Northwest Atlantic Fisheries Organization

Serial No. N4449 **NAFO SCR Doc. 01/71**

SCIENTIFIC COUNCIL MEETING – JUNE 2001

Description of the 2000 Yellowtail Flounder Fishery on the Grand Banks with a Comparison to the 1998 and 1999 Fishery

by

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Abstract

The yellowtail fishery on the Grand Banks was prosecuted for the third year in 2000 following a 3-year moratorium. Monitoring of the 2000 fishery in the form of nearly full coverage by fishery observers facilitated a detailed examination of the catch, effort and biological parameters of the fishery. The results were compared to 1998 and 1999. The fishery starting on in mid Feb. 2000 and ending in early December was prosecuted at locations similar to 1999 covering 9.4% (compared to 6.6%) of the total area of the Grand Bank where bottom depth was less than 100 m. The 2000 fishery differed from 1998 and 1999 in that it extended further to the north into NAFO Div. 3L, and the separate grounds identified in previous years were less distinct. Yellowtail dominated the catch in all areas. This pattern of directed fishing for yellowtail was very similar to 1998 and 1999 but in contrast to the past (pre-1998) practise of taking yellowtail in a mixed fishery over a much more extensive area of the Grand Bank. Yellowtail flounder was again successfully exploited as a single target species rather than part of a mixed fishery (per the historical fishery) by concentrating effort where it was most abundant and other species were minimal. Catch of yellowtail in 2000 was 9,414 t, up from 6,609 t in 1999. By-catch levels of cod (1.2%) and plaice (6%) were achieved primarily by targeted spatial concentration of effort. Plaice by-catch was higher than in 1999 (4.4%) as it became more difficult to avoid this species. As in 1998 and 1999, the deployment of an excluder grate also contributed to the low by-catch levels, particularly cod. Size of fish taken was similar to 1998 and 1999. Over all areas fished, using a n average codend mesh size of 150 cm, average size of males and females in the catch was 36.4 and 39.3 cm respectively, very similar to 1999. A total of 17.9 million individuals were estimated to have been removed by the fishery compared to 7.3 and 12.9 million in 1998 and 1999.

Introduction

Yellowtail flounder (*Pleuronectes ferruginea*) is distributed off Newfoundland across much of the shallow portions of the Grand Banks within NAFO (Northwest Atlantic Fisheries Organization) Divisions 3L, 3N, 3O and Subdivision 3Ps (Fig.1). Early research survey work showed that the largest concentrations in Canadian Atlantic waters were located on the central part of the bank in less than 100 m (Walsh et al. 2000). A trawl fishery was initiated in Divisions 3L, 3N and 3O in 1960 during an expansion of fishing effort by Canada to the offshore and yellowtail flounder was found to be commercially viable. Since that time, until 1994, yellowtail had been exploited primarily as a part of a mixed fishery with cod (*Gadus morhua*) and American plaice (*Hippoglossoides platessoides*). Effort occurred mainly during the summer months over a large proportion of the Grand Bank. Over that period, total annual catches varied ranging between 7 t in 1960 and 39,259 t in 1972 (Walsh et *al*. 1998). Except for the peak years of 1985 and 1986, catches between 1976-93 were in the range of 10,000 to 18,000 t. Walsh et *al*. (1999, 2000) provides further details of the historic fishery.

A productive mixed fishery for over 30 years, the NAFO Fisheries Commission closed the Grand Bank to directed fishing for yellowtail, plaice and cod in 1994. This action was taken even though a 7,000t TAC (Total Allowable

Catch) for yellowtail had been recommended for that year. The fishery was closed because TAC's had been exceeded each year from 1985 to 1993, unreported catches outside 200 miles were a concern and overlapping cod and plaice stocks were in decline (NAFO Scientific Council). From 1995 until 1997, the only commercial catches of yellowtail on the Grand Banks occurred outside Canada's 200 mile limit, Reported as by-catch in other fisheries, 2,069 t was reported as taken primarily by Spain in 1994 subsequently falling to less than 300 t annually in 1995-97. Following 3 years of closure, the NAFO Scientific Council indicated that yellowtail in 3LNO was abundant enough to support a limited fishery in 1998 and an expanded fishery in 1999. The Council stipulated that the fishery be carefully monitored and sampled in both years including 100% coverage by Canadian fishery observers.

Stock assessments for yellowtail in 3LNO from 1994 to 1996 indicated low biomass and a moratorium on fishing for yellowtail (as well as plaice and cod) remained in affect in those years. In 1997, no analytical assessment of yellowtail was possible due mainly to uncertainties with catch and catch-at-age data (NAFO Scientific Council). However, given the reduced mortality due to the three year moratorium on fishing, many age classes were contributing significantly to the biomass and that the stock size had increased since 1994. Thus, the Council indicated that the stock should be able to sustain a limited fishery. A commercial fishery for yellowtail flounder was re-instituted in 1998. However, the stock biomass had not returned to historic levels and Scientific Council recommended that the TAC not exceed 4,000 t for 1998. Based on increased biomass of fully recruited fish, the quota was increased to 6,000 t for 1999. Of this, 5,850 t was allocated to Canada to be fished solely within the 200 mile limit. NAFO allocated 80 t to the European Union and the remainder to "other". The quota was allocated in this manner based on pre-moratorium allocations.

Historically, the Canadian fishery was prosecuted offshore by otter trawlers greater than 100 ft and it was this fleet sector that received most of the Canadian allocation from the re-opened fishery; 202 (1998), 275 t (1999) and 40 t (2000) for Nova Scotia based vessels, 3,581 (1998), 5,439 t (1999) and 9,109 t (2000) for Newfoundland vessels for a total of 3,846 (1998) and 5,714 t (1999) and 9,149 t (2000). The remaining 54 (1998), 136 t (1999) and 280 t (2000) was allocated to Canadian vessels 65-100 ft. For 1998, it was recommended that fishing should take place only after peak spawning was completed in June-July and the start date was set for Aug. 1. In 1999, fishing was permitted year round except from June 15-July 31, the peak period of spawning. There were no time restrictions in 2000. Fishing on the northern part of the Grand Bank (NAFO Div. 3L) was prohibited in 1998 given the continued low biomass index in this area but was opened to fishing in 2000 as the biomass estimates in this area increased. Historically, 3L was not an area of dense concentration of yellowtail and thus not an important fishing ground for this species. Directed fishing was permitted only inside Canada's 200 mile limit.

Based in part on recommendations from NAFO, an Atlantic Canada Conservation Harvesting Plan (CHP) for vessels greater than 100 ft was used to define the parameters of the yellowtail fishery in 1998, 1999 and 2000. Restrictions were put in place to minimize by-catch of cod and American plaice still under moratorium: "Pursuant to NAFO Conservation and Enforcement Measures, "incidental catches of (each of plaice and cod) could not exceed 1,250 kg or 5% by weight of the total weight on board, whichever is greater". Exceeding this level would result in closure for 10 days and the invocation of a test fishery before reopening. Net material was restricted to diamond configuration and minimum mesh size permitted was 145 mm. Based on an earlier recommendation, the 1999 CHP specified use of a minimum 155 mm diamond mesh in the codend. However, mesh size as small as 145 mm were observed in 1998, 1999 and 2000. Although vessels were not required by regulation to deploy sorting grates for the purpose of reducing by-catch, all Newfoundland vessels used a rigid grate as a measure to maintain by-catch below the 5% threshold that would lead to closure of the fishery. An earlier joint study by Industry Development Division of Fisheries and Oceans and the fishing industry (Hickey et *al*. 1995) showed that by use of a rigid vertically oriented grate, cod by-catch could be reduced at locations where they mixed with flatfish species. A small fish protocol was employed to avoid excessive catch of small (not yet mature) fish. Under this directive, if the number of undersized fish exceeded 15% of the catch on any day, an area would be closed to yellowtail fishing for 10 days. For monitoring purposes, yellowtail flounder were considered undersized if less than 30 cm.

The 1998 season for yellowtail was prosecuted from Aug. 1 to Nov. 15 expanded to Apr. 23 to Nov. 24 in 1999 and Feb. 19 to Dec 1in 2000 total. Nine vessels in 1998 and 15 vessels in 1999 and 2000 participated in the large vessel fishery (full description of the 1998 and 1999 fisheries presented by Kulka 1999 and 2000). Fishery observers were required to monitor fishing activity in relation to regulations as well as guidelines laid out in the CHP. Complete coverage of the large vessel (greater than 100 ft) fleet by fishery observers was stipulated. Gear configuration, by-catch of restricted species and size of yellowtail (small fish protocol) were monitored. The limited Canadian 65-100

ft vessel effort was not observed (although landings were monitored dockside for all fleets). The information collected by fishery observers was also of use in assessing the impact of the fishery on the Grand Bank stocks and of benefit to industry is terms of strategic planning for upcoming fisheries. Set by set details of catch, by-catch, effort, fish size and details of gear configuration was acquired facilitating a detailed spatial/temporal examination of the 2000 Canadian fishery. The level of detail as recorded by observers is available from no other source.

The current paper focuses on spatial and temporal aspects of the 2000 fishery in comparison to 1998, 1999 and the pre-moratorium fishery. It examines spatial configuration of the fishing activity with respect to the distribution of yellowtail, plaice and cod derived from research surveys.

Methods

Fishery observers collected geo-referenced (latitude and longitude) information on the catch, effort and other details of the capture of yellowtail such as gear configuration and fishing strategies from the 1998-2000 large vessel yellowtail fishery in a manner specified in Kulka and Firth (1987). Observer data for Maritimes based vessels (amounting to only 3.5% of the catch) were not available for this analysis and 65-100 ft vessels were not monitored. It is estimated that a total of 3,647 fishing sets were prosecuted in the 2000. A ratio of the landed to the observed catch of yellowtail was used to adjust observed by-catch weight to an estimate of total weight caught for each species taken in the fishery. Tables 1a and b lists, by month, NAFO Division and gear, catches broken out by directed and non-directed fisheries. Table 1c specifies the number of sets from the observed fishery and provides a summary of the associated catch rates for directed and by-catch as well as average depth and gear parameters.

Potential mapping in SPANS (Anon 1997) was used to convert the commercial catch and effort to surface maps describing the distribution of the fishery and the distribution of yellowtail in NAFO Divisions 3N and 3O. The potential mapping method transforms points (fishing sets consisting of catch (tonnes) per hour for the commercial fisheries data and standardised catch (kg) per tow for survey data) to a continuous surface spatially depicting differential densities of fish (catch rate subareas) or density of fishing effort (areas depicting differential in sets per km^2) by placing a circle around each point. The values of all points that fall within the circle (ie all points that are located within a specified distance of the circled point) is averaged and this value is assigned to the area encompassed by the circle. The procedure is repeated for each point creating overlapping circular areas equal to the total number of sets. A further averaging takes place where the circles overlap resulting in the creation of many more areas. The values from resulting areas are assigned to an underlying quadcell (a quadcell being a variable sized raster dividing the study area into a fine grid). An integration of classified quadcells forms a surface depicting density of the fish. For this method, by choosing the appropriate circle size, the technique effectively smoothes the data at its maximum resolution, i.e. at the spatial distance of the fishing sets without extrapolating beyond the bounds of the data or interpolating within the matrix of points. Refer to Anon (1997) and Kulka (1998) for a more detailed technical description of the potential mapping method and quadcell structure within SPANS and its application to mapping and biomass analyses of marine species.

For commercial fisheries data, a circle radius of 6 km was selected from a range of 1 to 8 km circles based on the criteria described above. Choosing this size had the added advantage that it corresponded the spatial scale of fishing effort. The length of a fishing set i.e. a typical set by a trawler fishing for yellowtail in 1998-2000 extended over 14 km respectively. Thus, calculations of areas fished at the spatial resolution of fishing activity reflected the true extent of the fishing grounds. The fishery took place at the conjunction of Divisions 3L, 3N and 3O. Both density of fishing and catch rates for yellowtail, plaice and cod were mapped.

Biological monitoring of the 2000 yellowtail fishery comprised the collection of catch lengths and ageing materials (otoliths) by sex. However, difficulties in interpretation of the growth rings of the otoliths prevented ageing of the fish. This information was gathered using the protocols outlined in Kulka and Firth (1987). The length samples materials covered all time periods (with the exception of small catches in Sept.-Oct. in 3O and Dec. in 3N) and areas fished allowing for a detailed spatio-temporal analysis of fish sizes in the catches. Data on maturity were also collected by port samplers. Table 2 specifies the catch (landings) and sample weight, number of fish measured and number of otoliths collected for the analysis of fish size in the commercial catches by NAFO Division and month. A total of 766 length samples were taken comprising 146,182 fish were measured and sexed from the catches of the yellowtail fishery. Due to high the high level of coverage, the yellowtail catches were intensely sampled for length

by sex. Proportion of total catch sampled was high, about 1.6% by weight and 1.1% by number. For all samples, weight was obtained by direct measurement. Sampling was spread proportionately across all fishing grounds and time periods and were spatially well distributed. Each length frequency was adjusted to the catch weight for each set prior to estimation of numbers caught by sex for each length group by area (fishing ground) and by month. Numbers of fish at age were estimated. Other narrative information including industry opinions on the fishery, fishing strategies and the stock status recorded in observer trip reports are also discussed in the context of patterns observed in the data.

Results and Discussion

Spatial analysis of the Canadian fishery

At depths less than 100 m, the Grand Bank is a large relatively flat area covering 135,000 km^2 (Fig. 1). Yellowtail are distributed over most of this area in varying densities (refer to research survey results described below) but the records collected by fishery observers show that the 2000 fishery for yellowtail was restricted to 9,746 km^2 or 7.2% of the Grand Bank at depths less than 100 m (Fig. 2). This are is about 27% smaller than the area fished in 1998 but 16% of the area fished prior to the moratorium (1991-93). As in previous years, about half of the total area fished contained 98% of the fishing sets. Thus, as in 1998 and 1999, fishing effort for yellowtail was highly localized in 2000 compared to the pre-moratorium fishery.

Monthly trends in the catch and effort for the 2000 yellowtail fishery show that the fishery was protracted compared to 1998 and 1999 and the effort occurred to during two periods (Fig. 3). The fishery started on Feb. 19 and ended on Dec. Most of the effort was concentrated in Apr.-May and Sept.-Oct. During this period, 15 vessels took part in the large vessel (greater than 100 ft) fishery. The majority of the catch was taken during Apr-May and Sept. Oct. in Division 3O. On a more detailed biweekly time scale, periods of highest catch rates of yellowtail corresponded fairly closely with the peak periods of the fishery (Fig. 4). Plaice by-catch peaked in May and June. The period of reduced fishing in Jun.-Aug. was an effort by the industry to minimize fishing during spawning. It also had the effect of reducing by-catch.

Spatially, the fishery took place at a number of distinct locations overlapping the intersection of Divisions 3L, 3N and 3O (Fig. 5a). Three more or less distinct areas fished are delineated by boxes (illustrated on Fig. 5). The two main grounds, the northern box consisted of 37% of the total fishing effort while the southern box comprised 55% of the effort. Average depth fished in the northern box was somewhat deeper, 74 m for the northern box compared to 57 m to the south. Much of the area fished corresponded with locations fished in 1998 and 1999 (refer to Fig. 6b). However, two new locations were fished in 2000, a thin area stretching 62 km north of the 3L line and a small area just to the east of the Whale Deep. The 3L portion of the fishery (northern extent of the northern box in Fig. 5a) comprised 15% of the effort and average depth fished was 75 m. The Whale Deep ground was small, comprising only 4% of the total effort. The main grounds (fished in previous years) are described in detail in Kulka (2000).

Catch rate (t per hour), reflecting local density of the fish varied over the area fished. The areas that produced the best catch rates in 1991-93 were similar to the highly fished areas in 1998, 1999 and 2000 except for the most northerly areas (Fig. 6). The area of highest density observed on 2000, centred at Lat 45^0 45 Lon 50 15^0 has was observed on 1999 and 2000 but not in previous years. Catch rate (average 1 t per hour) was slightly higher than the rates to the south (0.88 t). The small concentration of fish just west of the Whale Deep appears to have persisted over the years. It was not fished in 1998 and 1999, but appears as a concentration of fish in 1991-93 (compare Fig. 6a to Fig. 6b, left panel). Catch rate at 0.7 t per hour was lower than in other areas (refer to Fig. 6a).

Figure 7, distribution of plaice by-catch rates in 2000 is similar to what was observed in 1998 and 1999. Plaice catch rates were highest to the north and extreme south (lowest in the middle grounds in 3N). Fig. 8 for cod shows the highest catch rates occurred on the middle grounds where plaice were relatively low (in contrast with previous years). The relationship between density of yellowtail (reflected by catch rate) and density of plaice and cod by-catch is further illustrated in Fig. 9. It shows that high plaice catch rates correspond with high yellowtail rates while cod is highest where yellowtail is low. Thus avoidance of plaice by-catch is problematic. Table 3c shows that overall, plaice comprised 6% of the total catch in the yellowtail fishery in 2000, up from 4.4% in 1999 and 4.2% in 1998. on the other hand, cod has decreased slightly from 2.3% in 1998 to 1.2% in 2000. Table 3 also illustrates the total estimated catch for all species taken in the yellowtail fishery. In 2000, 49 species were recorded in the catches.

The only other significant by-catch was skate, primarily thorny (*Raja radiata*). Out of a catch of 164 t of skate, 95% was discarded. Also from Fig. 9 it can be seen that effort was greatest where yellowtail catch rates were highest. Depth and month fluctuated in relation to yellowtail catch rate. The best catch rates generally corresponded with greatest depth.

The codend mesh size employed by the 15 vessels in the fishery ranged from 146-160 cm with an average of 150 mm. Most sets employed a mesh size close to the average. As well, a rigid grate was also employed to reduce the by-catch of cod. Although vessels were not required by regulation to deploy sorting grates for the purpose of reducing by-catch, all but two vessels used a rigid grate as a measure to try and maintain by-catch below the 5% threshold that would lead to closure of the fishery. An earlier joint study by Industry Development Division of Fisheries and Oceans and the fishing industry (Hickey et *al.* 1995) showed that by use of a rigid vertically oriented grate, cod by-catch could be reduced at locations where they mixed with flatfish species. Kulka (2000) reported on the effectiveness of the grate in the 1998-1999 fishery. Bar spacings on the grates were within a range of 83 to 127 mm and averaged 120 cm. As for mesh size, most grate spacing used were close to the average.

Length and Age Composition

Fisheries and Oceans, Resource Allocation landing records indicated that 9,409 t of yellowtail was taken in 2000 by Canada. It is this number that is used in the calculation of removals (numbers at length) in this section. Length frequencies of commercial catches of yellowtail are illustrated in Figure 10. The y axis is set to show estimated total numbers of fish at length taken in the fishery. Across all grounds and time periods, the shape of the catch frequencies were uni-modal with an average size of 37.7 cm and a range of 10 to 63 cm. Males averaged 36.3cm, females 40 cm. Table 2, lists fish sampling statistics and numbers of fish caught by area by month. It shows that the sampling of size by sex in the fishery was very intense. Overall, 1.53% of the total tonnage of fish landed from the otter trawl fishery was sampled amounting to 146,182 fish.

Figure 10a indicate that mean and mode of males and females was consistent among NAFO Divisions. The shapes of both the male and female curves and the average size of males and females were similar to what was observed in1999 (Kulka 2000). It was estimated that a total of 17.9 million fish (6.4 and 11.6 million males and females respectively) were taken in the 2000 fishery compared to 7.3 and 12.9 million fish in 1998 and 1999. The increased numbers related to the increase in allocation.

Conclusions

Intense monitoring of the 1998, 1999 and 2000 yellowtail fishery in the form of nearly full coverage by fishery observers facilitated a detailed spatial and temporal examination of the fishery. In terms of meeting both management and commercial objectives, analyses of the observer data indicate that the 2000 fishery for yellowtail can be considered largely successful. Nearly all of the quota was taken, catch rates of yellowtail were higher than what was achieved just prior to closure of the fishery in 1991-93 (because of localized fishing on areas of high abundance), by-catch of plaice and cod was minimized (due to the localized fishing and employment of a sorting grate, although plaice by-catch slightly exceed the 5% cutoff) and small fish (less than 30 cm) constituted only a very small proportion of the catch (using codend mesh ranging from 146 to 160 mm. In 2000, although there was very limited data available on maturities, the protracted season meant that part of the fishery did take spawning fish. However, the industry kept effort to a minimum during peak spawning season in the summer. Unlike pre-moratorium years, the 1998-2000 fisheries were truly directed for yellowtail and concentrating effort where yellowtail was abundant resulted in protection of the depressed cod and plaice stocks in Divisions 3N and 3O and higher average catch rates than in past years.

However, some industry participants in this fishery continue to suggest that by-catch restrictions set out in the management plans resulted in yellowtail being exploited over a very restricted area thus hampering the ability to fish for yellowtail over the entire extent of its distribution. For 2000, the fishery was extended further to the north into NAFO Div. 3L which did not result overall in a significant problem with by-catch. While the existence of other (un-fished) yellowtail concentrations is possible, fishing activity being limited to the 1998-2000 grounds did not appear to negatively affect the ability of the fleet to sustain very good catch rates. Based on historic patterns, it seems likely that if the fishing effort in 1998-2000 had extended to areas other than those fished then catch rates of yellowtail in those non-fished areas would likely have been lower over most of those areas and depending on location, by-catch

of cod and plaice would have been higher. Within the bounds of the 1998-2000 grounds, catch rates of yellowtail achieved in 1998 were similar to the 1991-93 rates. An additional concern is that yellowtail might be over-exploited within the localized areas fished. However, there was no evidence of cropping out on the grounds fished. Rather, catch rates achieved during 1998-2000 remained fairly constant or increased over time.

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Table 1a. Catch and effort for the 2000 observed offshore vessel yellowtail fishery by NAFO Division.

	3L		3N		3O		All Areas	
month	**Catch**	**Sets**	**Catch**	**Sets**	**Catch**	**Sets**	**Catch**	**# sets**
2	0.0	0	117.8	64	0.0	0	117.8	64
3	0.0	0	1058.9	362	2.3	3	1061.2	365
4	0.0	0	1454.4	500	17.5	8	1472.0	508
5	778.7	261	947.1	373	115.3	64	1841.1	699
6	54.1	23	71.4	33	142.7	89	268.2	145
7	30.4	23	74.9	50	0.0	0	105.3	73
8	27.3	16	68.4	27	0.0	0	95.6	42
9	471.2	219	1094.3	497	0.0	0	1565.5	716
10	26.7	16	1553.0	635	4.1	2	1583.8	653
11	3.8	2	1157.7	375	3.2	3	1164.6	380
12	0.0	0	7.8	2	0.0	0	7.8	2
Grand Total	1392.1	559	7605.8	2919	285.1	170	9283.0	3647
Percent	15.00%	15.32%	81.93%	80.02%	3.07%	4.66%		

Table 1b. Catch and effort for the 2000 yellowtail fishery from ZIF records by NAFO Division. This table includes small vessel catches.

	3L		3N		3O		All Areas
month	**Catch**	**Sets**	**Catch**	**Sets**	**Catch**	**Sets**	**Catch**
2			114.0				114.0
3			1015.0		2.0		1017.0
4			1424.0		17.0		1441.0
5	786		1092.0		92.0		1970.0
6	54		68.0		135.0		257.0
7	29		93.0		21.0		143.0
8	41		78.0		4.0		123.0
9	468		1125.0				1593.0
10	25		1575.0		4.0		1604.0
11	4		1136.0		3.0		1143.0
12			4.0				4.0
Grand Total	1407.0	0	7724.0	0	278.0	0	9409.0

Table 1c. Catch and catch rates of yellowtail, by-catch rates and average depth for the 2000 yellowtail fishery.

	Avg catch per set	**Avg catch rate (t per hour)**			**Avg**			
Month	**Yellowtail**	**Yellowtail**	**Plaice**	**Cod**	**Depth**	**Grtspc**	**Codend**	**# sets**
2	1.833	0.848	0.049	0.000	64	103	151	64
3	2.909	0.970	0.061	0.000	60	121	150	365
4	2.898	0.933	0.069	0.001	68	121	151	508
5	2.635	1.123	0.114	0.005	73	122	150	699
6	1.849	0.727	0.093	0.034	75	122	149	145
7	1.451	0.462	0.017	0.006	65	122	155	73
8	2.251	0.779	0.015	0.003	73	120	155	42
9	2.186	0.737	0.048	0.019	64	119	149	716
10	2.426	0.869	0.045	0.029	58	120	149	653
11	3.062	1.006	0.030	0.009	55	122	150	380
12	3.777	1.079	0.036	0.000	59	120	149	2
All	**2.545**	**0.910**	**0.063**	**0.013**	**64**	**120**	**150**	**3647**

Table 2. Landings and biological sampling coverage of the Canadian fishery for yellowtail, by fishing ground, by month for the 2000 yellowtail fishery. Table includes samples collected by both port samplers and fishery observers.

Fishing Ground	Month	[1] Landings (t)	[2] Catch weight sampled (t)	Percent of catch sampled (by weight)	Number samples	Number measured
3L	May	779	13.83	1.78	64	12,396
	June	54	0.65	1.20	2	543
	July	30	0.93	3.06	3	788
	August	27	1.43	5.25	5	1,312
	September	471	9.34	1.98	49	9,268
	October	27	1.24	4.63	7	1,199
	November	4				
3N	February	118	0.29	0.25	1	312
	March	1059	16.88	1.59	99	6,365
	April	1454	21.50	1.50	110	21,078
	May	947	12.20	1.30	68	14,782
	June	71	2.36	3.30	15	2150
	July	75	2.30	3.06	8	2103
	August	68	1.84	2.68	5	1,775
	September	1094	16.01	1.46	71	15,373
	October	1553	25.62	1.65	122	23,381
	November	1158	17.83	1.54	87	16,792
	December	8				
3O	March	2	0.25	11.07	1	261
	April	18	0.53	2.99	3	582
	May	115	1.27	1.10	5	1,126
	June	143	6.07	4.25	32	5,356
	September	16				
	October	4				
	November	3	0.11	3.43	1	104
All	February	118	0.29	0.25	1	312
	March	1061	17.13	1.61	100	16,626
	April	1472	21.62	1.47	111	20,989
	May	1841	27.08	1.47	134	26,342
	June	268	9.08	3.38	49	8,049
	July	105	3.22	3.06	11	2,891
	August	96	3.27	3.41	10	3,087
	September	1566	25.35	1.62	120	24,641
	October	1584	26.85	1.70	129	24,580
	November	1165	17.83	1.53	87	16,572
	December	8				

[1] Observed catch weight adjusted to landings
[2] Total weight of fish samples

Table 3a. Breakdown of all species captured during the 1998 yellowtail fishery.

Species	# sets	Kept Wt (t)	Discard Wt (t)	Total Wt (t)	% Kept	% Discarded	% of Catch	t per hour
Atl herring	1	0.00	0.00	0.00	0.00%	0.00%	0.000%	0.000
Redfish	1	0.00	0.00	0.00	0.00%	0.00%	0.000%	0.000
Sea urchin	1	0.00	0.00	0.00	0.00%	0.00%	0.000%	0.000
Lanternfish	1	0.00	0.00	0.00	0.00%	0.00%	0.000%	0.000
Cusk	1	0.00	0.00	0.00	0.00%	0.00%	0.000%	0.001
Silver hake	1	0.00	0.00	0.00	0.00%	0.00%	0.000%	0.001
Sponges	1	0.00	0.00	0.00	0.00%	0.00%	0.000%	0.001
Sabinea sp	1	0.00	0.01	0.01	0.00%	100.00%	0.000%	0.002
Starfish	3	0.00	0.01	0.01	0.00%	100.00%	0.000%	0.001
Squid (Illex)	7	0.00	0.01	0.01	0.00%	100.00%	0.000%	0.000
Spiny dogfish	4	0.00	0.01	0.01	0.00%	100.00%	0.000%	0.001
Lumpfish	10	0.00	0.03	0.03	0.00%	100.00%	0.001%	0.001
Northern wolfish	7	0.02	0.03	0.05	40.00%	60.00%	0.001%	0.002
Spotted wolfish	1	0.05	0.00	0.05	100.00%	0.00%	0.001%	0.015
Monkfish	6	0.04	0.02	0.06	66.67%	33.33%	0.001%	0.003
Cnidaria	9	0.00	0.07	0.07	0.00%	100.00%	0.002%	0.002
Capelin	39	0.00	0.07	0.07	0.00%	100.00%	0.002%	0.001
White hake	18	0.09	0.00	0.09	100.00%	0.00%	0.002%	0.002
Sandlance	126	0.00	0.16	0.16	0.00%	100.00%	0.004%	0.000
Toad crab	180	0.00	0.93	0.93	0.00%	100.00%	0.022%	0.001
Haddock	63	0.39	0.01	0.40	97.50%	2.50%	0.009%	0.002
Eelpouts	139	0.16	0.29	0.45	35.56%	64.44%	0.011%	0.001
Snow crab	257	0.00	0.93	0.93	0.00%	100.00%	0.022%	0.001
Striped wolfish	133	1.46	0.00	1.46	100.00%	0.00%	0.034%	0.004
Halibut	79	1.69	0.02	1.71	98.83%	1.17%	0.040%	0.007
Turbot	3	1.92	0.00	1.92	100.00%	0.00%	0.045%	0.275
Sea raven	474	5.58	2.46	8.04	69.40%	30.60%	0.189%	0.006
Sea cucumber	366	0.00	10.16	10.16	0.00%	100.00%	0.239%	0.009
Witch	1,234	14.56	0.02	14.58	99.86%	0.14%	0.344%	0.004
Sculpins	900	32.76	6.00	38.76	84.52%	15.48%	0.913%	0.010
Skates	1,611	9.45	84.28	93.73	10.08%	89.92%	2.209%	0.019
Cod	1,298	98.93	0.00	98.93	100.00%	0.00%	2.331%	0.025
Plaice	1,704	175.92	0.00	175.92	100.00%	0.00%	4.145%	0.034
Yellowtail	**1,707**	**3,794.00**	**1.13**	**3,795.13**	**99.97%**	**0.03%**	**89.430%**	**0.738**
Total		4,137.02	106.65	4,243.67				

Table 3b. Breakdown of all species captured during the 1999 yellowtail fishery.

Species	# sets	Kept Wt (t)	Discard Wt (t)	Total Wt (t)	% Kept	% Discarded	% of Catch	t per hour
John Dory	1	0.00	0.00	0.00	100.00%	0.00%	0.000%	0.0005
Squid Ns	1	0.00	0.00	0.00	0.00%	100.00%	0.000%	0.0003
N Wolfish	1	0.00	0.00	0.00	100.00%	0.00%	0.000%	0.0008
Atl Herring	2	0.00	0.00	0.00	100.00%	0.00%	0.000%	0.0005
Mackerel	3	0.00	0.00	0.00	50.00%	50.00%	0.000%	0.0004
At Hkear Sculpin	1	0.00	0.01	0.01	0.00%	100.00%	0.000%	0.0033
Redfish	1	0.00	0.01	0.01	0.00%	100.00%	0.000%	0.0033
Roughnose Gren	1	0.02	0.00	0.02	100.00%	0.00%	0.000%	0.0044
Black Dogfish	5	0.00	0.02	0.02	0.00%	100.00%	0.000%	0.0013
Blue Shark	1	0.00	0.02	0.02	0.00%	100.00%	0.000%	0.0053
Sea Urchin	23	0.00	0.03	0.03	0.00%	100.00%	0.000%	0.0007
Spiny Dogfish	13	0.00	0.03	0.03	0.00%	100.00%	0.000%	0.0007
Common Lumpfish	13	0.00	0.04	0.04	0.00%	100.00%	0.000%	0.0009
Illex	31	0.01	0.03	0.04	28.52%	71.48%	0.000%	0.0004
Monkfish	6	0.04	0.00	0.04	100.00%	0.00%	0.000%	0.0019
Turbot	1	0.06	0.00	0.06	100.00%	0.00%	0.000%	0.0196
Capelin	27	0.00	0.07	0.07	0.00%	100.00%	0.000%	0.0010
Sandlance	164	0.00	0.21	0.21	0.00%	100.00%	0.000%	0.0004
Sp Wolfish	15	0.30	0.00	0.30	100.00%	0.00%	0.000%	0.0052
Hyas corarctatus	87	0.00	0.31	0.31	0.00%	100.00%	0.000%	0.0011
Toad Crab Ns	197	0.00	0.53	0.53	0.00%	100.00%	0.010%	0.0009
White Hake	100	0.67	0.00	0.67	100.00%	0.00%	0.010%	0.0018
Eelpout Ns	288	0.99	0.07	1.06	93.58%	6.42%	0.010%	0.0013
S H Sculpin	89	0.50	1.34	1.84	27.04%	72.96%	0.030%	0.0057
Snow Crab	330	0.00	2.15	2.15	0.00%	100.00%	0.030%	0.0024
Halibut	78	2.30	0.01	2.31	99.53%	0.47%	0.030%	0.0082
Haddock	276	3.05	0.00	3.05	99.96%	0.04%	0.040%	0.0030
Hyas Araneas	532	0.00	3.26	3.26	0.00%	100.00%	0.050%	0.0021
St Wolfish	262	5.73	0.01	5.74	99.89%	0.11%	0.080%	0.0064
Sea Cucumber	484	0.00	8.63	8.63	0.00%	100.00%	0.120%	0.0054
Witch	656	9.71	0.03	9.74	99.68%	0.32%	0.140%	0.0045
Sea Raven	481	3.25	9.24	12.49	26.01%	73.99%	0.170%	0.0076
Lh Sculpin	702	15.72	5.32	21.04	74.72%	25.28%	0.290%	0.0089
Sculpin Ns	942	13.89	12.96	26.85	51.72%	48.28%	0.370%	0.0083
Skates Ns	2273	2.68	87.54	90.21	2.97%	97.03%	1.250%	0.0120
Cod	2047	93.60	0.00	93.60	100.00%	0.00%	1.300%	0.0144
Plaice	2641	314.10	0.12	314.22	99.96%	0.04%	4.360%	0.0374
Yellowtail	**2673**	**6608.36**	**0.64**	**6609.00**	99.99%	0.01%	91.690%	**0.7766**
Total		7,074.98	132.63	7,207.60				

Table 3c. Breakdown of all species captured during the 2000 yellowtail fishery.

Species	# sets	Kept Wt (t)	Discard Wt (t)	Total Wt (t)	% Kept	% Discarded	% of Catch	t per hour
Atl. Herring	1	0	0	0	0.00%	100.00%	0.000%	0.0003
Dusky Seasnail	1	0	0	0	0.00%	100.00%	0.000%	0.0004
RH Grenadier	1	0	0	0	0.00%	100.00%	0.000%	0.0004
Pandalus borealis	1	0	0	0	0.00%	100.00%	0.000%	0.0005
Iceland scallop	1	0	0	0	0.00%	100.00%	0.000%	0.0004
Neolithodes grim	1	0	0	0	0.00%	100.00%	0.000%	0.0003
Grenadier NS	1	0	0	0	0.00%	100.00%	0.000%	0.0007
Lithodes maja	1	0	0	0	0.00%	100.00%	0.000%	0.0006
Mailed sculpin	2	0	0	0	0.00%	100.00%	0.000%	0.0003
Loligo pealei	1	0	0	0	0.00%	100.00%	0.000%	0.0010
Black dogfish	1	0	0.01	0.01	0.00%	100.00%	0.000%	0.0020
Lumpfishes NS	1	0	0.01	0.01	0.00%	100.00%	0.000%	0.0017
Atl hookear sculpin	3	0	0.01	0.01	0.00%	100.00%	0.000%	0.0006
Sea urchin	6	0	0.01	0.01	0.00%	100.00%	0.000%	0.0003
Squid NS	7	0	0	0.01	0.00%	0.00%	0.000%	0.0004
Illex	8	0	0.01	0.01	0.00%	100.00%	0.000%	0.0004
Spiny dogfish	5	0	0.02	0.02	0.00%	100.00%	0.000%	0.0010
Pollock	3	0.03	0	0.03	100.00%	0.00%	0.000%	0.0031
Spider crab ns	15	0	0.03	0.03	0.00%	100.00%	0.000%	0.0007
Nor wolffish	9	0.04	0	0.04	100.00%	0.00%	0.000%	0.0016
Harp seal	1	0	0.05	0.05	0.00%	100.00%	0.000%	0.0300
Nfld lumpfish	8	0	0.05	0.05	0.00%	100.00%	0.000%	0.0021
Greenland cod	1	0.06	0	0.06	100.00%	0.00%	0.001%	0.0171
Flounder NS	1	0.09	0	0.09	100.00%	0.00%	0.001%	0.0300
Spot wolffish	9	0.1	0	0.1	100.00%	0.00%	0.001%	0.0034
SH sculpin	46	0	0.14	0.14	0.00%	100.00%	0.001%	0.0011
Sea urchin	150	0	0.15	0.15	0.00%	100.00%	0.001%	0.0004
Sandlance	170	0	0.19	0.19	0.00%	100.00%	0.002%	0.0007
Capelin	78	0	0.22	0.22	0.00%	100.00%	0.002%	0.0012
Monkfish	19	0.19	0.05	0.24	79.17%	20.83%	0.002%	0.0041
Common Lumpfish	78	0	0.32	0.32	0.00%	100.00%	0.003%	0.0014
Toad crab NS	327	0	0.52	0.52	0.00%	100.00%	0.005%	0.0006
White jhake	74	0.5	0.02	0.53	94.34%	3.77%	0.005%	0.0022
Hyas corarctatus	221	0	0.98	0.98	0.00%	100.00%	0.010%	0.0015
Eelpouts NS	242	0.18	0.96	1.14	15.79%	84.21%	0.011%	0.0016
Attl halibut	64	1.32	0.05	1.37	96.35%	3.65%	0.013%	0.0073
Snow Crab	593	0	1.53	1.53	0.00%	100.00%	0.015%	0.0009
Hyas areneaus	797	0	2.98	2.98	0.00%	100.00%	0.029%	0.0013
St Wolffish	217	5.35	0.02	5.37	99.63%	0.37%	0.052%	0.0081
Witch	700	6.43	0.11	6.54	98.32%	1.68%	0.063%	0.0030
Haddock	279	12.16	0.03	12.19	99.75%	0.25%	0.118%	0.0136
Sea cucumber	1,099	0	15.22	15.22	0.00%	100.00%	0.148%	0.0045
Sculpin NS	802	0	19.27	19.27	0.00%	100.00%	0.187%	0.0079
Sea Raven	1,069	0	23.61	23.61	0.00%	100.00%	0.229%	0.0071
LH Sculpin	1,568	0	31.67	31.67	0.00%	100.00%	0.307%	0.0065
Cod	1,990	125.94	0.08	126.02	99.94%	0.06%	1.222%	0.0208
Skates Ns	2,995	7.54	156.51	164.05	4.60%	95.40%	1.591%	0.0180
Plaice	3,503	616.02	0.33	616.35	99.95%	0.05%	5.976%	0.0591
Yellowtail	**3,519**	**9,282.03**	**0.97**	**9,283.00**	99.99%	0.01%	90.003%	**0.8829**
Total		10,057.98	256.13	10,314.13				

Table 4 – Statistics of yellowtail sizes in the commercial fishery in 2000.

Sex	NAFO Div	Landed Wt (t)	cm MEAN	MEDIAN	STDEV	MIN	MAX	MODE	# of fish
Male	3L	1,407,000	*36.8*	*36.5*	*2.9*	*20*	*50*	*37*	*1,035,433*
Female	3L		*39.1*	*38.5*	*3.7*	*24*	*54*	*38*	*1,517,583*
Male	3N	7,724,000	*36.2*	*35.5*	*3.5*	*10*	*51*	*37*	*5,103,244*
Female	3N		*38.9*	*38.5*	*4.1*	*10*	*63*	*38*	*9,793,830*
Male	3O	278,000	*36.4*	*35.5*	*3.3*	*23*	*47*	*36*	*222,451*
Female	3O		*39.9*	*39.5*	*4.2*	*20*	*55*	*40*	*288,174*
Male	3LNO	9,409,000	*36.3*	*35.5*	*3.4*	*10*	*51*	*37*	*6,361,129*
Female	3LNO		*39.0*	*38.5*	*4.0*	*10*	*63*	*38*	*11,599,587*
Both sexes	**3LNO**		37.7	37.0	3.7	10.0	57.0	37.5	17,960,716

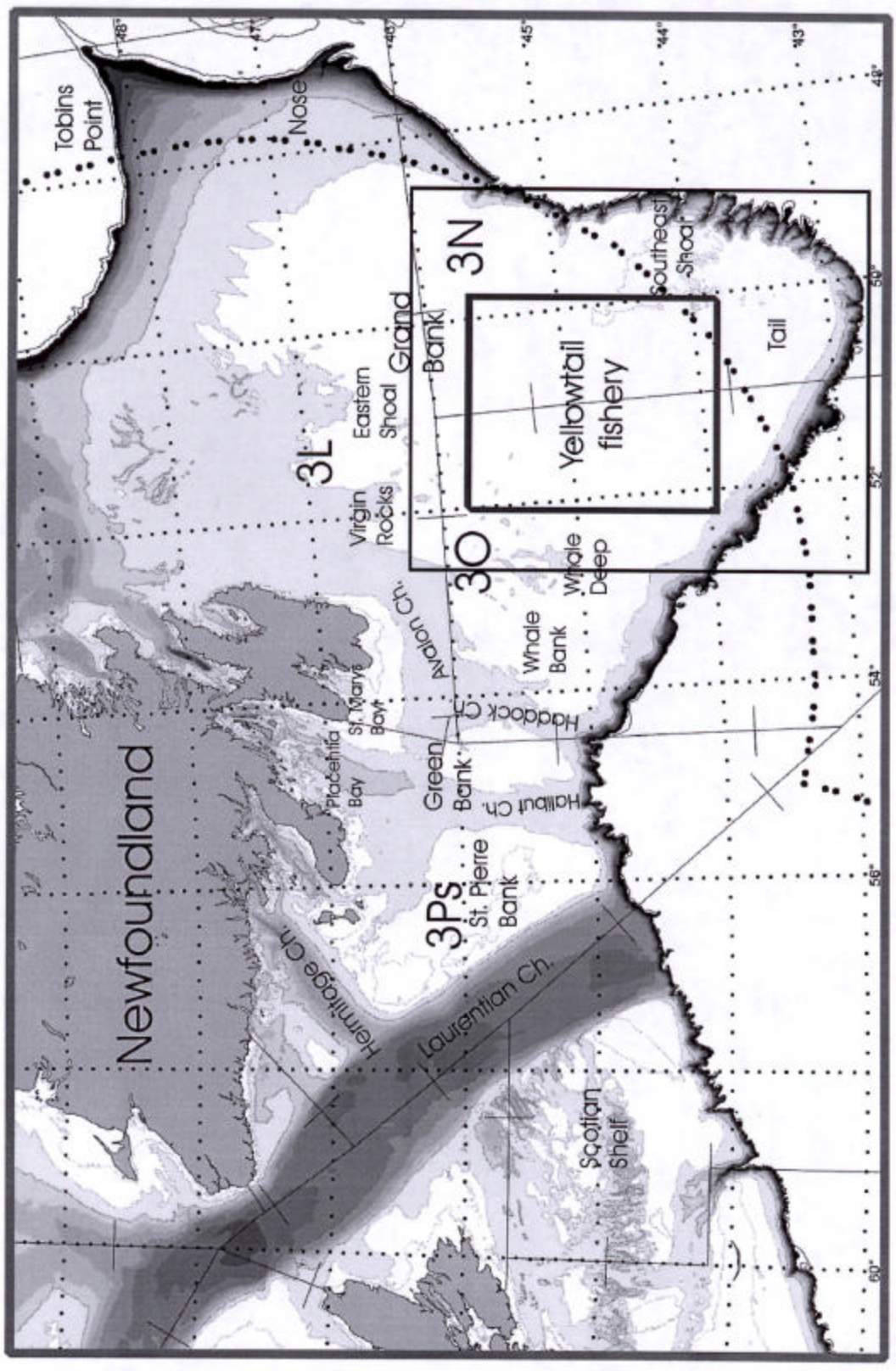

Figure 1. Features of the Grand banks showing NAFO Divisions, the 200 mile limit, specific locations and bathymetry (0 to 450 m by 50 m then 500 to 1000 m by 100m). The inner box illustrates the extent of the 1998 yellowtail fishery. The outer box shows the area illustrated in subsequent map figures.

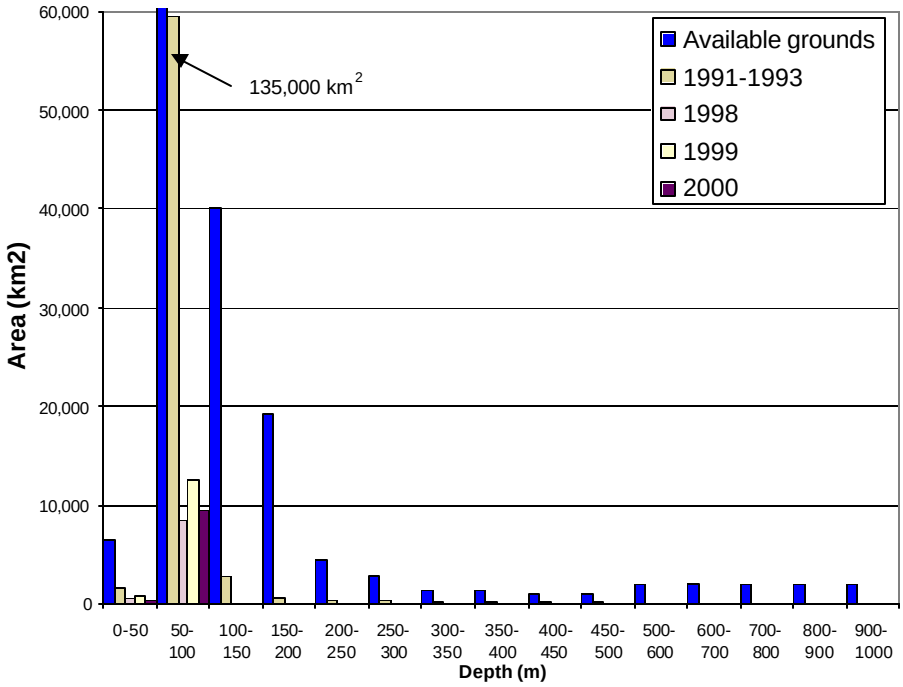

Figure 2. Area (km^2) of the Grand Banks in comparison the extent of area fished for yellowtail flounder in 1991-93 (mixed fishery for yellowtail, plaice and cod), 1998, 1999 and 2000. Available area at 50-100 m was 135,000 km^2.

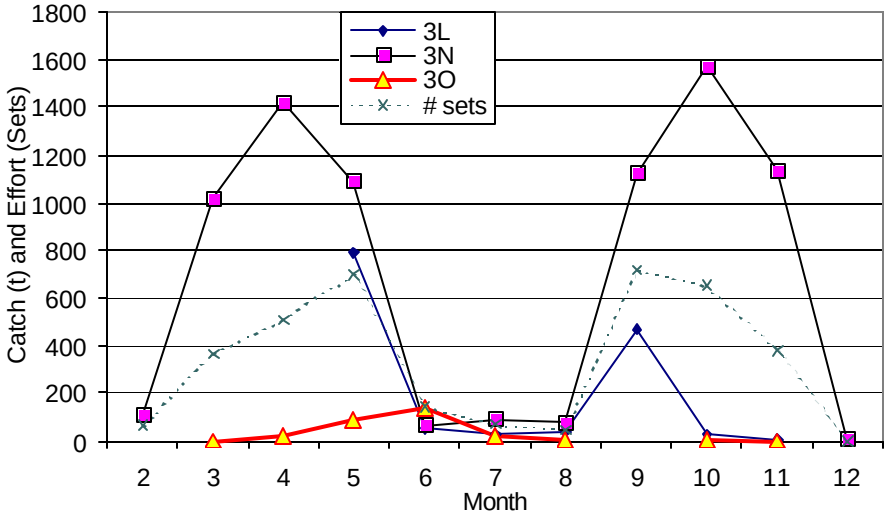

Figure 3. Monthly trends in catch and effort for the 2000 yellowtail fishery. Solid lines depict catch (t) by NAFO Division.

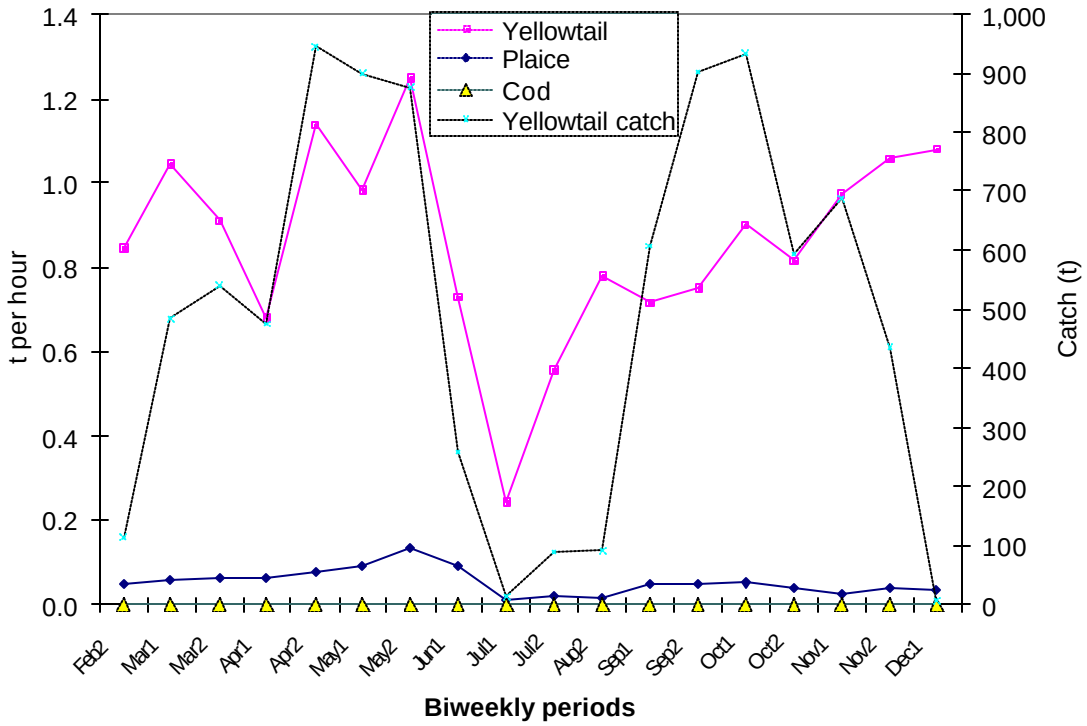

Figure 4. Biweekly trends in catch rate (t per hour) for the 2000 yellowtail fishery (solid lines). Dashed line depicts yellowtail catch.

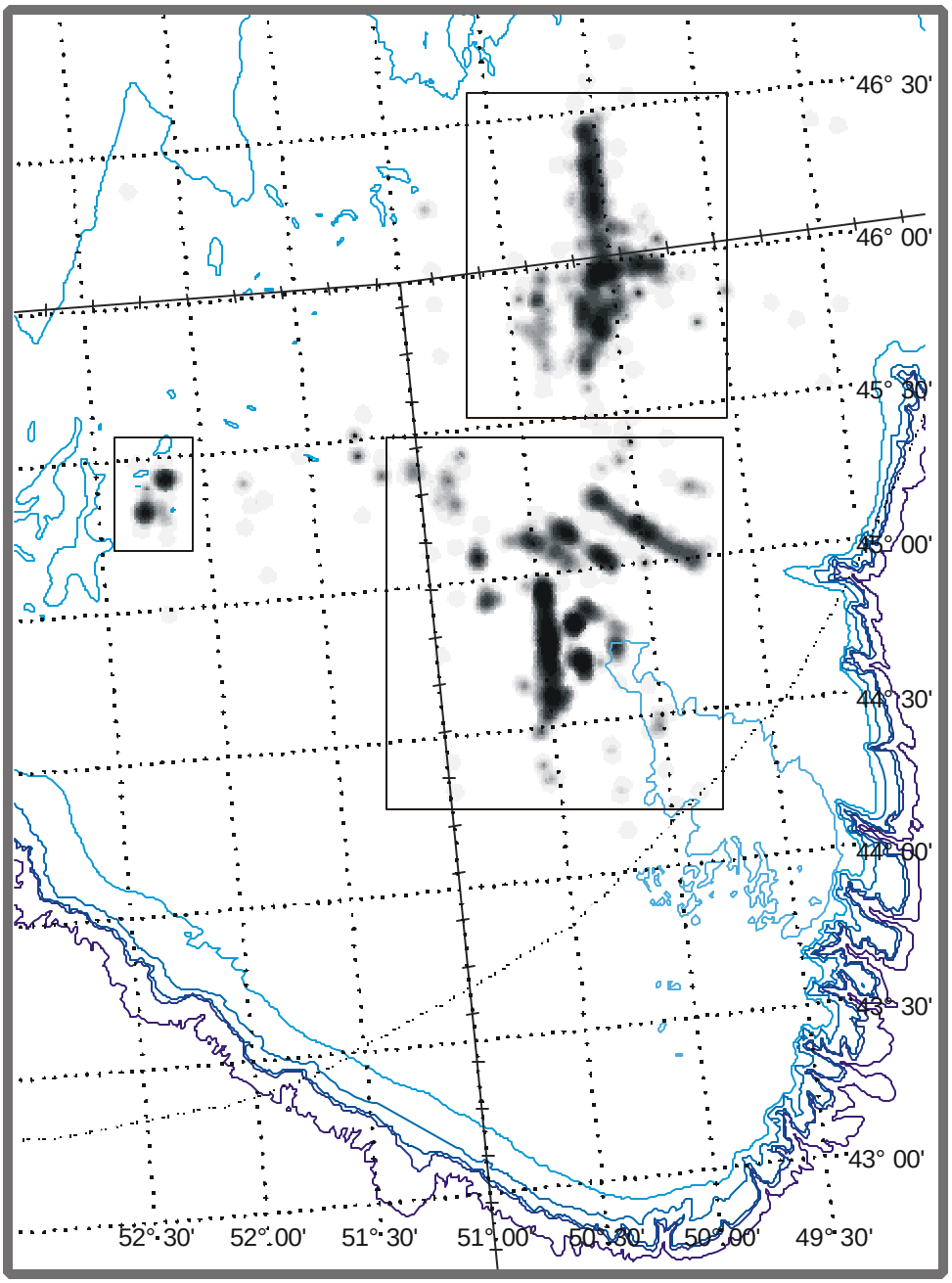

Figure 5a. Fishing grounds for yellowtail flounder in 2000. Darker grey shades denote more densely fished areas. Refer to Fig. X for a description of catch rates within fishing density classes.

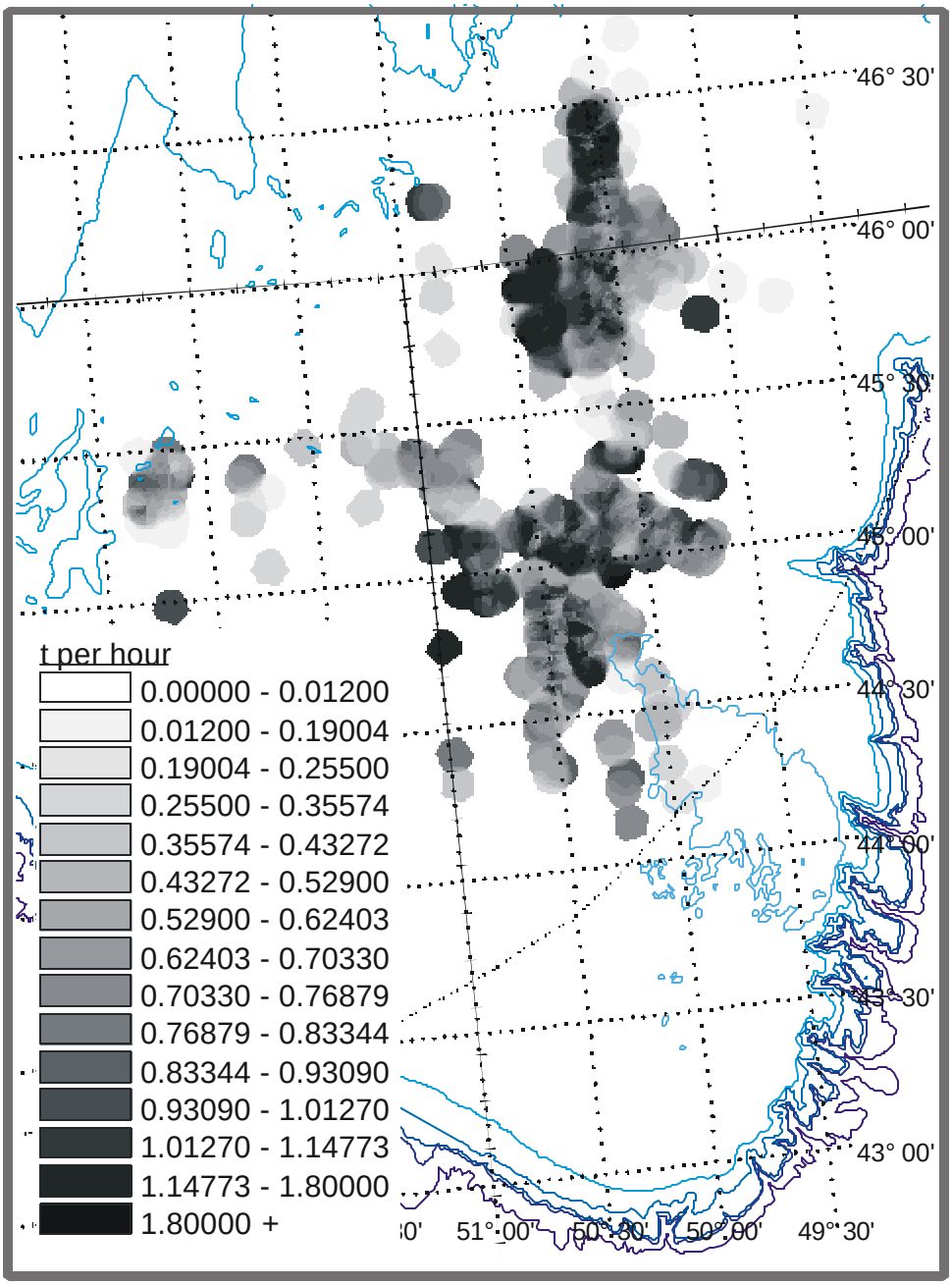

Figure 6a. Density (catch per hour) of yellowtail from the fishery for the 2000 fishery on the Grand Banks.

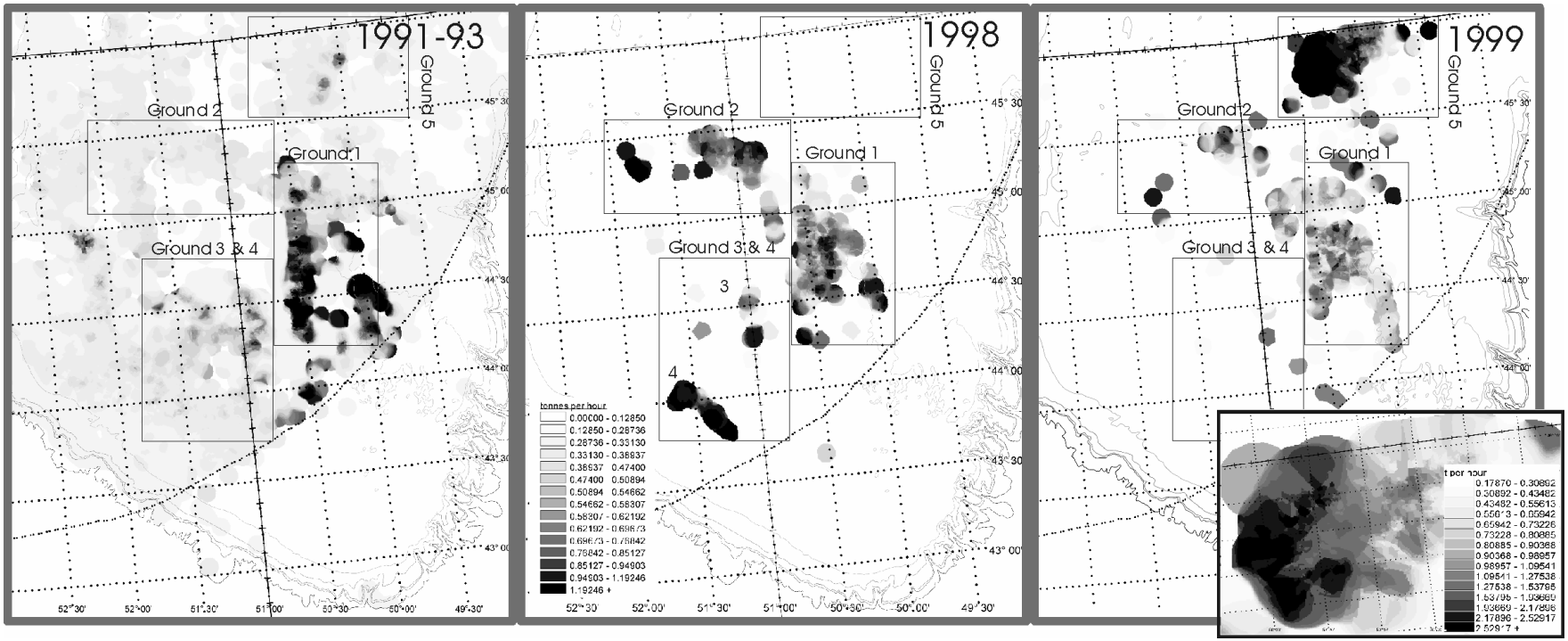

Figure 6b. Fishing grounds for yellowtail flounder in 1991-1993 (left panel), 1998 and 1999. Darker grey shades denote higher catch rates of yellowtail.

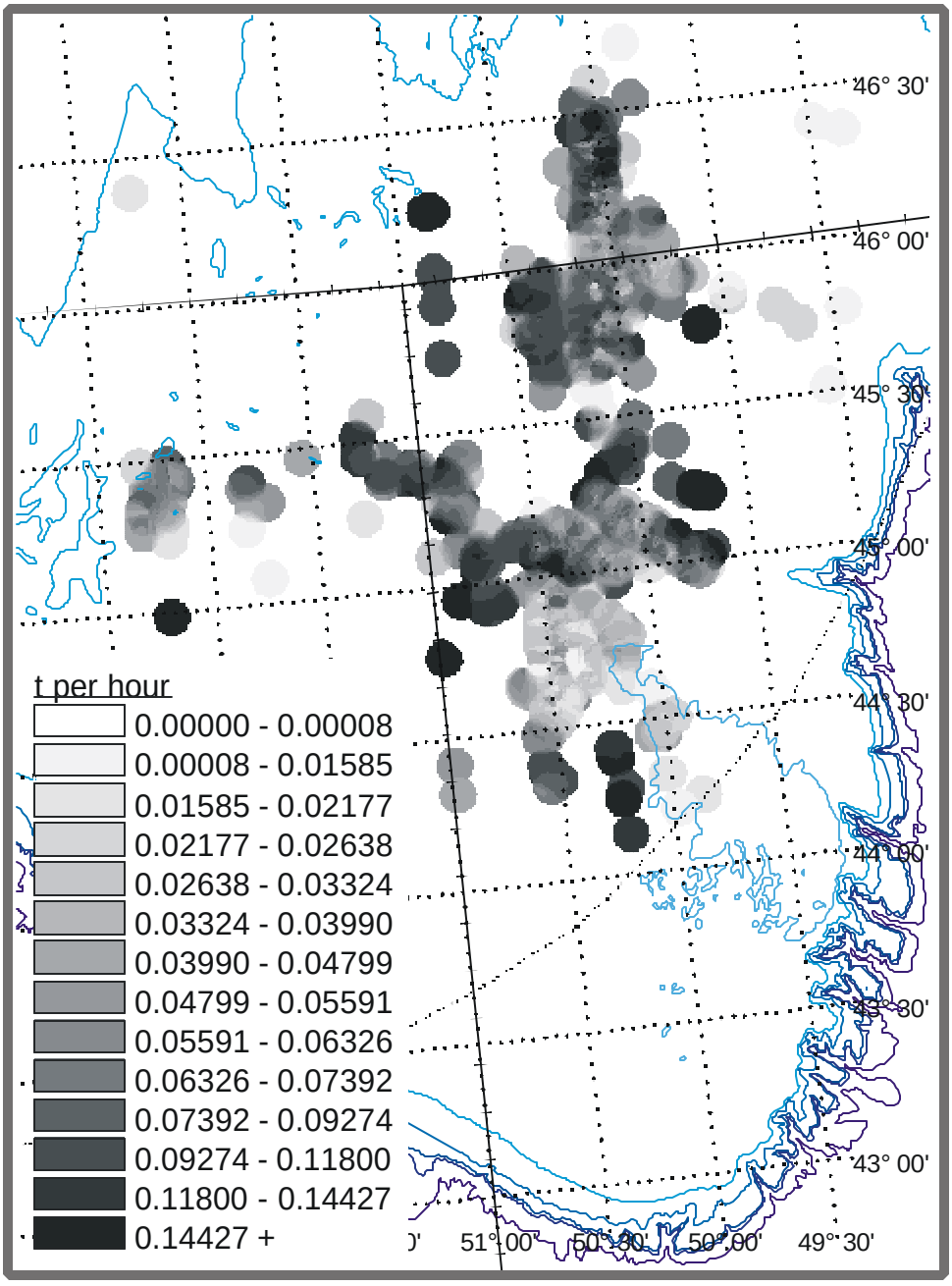

Figure 7. Density (catch per hour) of American plaice from the yellowtail fishery for 2000 on the Grand Banks.

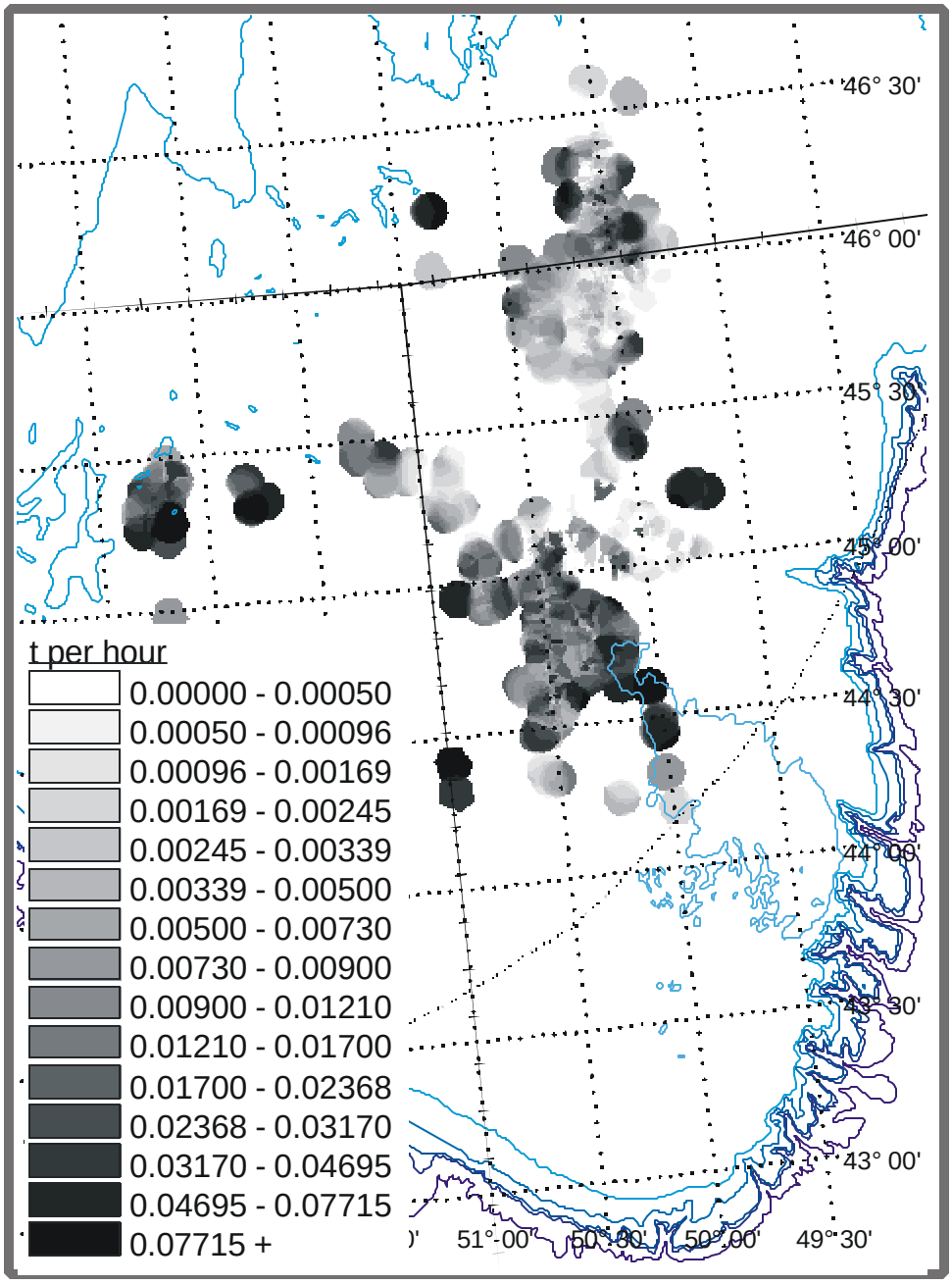

Figure 8. Density (catch per hour) of cod from the yellowtail fishery for 2000 on the Grand Banks.

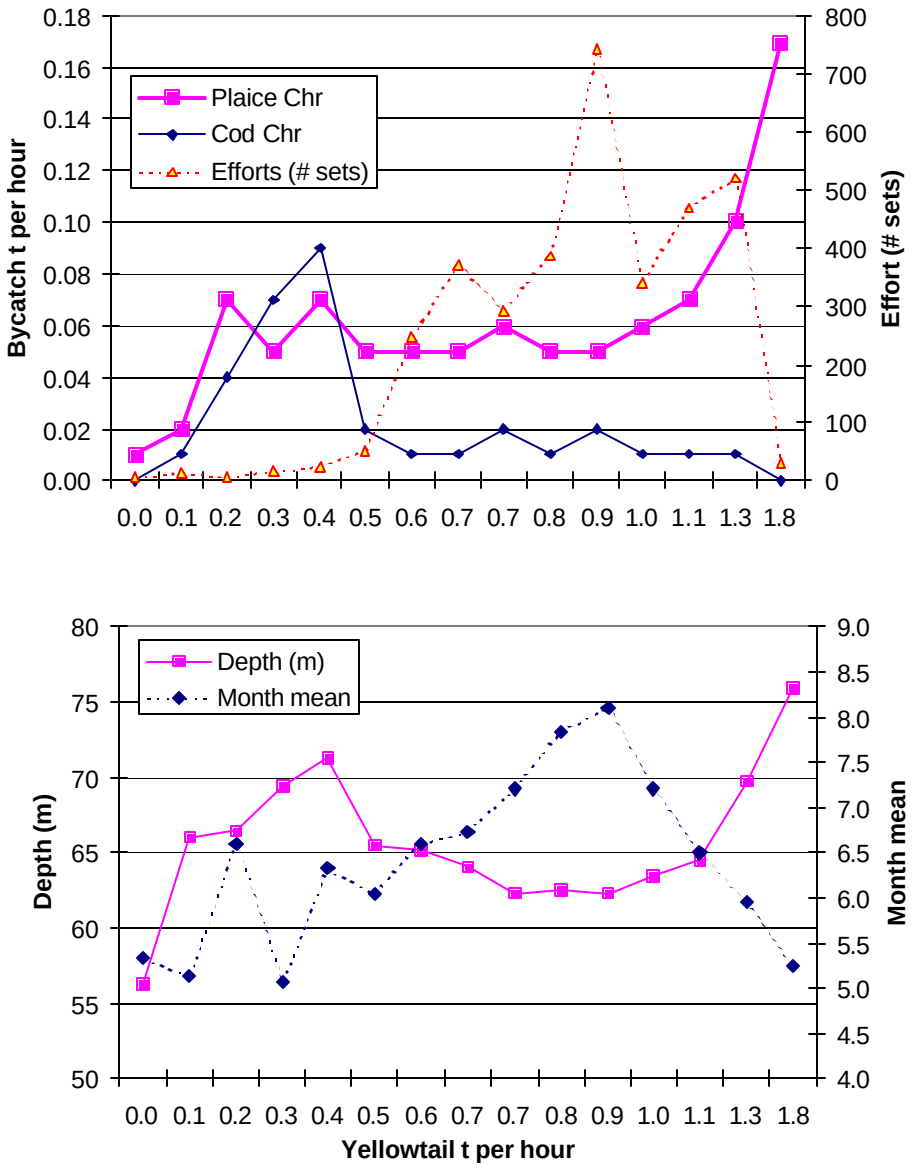

Figure 9. By-catch per hour (cod and plaice), effort, depth and month with respect to yellowtail catch per hour for the 2000 yellowtail fishery.

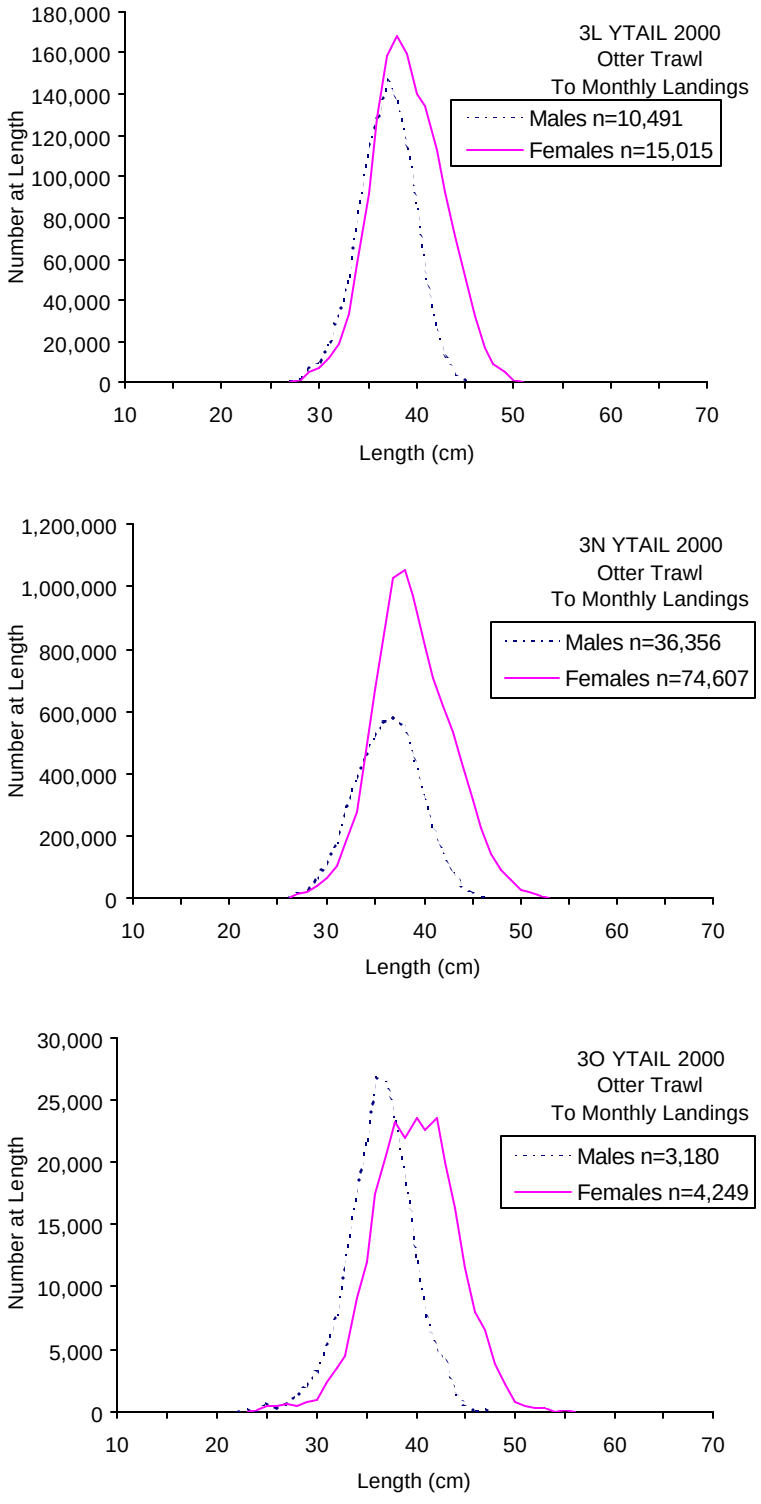

Figure 10a. Frequency of numbers of yellowtail by length taken from the 2000 fishery, by NAFO Division.

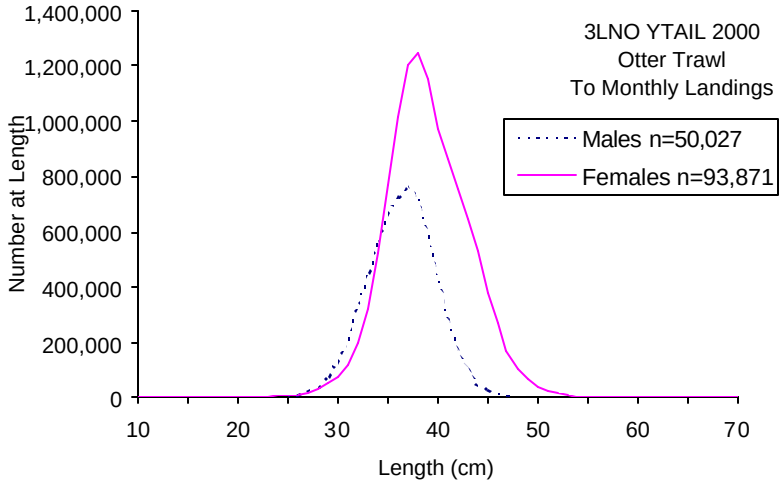

Figure 10b. Frequency of numbers of yellowtail by length taken from the 2000 fishery, across all NAFO Division.