1999; Simpson and Walsh, 1999), but in later years (1990 onwards) the catches were more aggregated in the southern portions of Div. 3NO. In some years large catches were only taken in NAFO 3N (1995, 1996 and 1997) mainly on and around the Southeast Shoal, extending into the NAFO Regulatory Area.

Further analysis of the geographical distribution of yellowtail catches was conducted on individual age classes using ACON plots. The distribution of each of the 1983 to 1993 cohorts were plotted from the trawl data from the 1985-97 surveys to follow their movements in each year (Figs. 5-16). Juvenile and young adult yellowtail flounder up to age 4 yrs are concentrated both on the Southeast Shoal(strata 375 and 376) and the area adjacent of the shoal (strata 360 and 361) in Div. 3N. However, by age 5 and 6, yellowtail flounder are no longer localized in the Southeast Shoal area and their range extends out from the shoals in a west and northerly direction. In earlier years this range extended into Div. 3L. In some cases, by age 7 and 8, fish may be found equally in catches in Div. 3N and 3O. By age 9, there are fewer fish found in general.

Southeast Shoal Area

Using a swept area model, the densities (average numbers–per-square nautical mile) of yellowtail flounder juveniles within each strata were calculated and expressed as a percent of the total population of juveniles in Div. 3LNO (Table 1). With the exception of 1985, the abundance of juveniles in Div. 3L does not exceed 5%. Most juveniles in this area are age 3 yrs. Similar to the ACON point plots, the main concentration of juveniles occurs in strata 375, 376, 360 and 361, the Southeast Shoal area of Div. 3N and to a lesser extent stratum 352 (3-15%) in Div. 3O.

To further consider the importance of the Southeast Shoal area to juvenile yellowtail flounder distribution, we investigated the percent concentration of juveniles by those depth strata that define the shoal (strata 375 and 376; see Fig. 1) and the area west of the shoal (strata 360 and 361) within NAFO Division 3N. From 1986-1997[1], on average, 92% (± 1.3) of all juvenile yellowtail flounder on the Grand Bank were found in Div. 3N, of which an average 88% (± 2.8) of all juveniles were found in strata 360 and 361 (47% ± 5.2) off the shoal and strata 376 and 375 (53% ± 5.2) which define the shoal (Table 2). With the exception of 1995 and 1997, when the percentage was 70%, greater than 81% of all juveniles on the Grand Bank were located from year to year in these 4 strata.

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[1] In 1985, there was poor coverage in two key strata (376 and 360) and we have dropped this year from additional analysis.

We further determined the distribution of yellowtail juveniles in NAFO 3N in relation to the Southeast Shoal by using Voronoi polygons to map the 1986-97 trawl catch data (Black, 1993). These polygons interpolate between standardized trawl catch (numbers) to encompass areas of influence of each data point. The number of fish per nautical mile within each polygon is estimated and the percentage of juveniles located on and off the shoal is presented in Table 3. On the average 53% ± 5.0 of the juveniles were found on the shoal similar to the swept area model estimates above. Furthermore, the polygon mapping shows that there is a fairly consistent area of aggregation which overlaps the southern part of the Southeast Shoal (stratum 376) and the area immediate to the west of the shoal (stratum 360) (Figs. 17-28).

Semi-variance Analysis and Kriging

Semi-variance analysis of the spatial autocorrelation between fishing sets was determined for juvenile (ages 0 to 3) yellowtail flounder using survey data from 1986-1997. An isotropic model was chosen in which the variograms are omni-directional, that is, they are an average over all pairs of data regardless of their orientation or direction to each other. After some initial trials an interval of 30 n.m. was chosen as a lag distance. In most years, greater than 70% of the sample variance, i.e. the proportion of the total variance that can be modeled as spatial dependence, was explained by spatially structured variance in the range of 34 to 540 n.m.(Table 4: proportion and range columns). On average, from 1986 to 1997, autocorrelation in juvenile abundance in survey trawls extended over 173.3 n.m., i.e. the average distance within which the catches remained spatially correlated. In three years 1986, 1992 and 1993, 50% or less of the sample variance was described by spatial structure in the data. We interpret this to mean that there was no small scale spatial structure in those years as indicative by the high values estimated for the range, i.e. the data are further apart, more dissimilar or spatially discontinuous. Furthermore, in 1997 the poor fit of the model (r^2 =.07) is associated with spatial dependence at small and large ranges in the variogram data which are not being modeled well.

Comparisons of the temporal patterns in spatial structure between years was carried out using correlation analysis and the results presented in Table 5. In general, from 1988 onwards, the interpolated distribution of yellowtail flounder is generally highly correlated between years (1986 and 1987) correlated very poorly with each other and all other years. This indicates that the integrity of the spatial patterns of juveniles in Div. 3N are consistent (see kriged contours Fig.29).

Analysis of the semi-variance statistics by age group are presented in Tables 6-8 for juveniles In most years a very high proportion of the sample variance was explained by spatially structured variation. However, for age 0 and 1 juveniles, less than 1% of the sample variation could be described by the isotropic model in most years (Table 6 and 7). Age 0 juveniles are poorly sampled in most years and this would account for poor model fit. Age 1 juveniles had a high proportion of the sample variance explained by the spatial structure variance with an average spatial autocorrelation range of 98 n.m. However, in most years there was a poor model fit. In age-2 and age-3 juveniles a high proportion of the sample variance was explained by spatial variation though it was poorly described by the isotropic models in many years. Overall, the average range of the spatial dependence in the variogram data was found to increase in range from 98 n.m. in age 1 to 135 n.m. in age 2 (Table 8) and to 156 n.m. in age3

(Table 9). A small autocorrelation range is indicative of patchiness in the data while a large range is indicative of more dispersion (spatial discontinuity) in the data. The increase in the autocorrelation ranges of ages 1 to 3 is indicative of our perception of the increase in spatial distribution in the nursery area with age as seen in the ACON point plots of individual cohorts. (see Figs 2-16). It is also conforms to the pattern of increased spatial distribution observed in kriged plots of yellowtail flounder age groups (see Fig. 30 for an illustration).

Variograms are generally used to model the average degree of similarity between data points as a function of their separation distance. Because the data being used are derived from annual stratified random trawl surveys whose sampling scheme is tailored to estimation of population abundance, some of the spatial variability may not always be modeled due to this survey design. The data maybe heavily skewed or clustered resulting in poor model fits. However, the autocorrelation ranges and kriged values are robust estimators of spatial dependence.

Conclusions

The Southeast Shoal is not exclusively the nursery area for juvenile yellowtail flounder on the Grand Bank; the nursery area comprises the shoal and the area immediately adjacent to the western side of the shoal, as indicated by point maps, Voroni polygons and kriged values. By limiting the boundaries of the nursery area to the Southeast Shoal, a large percentage of the juvenile abundance could potentially be found outside the “nursery area” in some years since the proportion varies extensively from year to year. These analyses have focused on the investigation of various analytical and mapping techniques to delineate quantitatively the spatial and temporal structure of the nursery area for yellowtail flounder.

Future analysis will refine the present techniques and then proceed to define the physical boundary coordinates of the juvenile nursery area. A major requirement of this boundary definition will be a measure of the accuracy associated with the prediction of the numbers expected in this nursery area from year to year. Once these spatial techniques have been refined attention will be directed to applying these techniques to investigating juvenile American plaice and cod nurseries on the southern Grand Bank. The effect of density and environmental factors such as temperature, salinity, depth, substrate type and current patterns on distribution of juvenile should also be included.

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Table 1 Distribution of juvenile densities in each stratum calculated from trawl catches in annual surveys. Numbers are expressed as percentages of the average numbers per square nautical mile (missing stratum which had zero catches in every year are not listed).

Div	Stratum	85	86	87	88	89	90	91	92	93	94	95	96	97
3L	363	-	0.05	-	-	-	-	-	-	-	-	-	-	-
	372	27.30	-	-	-	0.25	-	0.50	5.10	0.10	-	-	2.00	1.80
	784	-	-	-	-	-	-	-	-	-	-	-	0.02	-
	786	-	-	-	-	-	-	-	-	-	-	-	0.01	-
Total		27.30	0.05	0.00	0.00	0.25	0.00	0.50	5.10	0.10	0.00	0.00	2.00	1.80
3N	360	14.80	81.80	21.50	21.90	23.00	24.70	15.30	34.40	43.90	15.00	11.70	14.90	4.00
	361	5.30	4.30	1.30	11.60	9.80	8.90	7.70	7.10	11.10	10.60	12.10	14.20	4.00
	362	8.40	0.07	0.07	0.40	0.40	0.20	2.20	0.20	0.10	0.80	21.00	4.00	11.00
	373	1.20	0.05	-	-	0.07	0.02	-	0.02	0.07	0.20	1.20	-	3.00
	374	1.60	0.10	0.05	0.03	-	0.04	-	-	-	-	-	-	-
	375	6.70	2.30	23.50	17.60	14.30	8.50	5.60	6.20	0.40	10.20	16.90	15.20	6.80
	376	24.70	8.50	50.60	37.80	44.40	54.80	64.90	38.10	29.90	57.90	29.90	37.30	54.50
	377	-	-	-	-	-	-	-	-	-	-	-	-	0.01
Total		62.80	97.10	97.00	89.40	92.00	97.20	95.70	86.10	85.60	94.60	92.80	85.50	83.30
3O	330	-	-	-	-	0.01	0.00	-	0.30	-	-	0.10	-	-
	331	-	-	-	-	0.01	0.02	-	0.03	-	-	0.03	-	0.05
	332	-	-	-	-	-	0.02	0.04	-	-	-	-	-	-
	337	-	-	-	-	-	0.20	0.01	0.06	-	-	-	0.10	-
	338	-	0.20	-	0.20	1.00	0.10	0.03	0.40	0.20	0.30	3.10	-	0.10
	340	-	-	-	-	-	-	-	-	0.10	-	-	-	0.50
	351	9.80	0.25	-	2.00	0.05	0.20	0.05	0.50	0.80	0.20	0.10	1.40	3.80
	352	-	1.80	3.00	8.10	6.70	2.20	3.50	7.50	13.10	4.90	3.60	11.00	10.20
	353	-	0.50	-	0.30	0.05	-	0.20	0.07	-	-	0.03	-	0.10
Total		9.80	2.80	3.00	10.60	7.80	2.80	3.80	8.80	14.30	5.40	6.90	12.50	14.80

Table 2. Distribution of juveniles within Div. 3N and the 4 strata which make up the nursery area. Numbers are expressed as percentages of the average numbers per square nautical mile.

	3N	4 strata (360, 361, 375, 376)	on shoal	off shoal
1986	97.1	96.9	10.8	86.1
1987	97.0	96.9	74.1	22.8
1988	89.4	89.0	55.5	33.5
1989	92.0	91.5	58.7	32.8
1990	97.2	97.0	63.4	33.6
1991	95.7	93.6	70.5	23.0
1992	86.1	85.9	44.4	41.5
1993	85.6	85.4	30.4	55.0
1994	94.6	93.6	68.1	25.6
1995	92.8	70.8	46.9	23.9
1996	85.5	81.5	52.5	29.0
1997	93.4	69.6	61.6	8.0
Average S.E.	92.2 1.3	87.7 2.8	53.1 5.2	46.9 5.2

Table 3. Percent distribution by area of Voronoi polygons of juvenile yellowtail flounder in Division 3N.

Year	% on Southeast Shoal	% off Southeast Shoal
1986	19.4	80.6
1987	66.9	33.1
1988	33.3	66.7
1989	48.8	51.2
1990	46.6	53.4
1991	78.6	21.4
1992	52.4	47.6
1993	42.4	57.6
1994	72.4	27.6
1995	56.1	43.9
1996	47.5	52.5
1997	71.3	28.7
Mean S.E.	53.0 5.0	47.0 5.0

Table 4. Statistical parameters for semi-variance analysis of juvenile yellowtail flounder.

Year	N	Nugget	Sill	Range	Proportion	r^2	RSS
1986	99	1.999	3.985	254.16	0.498	0.951	0.160
1987	49	1.160	5.905	54.60	0.804	0.847	0.840
1988	134	0.662	3.335	34.00	0.801	0.307	0.745
1989	215	0.602	2.719	92.4	0.779	0.656	0.557
1990	195	0.400	4.383	81.5	0.909	0.718	2.354
1991	207	0.480	4.062	85.6	0.882	0.699	2.029
1992	258	1.473	2.231	374.61	0.340	0.284	1.528
1993	258	1.117	2.235	541.8	0.500	0.418	1.251
1994	195	0.874	4.028	190.8	0.753	0.723	2.175
1995	359	0.683	3.019	135.6	0.774	0.712	1.099
1996	356	0.457	1.669	334.5	0.726	0.52	1.133
1997	386	0.155	1.197	50.70	0.871	0.07	0.958
Mean S.E.				185.9 46.1			

Table 5. Temporal correlations between kridged values (Z) of juvenile yellowtail flounder distribution from annual survey data, 1986-97.

Year	1996	1995	1994	1993	1992	1991	1990	1989	1988	1987	1986
1997	0.71	0.72	0.56	0.63	0.47	0.76	0.84	0.40	0.54	0.07	0.33
1996		0.59	0.84	0.72	0.69	0.44	0.63	0.74	0.63	-0.10	0.41
1995			0.80	0.56	0.29	0.91	0.86	0.34	0.93	0.003	0.36
1994				0.69	0.44	0.63	0.69	0.66	0.90	-0.14	0.44
1993					0.20	0.60	0.64	0.44	0.58	0.01	0.44
1992						0.14	0.37	0.56	0.29	0.21	0.27
1991							0.91	0.21	0.77	0.08	0.35
1990								0.53	0.74	0.10	0.55
1989									0.45	-0.09	0.65
1988										-0.06	0.43
1987											0.47

Table 6. Statistical parameters for semi-variance analysis of juvenile yellowtail flounder (age 0) by year.

YEAR	NUGGET	SILL	RANGE	PROPORTION	R^2	RSS
1986	0.107	0.152	254.16	0.296	0.123	6.572e03
1987	0.073	0.425	1.50	0.828	0.000	0.104
1988	1.300e04	3.360e03	19.70	0.961	0.000	4.039e05
1989	0.0008	0.0646	20.40	0.988	0.000	9.389e03
1990	-	-	-	-	-	-
1991						
1992						
1993						
1994						
1995						
1996						
1997						
Mean S.E.			73.94 60.3			

Table 7. Statistical parameters for semi-variance analysis of juvenile yellowtail flounder (1) by year.

YEAR	NUGGET	SILL	RANGE	PROPORTION	R^2	RSS
1986	1.187	2.058	254.16	0.423	0.598	0.393
1987	0.310	3.548	19.50	0.913	0.000	3.054
1988	0.013	1.164	19.70	0.989	0.000	1.254
1989	0.005	0.494	20.40	0.990	0.000	0.203
1990	0.070	0.665	20.10	0.895	0.000	0.194
1991	0.002	0.136	19.90	0.985	0.000	0.0196
1992	0.147	0.215	374.72	0.316	0.111	0.0347
1993	0.206	0.324	373.72	0.364	0.282	0.0379
1994	0.123	0.946	23.20	0.870	0.003	0.174
1995	0.070	0.428	25.80	0.836	0.024	0.0274
1996	0.018	0.116	19.50	0.845	0.000	9.502e03
1997	0.001	0.131	1.50	0.992	0.000	0.0184
Mean S.E.			97.68 42.1			

Table 8. Statistical parameters for semi-variance analysis of juvenile yellowtail flounder (age 2) by year.

YEAR	NUGGET	SILL	RANGE	PROPORTION	R^2	RSS
1986	1.195	1.802	254.16	0.337	0.768	0.0877
1987	0.940	5.270	34.30	0.822	0.601	0.559
1988	0.223	1.569	1.50	0.858	0.000	0.956
1989	0.274	1.404	24.60	0.805	0.007	0.253
1990	0.351	2.584	45.70	0.864	0.374	1.104
1991	0.180	1.573	29.10	0.886	0.055	0.542
1992	0.083	0.664	19.90	0.875	0.000	0.200
1993	0.918	1.371	373.72	0.330	0.299	0.506
1994	1.583	2.581	344.05	0.387	0.584	0.722
1995	0.312	1.832	55.90	0.830	0.553	0.382
1996	0.499	0.714	434.11	0.301	0.114	0.216
1997	0.001	0.415	19.50	0.998	0.000	0.148
Mean S.E.			135.4 47.4			

Table 9. Statistical parameters for semivariance analysis of juvenile yellowtail flounder (age 3) by year.

YEAR	NUGGET	SILL	RANGE	PROPORTION	R^2	RSS
1986	1.716	2.430	254.16	0.294	0.469	0.271
1987	0.700	5.230	46.90	0.866	0.663	1.435
1988	0.533	2.960	28.80	0.820	0.104	0.801
1989	0.512	2.202	83.70	0.767	0.662	0.294
1990	0.300	3.697	75.60	0.919	0.606	2.359
1991	0.460	3.805	84.30	0.879	0.687	1.837
1992	1.460	2.135	374.72	0.316	0.233	1.379
1993	1.050	1.589	373.72	0.339	0.295	0.738
1994	0.319	3.115	92.40	0.898	0.694	1.566
1995	0.346	2.272	68.00	0.848	0.682	0.651
1996	0.426	1.458	342.90	0.708	0.524	0.818
1997	0.141	1.074	41.70	0.869	0.047	0.784
Mean S.E			155.6 39.9			

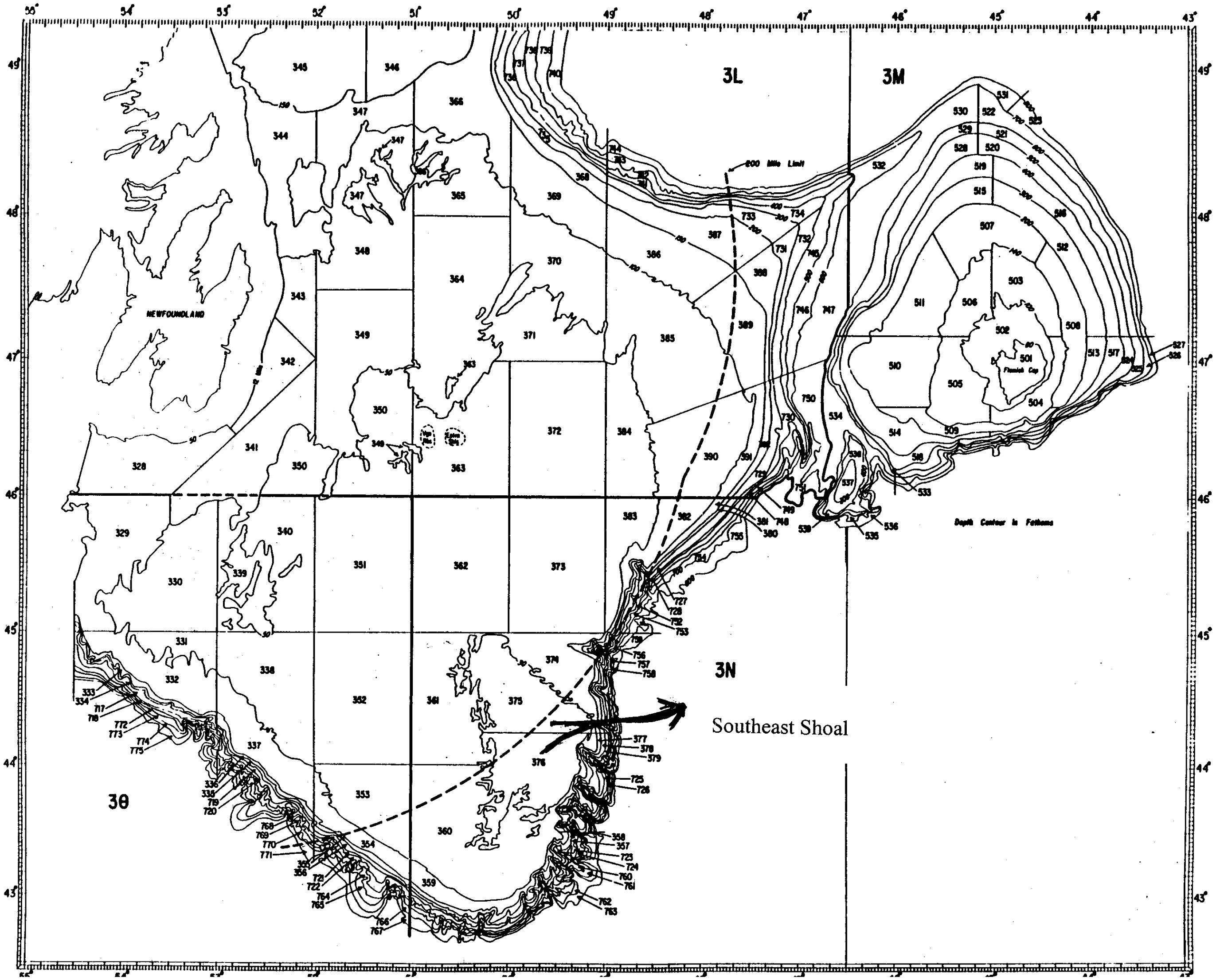


Fig. 1 Stratification chart used in annual Canadian surveys of the Grand Bank, NAFO Div. 3LNO.

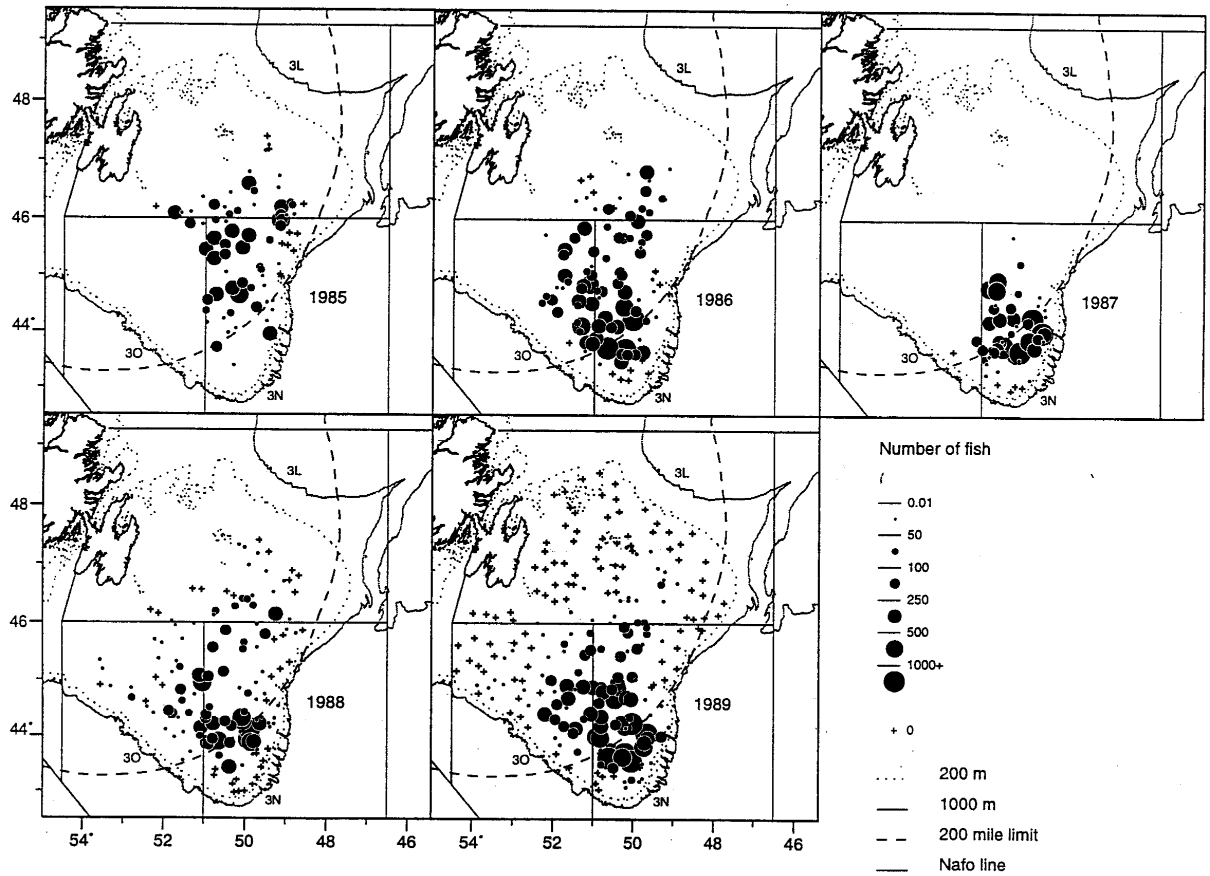


Fig. 2. Distribution of Yellowtail Flounder (number per tow) from stratified random surveys in Div. 3LNO for 1985, 1986, 1987, 1988 and 1989.

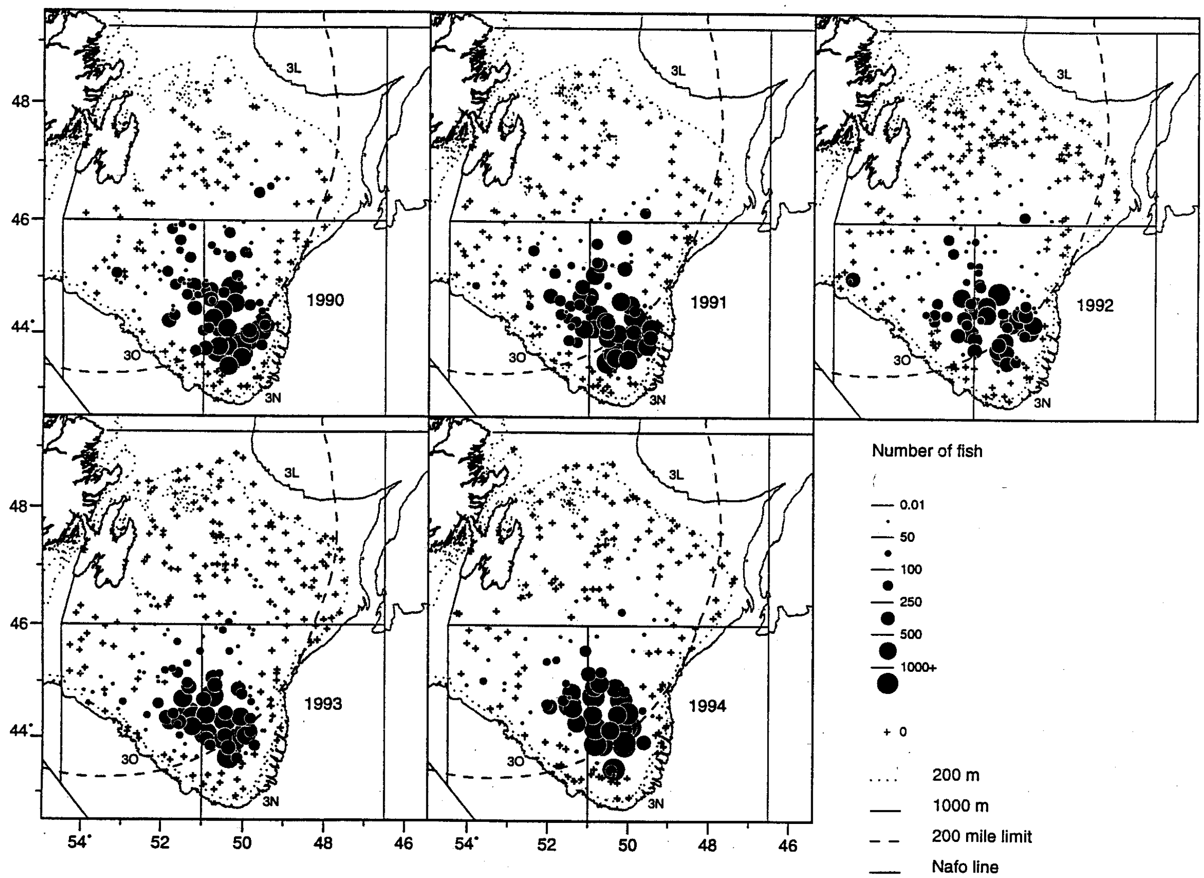


Fig. 3. Distribution of Yellowtail Flounder (number per tow) from stratified random surveys in Div. 3LNO for 1990, 1991, 1992, 1993 and 1994.

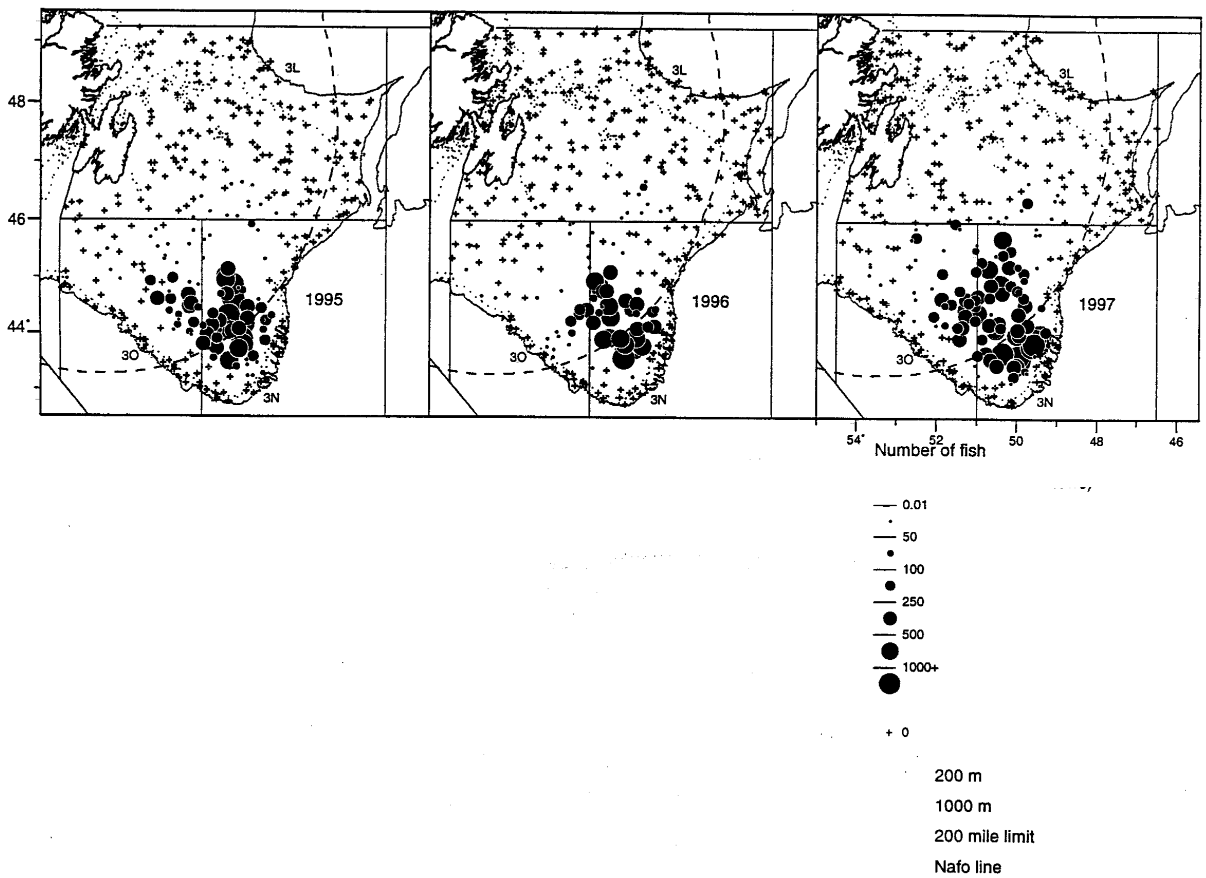


Fig. 4. Distribution of Yellowtail Flounder (number per tow) from stratified random surveys in Div. 3LNO for 1995, 1996 and 1997.

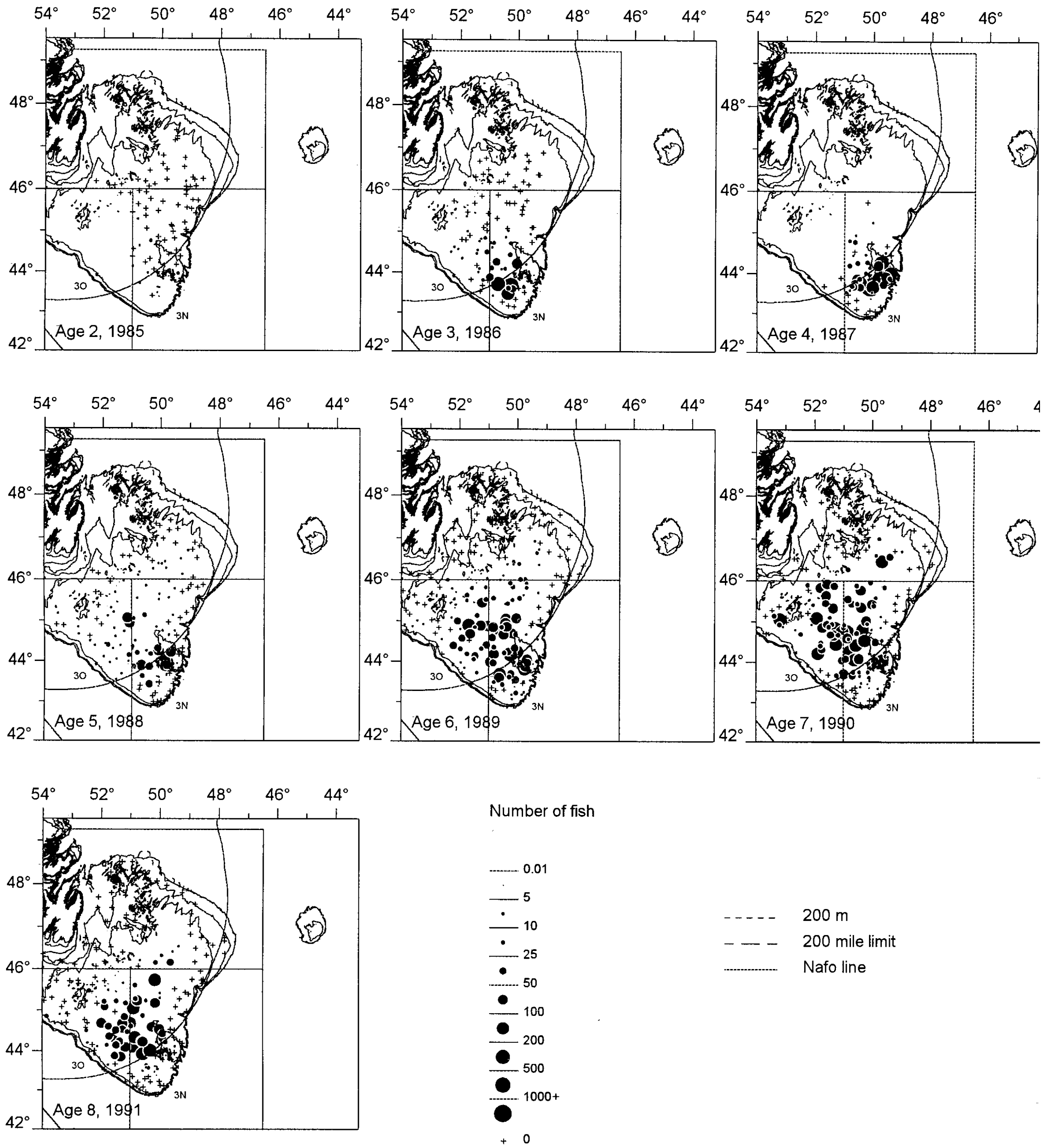
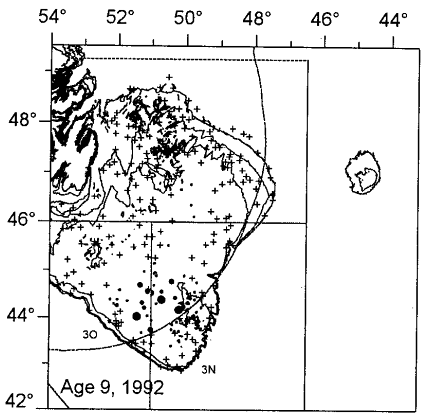


Fig. 5A. Distribution of yellowtail flounder 1983 cohort from stratified random surveys in Div. 3LNO.



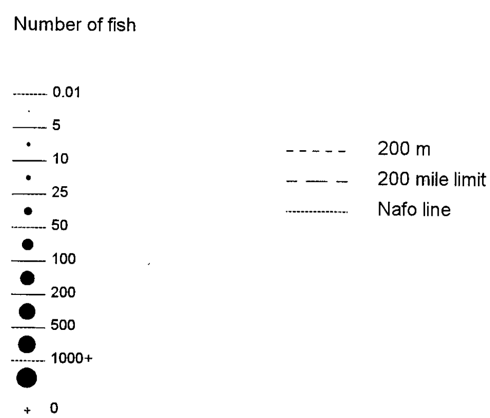


Fig. 5B. Distribution of yellowtail flounder cohort from stratified random surveys in Div. 3LNO.

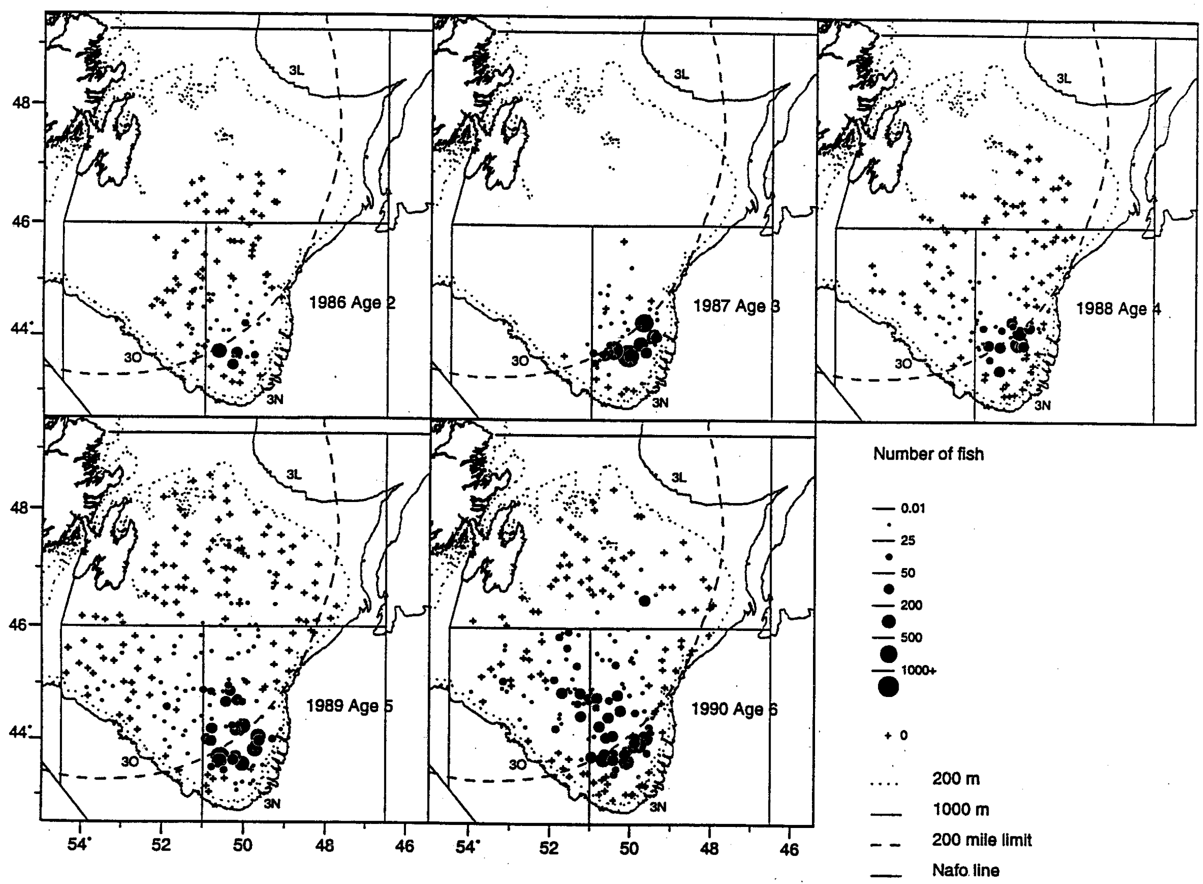


Fig. 6A. Distribution of Yellowtail catches (1984 year class) from stratified random surveys in Div. 3LNO for number of fish per tow.

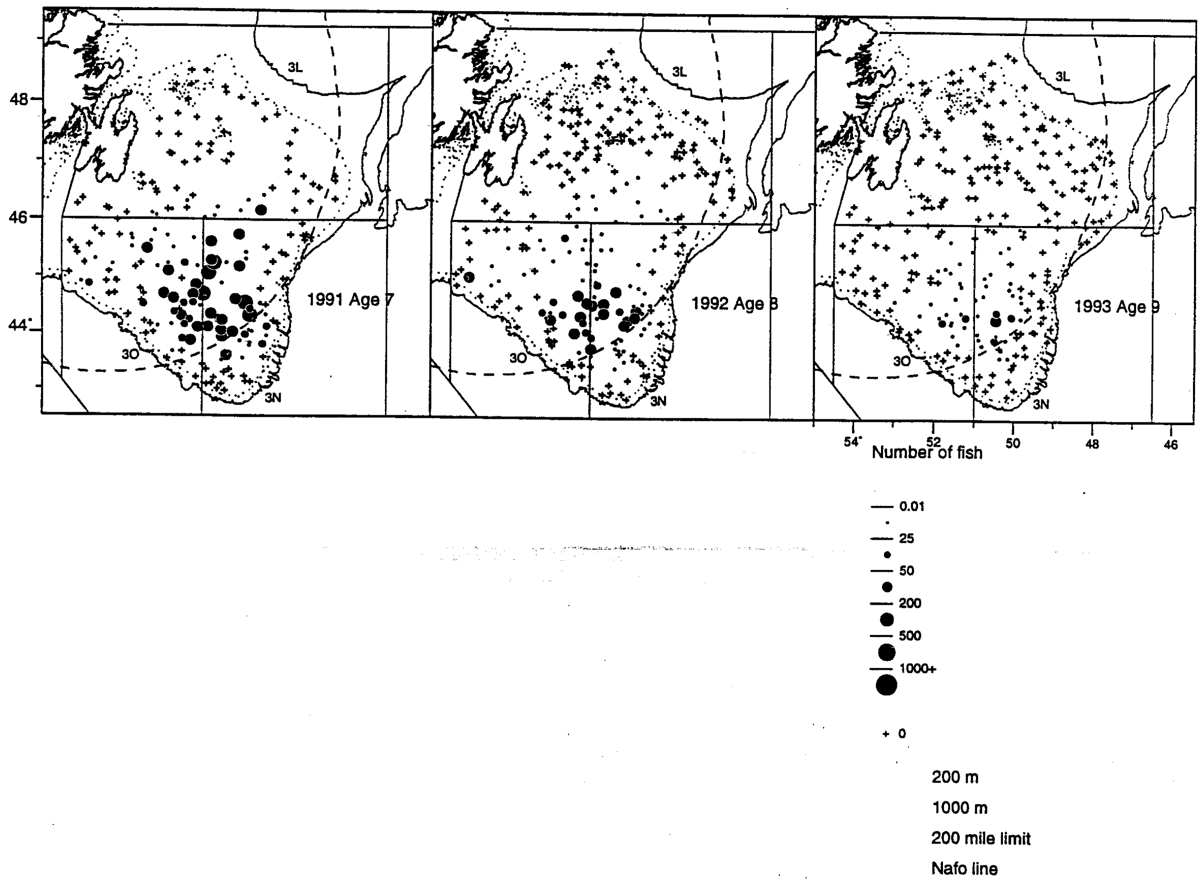


Fig. 6B. Distribution of Yellowtail Flounder (1984 year class) from stratified random surveys in Div. 3LNO for number of fish per tow.

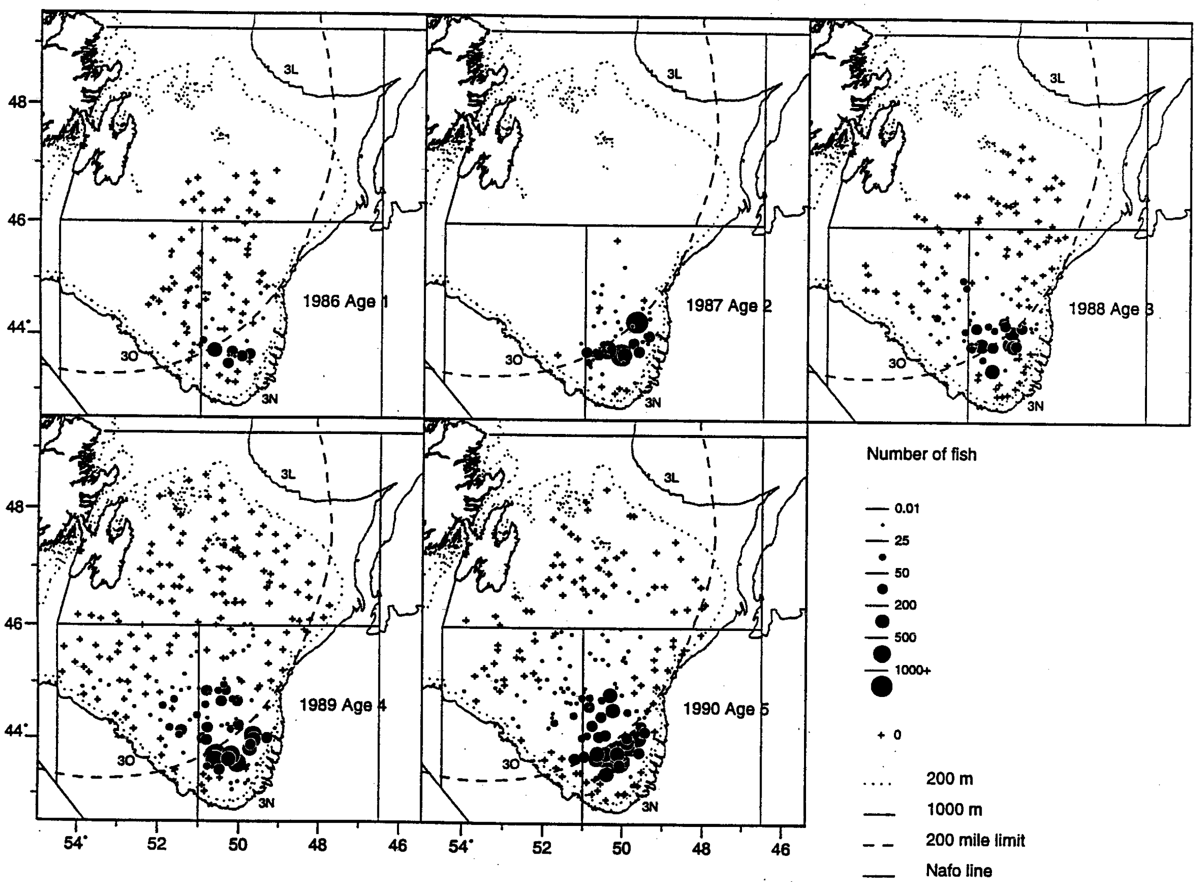


Fig. 7A. Distribution of Yellowtail catches (1985 year class) from stratified random surveys in Div. 3LNO for number of fish per tow.

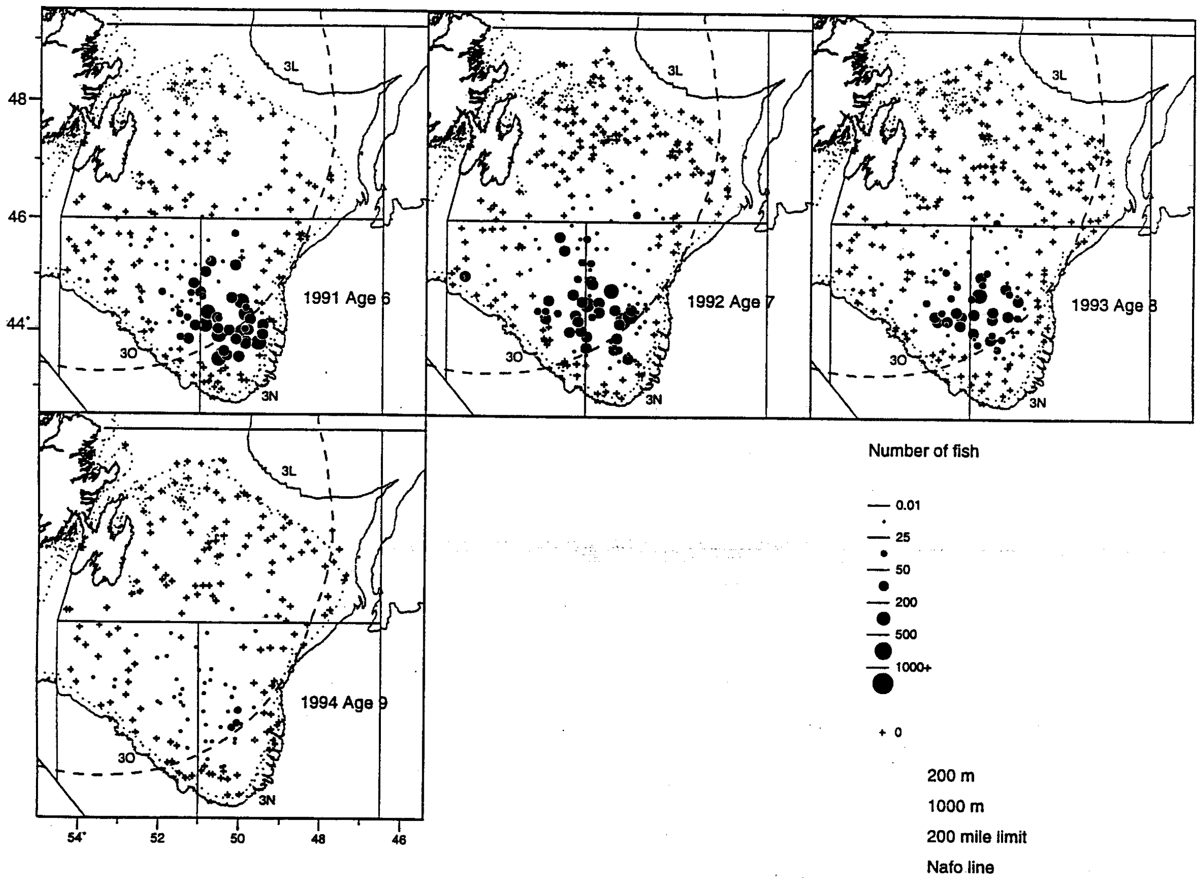


Fig. 7B. Distribution of Yellowtail Flounder (1985 year class) from stratified random surveys in Div. 3LNO for number of fish per tow.

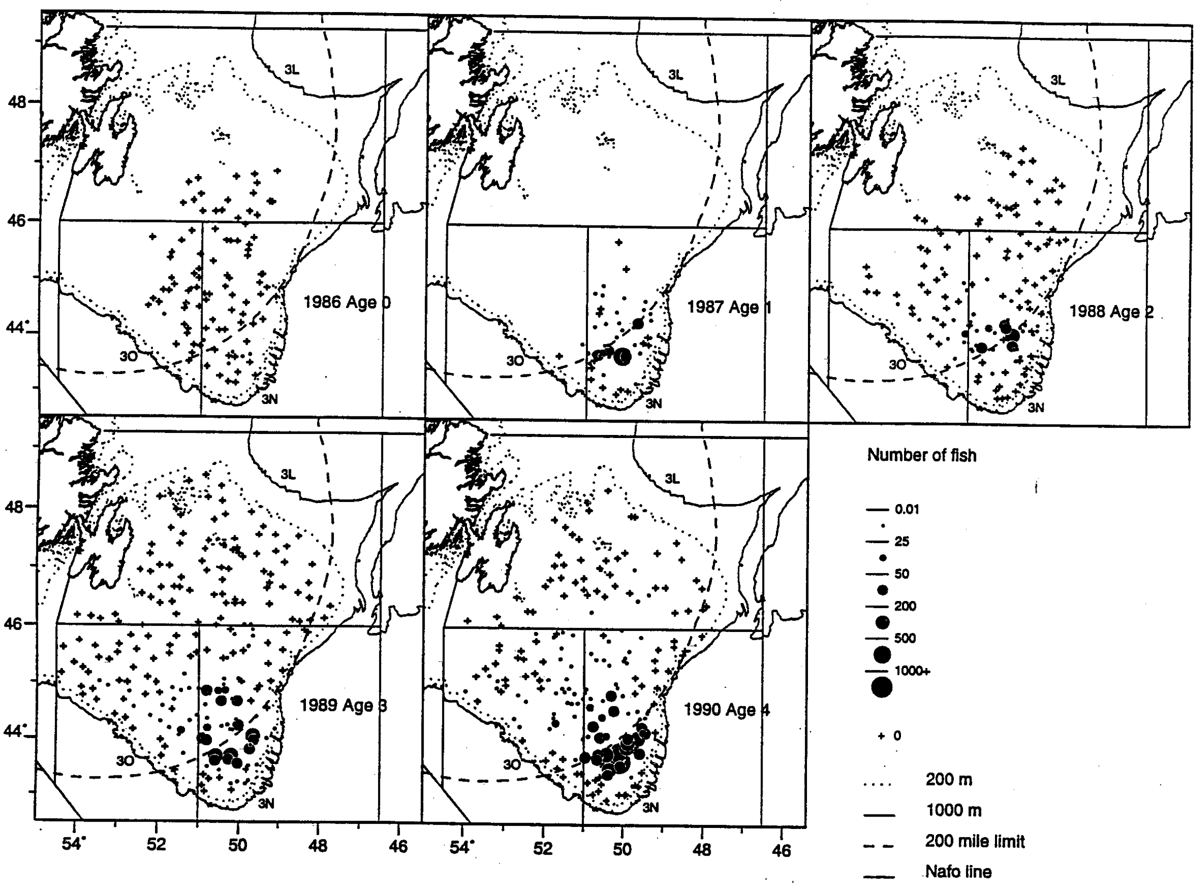


Fig. 8A. Distribution of Yellowtail catches (1986 year class) from stratified random surveys in Div. 3LNO for number of fish per tow.

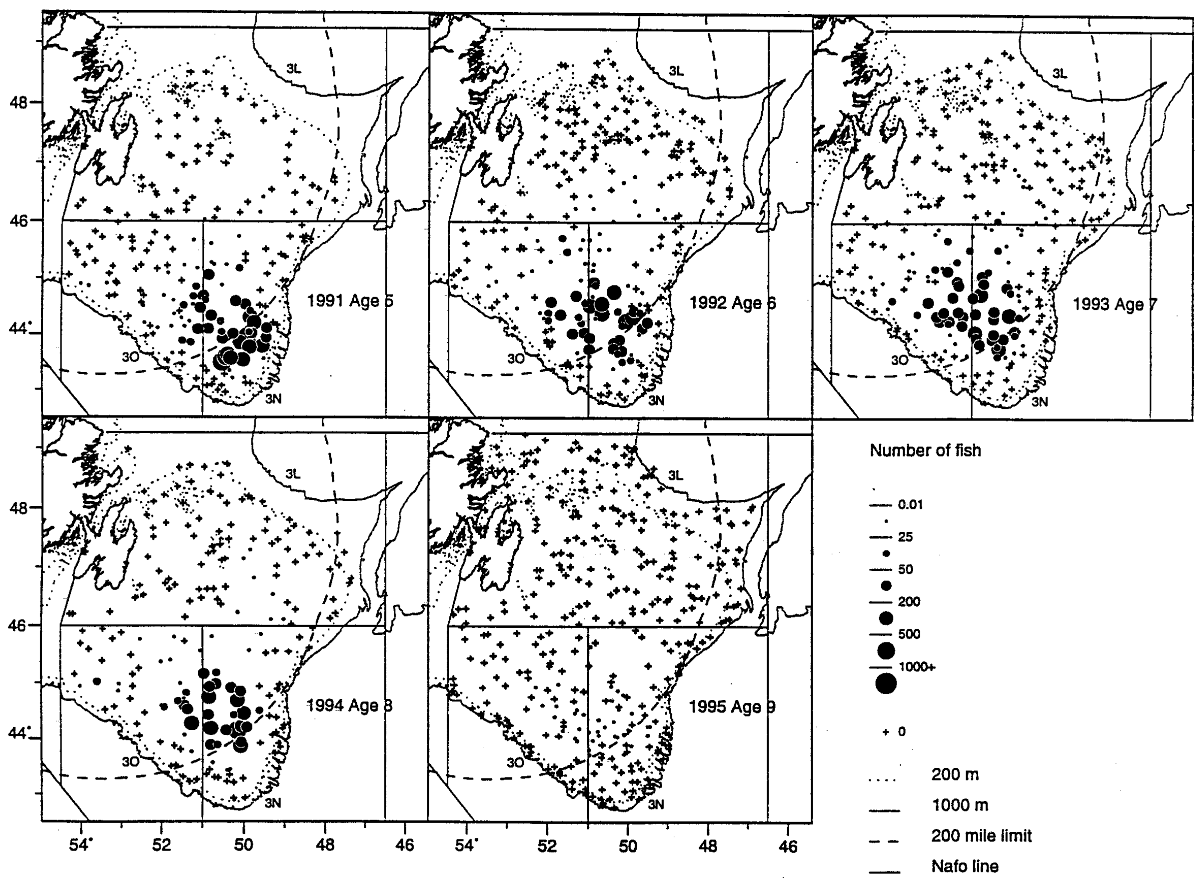


Fig. 8B. Distribution of Yellowtail catches (1986 year class) from stratified random surveys in Div. 3LNO for number of fish per tow.

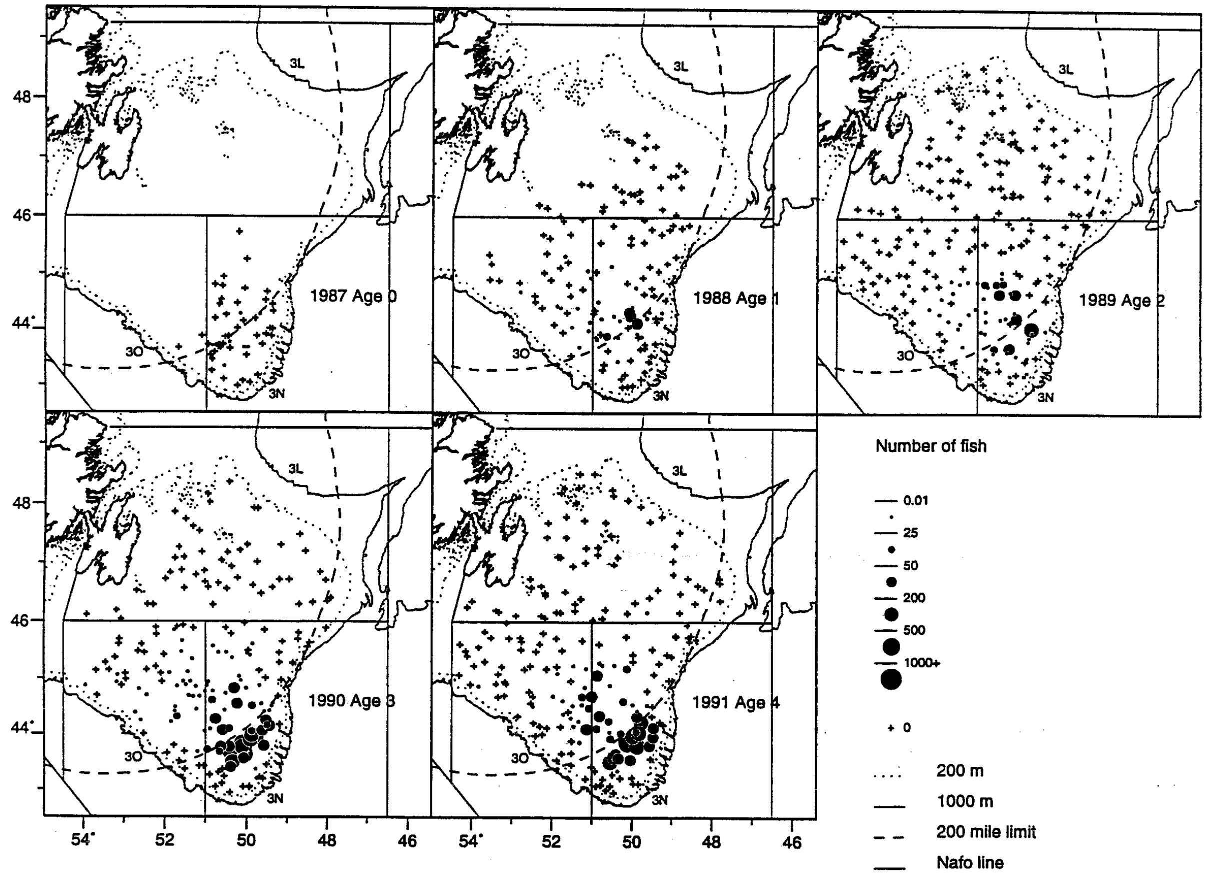


Fig. 9A. Distribution of Yellowtail catches (1987 year class) from stratified random surveys in Div. 3LNO for number of fish per tow.

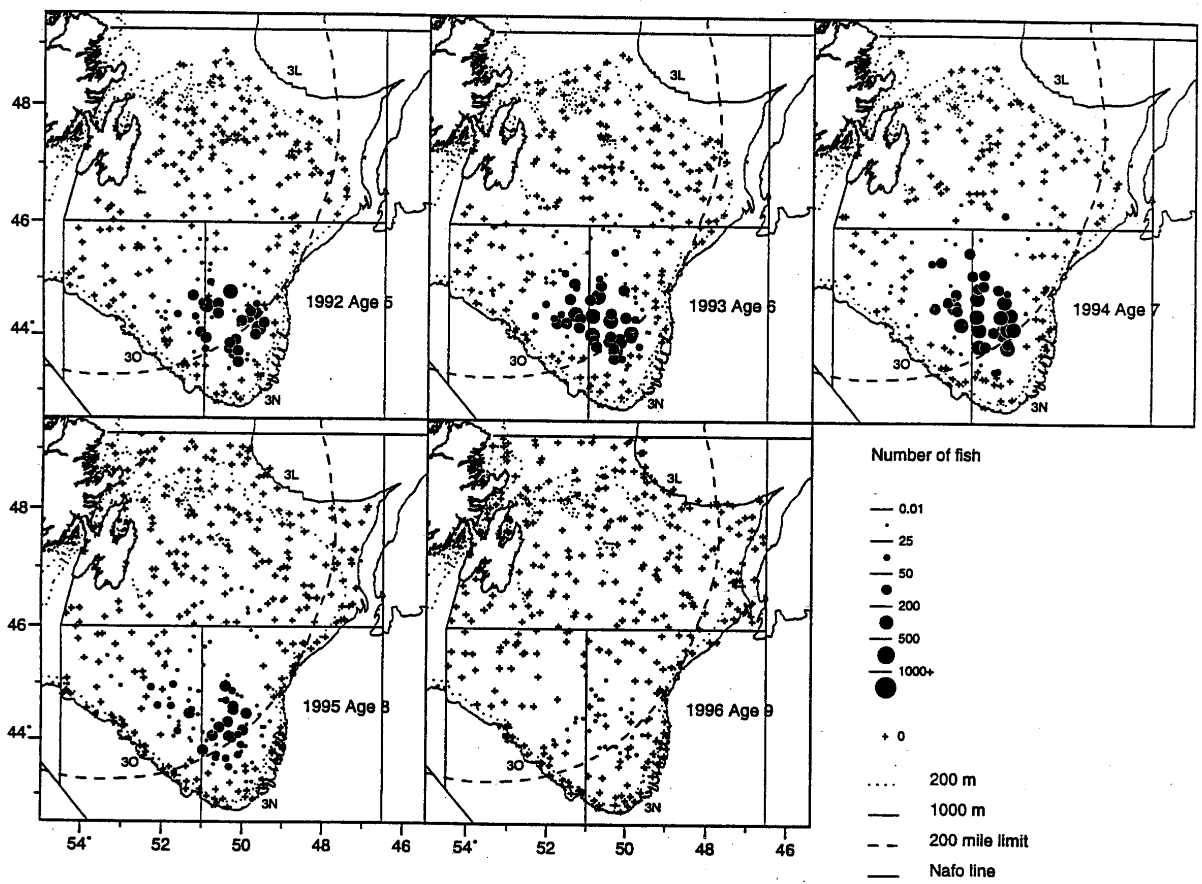


Fig. 9B. Distribution of Yellowtail catches (1987 year class) from stratified random surveys in Div. 3LNO for number of fish per tow.

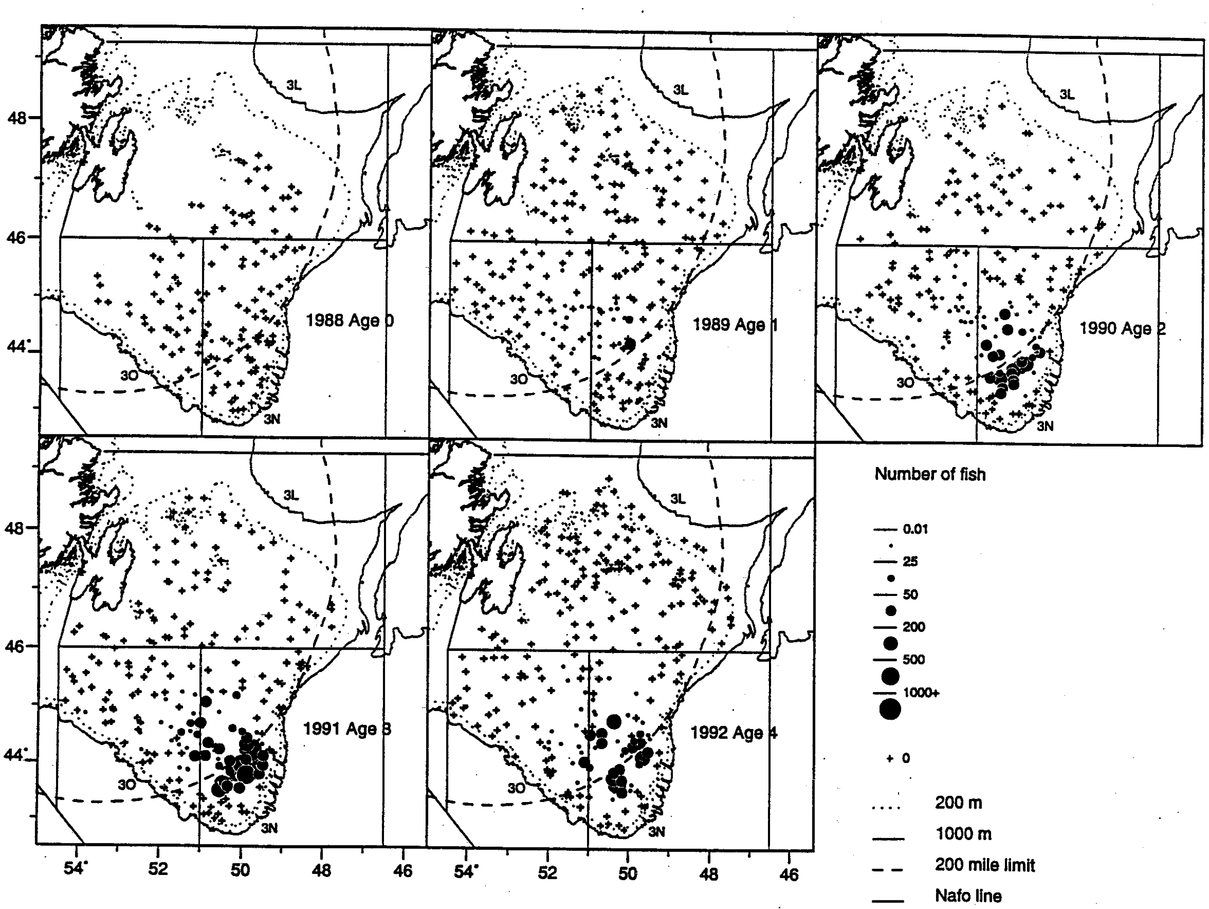


Fig. 10A. Distribution of Yellowtail catches (1998 year class) from stratified random surveys in Div. 3LNO for number of fish per tow.

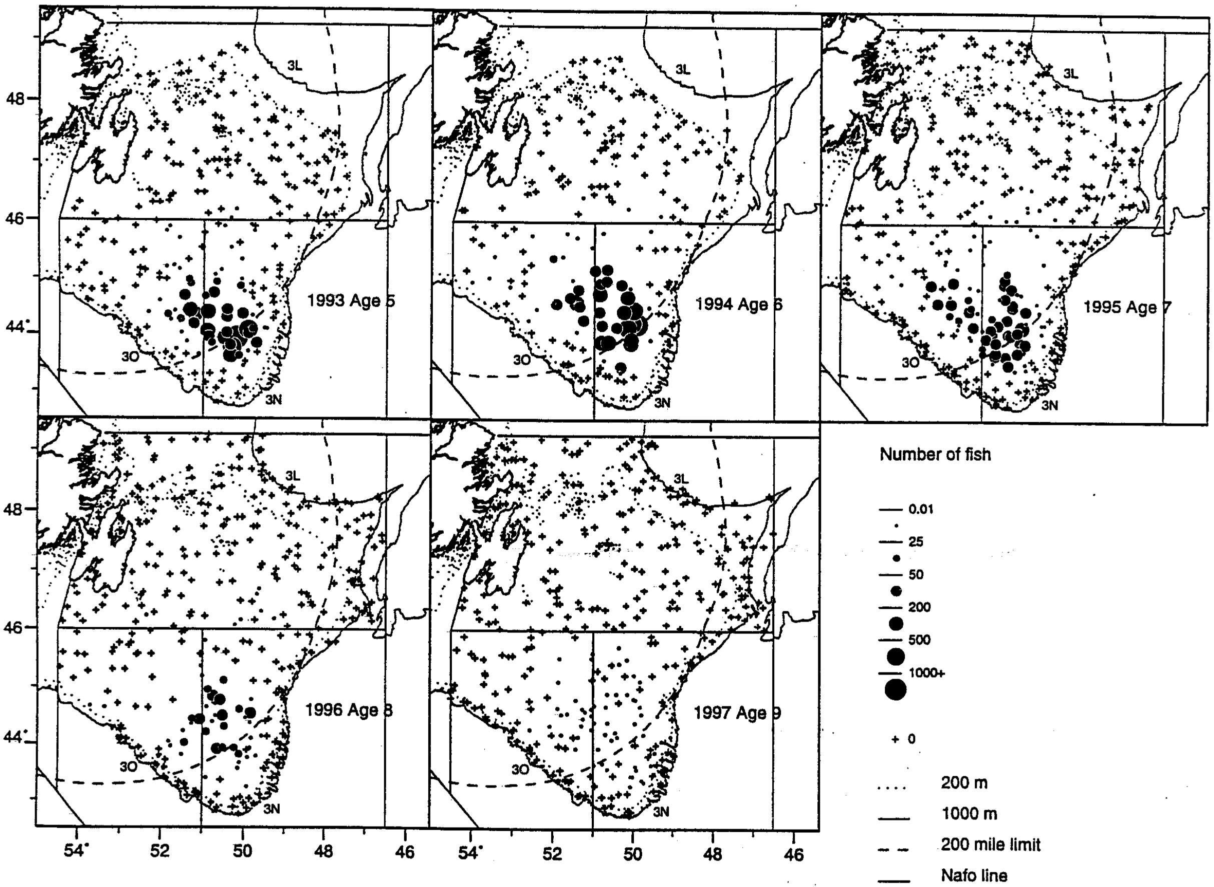


Fig. 10B. Distribution of Yellowtail catches (1988 year class) from stratified random surveys in Div. 3LNO for number of fish per tow.

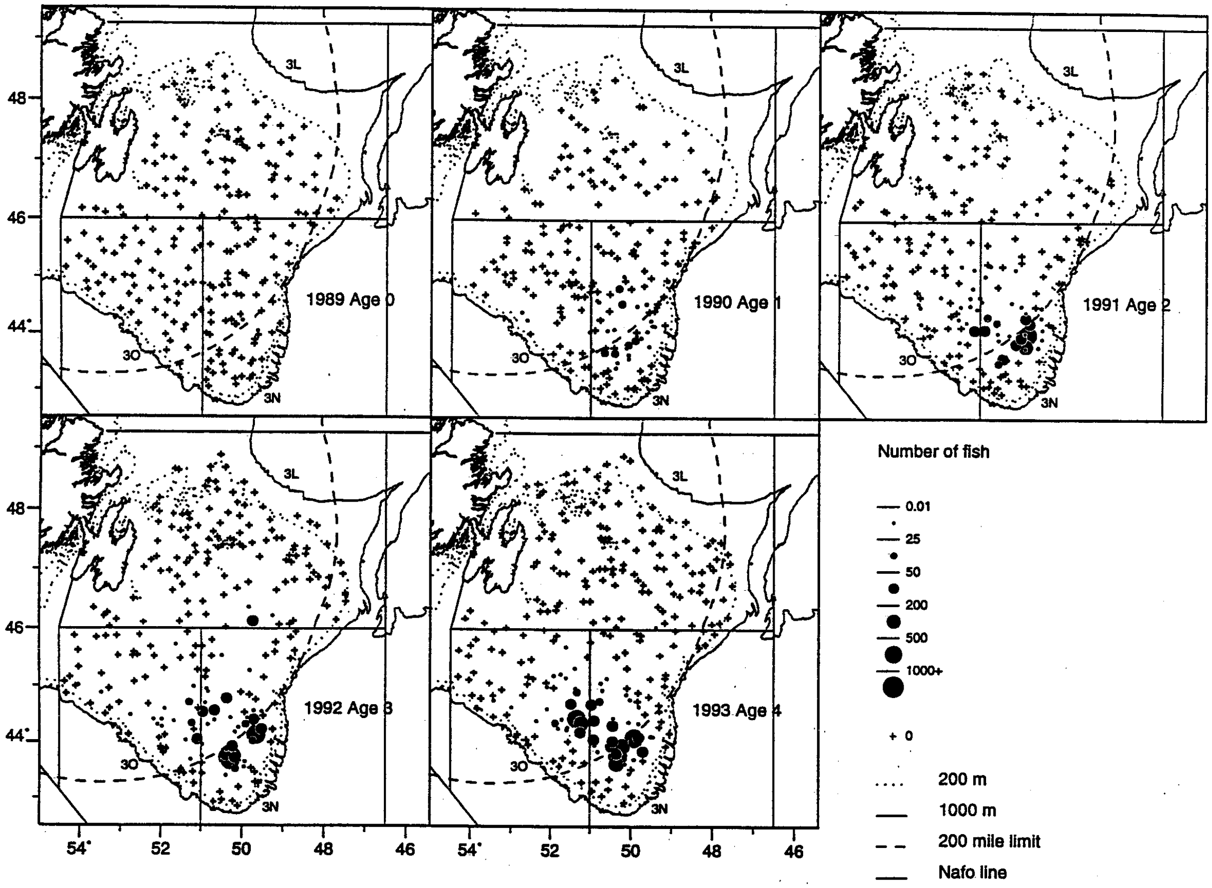


Fig. 11A. Distribution of Yellowtail catches (1989 year class) from stratified random surveys in Div. 3LNO for number of fish per tow.

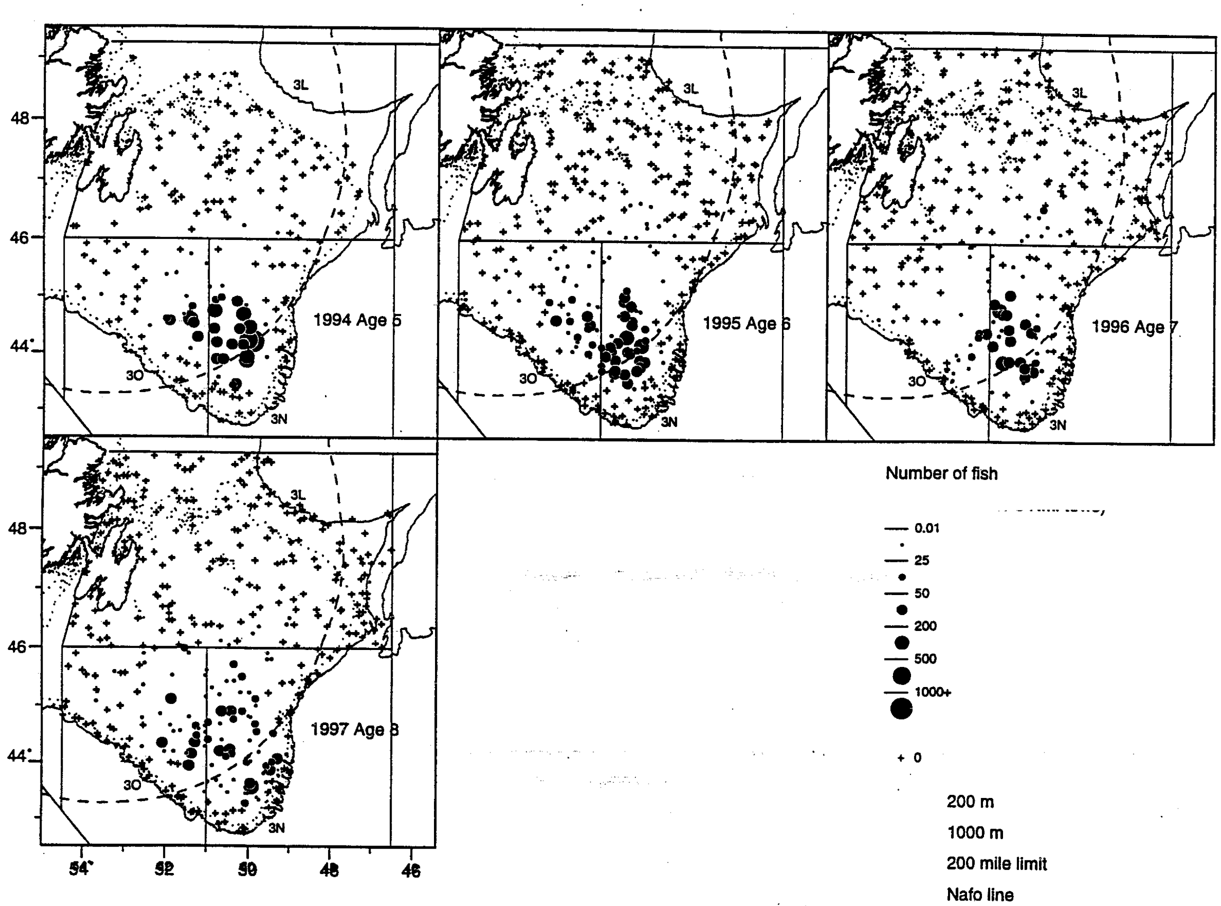


Fig. 11B. Distribution of Yellowtail catches (1989 year class) from stratified random surveys in Div. 3LNO for number of fish per tow.

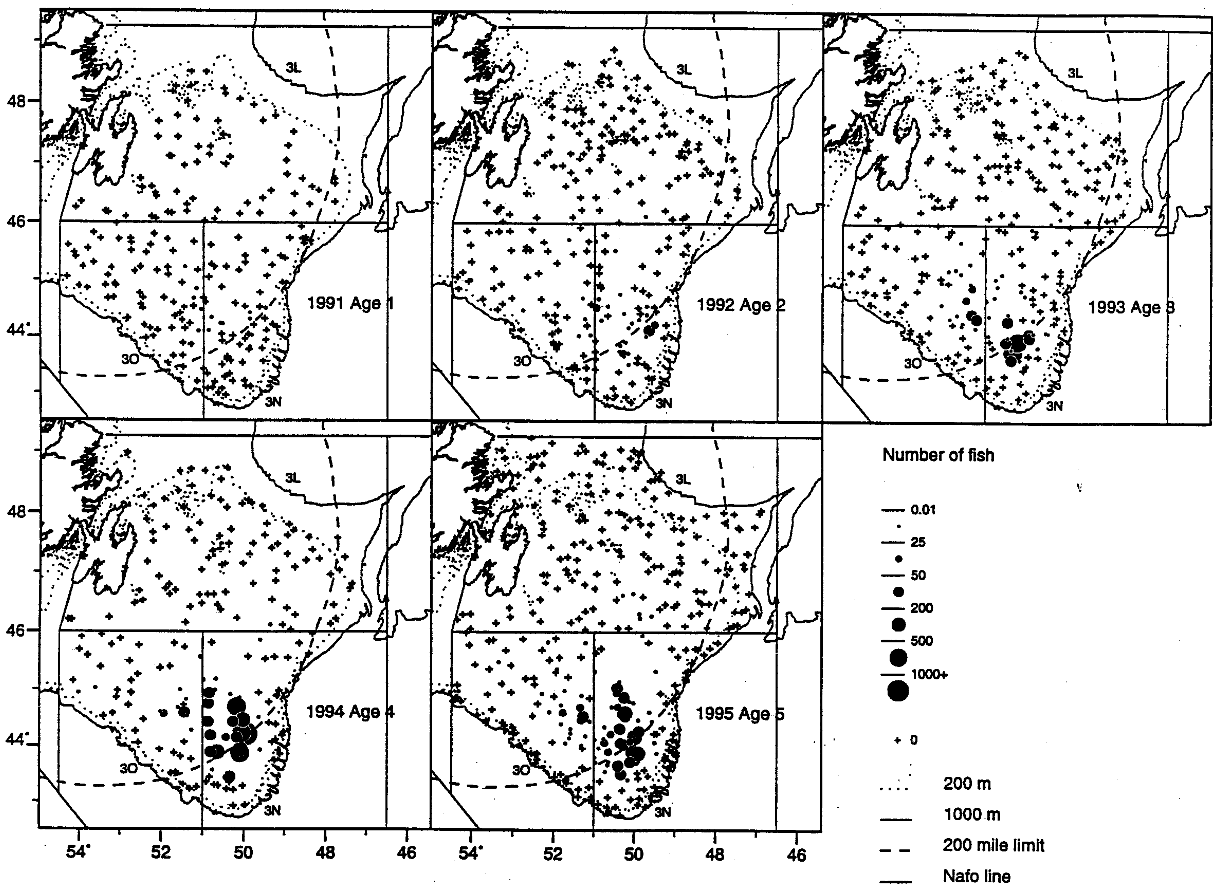


Fig. 12A. Distribution of Yellowtail catches (1990 year class) from stratified random surveys in Div. 3LNO for number of fish per tow.

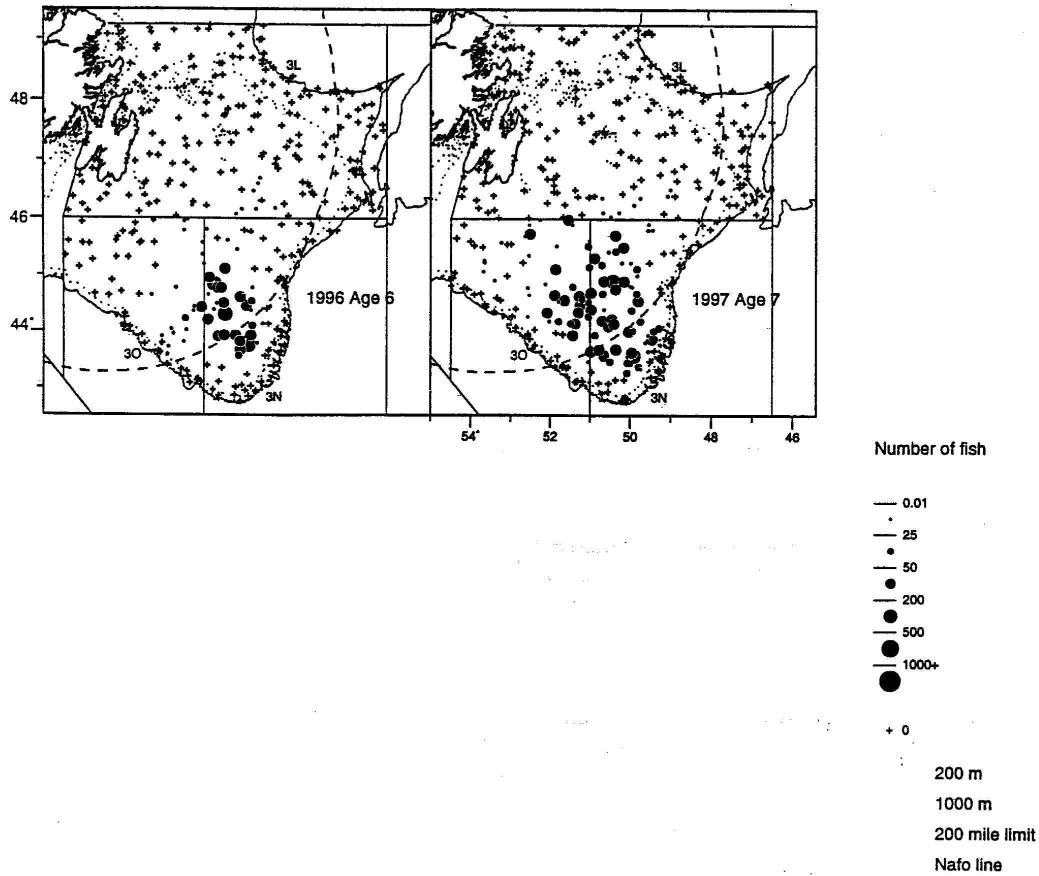


Fig. 12B. Distribution of Yellowtail catches (1990 year class) from stratified random surveys in Div. 3LNO for number of fish per tow.

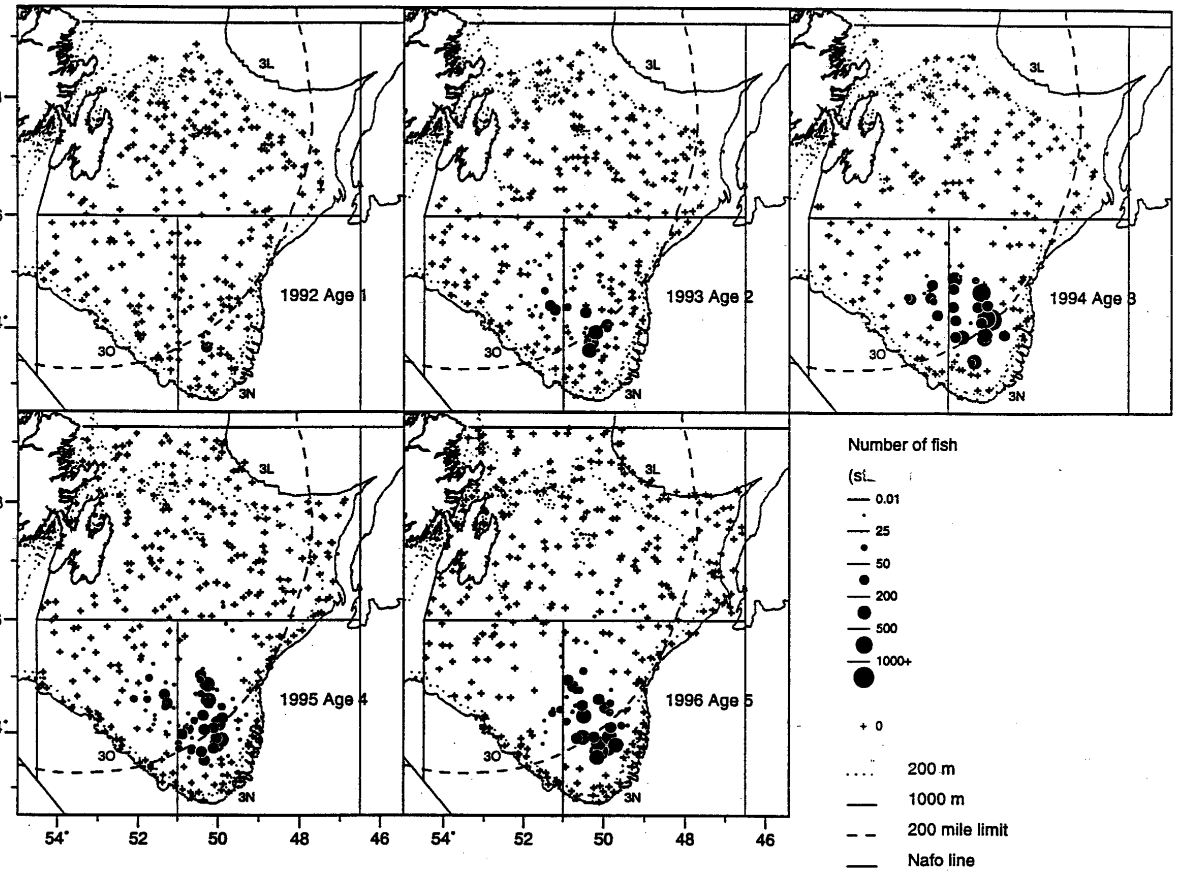


Fig. 13A. Distribution of Yellowtail catches (1991 year class) from stratified random surveys in Div. 3LNO for number of fish per tow.

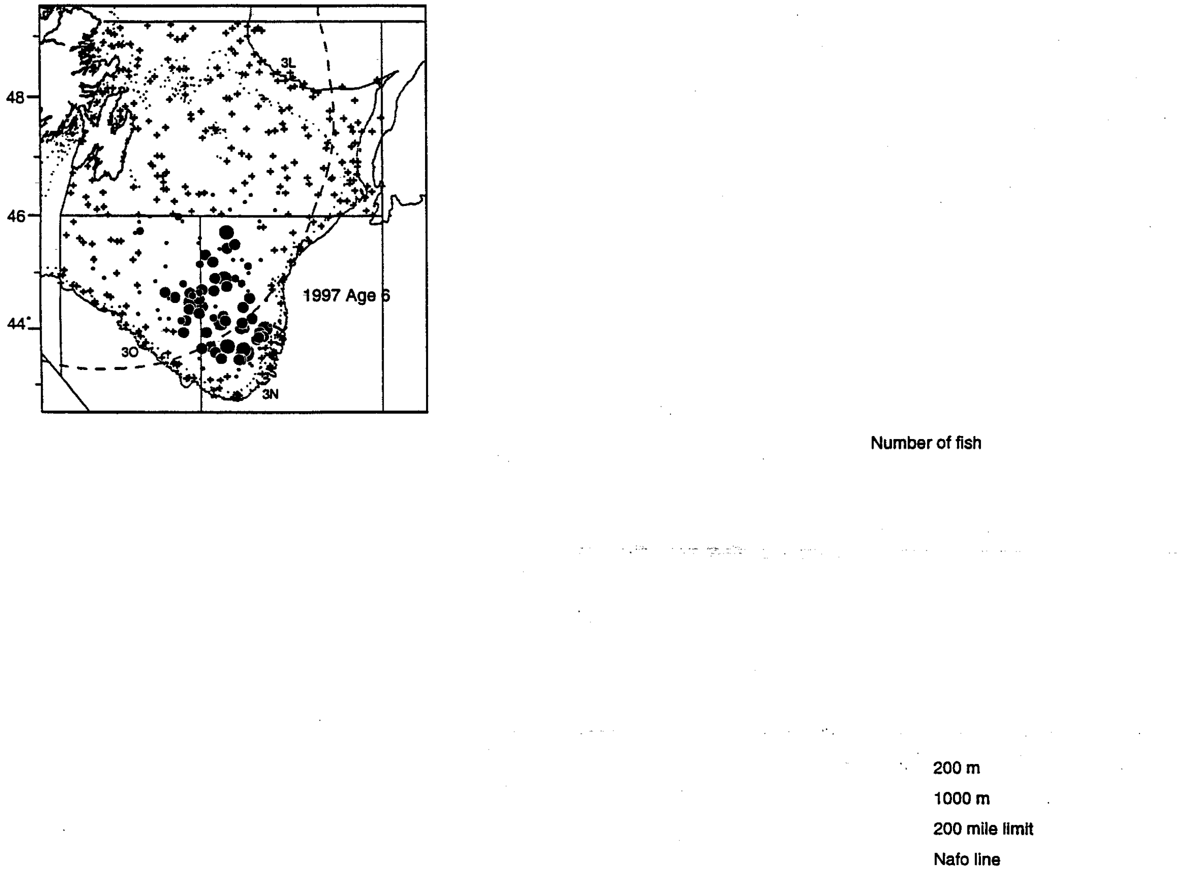


Fig. 13B. Distribution of Yellowtail catches (1991 year class) from stratified random surveys in Div. 3LNO for number of fish per tow.

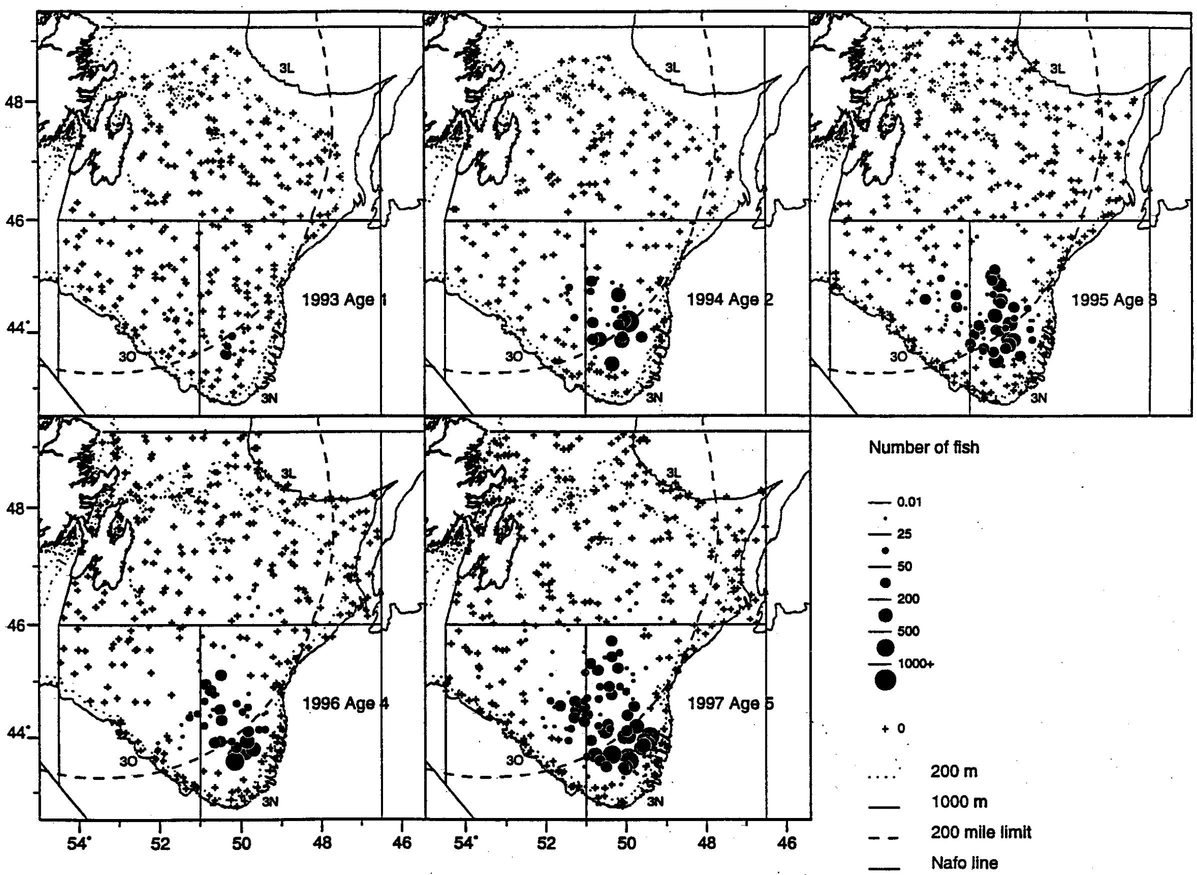


Fig. 14A. Distribution of Yellowtail catches (1992 year class) from stratified random surveys in Div. 3LNO for numbe of fish per tow.

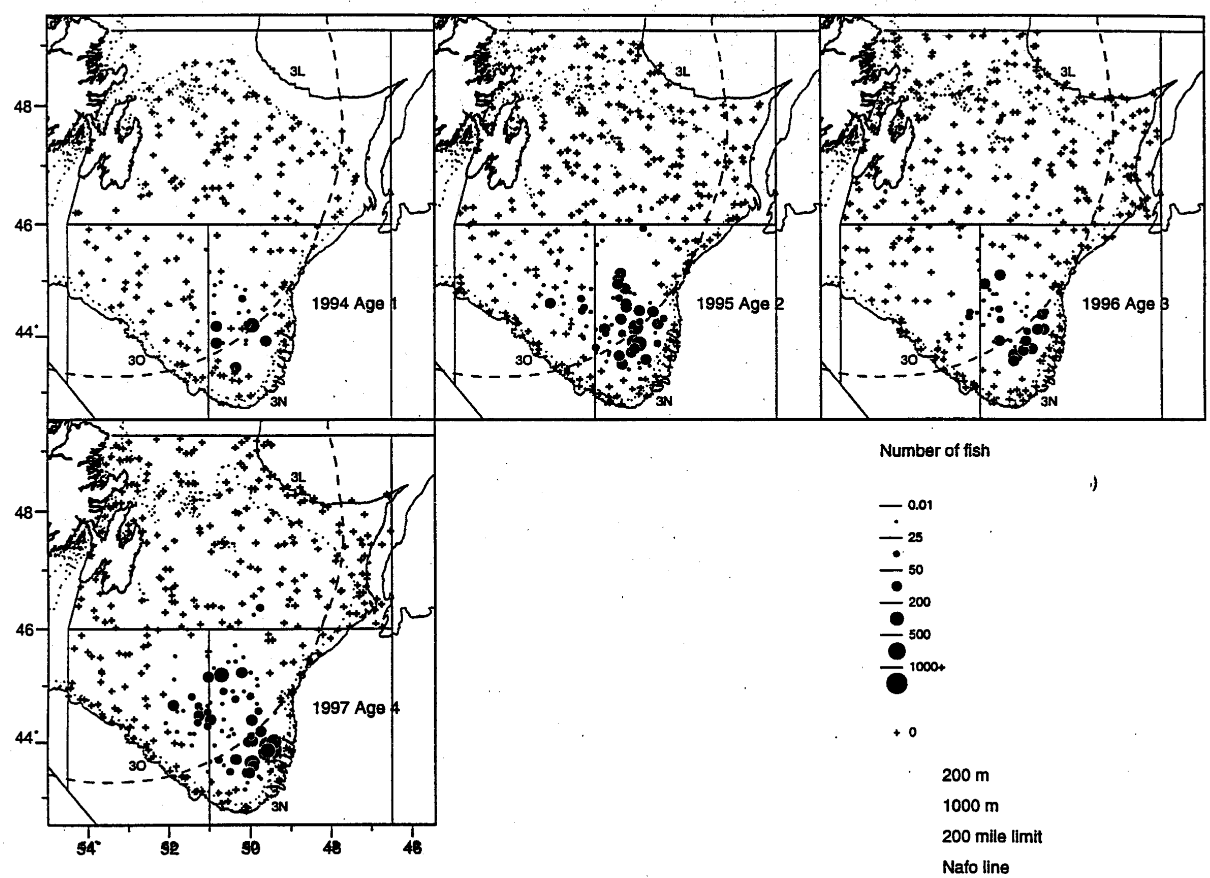


Fig. 14B. Distribution of Yellowtail catches (1993 year class) from stratified random surveys in Div. 3LNO for number of fish per tow.

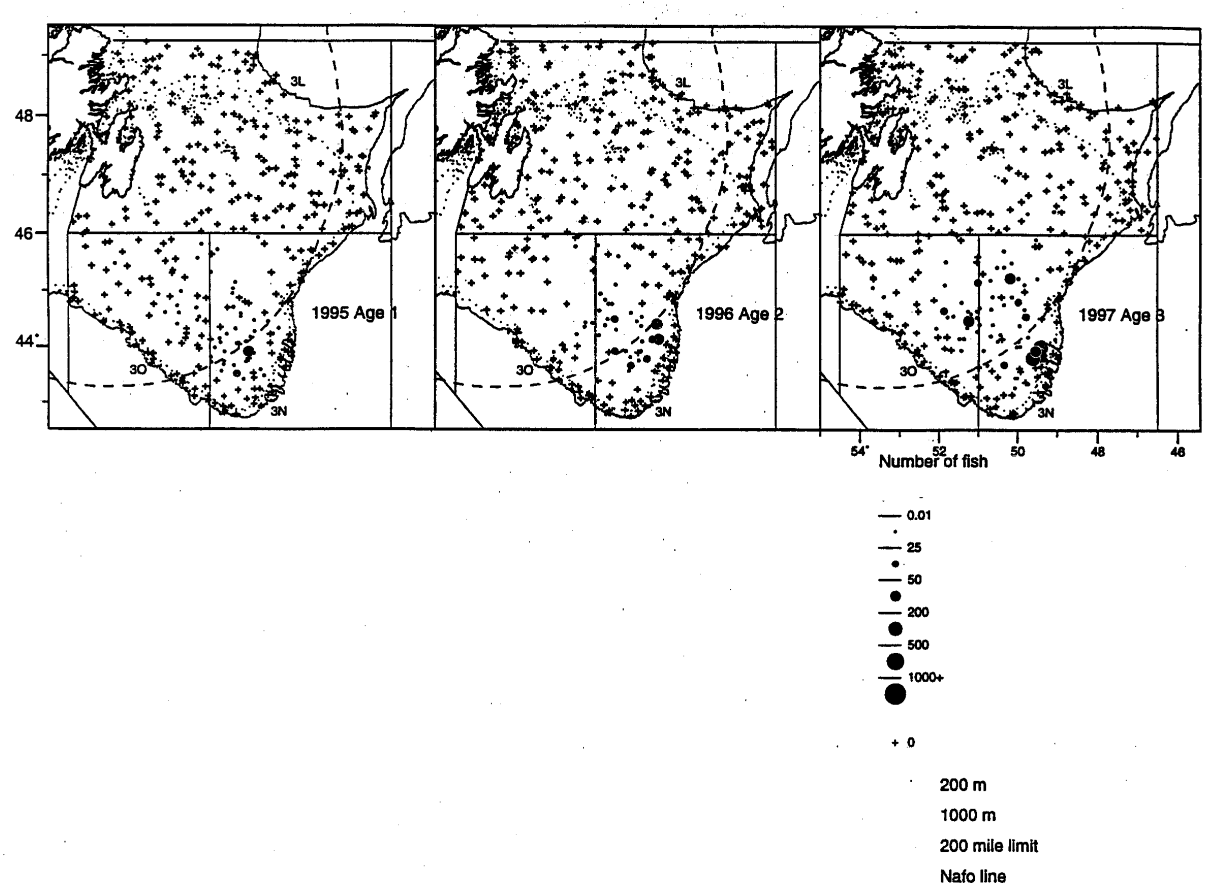


Fig. 15A. Distribution of Yellowtail catches (1994 year class) from stratified random surveys in Div. 3LNO for number of fish per tow.

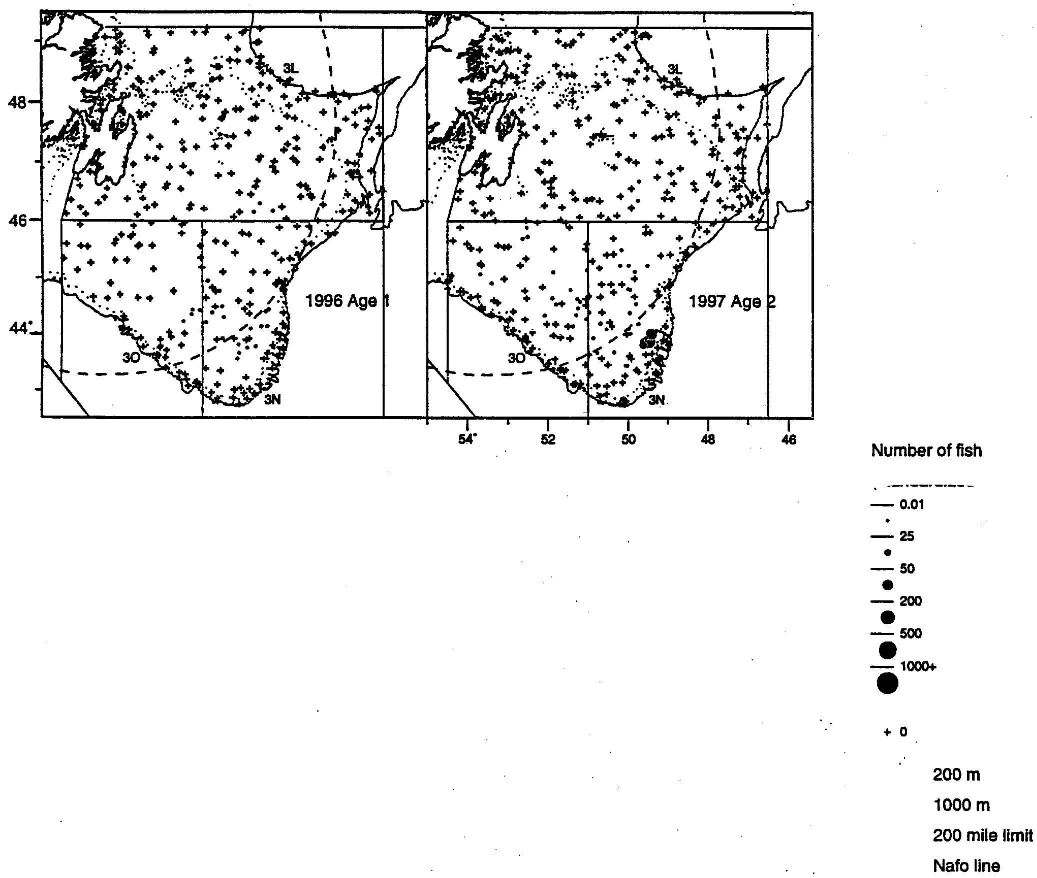


Fig. 15B. Distribution of Yellowtail catches (1995 year class) from stratified random surveys in Div. 3LNO for number of fish per tow.

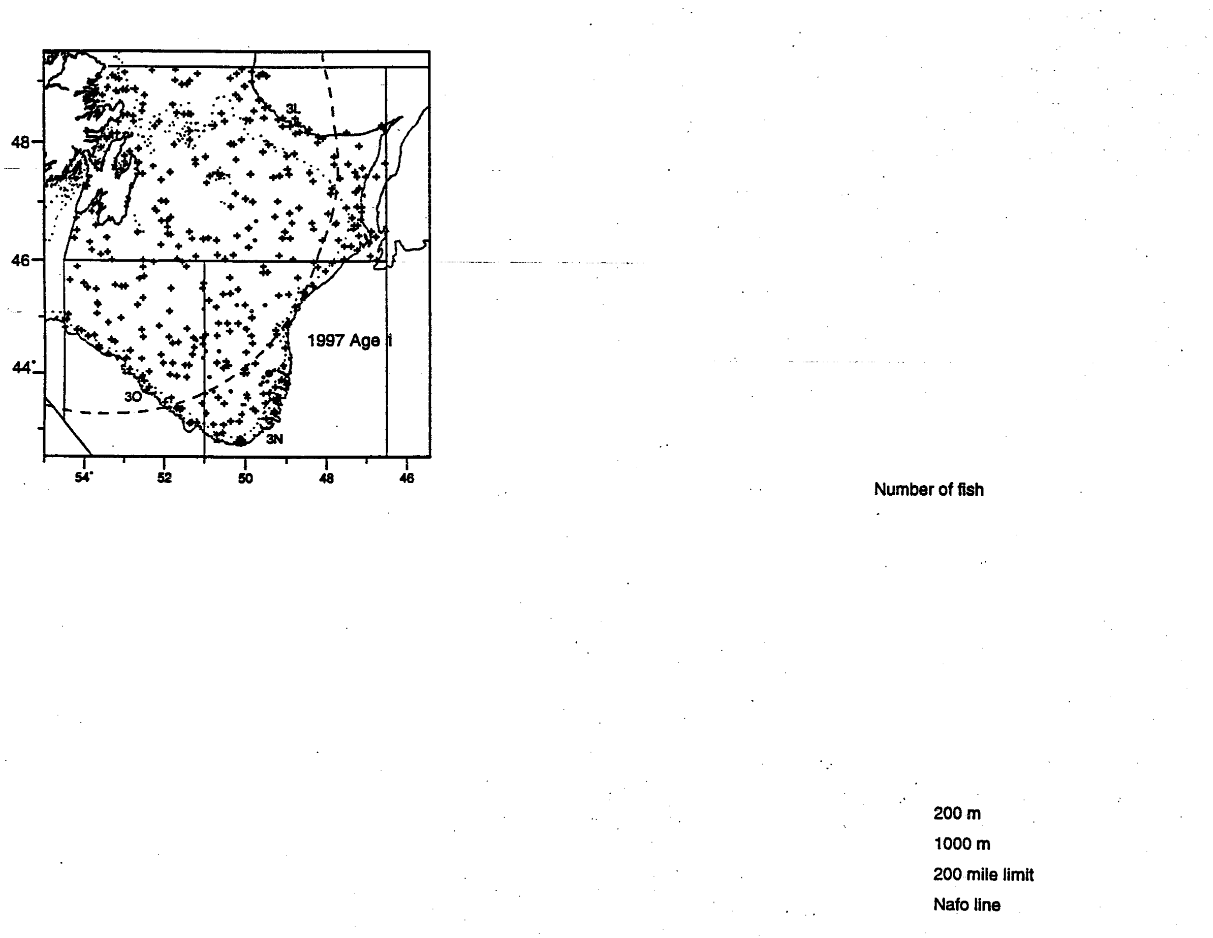


Fig. 16 Distribution of Yellowtail catches (1996 year class) from stratified random surveys in Div. 3LNO for number of fish per tow.

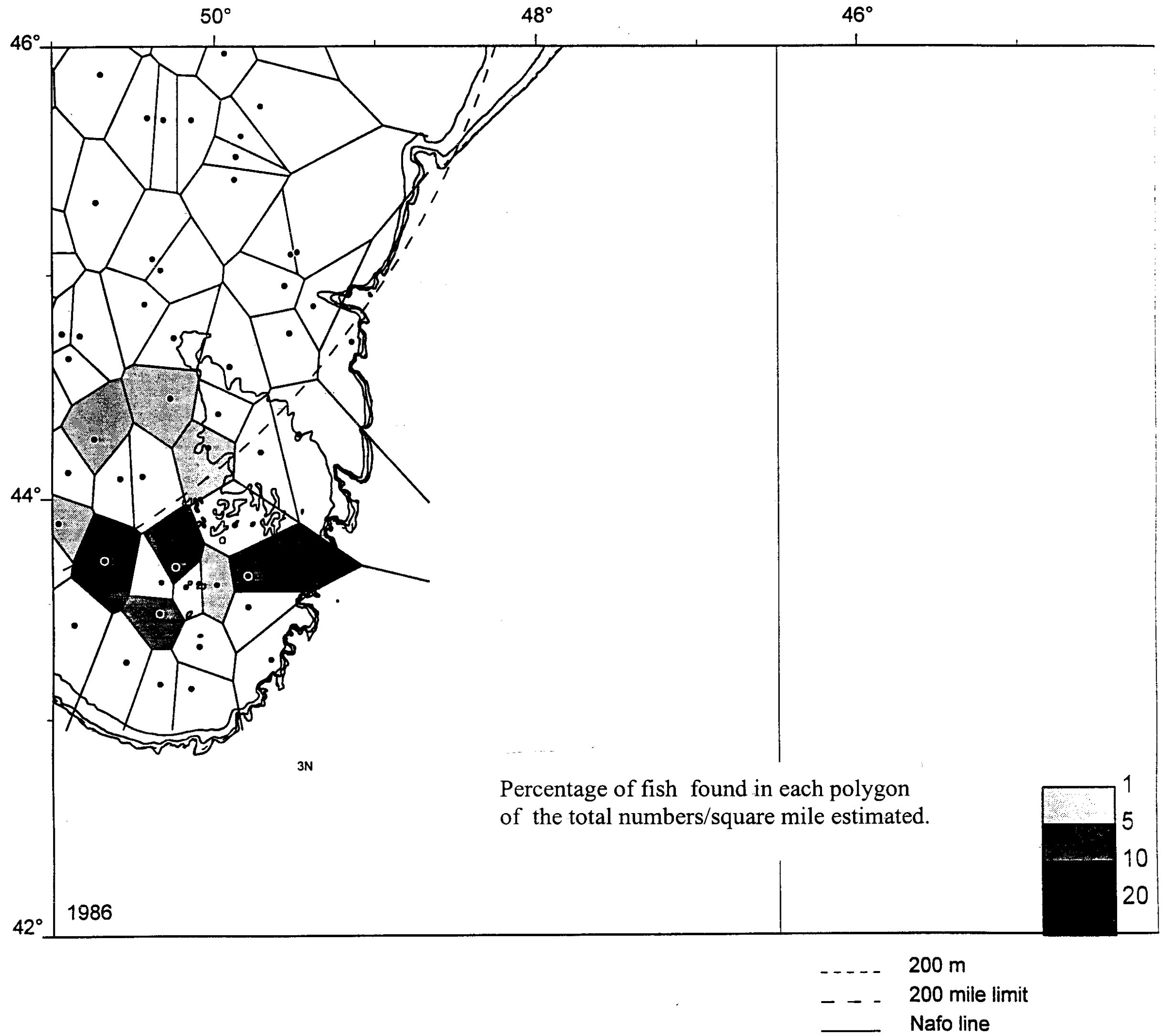


Fig. 17. Distribution of concentrations of juvenile yellowtail flounder in Div. 3N from Voronoi polygons. Highest concentrations are those greater than 20% of total abundance.

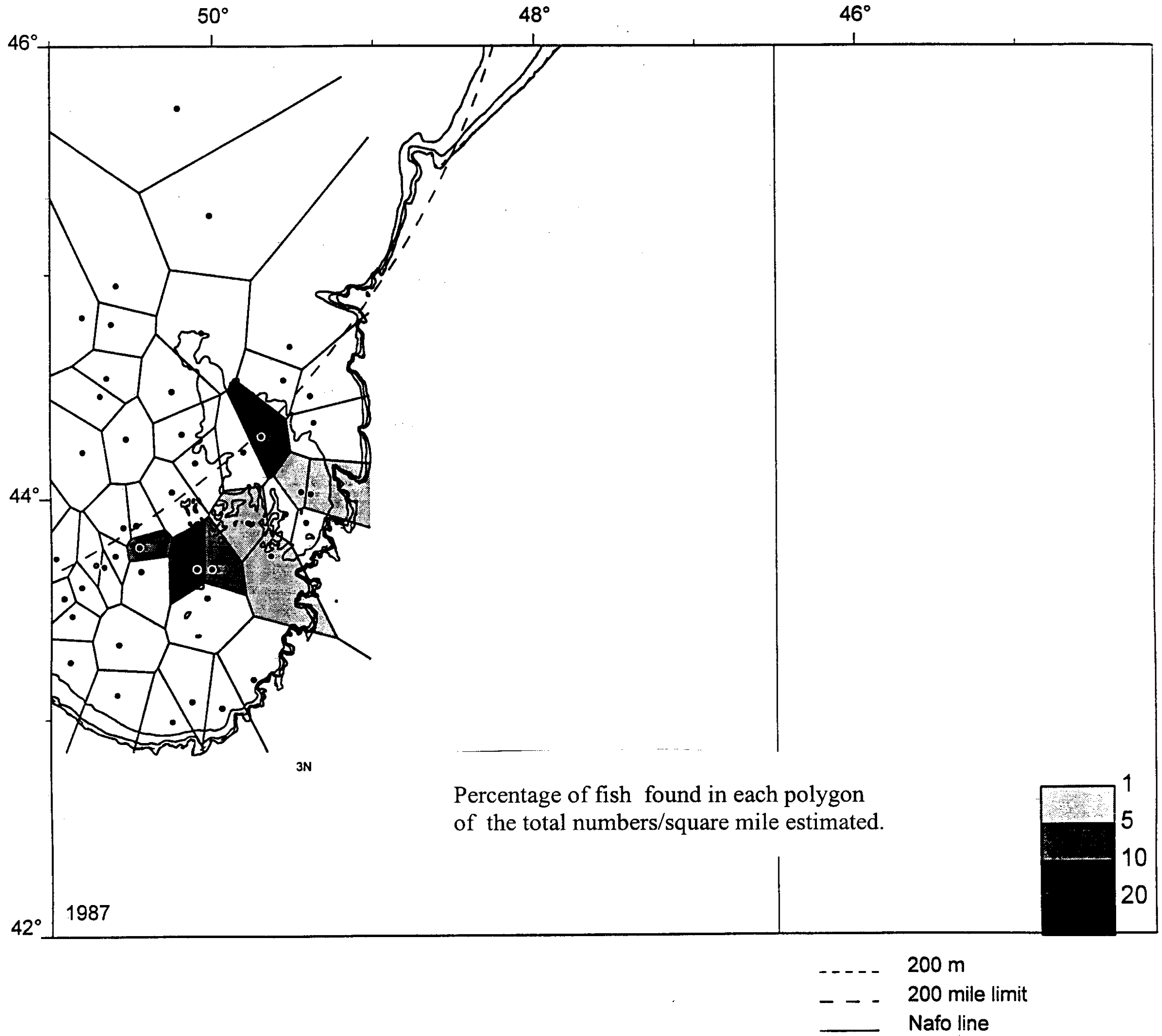


Fig. 18. Distribution of concentrations of juvenile yellowtail flounder in Div. 3N from Voronoi polygons. Highest concentrations are those greater than 20% of total abundance.

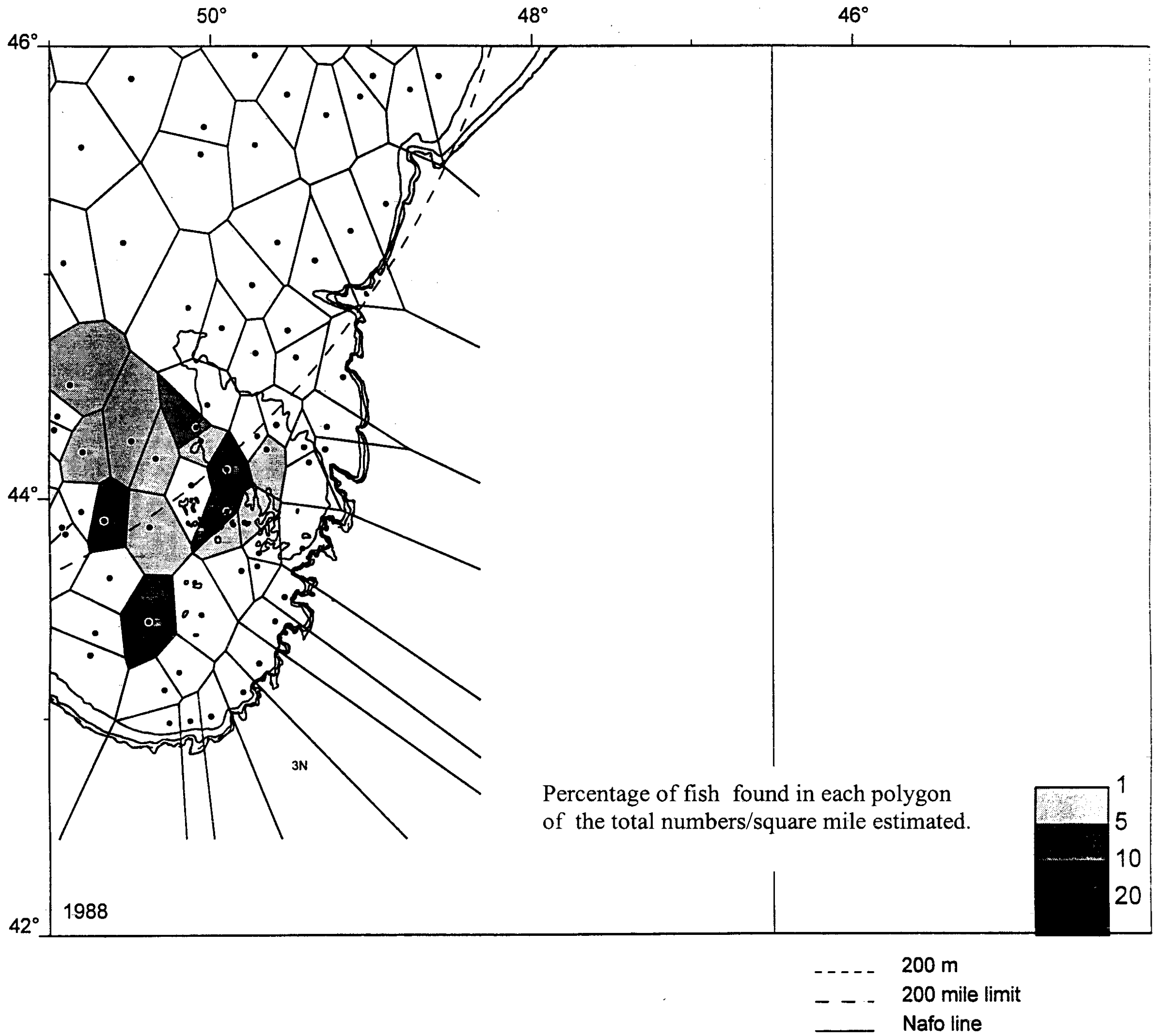


Fig. 19. Distribution of concentrations of juvenile yellowtail flounder in Div. 3N from Voronoi polygons. Highest concentrations are those greater than 20% of total abundance.

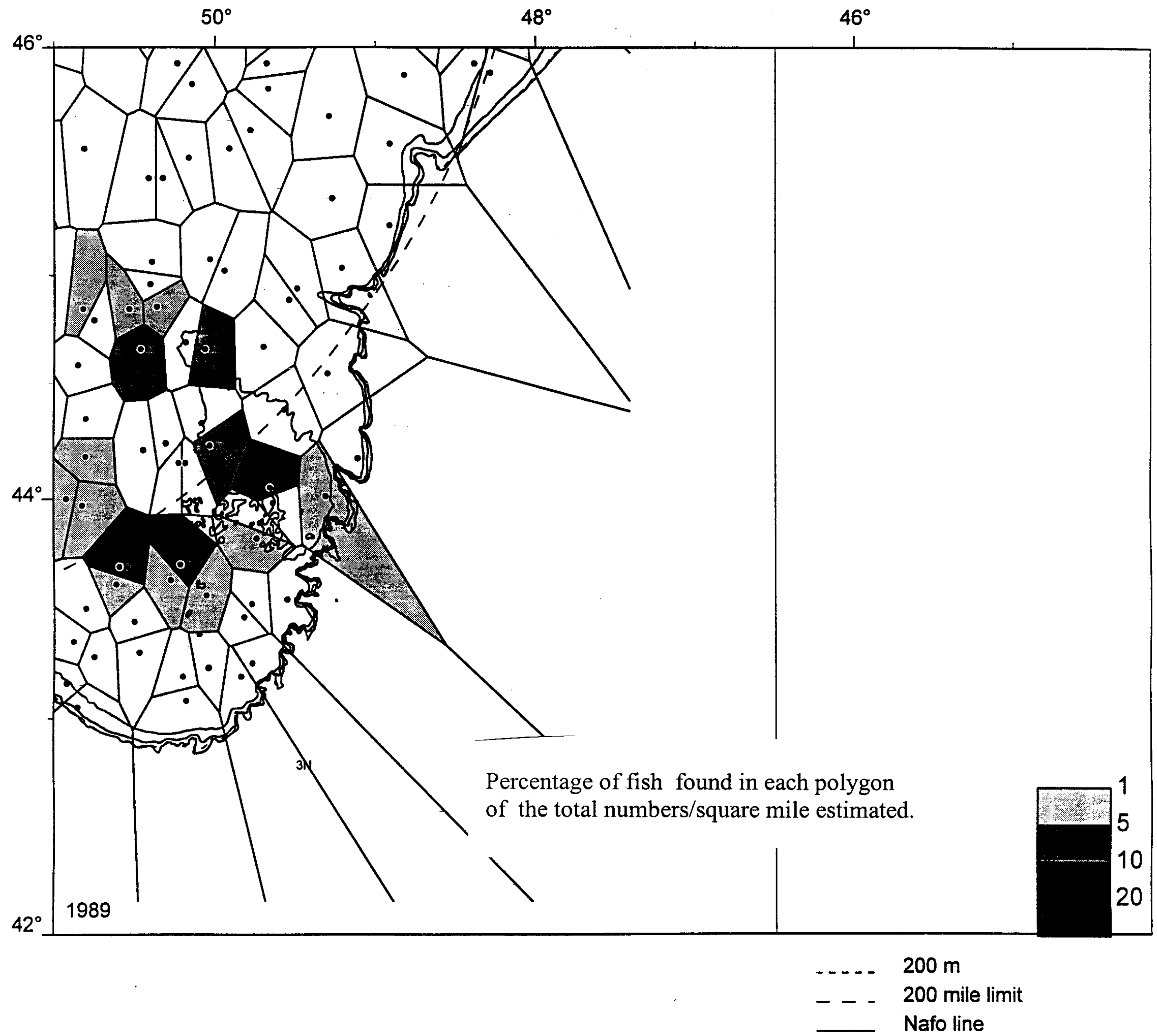


Fig. 20. Distribution of concentrations of juvenile yellowtail flounder in Div. 3N from Voronoi polygons. Highest concentrations are those greater than 20% of total abundance.

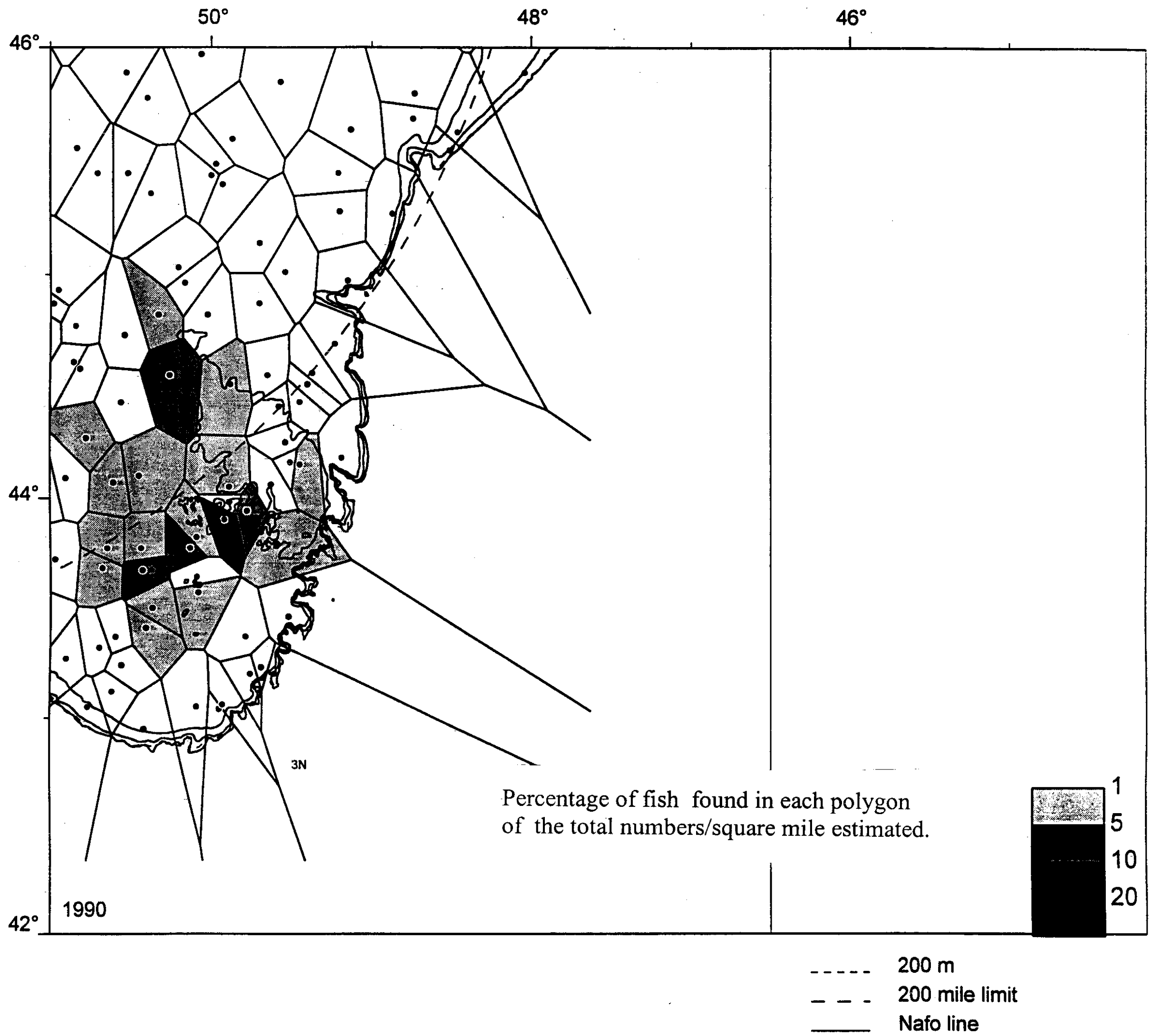


Fig. 21. Distribution of concentrations of juvenile yellowtail flounder in Div. 3N from Voronoi polygons. Highest concentrations are those greater than 20% of total abundance.

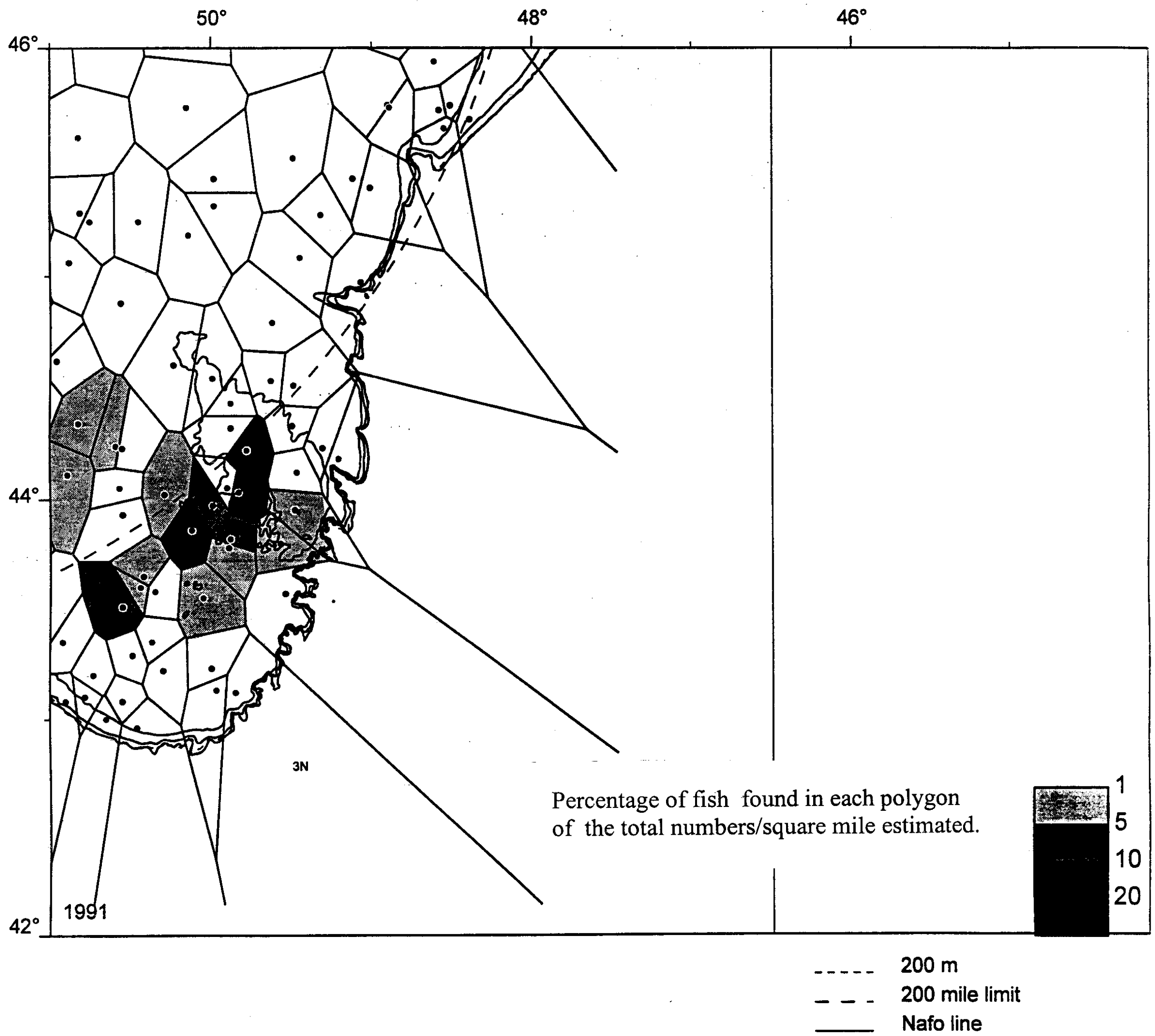


Fig. 22. Distribution of concentrations of juvenile yellowtail flounder in Div. 3N from Voronoi polygons. Highest concentrations are those greater than 20% of total abundance.

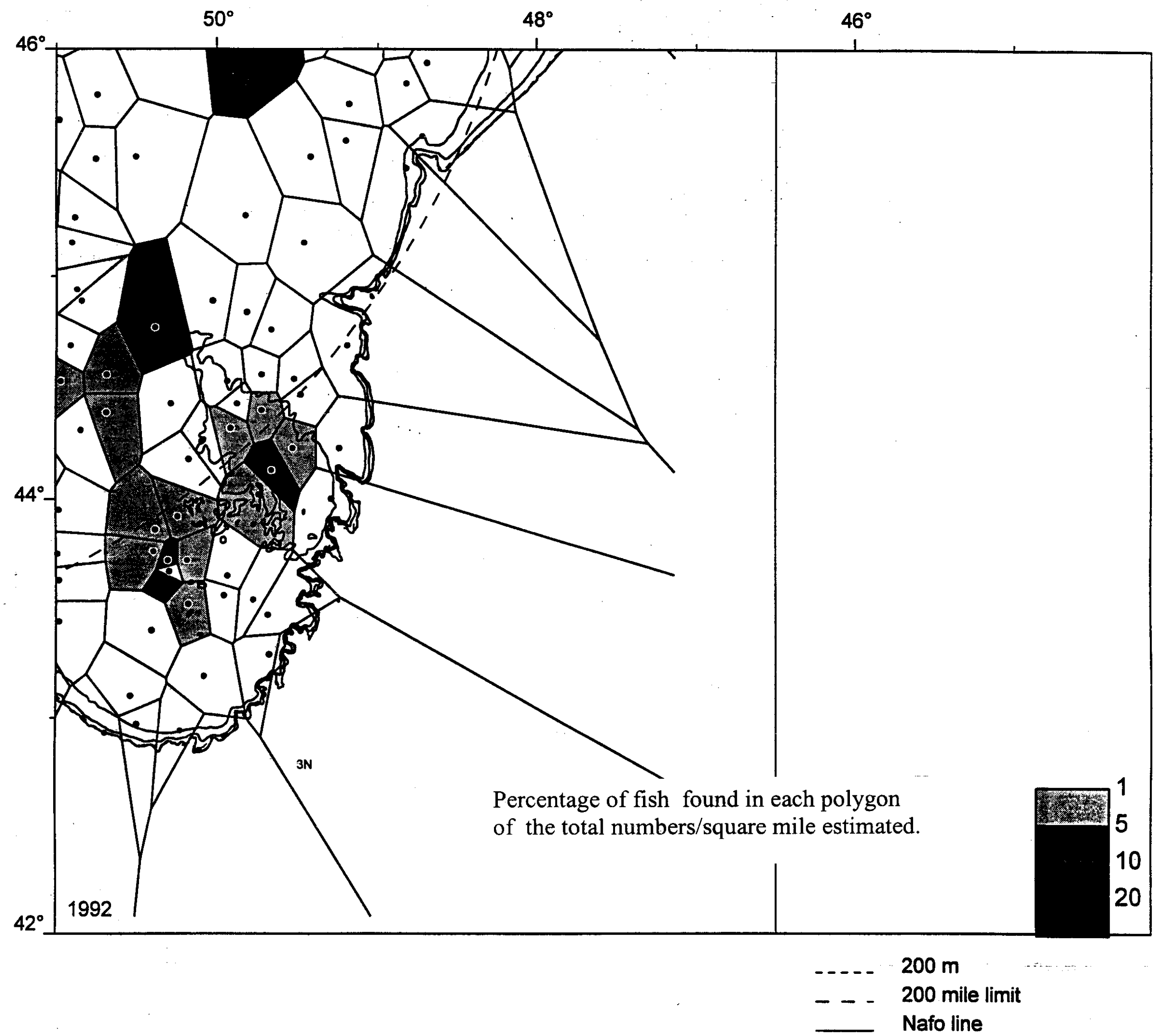


Fig. 23. Distribution of concentrations of juvenile yellowtail flounder in Div. 3N from Voronoi polygons. Hishest concentrations are those greater than 20% of total abundance.

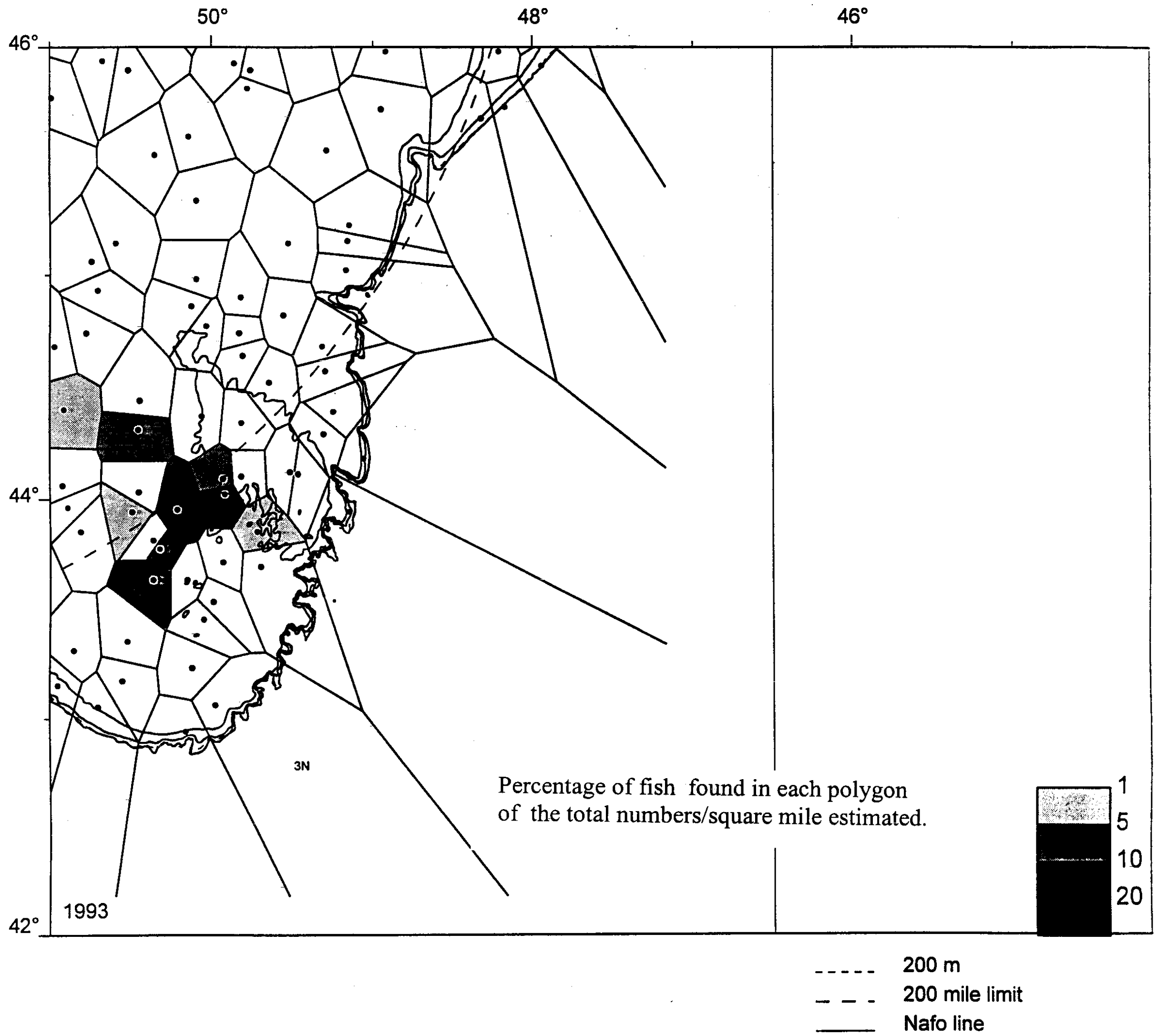


Fig. 24. Distribution of concentrations of juvenile yellowtail flounder in Div. 3N from Voronoi polygons. Highest concentrations are those greater than 20% of total abundance.

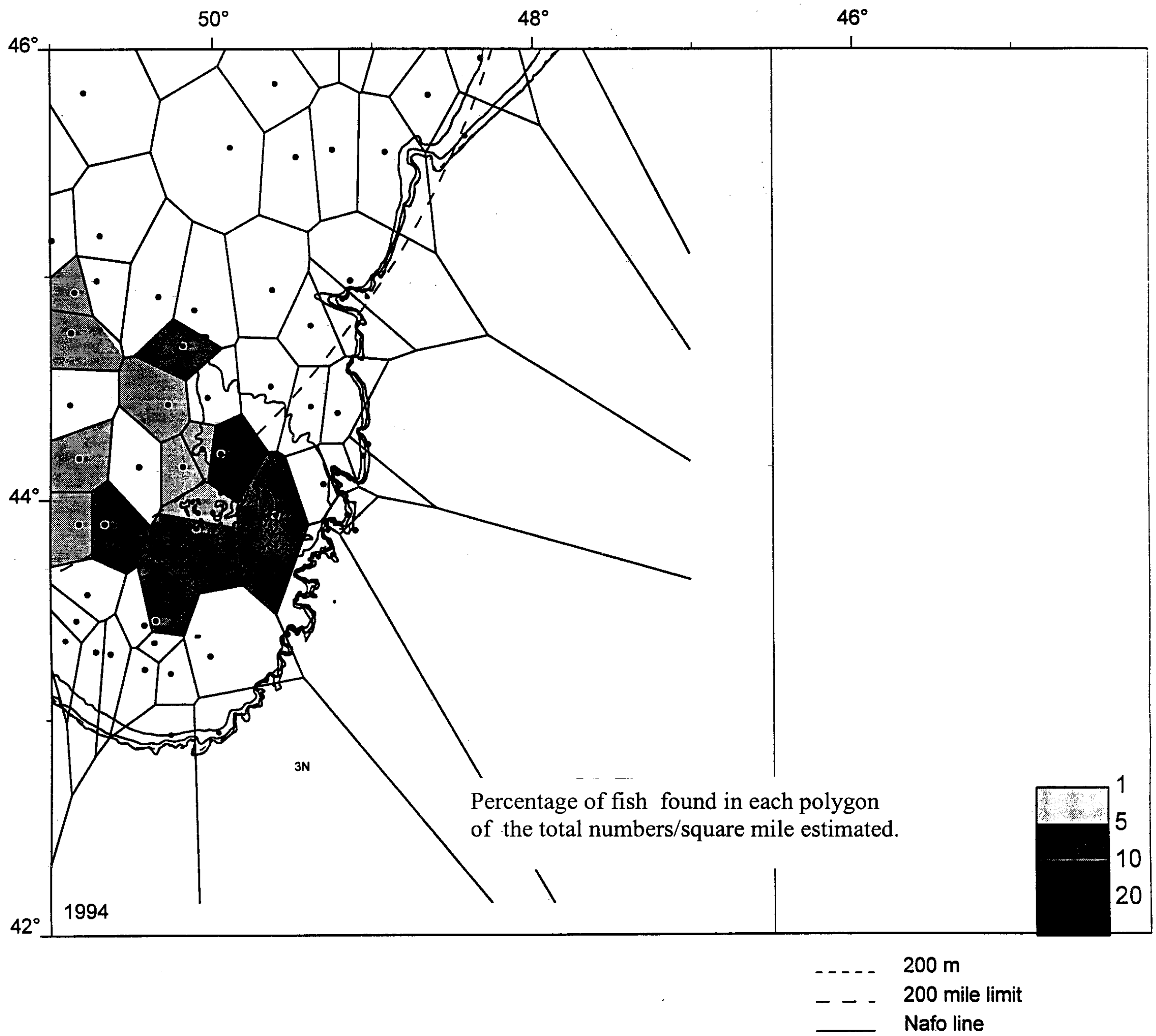


Fig. 25. Distribution of concentrations of juvenile yellowtail flounder in Div. 3N from Voronoi polygons. Highest concentrations are those greater than 20% of total abundance.

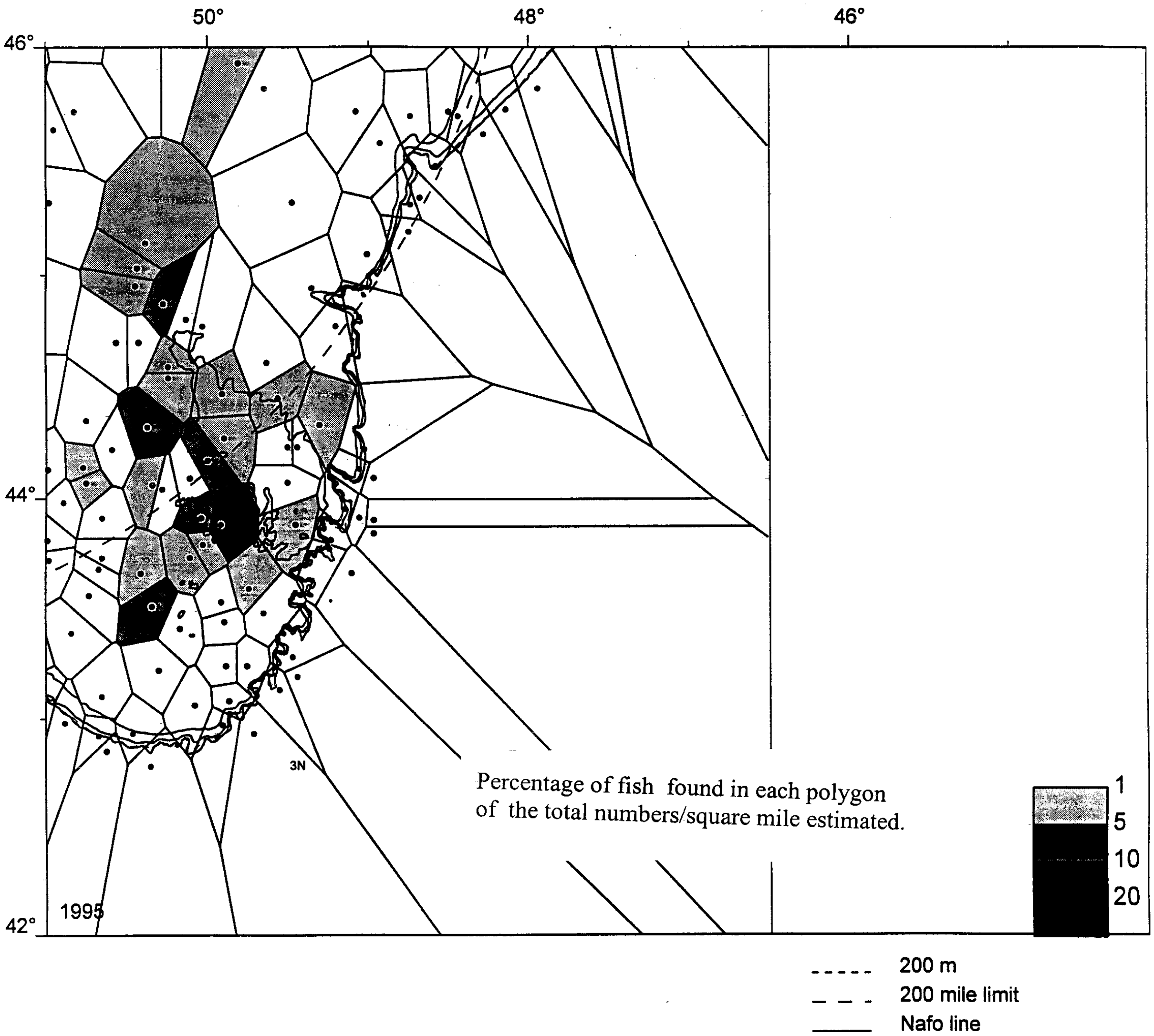


Fig. 26. Distribution of concentrations of juvenile yellowtail flounder in Div. 3N from Voronoi polygons. Highest concentrations are those greater than 20% of total abundance.

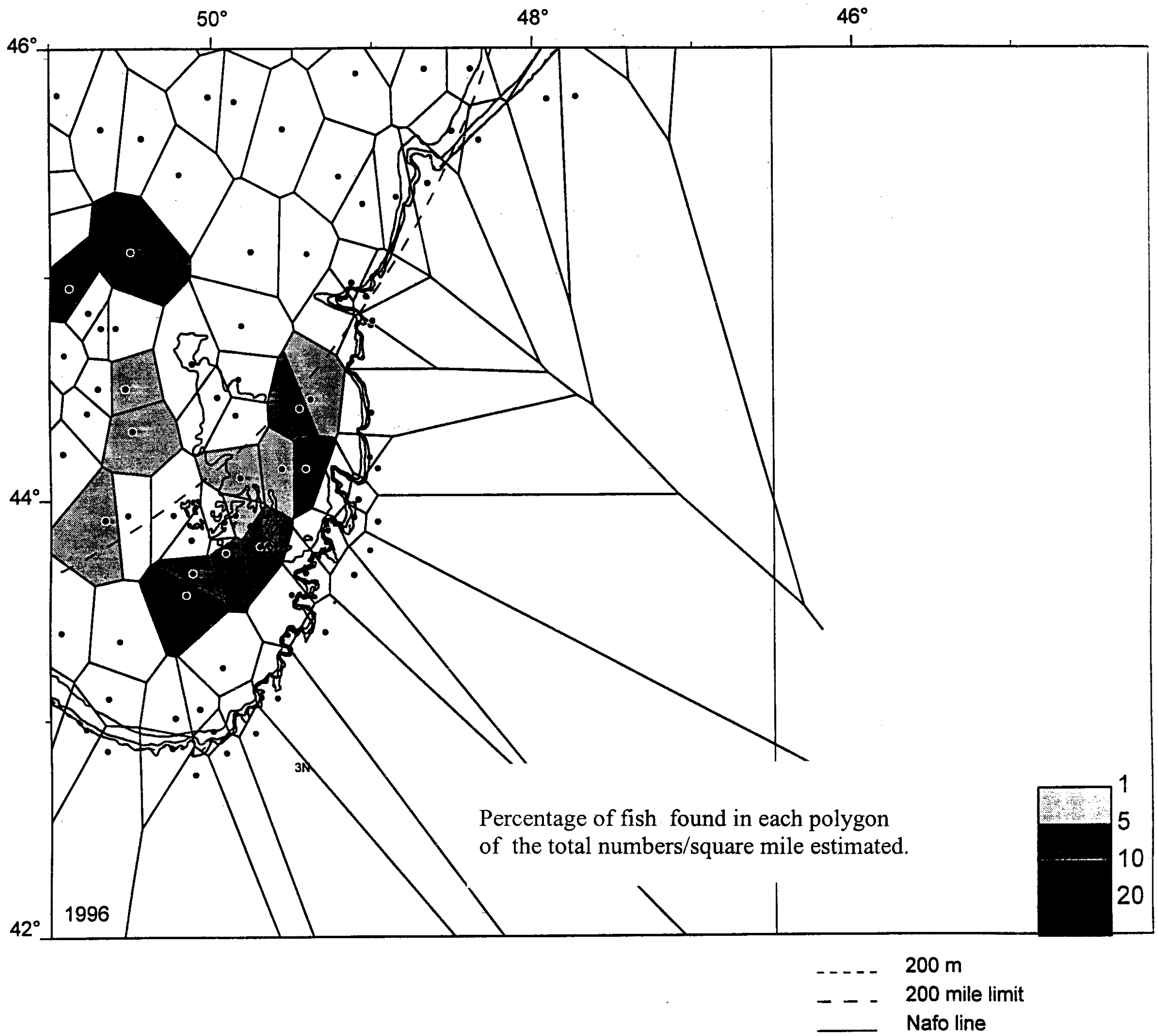


Fig. 27. Distribution of concentrations of juvenile yellowtail flounder in Div. 3N from Voronoi polygons. Highest concentrations are those grerater than 20% of total abundance.

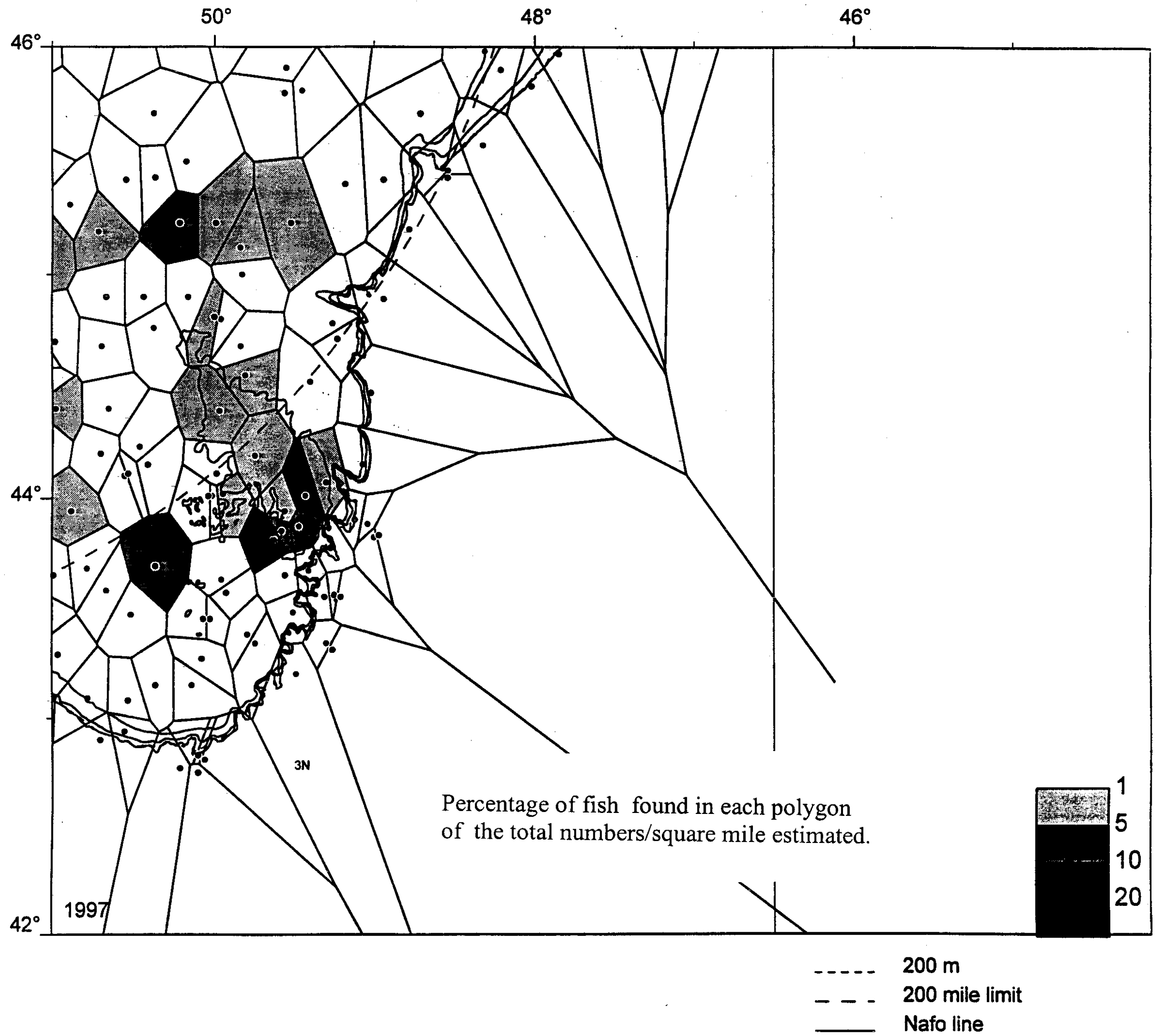


Fig. 28. Distributions of concentrations of juvenile yellowtail flounder in Div. 3N from Voronoi polygons. Highest concentrations are those greater than 20% of total abundance.

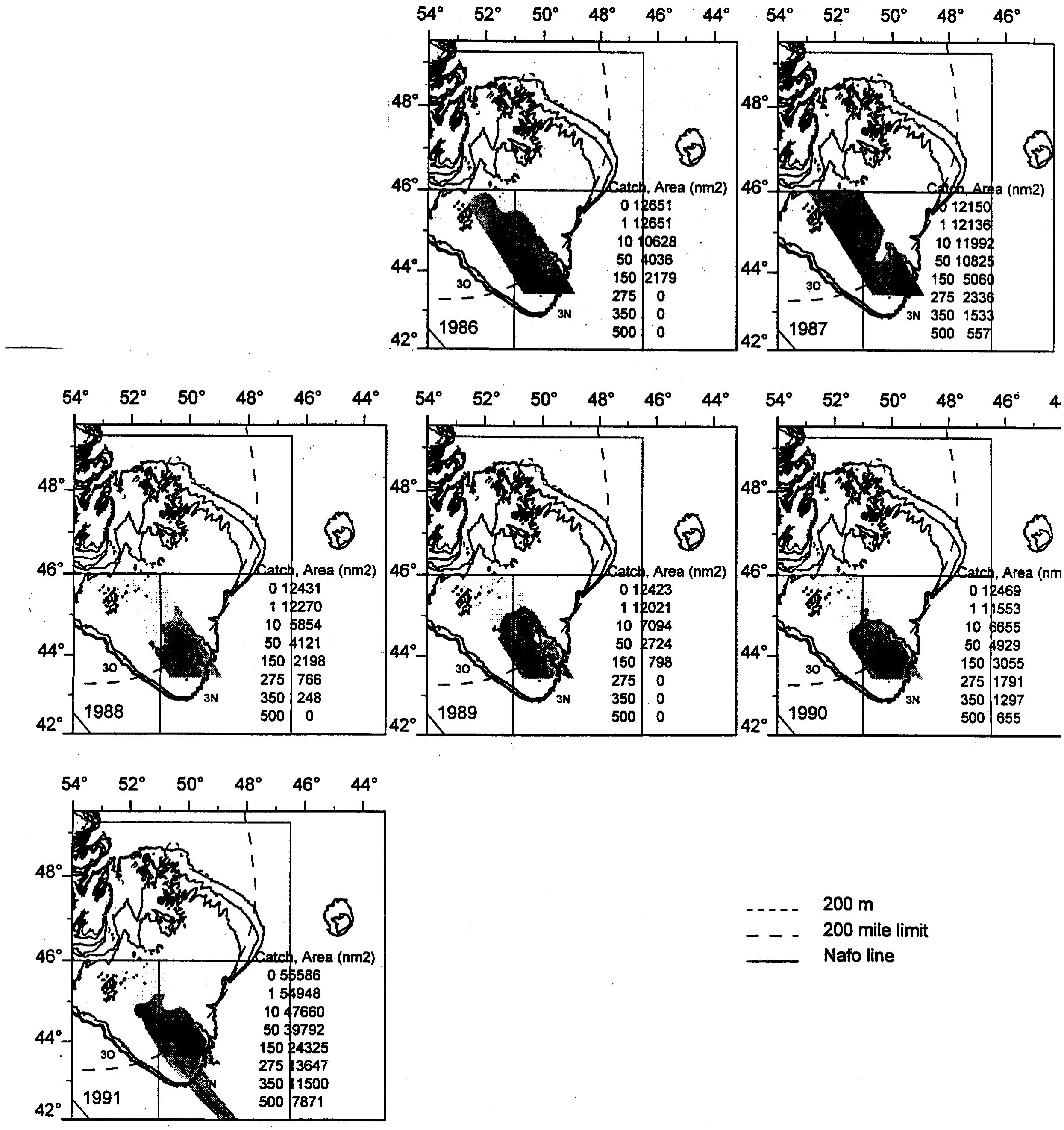


Fig. 29A. Spatial structure of juvenile (ages 0-3) yellowtail flounder on the Grand banks, NAFO Div. 3LNO using kriged contours.

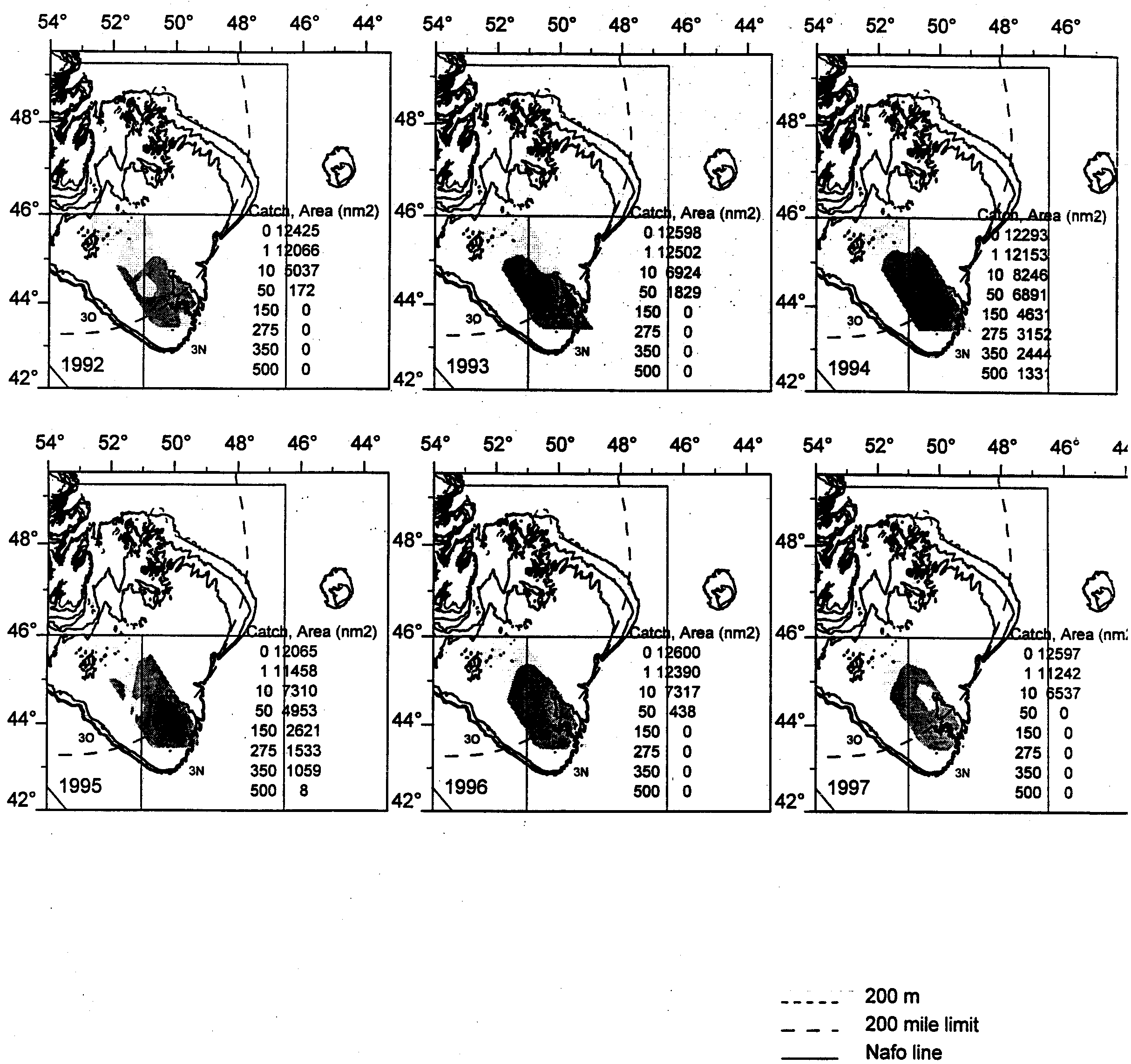


Fig. 29B. Spatial structure of juvenile (ages 0-3) yellowtail flounder on the Grand Banks, NAFO Div. 3LNO using kriged contours.

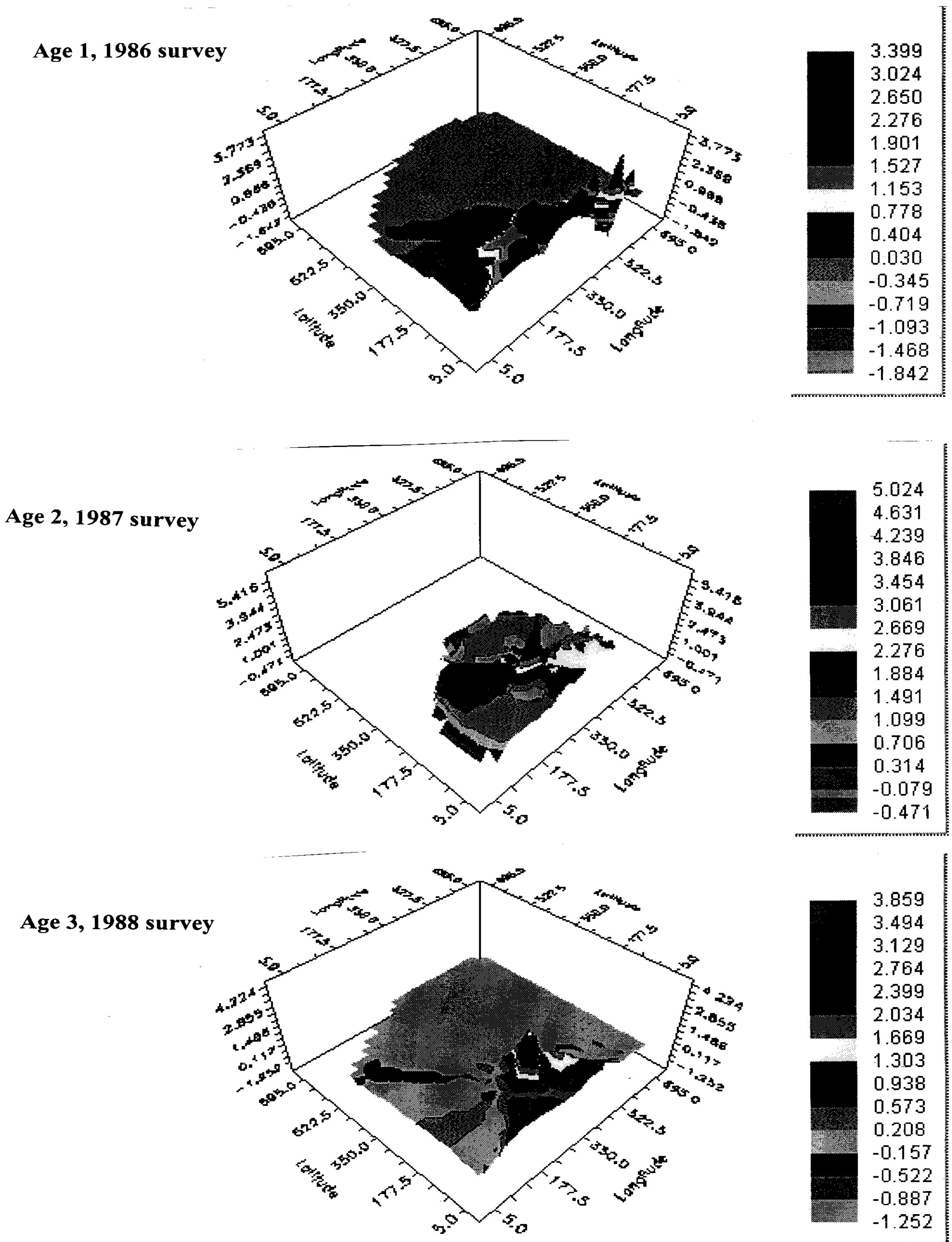


Fig. 30. Kridged maps of the distribution of the 1985 cohort of yellowtail flounder at ages 1,2 And 3 from trawl catches in the 1986-1988 surveys. Numbers are standardized number per tow which are transformed into kriged values using a semi-variogram model.