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Assessment of Georges Bank Yellowtail Flounder

by

S. Gavaris, J.J. Hunt, J.D. Neilson and F. Page
Department of Fisheries and Oceans
Biological Station
St. Andrews, New Brunswick

ABSTRACT

Yellowtail flounder (*Limanda ferruginea*) on Georges Bank is a transboundary resource which has supported a directed Canadian fishery since 1993. Removals of flatfish specified as yellowtail flounder peaked in 1994, when 1328 t were landed. Under a newly introduced quota in 1995, landings were 397 t. The fishery is mainly prosecuted by mobile gear. Landings of unidentified flounder were substantial in 1993 and 1994 and are thought to be mainly comprised of yellowtail flounder. There have also been reports of discarding in this fishery.

To assess stock status, the most recent published US catch at age was used which included removals through 1993. Using US values for partial recruitment and estimated US total landings in 1994 and 1995, the US removals at age was updated for those years. The Canadian catch at age was constructed using Canadian length-frequency samples and by applying seasonal USA age-length keys.

Biomass decreased rapidly from 1973 to 1985, associated with a marked decline in recruitment, reaching the lowest observed level and has since only increased moderately fluctuating at about 5,000 t. Recruitment during the 1980s has been considerably poorer than that experienced during the 1970s. Only the 1987, 1990 and 1992 year-classes have been near average in the past decade. The exploitation rate on ages 4 and older has been very high, often exceeding 60% since 1973. Since the mid 1980s, the exploitation rate shows a modest declining trend, reaching the lowest observed level of about 40% in 1995. The exploitation rate on age 3 is often as high and sometimes higher than that observed on ages 4 and older. Maintaining the 1996 Canadian catch at about the 1995 Canadian allocation of 400 t should, if the USA target TAC of 385 t is not exceeded, result in a fishing mortality rate in 1996 approximating the $F_{0.1} = 0.29$.

Résumé

La limande à queue jaune (*Limanda ferruginea*) du banc Georges constitue une ressource transfrontalière à l'origine d'une pêche sélective canadienne depuis 1993. Les prélèvements de poissons plats identifiés comme étant des limandes à queue jaune ont atteint un maximum en 1994 avec des débarquements de 1328 tonnes. Par suite de la mise en vigueur d'un nouveau quota en 1995, les débarquements sont passés à 397 tonnes. Les captures se font surtout au moyen d'engins mobiles. Les débarquements de limandes non identifiées ont été importants en 1993 et 1994; on pense qu'il s'agissait principalement de limandes à queue jaune. Des rapports signalent le rejet de poissons dans cette pêcherie.

Afin d'évaluer l'état des stocks, on a eu recours aux relevés publiés les plus récents des prises selon l'âge aux États-Unis où figuraient les prélèvements jusqu'en 1993 inclusivement. En prenant les valeurs du recrutement partiel pour les États-Unis et des évaluations des débarquements totaux de 1994 et 1995 dans ce pays, il a été possible de calculer l'importance des prélèvements américains pour ces années-là. La prise canadienne selon l'âge a été déterminée à partir d'échantillons canadiens de la fréquence des longueurs et grâce à l'application de barèmes saisonniers américains de longueur selon l'âge.

Entre 1973 et 1985, la biomasse a diminué rapidement. Elle était associée à un recul marqué au plan du recrutement, atteignant la plus faible valeur jamais observée; depuis, elle ne s'est redressée que modérément pour atteindre environ 5000 tonnes. Au cours des années 1980, le recrutement a été considérablement inférieur à celui des années 1970. Seules les classes annuelles de 1987, de 1990 et de 1992 se sont approchées de la moyenne au cours des dix dernières années. Le taux d'exploitation des classes d'âge de 4 ans et plus a été très élevé, pour dépasser souvent la marque de 60 % depuis 1973. Depuis le milieu des années 1980, il a tendance à s'abaisser un peu, atteignant sa plus basse valeur observée, soit environ 40 %, en 1995. Le taux d'exploitation de la classe de 3 ans est souvent aussi élevé, parfois plus, que celui des classes d'âge de 4 ans et plus. Le maintien des prises canadiennes de 1995 sensiblement au niveau attribué au Canada en 1995, soit 400 tonnes, devrait conduire à un taux de mortalité par pêche au Canada, pour 1996, de l'ordre de $F_{0,1} = 0,29$ si le TPA visé par les États-Unis, soit 385 tonnes, n'est pas dépassé.

INTRODUCTION

Yellowtail flounder (*Limanda ferruginea*) occur on both the Canadian and USA sides of the international maritime boundary on Georges Bank. Based on tagging investigations (Royce *et al.* 1959; Lux 1963), the management unit is considered to include Georges Bank east of the Great South Channel encompassing statistical areas 5Zj, 5Zm, 5Zn and 5Zh (Fig. 1). An earlier Canadian summary of stock status indicated that yellowtail flounder on the Canadian portion of Georges Bank could be the basis of a sustainable managed fishery (Anon. 1994a). This conclusion was based on the observation that yellowtail flounder are comparatively sedentary as adults, the presence of more than one year-class in the Canadian landings and the observation that spawning (which occurs in late spring) is likely occurring in Canadian waters. However, the sources of recruitment and the degree of mixing across the international boundary are not clear.

A recent assessment conducted by the National Marine Fisheries Service, USA concluded that the stock was at low biomass levels, overexploited and was considered collapsed relative to historic abundance levels (Anon. 1994b).

The Fisheries

The USA yellowtail fishery is almost exclusively conducted by vessels using otter trawl gear. USA landings were negligible prior to the mid-1930s, but landings increased to average 6,500 t in 1948-1949 (Anon. 1994b). After declining to 1,600 t by 1955, landings recovered to a peak of 18,300 t in 1969. Between 1968 and 1974, landings averaged 15,600 t but more recently landings have averaged 2,060 t between 1986 and 1995 (Table 1). The low landings since 1995 may be attributable, at least in part, to the recent expansion (both spatially and seasonally) of the haddock spawning closed area on eastern Georges Bank. Discarding of undersized yellowtail is considered a major contributor to overall mortality in the United States fishery, but quantifying the extent of discarding in recent years has proved difficult (Anon. 1994b).

The Canadian yellowtail fishery is also conducted almost exclusively by vessels using otter trawl gear. Prior to 1993, Canadian landings were small, typically less than 100 t (Table 1, Fig. 2). Peak landings of 1328 t of specified yellowtail occurred in 1994 in an unrestricted fishery, and after a TAC of 400 t was established, specified yellowtail landings dropped to 397 t in 1995. There was also a trip limit of 17,000 lb. imposed by industry in 1995 to equitably share the reduced quota among eligible participants. Actual removals in 1994 were thought to be considerably higher (according to some industry reports, 1800 t would be a reasonable estimate), as flatfish landed as "unspecified" were actually largely comprised of yellowtail flounder, with smaller quantities of winter flounder and American plaice. The unspecified flounder problem was thought to be less of a concern in 1995 due to improved monitoring of the landings. Assuming that the unspecified flounder is comprised of yellowtail flounder in proportion to the landings of yellowtail, winter flounder and American plaice, the adjusted total landings for yellowtail are shown below:

	Yellowtail Flounder	Winter Flounder	American Plaice	Unspecified Flounder	Adjusted Yellowtail
1993	152	21.3	0	620.1	696.0
1994	1328	64.6	29.5	871.3	2141.6
1995	397	45.2	2.3	109.7	495.0

Over the 1994-1995 period, there have also been some reports from industry of highgrading of landings by size to meet the 13 in minimum size requirement for USA importation. However, when we compared the length-frequency composition of samples taken by observers at sea with those obtained by port samplers, no indication of discarding was detected (Fig. 3), although few samples were available for such comparisons. While industry reports that some discarding occurred, it was not possible to quantify discarding rate or whether the discarding rate has varied over the three year duration of the fishery.

The majority of Canadian landings of yellowtail flounder are made by less than 65 ft otter trawlers of tonnage classes 2 and 3 (Table 2). Peak months for fishing were August and September in 1994 and 1995. The number of vessels participating in the fishery was about 55 in 1994, and dropped to about 40 in 1995 because of a requirement for participants to have a catch history of greater than 5 t of flounders. About half the fleet fished 140 mm square mesh in 1994, with one quarter fishing 130 mm square mesh and one quarter fishing 155 square mesh. By agreement among those participating in the 1995 fishery, only 155 mm square mesh was used. The same rigging of the foot gear was used in 1994 and 1995. Some yellowtail flounder are landed in the scallop fishery. Industry representatives suspected that the reported landings of yellowtail flounder underestimate the true landings by that sector considerably. However, offshore scallop vessels are subject to 100% dockside monitoring and statistics should accurately reflect their catch.

Location information was available for 84, 97 and 98% of reported landings in 1993-1995, respectively. Canadian yellowtail directed fishing activity was concentrated on the southern half of Canadian waters, in the area referred to as the "Yellowtail Hole" (Fig. 4).The distribution of fishing activity changed somewhat from 1994 to 1995, with the area fished being more constricted in 1995, probably due to the reduced quota.

Catch at Age

The assessment provided here represents the first attempt by DFO, Canada to provide an analytic assessment of this resource. Previous assessments of yellowtail flounder by NMFS, USA have not considered Canadian removals explicitly. For this assessment we compiled. the Canadian catch at age for 1993 to 1995. Data sources included Canadian port samples and Observer Program (OP). Canada does not age yellowtail flounder at present, thus seasonal USA age-length keys were applied to the length composition of the Canadian catch.

The available data are somewhat limited to reconstruct the Canadian catch at age, particularly in 1993. In all, the following samples were used:

		Port Samples							OP Samples								
		1993	1993 Total	1994		1994 Total	1995	1995 Total	1993		1993 Total	1994	1994 Total	1995			1995 Total
		Q 4		Q 2	Q 3		Q 3		Q 1	Q 4		Q 3		Q 1	Q 2	Q 3	
Gear Type	TC																
OTB	1-3	5	5	2	5	7	8	8	0	16	16	77	77	0	0	4	4
	>3	0	0	0	0	0	0	0	3	2	5	9	9	0	0	0	0
OTB Total		5	5	2	5	7	8	8	3	18	21	86	86	0	0	4	4
Dredge	>3	0	0	0	0	0	0	0	0	0	0	0	0	362	63	0	425
Dredge Total		0	0	0	0	0	0	0	0	0	0	0	0	362	63	0	425
Grand Total		5	5	2	5	7	8	8	3	18	21	86	86	362	63	4	429

Port samples included length frequencies on a trip basis, whereas OP samples are length samples from individual tows where an observer was present. The OP length samples were obtained from 3, 11, and 5 trips for 1993 to 1995, respectively.

The length-frequency samples from the OP were combined by trip, samples being weighted according to tow caught weight. The port samples and OP samples were then combined by month, gear type/tonnage class (OTB/TC1-3, OTB/TC4+ and dredge/all) being weighted according to trip caught weight, before being further combined by half-year and year. USA length weight relationships by quarter for sexes combined were used to conduct these calculations. In the case of miscellaneous gear (which included longline, gillnet, etc.) combinations were done on a half year basis rather than monthly. USA age length keys for sexes combined (available from surveys conducted in the spring and fall) were then applied by quarter and/or half-year to get catch at age. The impact of using combined age keys for a species with known sexual dimorphism was not investigated. Since the fisheries typically take place during the latter half of the year, age-length keys from the fall surveys were used. However, in 1995, there were samples from the spring (scallop dredges) available and the age-length key from the spring survey was employed in that instance.

Fig. 5 and the text table below illustrate the Canadian catch at age results.

Age	Catch (000s)			Weight at Age (kg)		
	1993	1994	1995	1993	1994	1995
1	7	121	1	0.150	0.199	0.200
2	70	263	49	0.242	0.222	0.247
3	831	2847	529	0.344	0.311	0.333
4	835	1907	579	0.427	0.381	0.435
5		574	48		0.527	0.538
6		39	9		0.785	0.658
7	5	26	0	0.685	0.494	

The Canadian fishery is mainly on ages 3 and 4, and there is no indication of an usually strong or weak year-class in the three years of data available. These results for Canada were combined with USA catch at age (Table 3), which show that strong year-classes included 1973, 1974, and 1980. More recently, only the 1990 year-class appears relatively strong but not as strong as the earlier notable year-classes. .

ABUNDANCE INDICES

Commercial Fishery Catch Rates

Catch and effort, in hours, for less than 65 ft Canadian otter trawlers fishing for yellowtail flounder in 1993-95 were summarized on a trip basis. Initial examination of the trip records showed a large proportion of trips with very small amounts of yellowtail included in the total catch. These trips were not considered to be representative of effort directed towards yellowtail and therefore only trips with reported landings of more than 100 kg (225 lb.) were considered further. As well, only vessels with reported landings in the three years 1993, 1994 and 1995 were included in the analysis.

As noted above, landings of unspecified flounder in 1993 and 1994 were substantial and the ratio of yellowtail to other flounders (plaice and winter flounder) in specified landings was used to estimate the weight of yellowtail flounder for the unspecified proportion. A small number of trips included both yellowtail and unspecified flounder. Therefore, the combined yellowtail plus the yellowtail proportion of unspecified flounder trips were used to derive an alternate catch rate series.

Catch and effort for trips were aggregated by month and year in Fig. 6. Catch rate series are given for both specified yellowtail flounder only, and yellowtail flounder plus prorated unspecified flounder. Catch rates in 1993 increased between June and October. In 1994, catch rates were marginally higher than 1993 but increased by a factor of over two between 1994 and 1995. This is consistent with industry observations that rates doubled from about 500-1000 lb./hr in 1994 to about 1500-2500 lb./hr in 1995.

Substantial gear changes occurred in the fishery between 1993 and 1994 with the introduction of 'flounder gear' which uses a small diameter footgear. Changes in mesh size also occurred, as described earlier.

Factors, other than stock abundance, which might have influenced catch rates include:

Factor	Likely Impact Over Time
Relatively new fishery, so some learning and development of fishing practices expected	Catch rates would tend to increase
Differential rates of discarding from year to year	Catch rates would either increase or decrease
Mesh size increased	In the short term, catch rates could decrease
Changes in areas fished from 1994 to 1995	Impact not known
Fewer vessels involved in 1995, but may include more yellowtail "specialists"	Catch rates would tend to be higher in 1995

The likely impact of each of these factors was discussed and industry representatives commented that apart from the change in mesh size (which, as noted, would deflate catch rates in the short term), all other factors would not impact catch rates. They noted that catch rates from the yellowtail commercial fishery may be among the most reliable available for any fishery given the lack of diversity of vessels exploiting the resource, the circumscribed nature of the fishing area, and the short fishing season.

Research Vessel Surveys

Bottom trawl surveys are conducted annually on Georges Bank by Canada in spring and by the USA in spring and fall. Both Canada and USA use a stratified random design, though different boundaries are defined (Fig. 7). The spatial distribution of catches of yellowtail flounder (by numbers and weight) from the Canadian surveys conducted each spring since 1987 are shown in Fig. 8. The resource is distributed generally throughout Georges Bank, but since 1993, the major concentration appears to occur on the Canadian side of the international boundary. Further investigation of seasonal and size/age related distribution patterns and migration is warranted.

The age sampling from the USA spring survey was used to obtain abundance indices by age from the Canadian survey and trends over time are shown in Fig. 9 (also Tables 4-6) for all surveys. USA age sampling is not available yet to apply against the Canadian 1996 results. Based on examination of previous keys, we assumed that all fish of lengths 20-31 cm were 2 year olds, and fish equal to or greater than 32 cm were included in the 3-6 index. While approximate, this approach allowed us to use the most up to date information available.

The USA survey mean number per tow at ages 3-6 declined to a low in the mid 1980s and has since tended to increase somewhat. The 1995 USA spring index shows a substantial increase over the previous year. The Canadian survey results for ages 3-6 support the apparent increasing trend since the mid 1980s. The mean number per tow at age 2 from the USA spring and fall surveys and at age 1 from the USA fall survey (lagged ahead 1 year) show a generally declining trend since 1963. There is some moderate increase in recent years but it is almost imperceptible compared to historical levels. The trend for age 2 abundance from the Canadian survey also indicates some improved recruitment in recent years, but it lacks a historical perspective. The relative year-class strengths appear to be generally consistent between and within surveys at ages 1 and 2 but the pattern weakens considerably for ages 3 and older.

The most recent US indices diverge, with the spring survey giving a more optimistic view of the resource than does the fall survey. The 1996 values for the Canadian spring survey were the second highest and the highest for age 2 and for ages 3-6 respectively.

ESTIMATION OF STOCK PARAMETERS

The adaptive framework, ADAPT, (Gavaris 1988) was used to calibrate the sequential population analysis with the research survey results using the following data :

$C_{a,y}$ = catch

for ages a = 2 to 6 and for years y = 1973 to 1995 and

$I_{s,a,y}$ = abundance index

for s = Canadian spring survey, age a = 2, years y = 1986 to 1995
Canadian spring survey, ages aggregated for a = 3 to 6, years y = 1986 to 1995
USA spring survey, ages a = 2 to 3, years y = 1973 to 1995
USA spring survey, ages aggregated for a = 4 to 6, years y = 1973 to 1996
USA fall survey, ages a = 2 to 3, years y = 1973 to 1995
USA fall survey, ages aggregated for a = 4 to 6, years y = 1973 to 1995
USA fall survey, age a = 1, y = 1972 to 1995 lagged ahead

The spring survey results were compared to beginning of year population abundance in the same year while the fall survey results were compared to mid- year population abundance in the same year. The USA fall survey age 1 results were compared to the beginning of subsequent year at age 2. The age analyses for the Canadian surveys used the age length keys from the USA spring surveys in the same year. The model formulation employed assumed that the error in the catch at age was negligible. The error in the survey abundance indices was assumed to be independent and identically distributed after taking natural logarithms of the values. Natural mortality, M, was assumed constant and equal to 0.2 and fishing mortality, F, for age 6 was assumed equal to the arithmetic average for ages 4 to 5.

Following Gavaris (1993), a model formulation using as parameters the ln population abundance at the beginning of the year following the terminal year for which catch at age is available was considered. Define the model parameters as

$\theta_{a,1996}$ = ln population abundance

for a = 2 to 6 at the beginning of the year 1996,

$\kappa_{s,a}$ = ln calibration constants

for each survey source, denoted by s, and the relevant ages.

ADAPT was used to solve for the parameters by minimizing the sum of squared differences between the ln observed abundance indices and the ln population abundance adjusted for catchability. Define the objective function for minimization as

$$\Psi_{s,a,y}(\theta,\kappa) = \sum_{s,a,y}\left(\ln I_{s,a,y} - \kappa_{s,a} + \ln N_{a,y}(\theta)\right)^2$$

For convenience, the beginning of year population abundance $N_{a,y}(\theta)$ is abbreviated by $N_{a,y}$. For year y = 1996, the population abundance was obtained directly from the parameter estimates, $N_{a,1996} = e^{\theta_{a,1996}}$. For all other years, the population abundance was computed using the virtual population analysis algorithm which incorporates the exponential decay model

$$N_{a,y} = N_{a+1,y+1} e^{F_{a,y}+M}$$

where the natural mortality M is assumed and the fishing mortality $F_{a,y}$, for ages a = 2 to 5, is obtained by solving the catch equation using a Newton-Raphson algorithm

$$N_{a,y} = \frac{C_{a,y}\left(F_{a,y} + M\right)}{F_{a,y}\left(1 - e^{-\left(F_{a,y}+M\right)}\right)}$$

The fishing mortality rate for age 6 was assumed equal to the average for ages 4 to 5.

The magnitude of the residuals is large and there are some time trends for some indices which warrant further examination (Fig. 10). The USA spring ages 4-6 aggregated, USA age 2 fall and Canadian age 2 would be of particular concern. The residuals for the most recent year of observation are somewhat large, and are amongst the largest observed for 4 of the 9 series. The age 1 USA fall survey observation in 1989 resulted in a very large residual but that data point does not appear to be unduly influential. The variance and bias of population abundance estimates, survey calibration constants and corresponding projected yield were derived using an analytical approximation (Gavaris 1993). The population abundance estimates show a large relative error and substantial bias at ages 1 and 2 reflecting the variability in the abundance indices (Table 7).

The 1996 Canadian survey was not used in the assessment because an age length key from the USA survey for 1996 was not yet available. As an approximation, it was assumed that yellowtail between 20 and 32 cm were age 2 and those over 32 cm were age 3 or older and an exploratory calibration was attempted. The population abundance estimates for 1996 from this analyses were similar to those above except for the 1994 year-class which was estimated to be considerably greater.

	Age Group					
	2	3	4	5	6	7
without CAN 1996	3491	4628	3778	329	791	152
with CAN 1996	14221	5151	4125	319	815	151

Given the poor fit for the Canadian age 2 series (Fig. 10), the results with the Canadian 1996 data included were not considered further.

ASSESSMENT RESULTS

For each cohort, the terminal population abundance estimates from ADAPT were adjusted for bias and used to construct the history of stock status (Tables 8-10). In the absence of an unbiased point estimator with optimal statistical properties, this approach for bias adjustment was considered preferable to using the biased point estimates. The fishery catch weights at age were used to derive beginning of year weights at age for calculating beginning of year population biomass.

Biomass decreased rapidly from 1973 to 1985, associated with a marked decline in recruitment, reaching the lowest observed level and has since only increased moderately fluctuating at about 5,000 t (Fig. 11). Recruitment during the 1980s has been considerably poorer than that experienced during the 1970s (Fig. 12). Only the 1987, 1990 and 1992 year-classes have been near average in the past decade. The biomass increased temporarily to about 10,000 t in 1992 when the 1990 year-class recruited. The strength of the 1992 year class was estimated to be about 10 million, making it amongst the highest since the 1980 year-class. The exploitation rate on ages 4 and older has been very high, often exceeding 60% since 1973 (Fig. 13). Since the mid 1980s, the exploitation rate shows a modest declining trend, reaching the lowest observed level of about 40% in 1995. The exploitation rate on age 3 is often as high and sometimes higher than that observed on ages 4 and older.

The assumptions regarding 1994 and 1995 USA catches, the low level of sampling for ages, uncertainties about discarding by USA and species mis-reporting by Canada, potential for unaccounted differences in growth between males and females and poor fit of the data in relationships between indices and population abundance, suggest that these assessment results should only be considered as rough indicators.

PROGNOSIS

Commercial catch rates and the most recent survey observations suggest that abundance increased between 1995 and 1996. The assessment results also reflect this trend but indicate that biomass is very low compared to historic levels. Recent recruitment has generally been poor and exploitation rates have greatly exceeded common reference levels. The truncated age structure suggests that a rebuilding strategy should be followed. Though it was not considered appropriate to conduct formal yield projections, an illustrative calculation at $F_{0.1} = 0.29$ was done using the 1995 beginning of year population numbers as estimated from ADAPT. The partial recruitment to the fishery for ages 2 and 3 was 0.15 and 0.5 respectively. The projected yield at $F_{0.1} = 0.29$ in 1996 would be about 1,000 t and the biomass was projected to increase. Maintaining the 1996 Canadian catch at about the 1995 Canadian allocation of 400 t should, if the USA target TAC of 385 t is not exceeded, result in a fishing mortality rate in 1996 approximating the $F_{0.1} = 0.29$.

The uncertainty associated with model assumptions has been noted but the uncertainty arising from imprecision of the observed data is also considerable for this resource. To reduce the chances to less than 20% that the $F_{0.1}$ reference is not exceeded, the combined Canada and USA yield would have to be reduced to less than 700t (Fig. 14). On the other hand, the chances are better than 50% that the biomass will increase in 1997 for yields up to about 1600t. For yields greater than 1600t, the 1997 biomass is more likely to decrease.

The apparent relationship between abundance at age 2 and beginning of year biomass for ages 3 and older suggests that recruitment could be improved by rebuilding the spawning biomass. High levels of recruits were only observed when the biomass exceeded about 8,000 tons (Fig. 15).

Discarding of small yellowtail results in lost potential yield and contributes to the reduction of spawning biomass. Measures to avoid the capture of small yellowtail could considerably enhance the benefits from this fishery.

The reported quantity of unspecified flounder landings decreased in 1995, improving the quality of data. Further progress in this regard is strongly encouraged.

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Table 1. Landings of yellowtail flounder ('000s t) from Georges Bank by the United States and Canada, 1973 to 1995. The 1994 and 1995 landings for the United States are estimates only (P. Rago, NMFS, Woods Hole), earlier values are from Anon. (1994b).

	USA		Canada	
	Landings	Discards	Yellowtail	Unspecified flatfish
1973	15.9	0.4	0	<0.1
1974	14.6	1.0	0	<0.1
1975	13.2	2.8	0	<0.1
1976	11.3	3.1	0	<0.1
1977	9.4	0.6	0	<0.1
1978	4.5	1.8	0	<0.1
1979	5.5	0.7	0	<0.1
1980	6.5	0.4	0	<0.1
1981	6.2	0.1	0	<0.1
1982	10.6	1.4	0	<0.1
1983	11.3	0.1	0	<0.1
1984	5.8	0.0	0	<0.1
1985	2.5	0.0	0	<0.1
1986	3.0	0.0	0	<0.1
1987	2.7	0.2	0	<0.1
1988	1.9	0.3	0	<0.1
1989	1.1	0.1	<0.1	<0.1
1990	2.7	0.9	<0.1	<0.1
1991	1.8	0.3	<0.1	<0.1
1992	2.8	2.0	<0.1	<0.1
1993	2.1	1.2	0.2	0.6
1994	1.5	2.3	1.3	0.9
1995	1.0	0.7	0.4	0.1

Table 2. Canadian landings of yellowtail flounder in 5Zjmhn, by gear type, tonnage class and month, 1993-1995.

Year	Month	Otter Trawl				Longline	Dredge	Total
		TC2	TC3	TC>4	Total			
1993	Feb	0	0	0	0	0	0	1
	Mar	0	0	0	0	0	2	2
	Apr	0	0	0	0	0	3	3
	May	0	0	0	0	0	4	4
	Jun	2	4	0	6	0	1	7
	Jul	0	0	0	0	0	0	1
	Aug	4	0	0	4	0	1	5
	Sep	0	0	0	0	0	1	1
	Oct	66	0	0	66	0	3	68
	Nov	34	13	0	47	0	0	47
	Dec	0	13	0	13	0	0	13
1993 Total		106	30	1	137	0	15	152
1994	Feb	0	0	0	0	0	1	1
	Mar	0	0	0	0	0	3	3
	Apr	0	0	0	0	0	3	3
	May	0	0	0	0	0	5	5
	Jun	45	22	0	67	0	2	68
	Jul	151	30	0	181	0	1	182
	Aug	269	76	14	359	0	2	360
	Sep	357	293	0	650	0	1	651
	Oct	32	21	0	52	0	2	54
1994 Total		853	442	14	1308	0	20	1328
1995	Mar	0	0	0	0	0	1	1
	Apr	0	0	0	0	0	1	1
	May	0	0	0	0	0	2	2
	Jun	0	0	0	1	0	2	3
	Jul	0	0	0	0	0	4	4
	Aug	182	54	0	236	0	1	237
	Sep	99	49	0	148	0	1	148
	Oct	0	0	0	0	0	0	1
1995 Total		281	104	1	386	0	12	397

Table 3. Total removals at age (Canada and the United States combined) in the yellowtail flounder fishery on Georges Bank, 1973-1995.

Catch	2	3	4	5	6	7	8	Total
1973	4890	13243	9276	3743	1259	278	81	33117
1974	8971	7904	7398	3544	852	452	173	31437
1975	25284	7057	3392	2084	671	313	164	43336
1976	31012	5146	1347	532	434	287	147	39520
1977	8580	9917	1721	394	221	129	124	21417
1978	3105	4034	1660	459	102	37	35	19092
1979	9505	3445	1242	550	141	79	52	15247
1980	3572	8821	1419	321	85	4	10	14542
1981	729	5351	4556	796	122	4	0	11612
1982	17491	7122	3246	1031	62	19	3	31036
1983	7689	16016	2316	625	109	10	8	27469
1984	1917	4266	4734	1592	257	47	17	13258
1985	3345	816	652	410	60	5	0	5939
1986	5771	978	347	161	52	16	8	7491
1987	2653	2751	761	132	39	32	41	6549
1988	2367	1191	624	165	15	20	3	4869
1989	1516	668	262	68	11	8	0	2718
1990	1931	6123	800	107	17	3	0	9200
1991	54	1222	2429	294	56	4	0	4470
1992	8359	2527	1269	509	20	7	0	15031
1993	993	2881	2327	292	65	9	1	11757
1994	2949	3394	2836	1133	62	58	0	10432
1995	1355	2387	739	177	86	3	0	4747

Table 4. United States NEFSC spring survey mean number per tow at age for yellowtail flounder on Georges Bank, 1973 - 1995.

	2	3	4	5	6	7	8	Total
1973	3.266	2.368	1.063	0.410	0.173	0.023	0.020	9.254
1974	2.224	1.842	1.256	0.346	0.187	0.085	0.009	6.265
1975	2.939	0.860	0.298	0.208	0.068	0.000	0.013	4.806
1976	4.368	1.247	0.311	0.196	0.026	0.048	0.037	7.267
1977	0.671	1.125	0.384	0.074	0.013	0.000	0.000	2.267
1978	0.798	0.507	0.219	0.026	0.000	0.008	0.000	2.494
1979	1.933	0.385	0.328	0.059	0.046	0.041	0.000	3.071
1980	4.644	5.761	0.473	0.057	0.037	0.000	0.000	11.029
1981	1.027	1.779	0.721	0.205	0.061	0.000	0.026	3.831
1982	3.742	1.122	1.016	0.455	0.065	0.000	0.026	6.471
1983	1.865	2.728	0.531	0.123	0.092	0.061	0.092	5.492
1984	0.093	0.809	0.885	0.834	0.244	0.000	0.000	2.865
1985	2.199	0.262	0.282	0.148	0.000	0.000	0.000	3.001
1986	1.806	0.291	0.056	0.137	0.055	0.000	0.000	2.372
1987	0.128	0.112	0.133	0.053	0.055	0.000	0.000	0.481
1988	0.275	0.366	0.242	0.199	0.027	0.000	0.000	1.187
1989	0.424	0.740	0.290	0.061	0.022	0.022	0.000	1.606
1990	0.065	1.108	0.393	0.139	0.012	0.045	0.000	1.762
1991	0.000	0.254	0.675	0.274	0.020	0.000	0.000	1.658
1992	2.010	1.945	0.598	0.189	0.000	0.000	0.000	4.742
1993	0.290	0.500	0.317	0.027	0.000	0.000	0.000	1.180
1994	0.621	0.638	0.357	0.145	0.043	0.000	0.000	1.804
1995	1.180	4.810	1.490	0.640	0.010	0.000	0.000	8.170

Table 5. United States NEFSC fall survey mean number per tow at age for yellowtail flounder on Georges Bank, 1973 - 1995.

	2	3	4	5	6	7	8	Total
1973.5	5.497	5.104	2.944	1.216	0.416	0.171	0.031	17.873
1974.5	2.854	1.524	1.060	0.460	0.249	0.131	0.000	10.901
1975.5	2.511	0.877	0.572	0.334	0.033	0.000	0.031	8.983
1976.5	1.929	0.475	0.117	0.122	0.033	0.000	0.067	3.079
1977.5	2.161	1.649	0.618	0.113	0.056	0.036	0.016	5.577
1978.5	1.272	0.773	0.406	0.139	0.011	0.000	0.024	7.354
1979.5	1.999	0.316	0.122	0.138	0.038	0.064	0.007	3.996
1980.5	5.086	6.050	0.678	0.217	0.162	0.006	0.033	12.993
1981.5	2.333	1.630	0.500	0.121	0.083	0.013	0.000	6.264
1982.5	2.185	1.590	0.423	0.089	0.000	0.000	0.000	6.711
1983.5	2.284	1.914	0.473	0.068	0.012	0.000	0.038	4.898
1984.5	0.400	0.306	2.428	0.090	0.029	0.000	0.018	3.932
1985.5	0.529	0.170	0.060	0.071	0.000	0.000	0.000	2.193
1986.5	1.107	0.341	0.081	0.000	0.000	0.000	0.000	1.810
1987.5	0.390	0.396	0.053	0.079	0.000	0.000	0.000	1.031
1988.5	0.213	0.102	0.031	0.000	0.000	0.000	0.000	0.365
1989.5	1.992	0.774	0.069	0.066	0.000	0.000	0.000	3.149
1990.5	0.326	1.517	0.280	0.014	0.000	0.000	0.000	2.137
1991.5	0.275	0.439	0.358	0.000	0.000	0.000	0.000	3.172
1992.5	0.396	0.712	0.162	0.144	0.027	0.000	0.000	1.592
1993.5	0.136	0.587	0.536	0.000	0.000	0.000	0.000	2.101
1994.5	0.22	0.98	0.71	0.26	0.03	0.03	0	3.350
1995.5	0.12	0.35	0.28	0.05	0.01	0	0	1.090

Table 6. Canadian spring survey mean number per tow at age for yellowtail flounder on Georges Bank, 1987 - 1995. The 1996 total value is also shown.

	2	3	4	5	6	Total
1987	0.12	0.74	2.58	0.56	0.02	4.02
1988	0.67	1.81	0.8	0.67	0.01	3.96
1989	0.76	0.91	0.29	0.04	0.01	2.01
1990	1.92	4.04	1.07	0.4	0.01	7.44
1991	0.61	1.86	2.93	0.82	0	6.22
1992	10.06	4.59	1.14	0.29	0	16.08
1993	2.63	6.32	2.45	0.21	0	11.61
1994	6.38	3.46	2.63	0.86	0.19	13.52
1995	1.17	4.55	2.16	0.95	0.07	8.9
1996						23.45

Table 7. Statistical properties of estimates for population abundance and survey calibration constants for Georges Bank yellowtail.

Age	Estimate	Standard Error	Relative Error	Bias	Relative Bias
		Population Abundance			
2	5136	4100	0.80	1645	0.32
3	5144	2486	0.48	516	0.10
4	4119	2138	0.52	342	0.08
5	488	793	1.63	159	0.33
6	969	964	1.00	178	0.18
		Survey Calibration Constants (x 1000)			
Canadian Spring Survey					
2	0.148	0.039	0.267	0.005	0.033
3-6	0.642	0.170	0.264	0.018	0.028
USA Spring Survey					
2	0.069	0.012	0.168	0.001	0.012
3	0.120	0.020	0.164	0.002	0.013
4-6	0.177	0.029	0.165	0.002	0.012
USA Fall Survey					
1-lag	0.055	0.009	0.168	0.001	0.012
2	0.094	0.015	0.165	0.001	0.013
3	0.179	0.030	0.165	0.003	0.017
4-6	0.243	0.041	0.167	0.005	0.020

Table 8. Bias adjusted estimates of beginning of year population numbers (000s) for yellowtail flounder, Georges Bank.

Age	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
2	23179	22445	38325	50784	17688	12033	31946	18181	17289	48813	15465	4035
3	28998	14579	10349	8994	14054	6826	7062	17625	11672	13497	24294	5805
4	16229	11913	4900	2234	2789	2751	2005	2709	6565	4777	4706	5711
5	5610	5039	3191	1014	633	756	778	540	953	1349	1041	1787
6	2021	1281	996	767	356	169	212	152	157	85	198	297
7	0	538	295	222	242	96	47	48	48	21	15	65
2+	76037	55795	58056	64015	35762	22631	42050	39255	36684	68542	45719	17700
3+	52858	33350	19731	13231	18074	10598	10104	21074	19395	19729	30254	13665
4+	23860	18771	9382	4237	4020	3772	3042	3449	7723	6232	5960	7860

Age	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
2	6535	11105	5262	5405	14938	6589	10066	19678	7369	12066	7142	3491
3	1593	2369	3950	1943	2310	10864	3662	8193	8637	5138	7228	4628
4	994	577	1065	803	533	1291	3448	1902	4441	4489	1202	3778
5	539	236	164	200	110	203	347	678	435	1562	1161	329
6	84	81	51	19	20	30	71	28	107	97	280	791
7	20	16	20	7	2	6	9	9	5	30	25	152
2+	9765	14384	10512	8377	17913	18983	17603	30488	20994	23382	17038	13169
3+	3230	3279	5250	2972	2975	12394	7537	10810	13625	11316	9896	9678
4+	1637	910	1300	1029	665	1530	3875	2617	4988	6178	2668	5050

Table. 9 Bias adjusted estimates of beginning of year population biomass (t) for yellowtail flounder on Georges Bank.

Age	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
2	7528	7437	10292	13808	5423	3463	9645	5454	6011	12886	4051	673
3	12096	6313	4463	3872	5940	2950	2787	7399	4876	5875	9016	1942
4	8025	6333	2579	1250	1639	1652	1157	1491	3587	2704	2552	2679
5	3162	3017	1958	650	446	536	549	392	649	906	720	1113
6	1303	847	681	544	285	142	173	133	126	73	167	219
7	0	425	208	170	222	86	45	49	45	19	16	62
2+	32114	24371	20181	20292	13957	8829	14354	14918	15294	22463	16521	6687
3+	24586	16934	9889	6485	8533	5365	4710	9465	9283	9577	12471	6014
4+	12490	10621	5426	2613	2593	2416	1923	2066	4407	3702	3455	4072

Age	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
2	1945	3085	1385	1525	4881	2083	2288	6382	2270	2382	1410	818
3	550	1049	1673	843	1008	4190	1316	2628	3097	1613	2074	1480
4	492	331	639	482	339	729	1553	855	1899	1807	457	1524
5	326	172	110	151	86	145	227	380	237	833	603	175
6	61	64	45	16	19	25	54	26	80	67	206	572
7	15	14	17	6	2	7	9	9	5	26	25	149
2+	3389	4716	3869	3023	6335	7179	5446	10279	7588	6729	4775	4718
3+	1444	1631	2483	1498	1454	5096	3158	3898	5318	4347	3365	3901
4+	893	582	810	655	445	906	1843	1270	2221	2734	1291	2420

Table 10. Bias adjusted estimates of instantaneous fishing mortality rates for yellowtail flounder on Georges Bank. The total (population weighted) fishing mortality for ages 4 and older is also indicated.

Age	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
2	0.264	0.574	1.250	1.085	0.752	0.333	0.395	0.243	0.048	0.498	0.780	0.730
3	0.690	0.890	1.333	0.971	1.431	1.025	0.758	0.788	0.693	0.854	1.248	1.565
4	0.970	1.117	1.375	1.061	1.105	1.063	1.112	0.844	1.382	1.324	0.768	2.161
5	1.277	1.421	1.226	0.846	1.123	1.074	1.436	1.036	2.212	1.718	1.053	2.357
6	1.123	1.269	1.300	0.954	1.114	1.068	1.274	0.940	1.797	1.521	0.911	2.509
4+	1.047	1.232	1.344	1.036	1.171	1.091	1.214	0.891	1.469	1.403	0.820	2.304

Age	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
2	0.815	0.834	0.796	0.650	0.119	0.388	0.006	0.623	0.161	0.312	0.234
3	0.816	0.600	1.392	1.092	0.381	0.948	0.455	0.412	0.455	1.252	0.449
4	1.237	1.057	1.471	1.791	0.766	1.113	1.426	1.276	0.845	1.153	1.097
5	1.699	1.333	1.972	2.123	1.113	0.852	2.315	1.643	1.295	1.518	0.184
6	1.468	1.195	1.722	1.957	0.940	0.982	1.871	1.459	1.067	1.166	0.410
4+	1.393	1.153	1.548	1.858	0.824	1.075	1.490	1.365	0.882	1.239	0.541

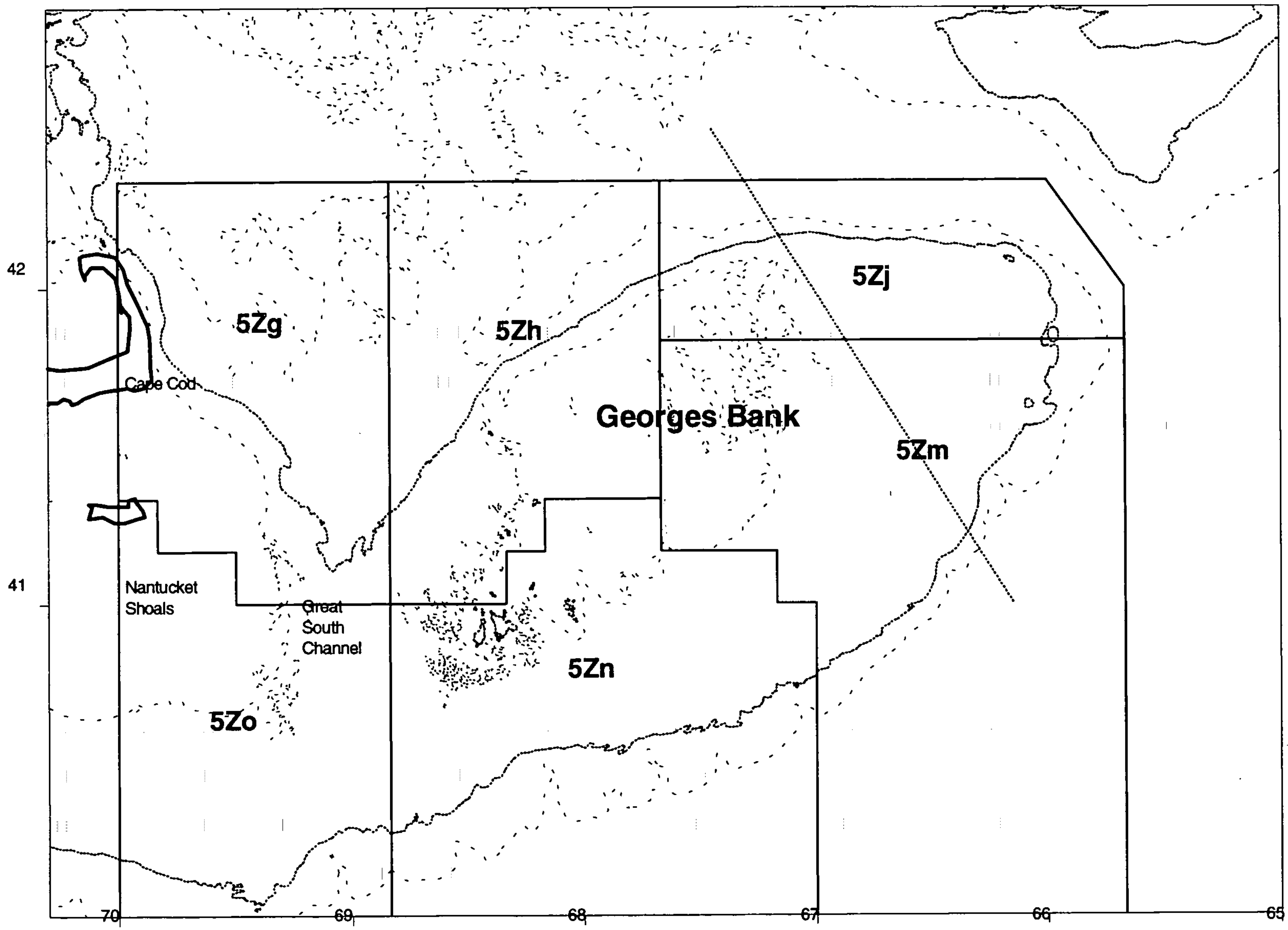


Fig. 1. Canadian fisheries statistical unit areas in NAFO Subdivision 5Ze.

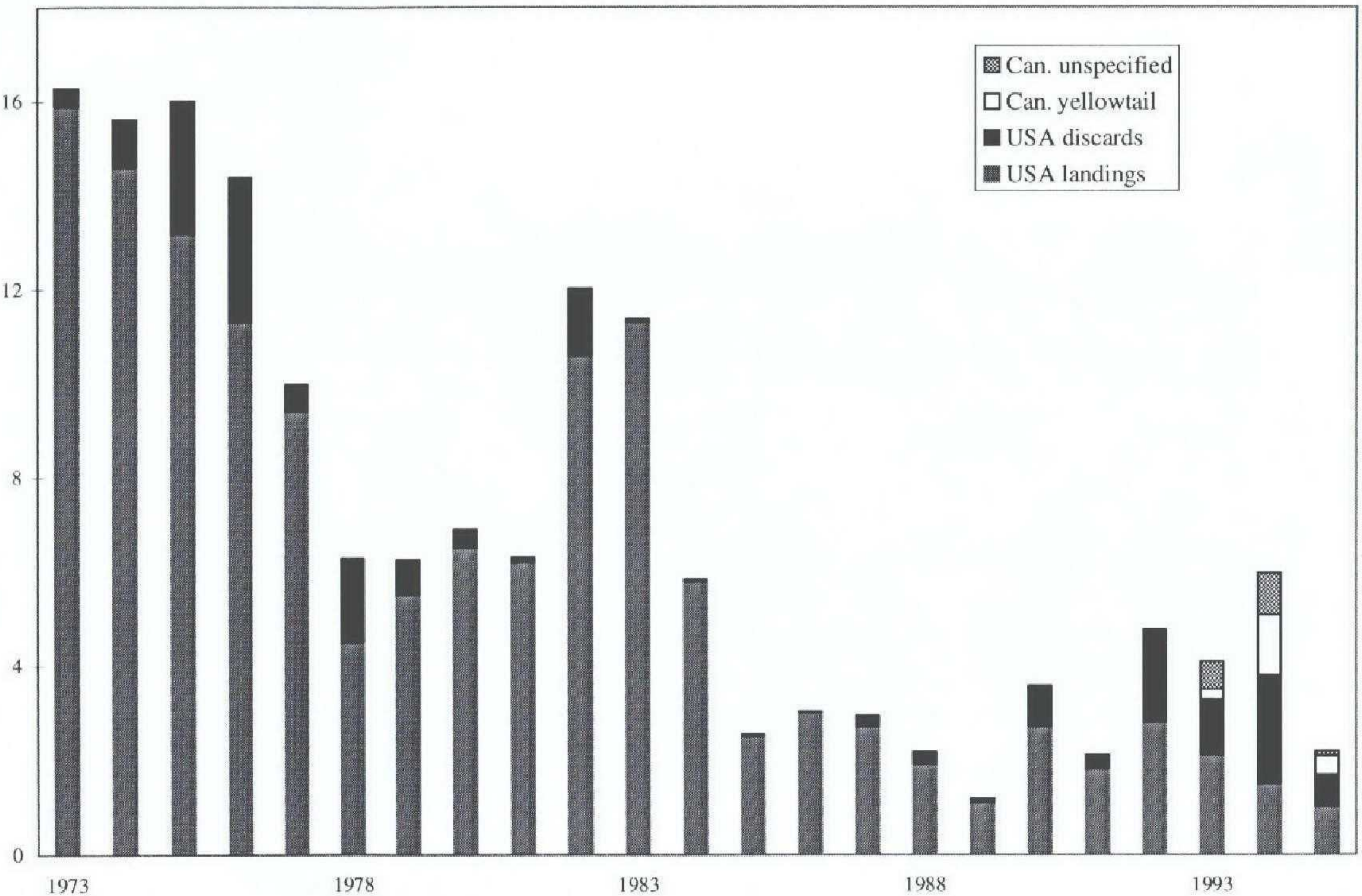


Fig. 2 Catches of Georges Bank yellowtail flounder by Canada and the USA. The 1994 and 1995 USA landings are estimates only (pers. com. P. Rago, NMFS, Woods Hole).

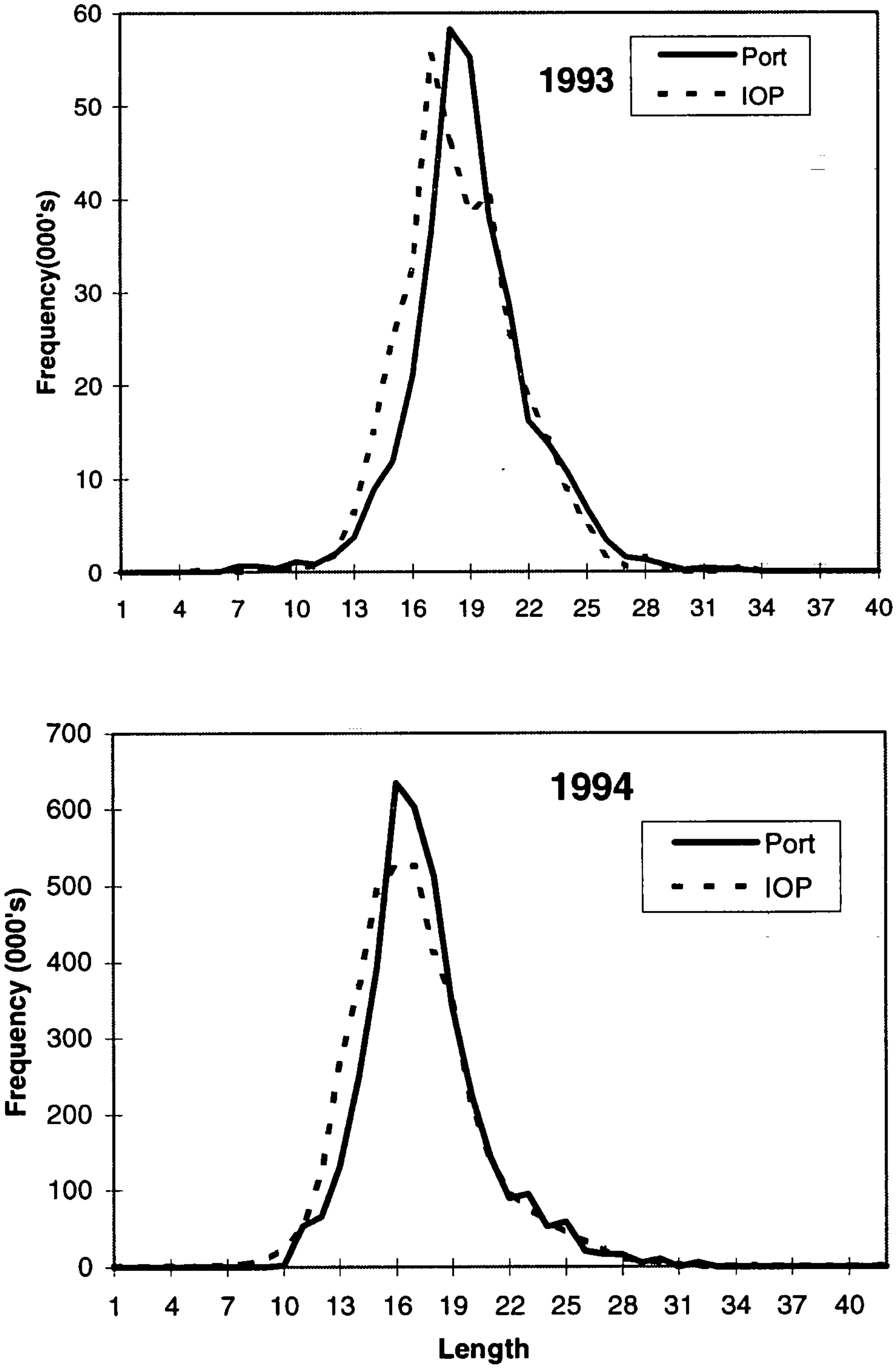
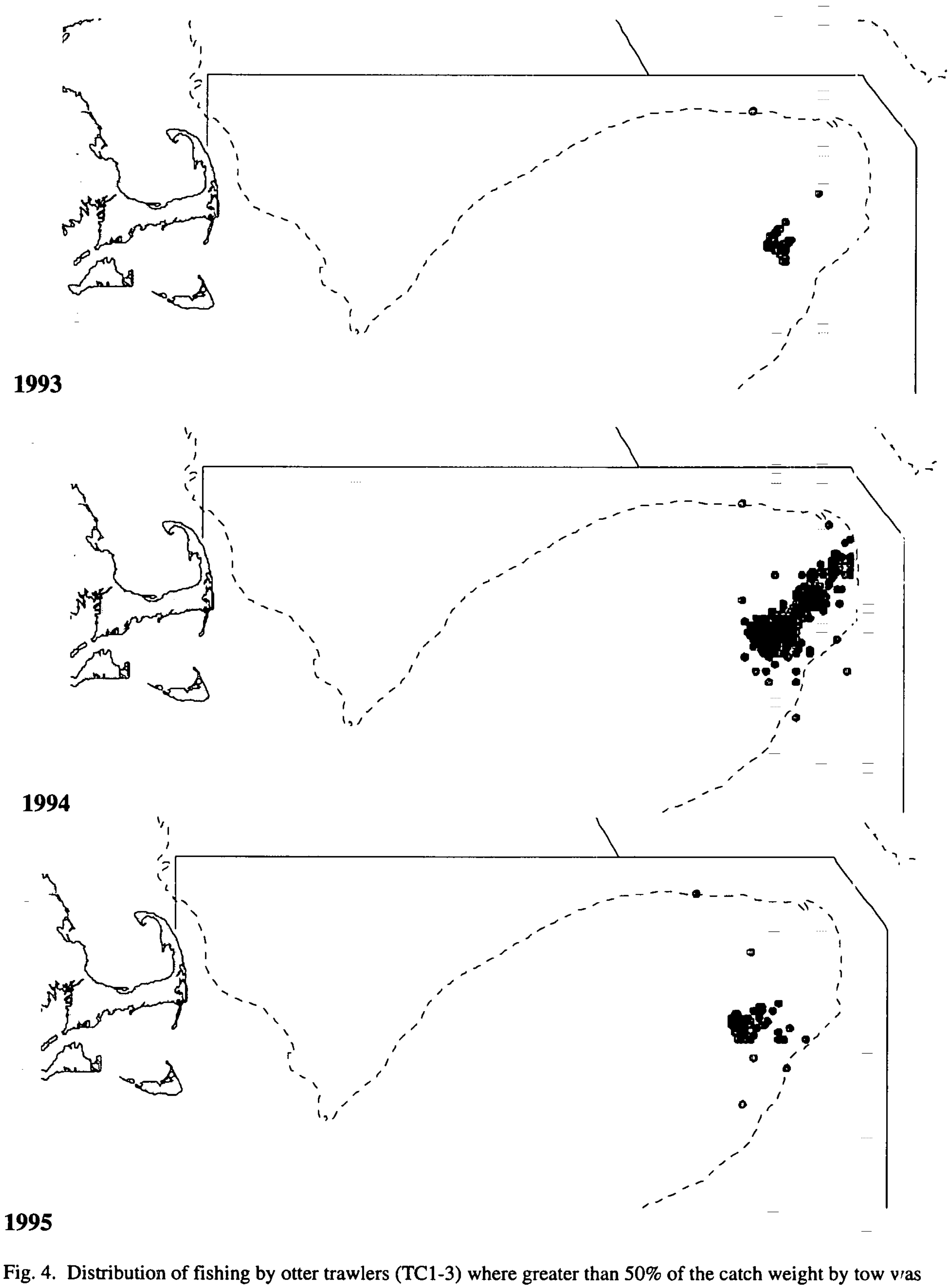


Fig. 3. Comparison of length frequency distributions of yellowtail flounder on Georges Bank from the Observer Program and the Port Sampling Program of DFO, 1993 and 1994.



1993

1994

1995

Fig. 4. Distribution of fishing by otter trawlers (TC1-3) where greater than 50% of the catch weight by tow was yellowtail flounder, Georges Bank 1993-1995 (some locations are questionable).

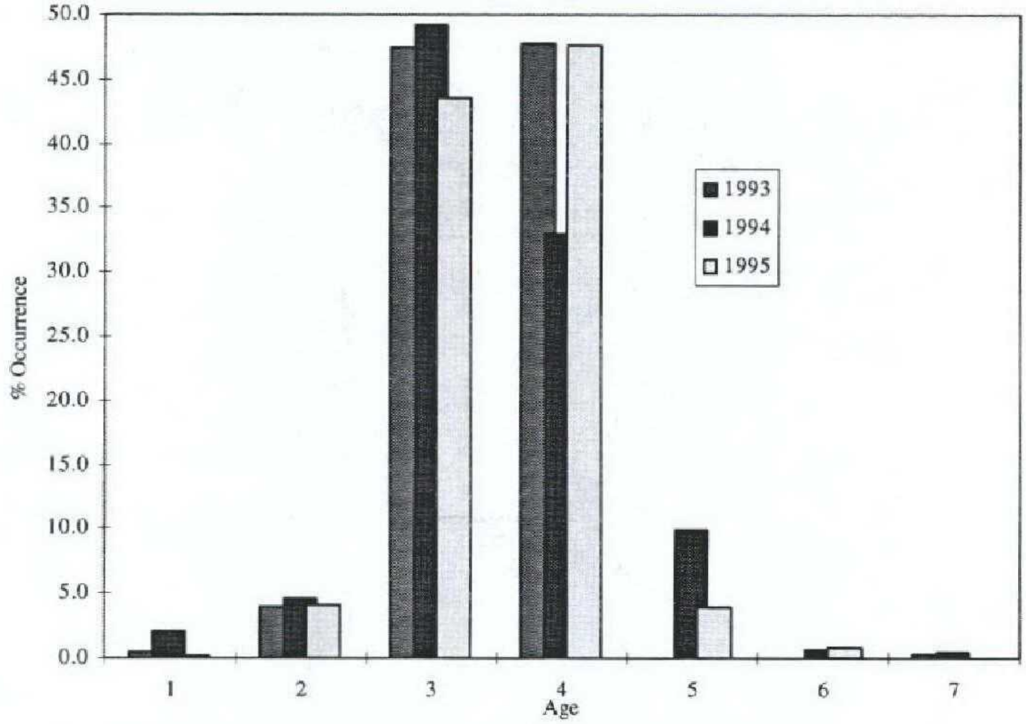


Fig. 5. Age composition of the Canadian commercial landings of Georges Bank yellowtail, 1993-1995.

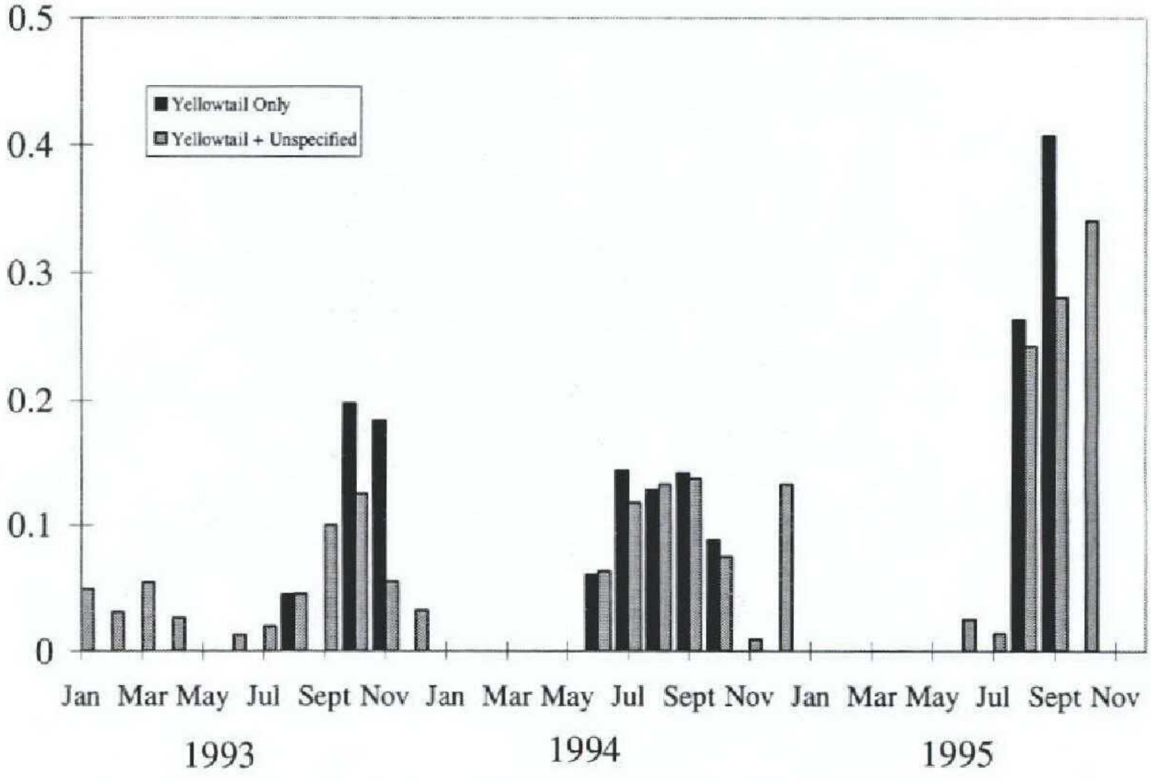


Fig. 6. Canadian otter trawl catch rates for yellowtail flounder on Georges Bank, 1993 - 1995. The solid bars represent catch rates for landings specified as yellowtail flounder. and the gray bars signify catch rates for yellowtail flounder plus unspecified flounder.

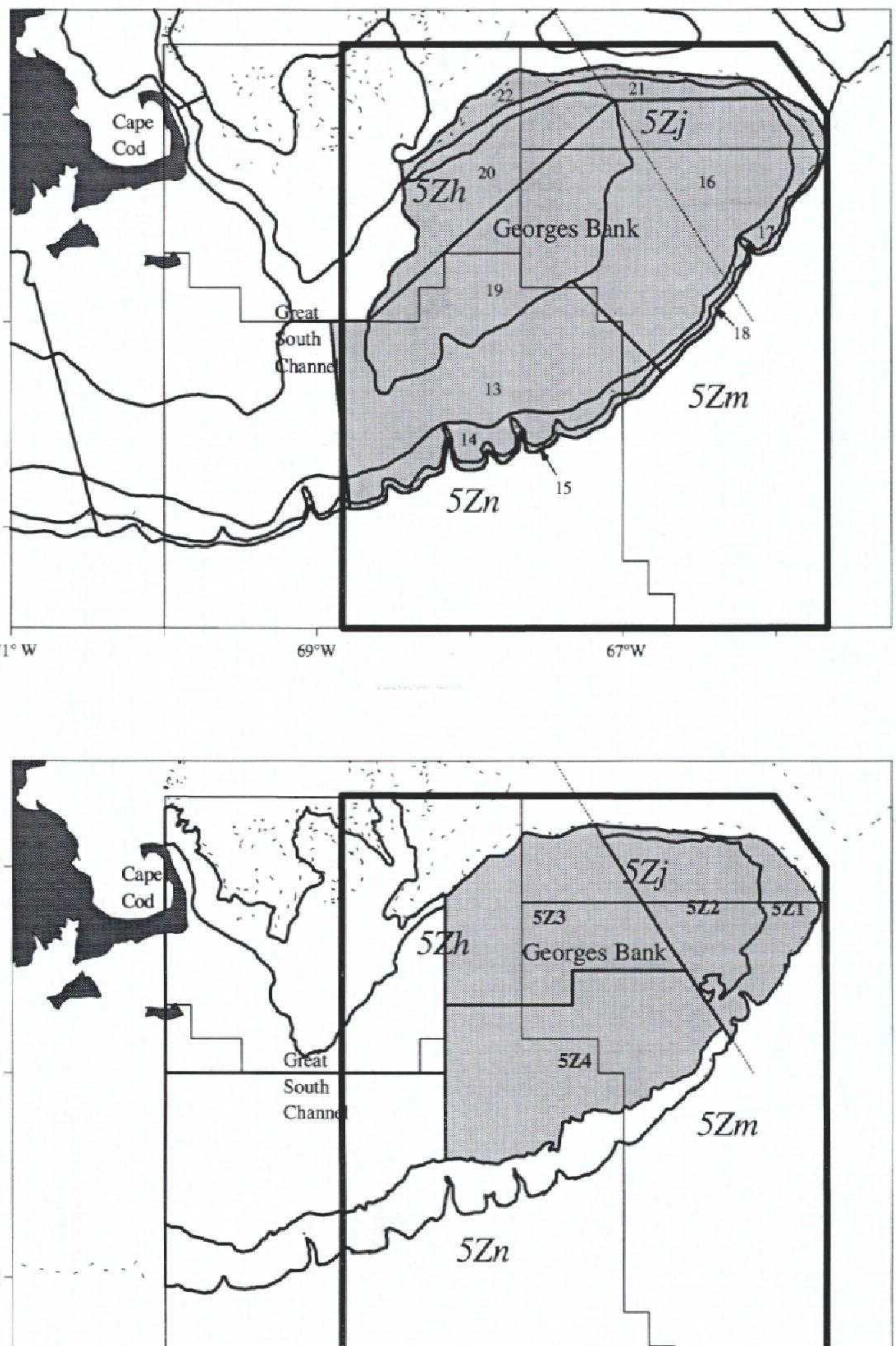


Fig. 7. USA and Canadian strata used to derive research survey abundance indices for Georges Bank yellowtail.

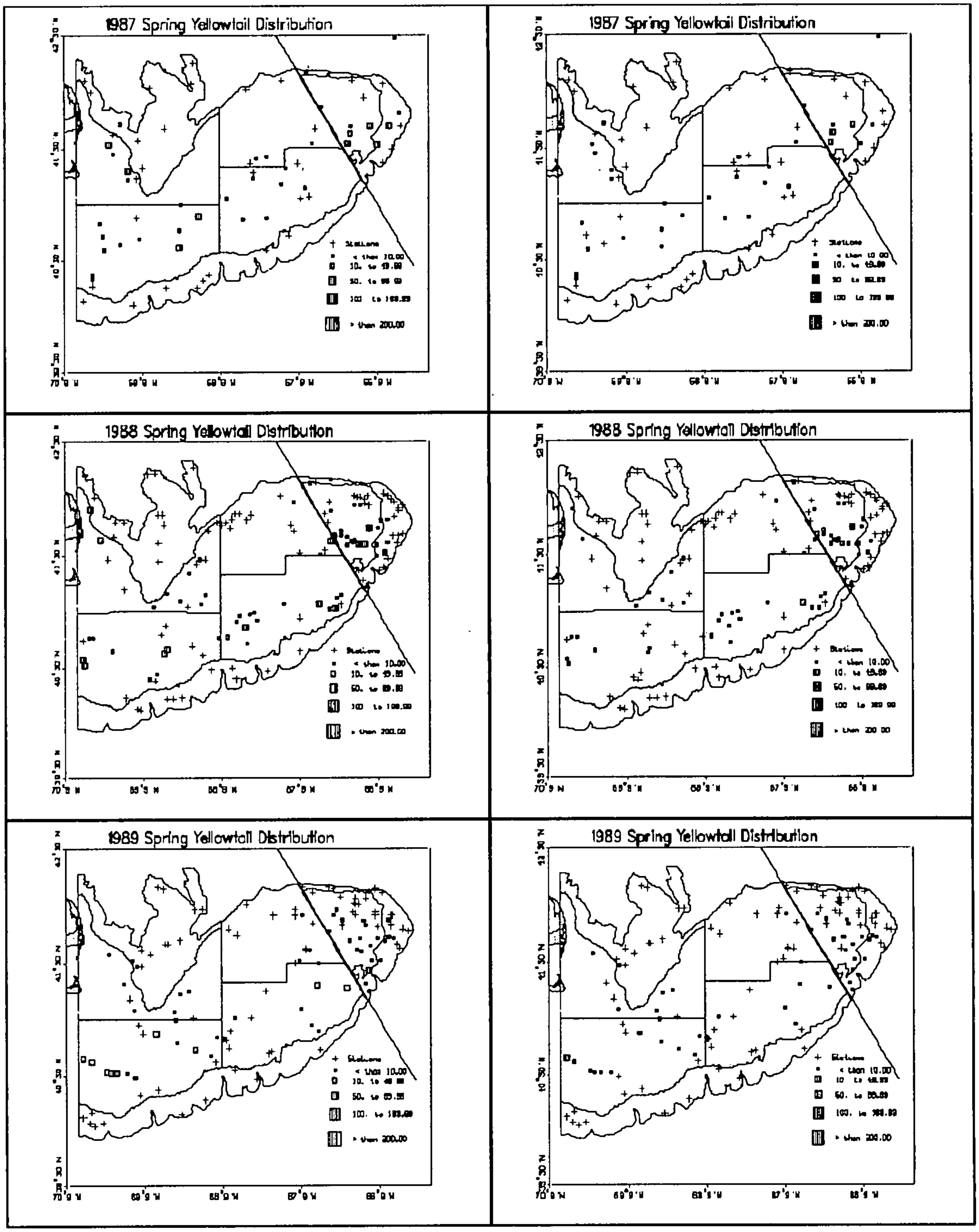


Fig. 8. Distribution of catches of yellowtail flounder on Georges Bank from Canadian research vessel surveys, 1987 to 1996. The left panels show number/tow and the right panels show weight/tow.

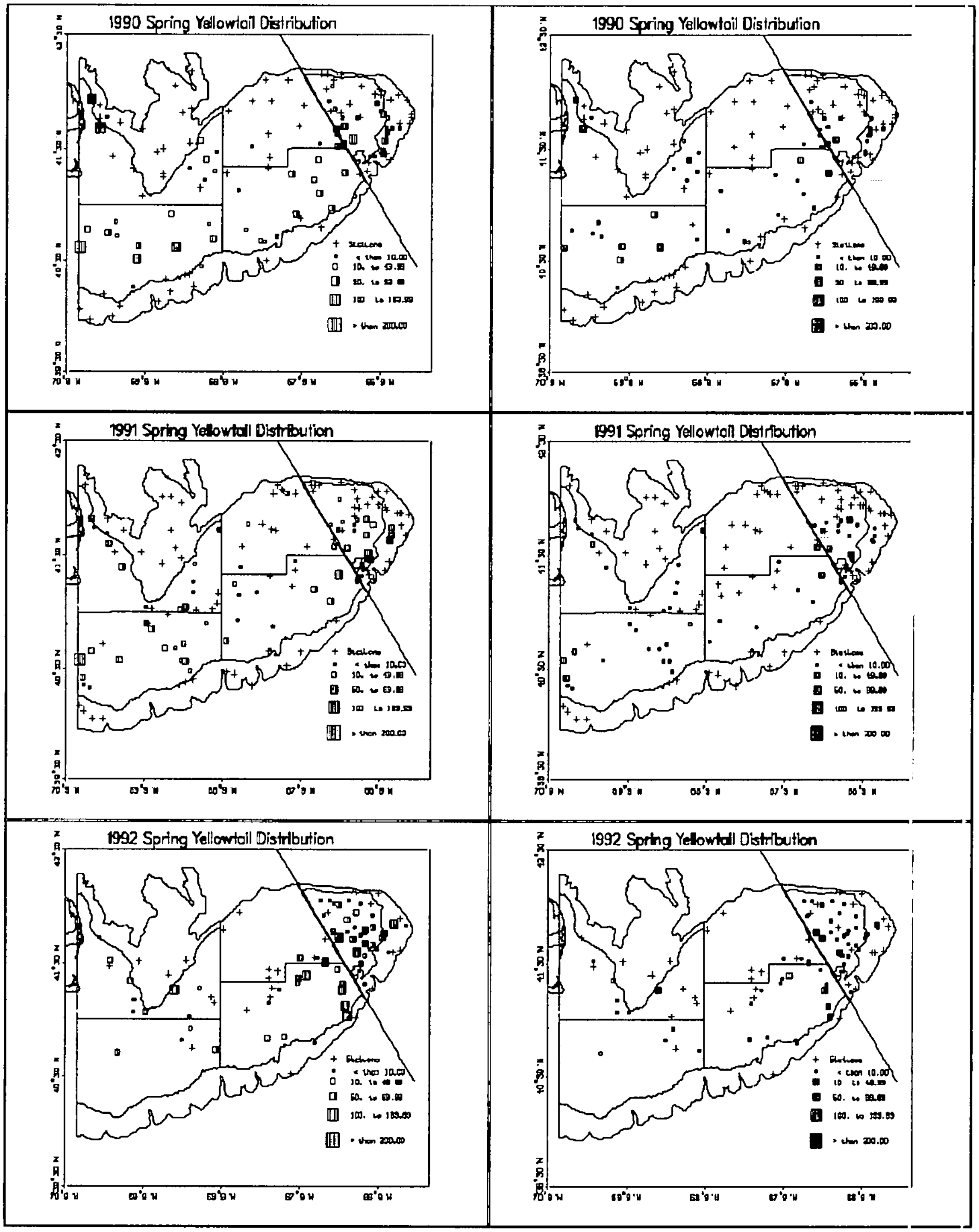


Fig. 8. continued

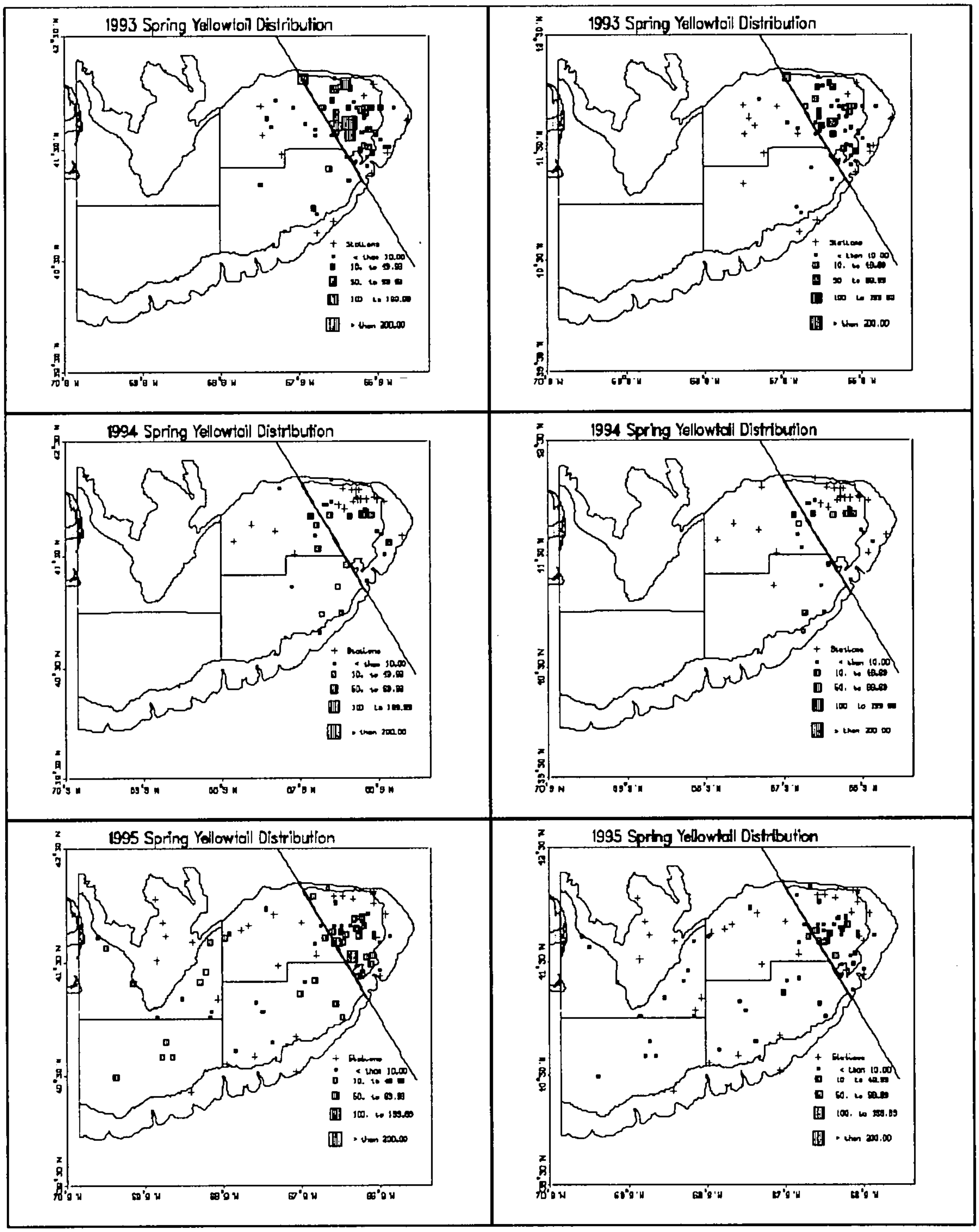
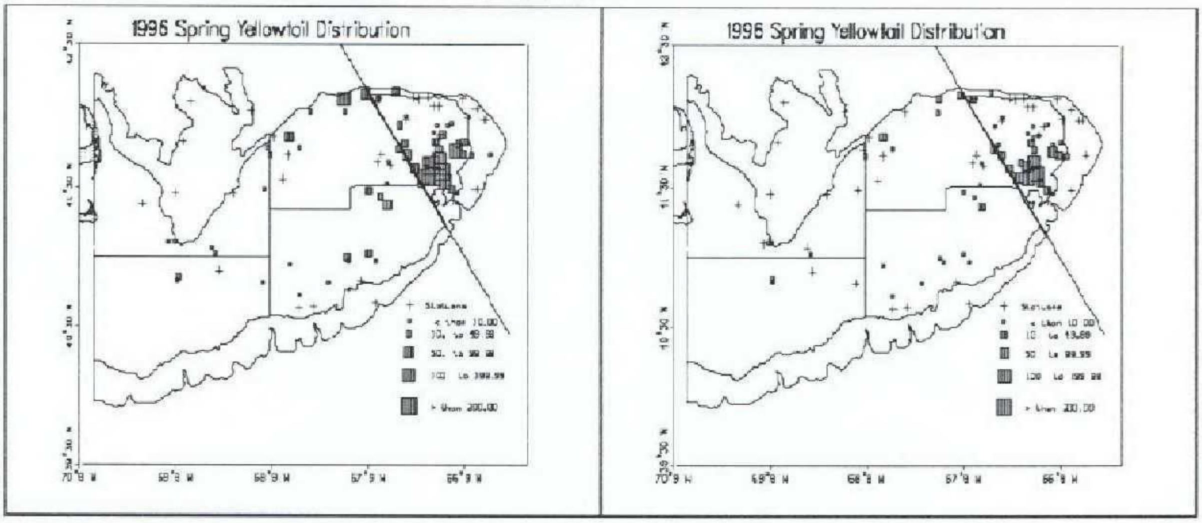


Fig. 8. continued



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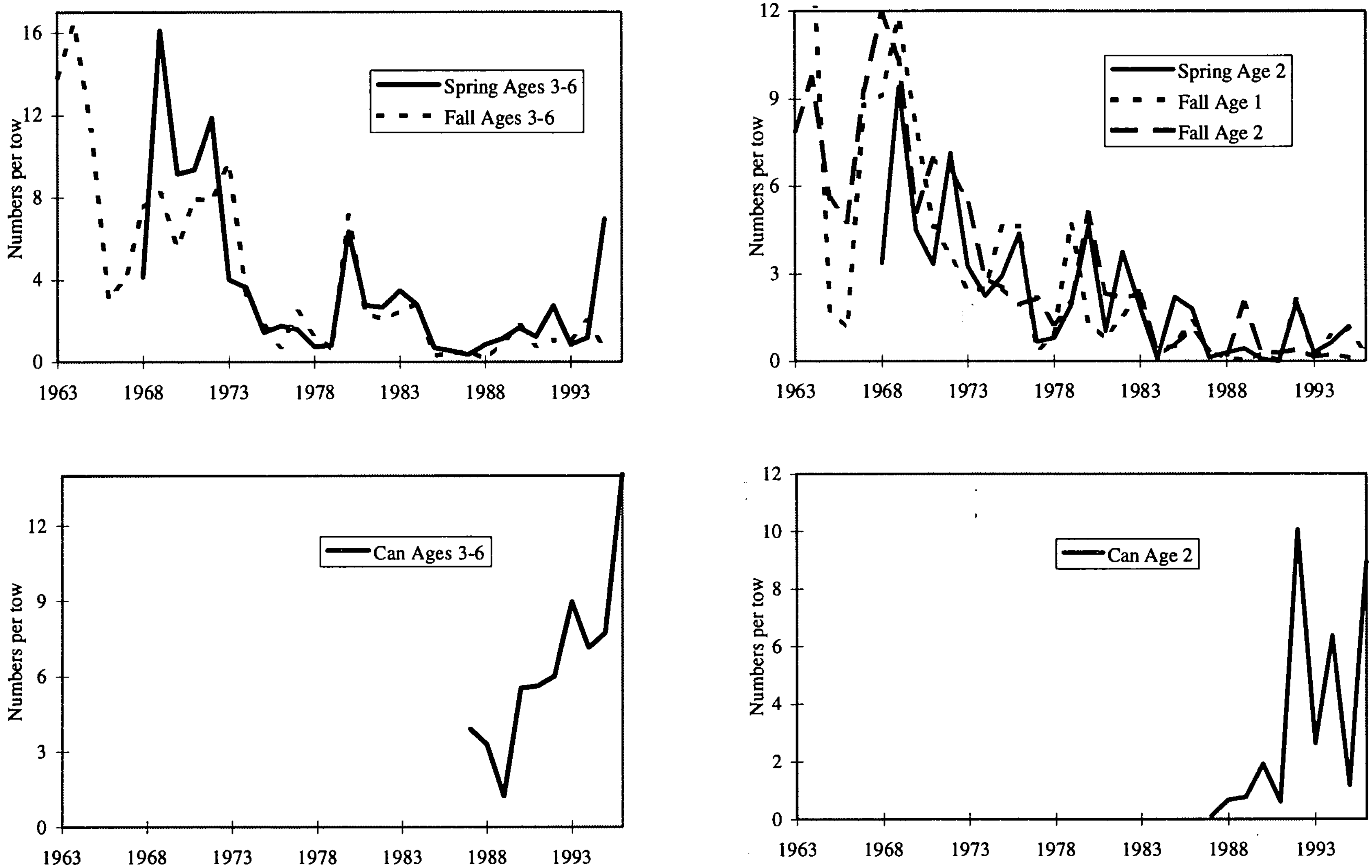

Fig. 9. Comparison of trends in survey abundance indices for ages 1 (lagged), 2 and 3-6 yellowtail on Georges Bank from the Canadian spring survey, the USA spring survey and the USA fall survey.

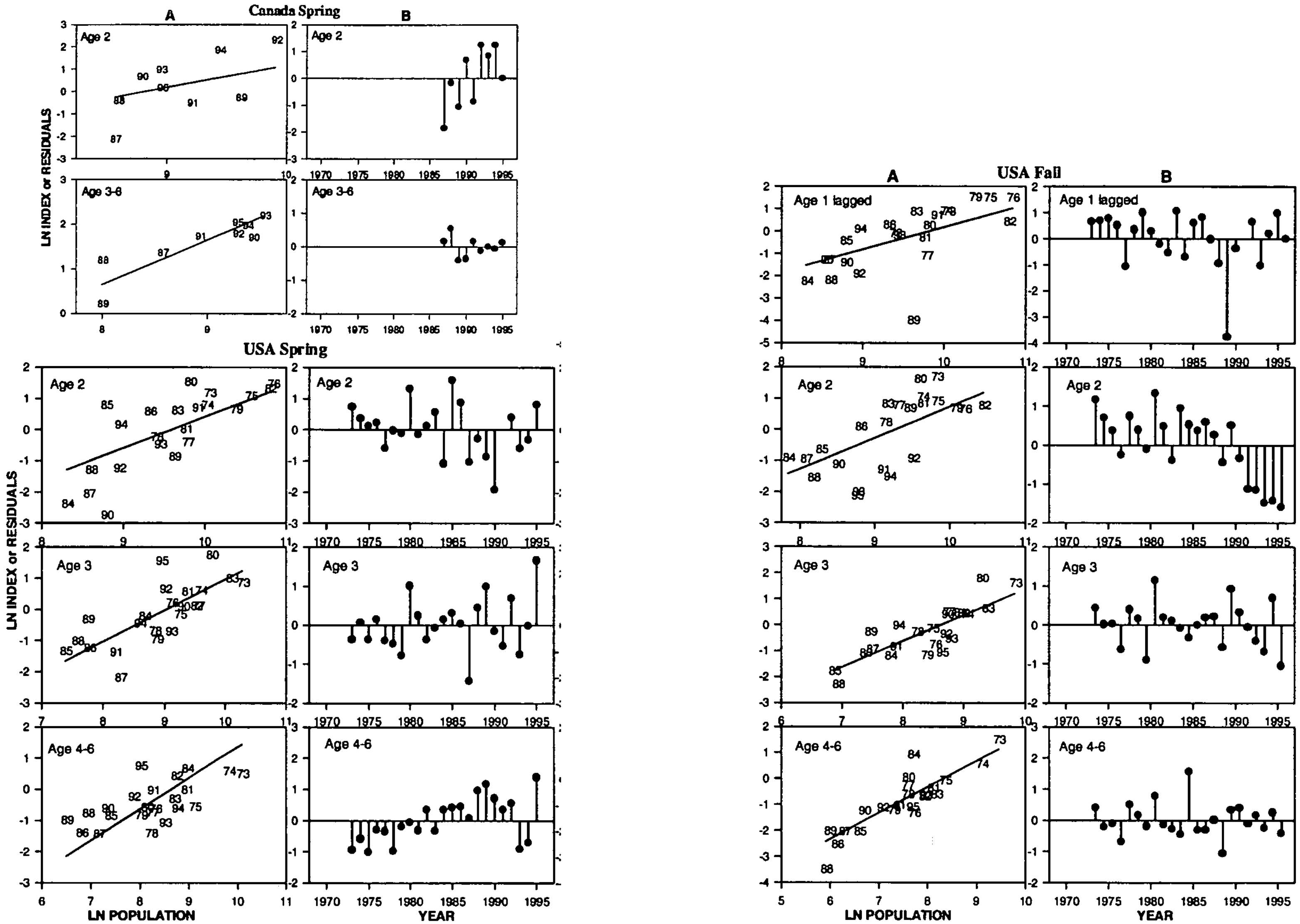

Fig. 10. Plots by age of A) the observed and predicted ln abundance index versus ln population numbers and B) residuals plotted against year for yellowtail on Georges Bank for the Canadian spring survey and the USA spring and fall surveys.

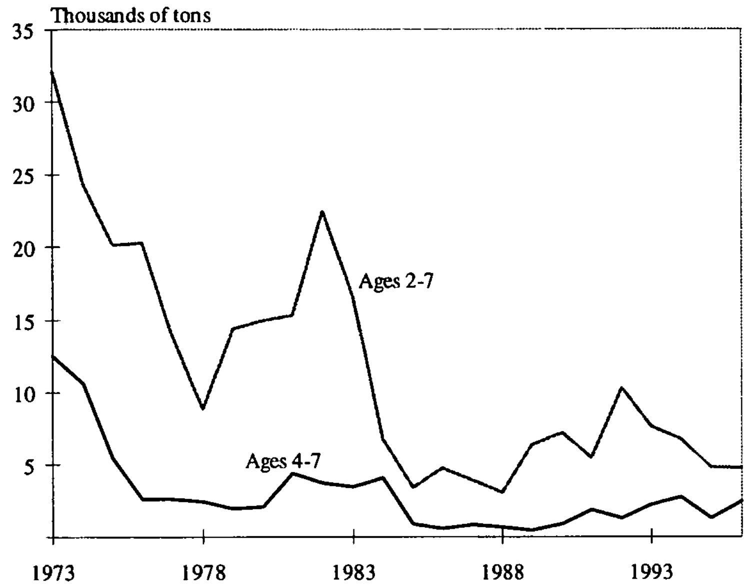

Fig. 11. Beginning of year biomass for yellowtail flounder on Georges Bank, 1973-1996.

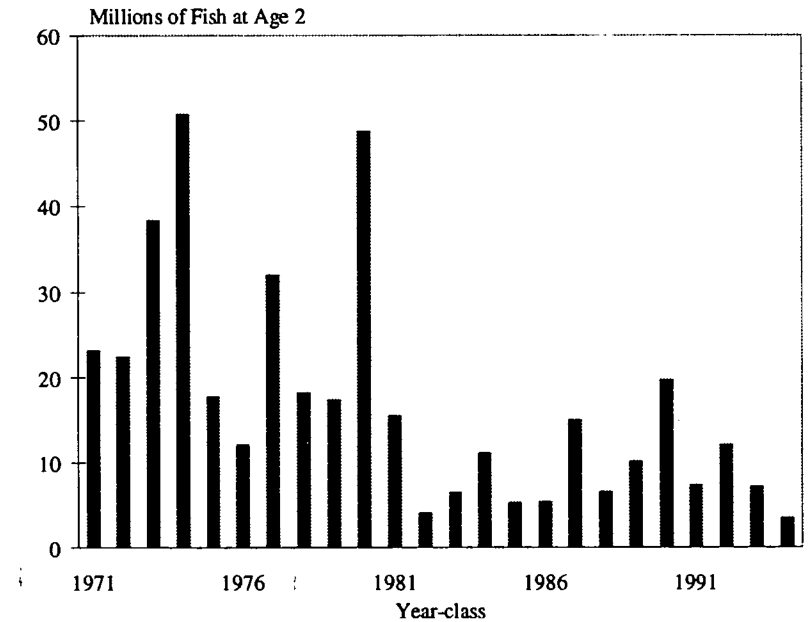

Fig. 12. Recruitment (age 2) for yellowtail flounder on Georges Bank.

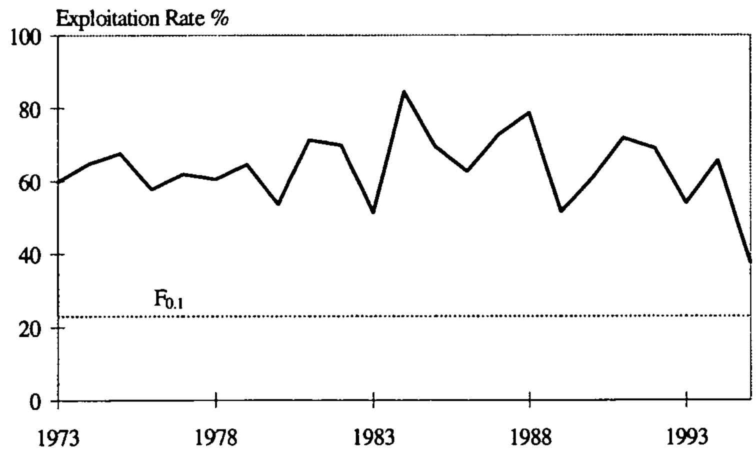

Fig. 13. Exploitation rate for yellowtail flounder ages 4 and older, Georges Bank, 1973-1995

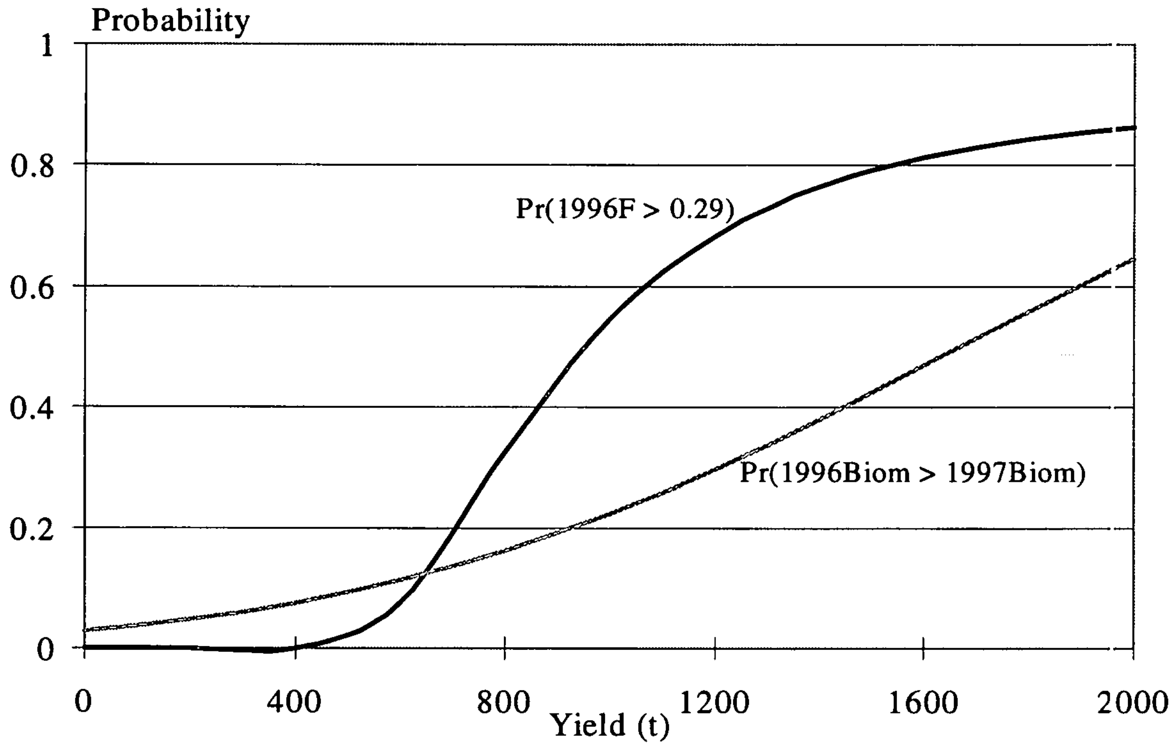

Fig. 14. Probability of exceeding $F_{0.1}$=0.29 in 1996 and of the 1997 biomass decreasing for various yield levels for Georges Bank yellowtail..

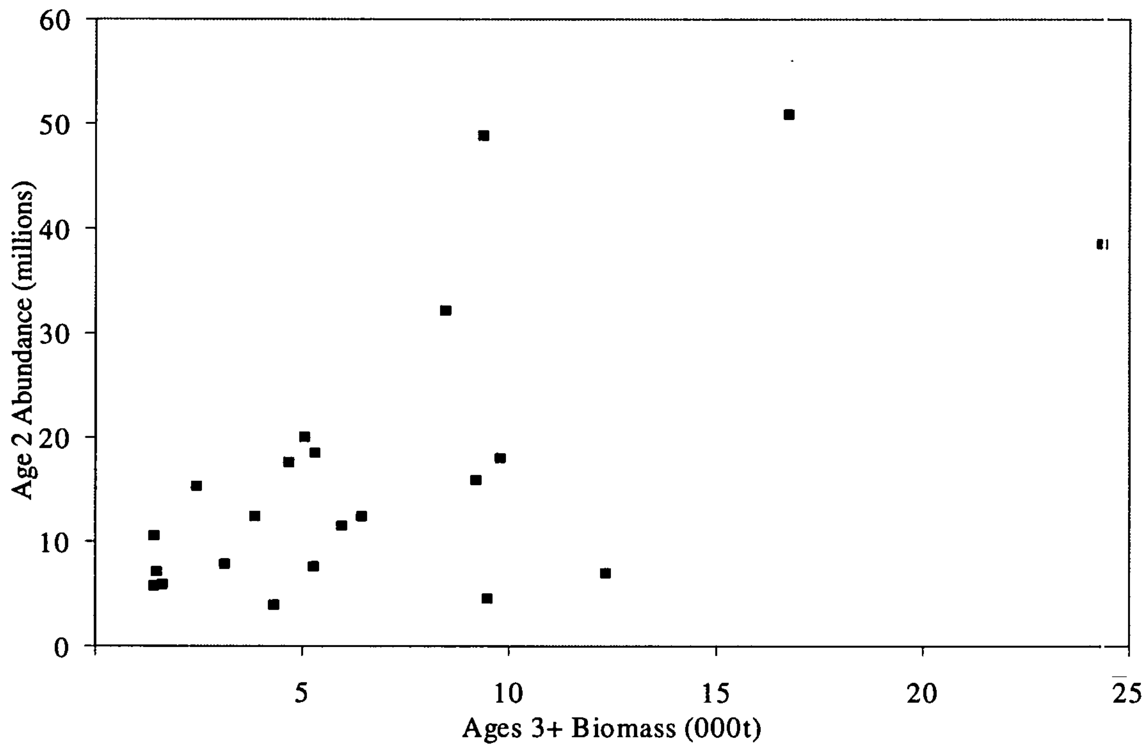

Fig. 15. Relationship between ages 3 and older stock bimass to recruitment at age 2 for Georges Bank yellowtail.