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A Re-emerging Fishery – Description of the 1998 Yellowtail Flounder Fishery on the Grand Banks with a Comparison to the Historic Effort

by

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Abstract

Intense monitoring of the re-emerging 1998 yellowtail fishery on the Grand Banks 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 fishery starting on Aug. 1 and ending in mid November was prosecuted on 4 distinct fishing grounds covering 6.6% of the total area of the Grand Bank where bottom depth was less than 100 m. In contrast to the past practise of taking yellowtail in a mixed fishery on the Grand Bank, yellowtail was successfully exploited as a single target species by concentrating effort where yellowtail was most abundant. Bycatch levels of cod (2.3%) and plaice (4.2%) were also controlled by this concentration of effort where the bycatch species were less abundant. The deployment of an excluder grate also contributed to the low bycatch levels, particularly cod. Size of fish taken and particularly ratio of males to females in the catch was observed to differ among the 4 grounds fished. Proportion of males was much higher on the more northerly Ground 2 than other areas fished. Over all areas, average size of males and females in the catch was 36.5 and 39.5 cm respectively Numbers of small fish, those less than 26 cm (juveniles) and those less than 30 cm (management cut-off) in the catches constituted only 0.91%and 5.31% respectively, a very small percentage of the catch. A total of 7.3 million individuals were estimated to have been removed by the fishery. The dominant ages in the catch were 6 to 8 and this age composition of removals was consistent across grounds. As well, the period of the fishery concentrated on a post-spawning fish.

Introduction

Yellowtail flounder (*Pleuronectes ferruginea*) is distributed off Newfoundland across much of the Grand Banks within NAFO 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. In 1960, during an expansion of fishing effort to the offshore, a trawl fishery was initiated in Divisions 3L, 3N and 3O. 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*). Over this period, total annual catches varied considerably ranging between 7 t in 1960, the initial year 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) 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 bycatch 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 but that steps would be required to minimize bycatch of cod and American plaice still under moratorium. The Council stipulated that the fishery be carefully monitored and sampled including 100% coverage by Canadian fishery observers. The data collected by observers and port samplers facilitated a detailed description of the newly re-opened Canadian fishery. This paper is a synthesis of these data examining spatial and temporal aspects of catch of yellowtail, bycatch and effort and size, maturity and number of fish at age in the catches. The 1998 effort is compared to the pre-moratorium fishery and patterns are compared to distribution of yellowtail derived from research surveys. The paper also looks at the relationship of catch rate and fish size to various codend mesh sizes used and also examines the effect of a sorting grate attachment on (by)catch rates and catch composition.

The fishery

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, it was noted that 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. A quota for the same amount was set for 1998. Of this, 3,900 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; 202 t for Nova Scotia based vessels and 3,581 t for Newfoundland vessels for a total of 3,846 t. The remaining 54 t was allocated to Canadian vessels 65-100 ft.
An Atlantic Canada Conservation Harvesting Plan (CHP) for vessels greater than 100 ft was used to define the parameters of the yellowtail fishery. 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. It was also recommended that fishing in NAFO Div. 3L be prohibited given the low biomass index in this area (Div. 3L was historically not an area of dense concentration of yellowtail and thus not an important fishing ground for this species). In NAFO Divisions 3N and 3O, fishing was permitted only inside Canada’s 200 mile limit. The CHP also specified use of a minimum 145 mm diamond mesh in the codend. An earlier recommendation for use of 155 mm mesh was not implemented. One hundred percent observer coverage was stipulated and a small fish protocol was employed by the observers to avoid excessive catch of small (not yet mature) fish. For monitoring purposes, yellowtail were considered undersized if less than 30 cm.

Given that a moratorium was still in effect in Divisions 3N and 3O for American plaice and cod, strict bycatch provisions were included in the CHP. 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 invokation of a test fishery before reopening. Both the small fish and bycatch provisions were monitored within quadrants defined by lines at 44^0 46’ N latitude and 50^0 45’ W longitude (refer to Fig. 2 for an illustration of the quadrants). All requirements of the CHP were to be monitored by 100% fishery observer coverage and additionally, landings were monitored dockside. In total, 9 vessels participated in the 1998 large vessel (greater than 100 ft) fishery. The Canadian 65-100 ft vessel effort was not monitored.

Although vessels were not required by regulation to deploy sorting grates for the purpose of reducing bycatch, all Newfoundland vessels used a rigid grate as a measure to maintain bycatch 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 bycatch could be reduced at locations where they mixed with flatfish species including yellowtail.

Methods

Fishery observers collected geo-referenced information on the catch and effort and other details of the capture of yellowtail such as gear configuration and fishing strategies from the 1998 large vessel yellowtail fishery in a manner specified in Kulka and Firth (1987). A comparison of total catch of yellowtail as recorded by the observers (3,555 t) to landing statistics recorded by Fisheries & Oceans, Resource Allocation (3,795 t) indicated that observer catch was 94% of the reported landings on NAFO Divisions 3N and 3O. It is estimated that a total of 1,777 fishing sets were prosecuted in the 1998 yellowtail fishery. A ratio of the landed to the observed catch of yellowtail was used to adjust observed bycatch weight to an estimate of total weight caught for each species taken in the fishery.

Table 1a specifies by month and fishing ground the number of sets from the observed fishery that were used for the spatial analysis and as well, it provides a summary of the associated catch, effort, bycatch, depth and gear parameters. The observed fishery extended from Aug. to Nov. over four separate and restricted areas. Table 1b shows the effort for the Canadian annual fall research survey. The research survey was spatially more extensive covering the entire Grand Bank and overlapped in time with the commercial fishery taking place during Oct.-Dec. Potential mapping in SPANS (Anon 1997) was used to convert the geo-referenced commercial catch and effort and fall research trawl point data to surface maps describing the distribution of the fishery and the distribution of yellowtail in NAFO Divisions 3N and 3O. Point data consisting of catch (tonnes) per hour for the commercial fisheries data and standardised catch (kg) per tow were imported into SPANS using latitude and longitude at the start of the set as the geo-reference and catch rate as the measure of local fish density. Spatial extent and density of fishing effort was examined also using potential mapping to produce effort distribution maps.

The potential mapping method transforms points (fishing sets) to a continuous surface spatially depicting differential densities of fish (catch rate subareas) or density of fishing effort (average number of 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 many (equal to the total number of sets) overlapping circular area. 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 density surface.

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. 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.

Different circle sizes were used for the commercial fisheries data and the research survey data because of very different average distances between sets (the commercial data points were much more closely situated than the survey points). In both cases, size of circle was increased until there were no gaps in the resulting surface thus defining optimal size. Further increasing circle size increasingly smoothes the data to a point where a single circle encompassing all points results in a single stratum with an average catch rate (density estimate) of all points. Thus, the smallest circle that can provide complete coverage of the survey area, the more detailed the definition of spatial variation of fish density (refer to Kulka 1998 for a detailed explanation of circle size selection).

For the commercial fisheries data, circle diameters ranging between 1 and 8 km were tested to determine optimal circle size based on distance between sets. A circle size of 6 km was selected based on the criteria described above. Choosing this size had the added advantage that it corresponded with length of a fishing set i.e. a typical set by a trawler fishing for yellowtail in 1998 extended over 5.6 km. Thus, calculations of areas fished was done at spatial resolution of fishing activity and surfaces created by this method reflected the true extent of the fishing grounds.

For the research survey data, the distance between sampling points ranged from about 20 to 70 km. A series of circle sizes with 2 to 42 km. diameters by 2 km intervals were tested. A 38 km circle was chosen as the smallest that would create a surface with minimal gaps for the 1998 survey data in Divisions 3NO. The perimeter of the resulting density surface was constrained by the land/water boundary and the 1000 m depth contour.

Biological monitoring of the 1998 yellowtail fishery comprised the collection of catch lengths and ageing materials (otoliths) by sex. This information was gathered by fishery observers using the methods outlined in Kulka and Firth (1987). The length samples and ageing materials covered all time periods and areas fished allowing for a detailed spatio-temporal analysis of fish sizes in the catches. Data on maturity at the start of the fishery were also collected by Canadian port samplers during the first two weeks of the fishery.

Table 2 specifies the catch (landings) and sample weight, number of fish measured and number of otoliths collected for the analysis of fish size and age in the commercial catches by fishing ground and month (refer to Fig. 2 for a delineation of fishing grounds). A total of 418 length samples were taken comprising 53,712 fish measured and sexed from the catches of the yellowtail fishery. Proportion of total catch sampled was about 1.5% by weight and 0.8% by number.

A total of 2,266 otoliths were collected for ageing purposes. For all samples, weight was obtained by direct measurement. Sampling was spread proportionately across all areas and time periods although maturity was recorded only during the first two weeks of the fishery. 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 by fishing ground by quarter of the year. Delineation of data by NAFO Division was not done since the areas fished were spatially unrelated to the line between Divisions. All areas fished bordered on or overlapped Divisions 3N and 3O. Estimates were done by quarter in the same manner as was done for stock assessments. 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 & Discussion

Spatial analysis of the Canadian fishery

At depths less than 100 m, the Grand Bank is a large relatively flat area covering 136,000 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 1998 fishery for yellowtail was restricted to 8,986 km^2 or 6.6% of the Grand Bank at depths less than 100 m (Fig. 2). About half of the total area fished (4,637 km^2 or 3.4% of the total area of the Grand Bank) contained 98% of the fishing sets. Thus, fishing effort for yellowtail was highly localized.

The fishery took place at a number of distinct locations near the border of Divisions 3N and 3O (Fig. 2). For the purpose of analyzing spatial patterns in catch rates, bycatch and size of fish in the catches, the area fished was delineated by 3 boxes encompassing 4 distinct grounds observed to have been fished in 1998. Grounds 1 and 2 (Fig. 2), the major fishing areas were each assigned to a separate box for the purpose of spatial analysis. Ground 3 and 4, minor areas that are adjacent, were combined as 1 box, hereafter are referred to as Ground 3&4 are analysed as a unit. NAFO Divisions were not used in the analyses because their borders bore no relationship to distribution of the fish or the fishery.

Ground 1, the most densely fished and largest area extending over 4,010 km^2, contained 67.7% of the total effort or 1,203 sets and was centered at Lat. 44’ 45^0, Lon. 50’ 25^0. At 54 m average depth fished, this was the shallowest of all grounds. This is the area fished in closest proximity to the nursery grounds located to the south on the Southeast Shoal (Walsh 1992). As well, it was the only area fished during all months (August-November) of the fishery. The other relatively densely fished area, Ground 2 at 2,630 km^2 was 2/3^{rds} the size of Ground 1 but contained only 514 sets or 28.9% of the total effort. It was centered northwest of Ground 1 at Lat. 45’ 15^0, Lon. 51’ 00^0. Depth fished in this area averaged 71 m and fishing occurred from August to October. The other two minor Grounds 3&4 covered 1,780 km^2 but contained only 3.5% of the total effort or 62 sets. Similar to Ground 2, average depth fished was 72 m but effort took place only at the start of the fishery in August up until mid September.

Catch rate (t per hour), reflecting local density of the fish varied over the area fished. Figure 3, right panel and Table 1a show that the highest catch rates (average 1.15 t per hour) were achieved at Ground 4 although fishing effort in this area amounted to only 34 sets. Effort in this area was likely limited because of high bycatch encountered in the area. Plaice averaged about 8-9% of the total catch, exceeding the 5% regulatory limit. For the main areas, Grounds 1 and 2, catch rates were similar averaging 0.739 and 0.812 t per hour respectively over the entire period of the fishery. On Ground 1, catch rates were fairly homogeneous although slightly higher at the center of the ground and also to the southeast. Best catches on Ground 2 were taken on the northeast portion of the ground. In addition, there were a few large sets to the west.

Figure 4 shows that best catch rates of yellowtail corresponded closely with the most densely fished areas. Over the periphery of the grounds where effort density was less than 6 sets per km^2, catch rates were low averaging only about 0.4 t per hour. As a result, only 2% of the fishing effort occurred over these areas. Where fishing density exceeded 10 sets per km^2 (33% of the total area where 93% of sets occurred) catch per hour averaged about 0.7 to 0.8 t. This showed that the fleet was prosecuting the large majority of the fishery where yellowtail was most dense (where catch rate was not only highest but most consistent). In contrast, plaice and cod bycatch rates were slightly to substantially lower at the more densely fished locations. Various fisheries observers noted that the primary fishing strategy employed by captains was to start fishing on known historical grounds then to adjust location to avoid bycatch, specifically cod and plaice. The data indicated that the fleet as a whole successfully avoided excessive bycatch over the period of the fishery without negatively affecting catch rate of the target species. This demonstrated that in contrast to the past practise of taking yellowtail in a mixed fishery on the Grand Bank, yellowtail can be successfully exploited as a single target species. It should be noted that in part, maintaining low bycatches was possible because of currently low biomass of cod and plaice and also because of the use of an excluder grate described below.

Figure 5 shows that fishing location and catch rate varied by month. Aug. and Sept. were the most heavily fished periods (661 and 724 sets respectively) covering the majority of the total area fished, 59% in Aug. and 75% in Sept. Thereafter, amount and extent of effort were reduced in October (447 sets, 25% of the total grounds) and November (27 sets, 12% of the grounds). Catch rates of yellowtail were highest in November (1.487 t per hour), midrange in August and October (0.8054 and 0.879 t per hour) and lowest in September (0.632 t per hour). On a more detailed biweekly temporal scale, Fig. 6, upper panel shows that the catch rate of yellowtail declined slightly over the first 8 weeks of the fishery then rose substantially over the last 6 weeks while plaice catch rates fluctuated and cod declined over time. In spite of the increase in yellowtail rates, effort dropped off rapidly during those last 6 weeks of the as the quota was being reached (lower panel of Fig. 6). This suggests that concentrating effort later in the 1998 season (or a later start in the season) could have resulted in an even higher average catch rate of yellowtail. The lower panel of Fig. 6 also shows that average depth fished, codend mesh size and grate spacing (discussed in detail later) although variable did not change significantly over the life of the fishery (refer to Table 1a for a summary of the fishery and gear statistics by ground, by month).

Figure 3, left panel (in comparison to the 1998 fishery, right panel) shows catch rates of yellowtail achieved during the 1991-1993 period of mixed fishing on the Grand Banks, the last years prior to the closure of this (Canadian) fishery inside 200 miles. Yellowtail was also fished outside 200 miles, primarily by Spain but no geo-referenced data were available for this portion of the fishery. The 1991-93 fishing period in one respect is similar to the Canadian mixed fishery of the 1980 to 1987 years in that it covered a similar (wide) area of the bank. However, Kulka (1991) shows that the main yellowtail catches (as part of a mixed plaice/cod/yellowtail fishery) from 1980-1987 were centred slightly northeast of the 1991-1993 grounds. Similar vessels and gear, otter trawlers greater than 100 ft were used to fish both periods.

Before 1994, effort for the mixed fishery on the Grand Bank was more extensive covering about 50,000 km^2 annually or 5 times the area of the 1998 fishery and occurred over a greater period of time, Jan. to Dec. (Brodie et *al* 1997). The historic Grand Bank fishery was fished over a longer period because of larger quotas and was more spatially extensive because it targeted the more widely distributed species cod and plaice as well as yellowtail in a mixed fishery. In 1991-93, higher catch rates similar to those achieved in 1998 were restricted primarily to Ground 1. The average catch rate on Ground 1 during Aug.-Nov. in 1991-93 was 0.715 t per hour, almost identical to the 0.739 t per hour taken in 1998 during the same time period. However, the catch rates for Grounds 2-4 and peripheral areas averaged only 0.30 t per hour in 1991-93, a little more than 1/3rd of the 1998 rates for the same area and time period. This suggests that during the Aug.-Nov. period, dense concentrations of yellowtail were more extensive in 1998 (occurring over grounds) than in 1991-93 (Ground 1 only).

A total of 34 species or species groups were captured incidentally with yellowtail in the 1998 fishery as shown in Table 3. Bycatch taken with the yellowtail amounted to 449 t or 10.6% of the catch and comprised. The large majority was American plaice (4.2% of the total catch) and cod (2.3%). All of the plaice and cod were retained for landing. The only other significant bycatch was skate, primarily thorny (*Raja radiata*). Out of a catch of 94 t of skate, 90% was discarded. Small amounts of such valuable species as witch, turbot, halibut and haddock captured were kept and processed.

Based on catch rate data from the 1998 yellowtail fishery, density distribution of the two dominant bycatch species, plaice and cod are shown in Fig. 7. Plaice, generally distributed at greater depths than yellowtail was more dense (catch rate was higher) around the periphery of Grounds 1, 2 and 3 and over the entire Ground 4 where depths fished were greater. This is probably the main reason for the low level of effort fishing effort in these areas. Cod on the other hand tended to be taken in lower amounts and more variably across all grounds, lowest on Ground 2, highest on Ground 4. In general, catch rate of any species other than yellowtail was lowest on Ground 2 and this was one reason why Ground 2 was the most highly fished area. Thus, based on spatial catch rate patterns of plaice and cod observed in the 1998 fishery, best locations for minimizing bycatch of theses two species was to fish the central portions of Ground 1 and 2 and it was there that most of the 1998 fishing effort took place.

Figure 8 compares distribution of yellowtail (kg per tow) and distribution of average fish size (cm) based on fall research survey data. The upper left panel shows that fishing effort (white dots) for Ground 1 corresponded with areas of dense concentrations of yellowtail as determined from the fall research survey. However, Grounds 2-4 occurred at locations where moderate rather than dense concentrations of yellowtail were identified by the fall survey. Commercial catch rates at these locations were similar or higher than on Ground 1. The period of the survey and commercial fishery did not overlap and completely different gears were used (the Campelen survey gear employed a much smaller mesh). The fishery started earlier (Aug. vs. Oct. for the survey). Both fishery and survey occurred during October and November only. This different but overlapping time frame plus the different gears used; larger gear, larger mesh targeting larger fish for the commercial gear may account for the imperfect correspondence between high yellowtail density in the survey and fishing effort (and associated high catch rates) on Grounds 2-4 if the fish shifted their distribution at time of year or more likely, the fish were distributed differently by size.

The lower left panel of Fig. 8 shows that sets containing larger fish, averaging greater than 0.4 kg tended to be located around the periphery of the distribution of dense concentrations of yellowtail and away from the commercial fishing grounds. In these areas, density of yellowtail was lower and concentrations of American plaice was generally higher (upper right panel). Thus, fishing effort in 1998 was not distributed to optimize size of fish taken because a small gain in average size of fish caught that would occur by fishing toward the periphery of the bank would have resulted in a lower catch rate of yellowtail and an increase in bycatch of plaice. That the fleet did not concentrate its effort in these areas is consistent with fishing strategies reported to the fishery observers by various vessel captains; to minimize bycatch of plaice while maintaining adequate catch rates of yellowtail.

Yellowtail is known to inhabit shallower (but overlapping) range of depths compared with cod and plaice. Thus, shifting location to avoid bycatch usually resulted in a reduction of depth fished. Figure 9, upper panel, an analysis of catch rate of yellowtail and bycatch levels in relation to depth fished shows that yellowtail catch rates were fairly similar across the fairly narrow depth zones fished. Although higher in 81-90 m, only one set was fished in this zone. Bycatch of plaice was lowest in the shallowest areas, 41-60 m. and correspondingly, most sets were prosecuted in 51-60 m where plaice bycatch was low. Cod bycatch was lowest in 51-80 m. The low level of effort in 41-50 m may in part be the result of avoidance of cod bycatch. These patterns in bycatch rate with respect to effort intensity by depth confirms that the captains strategy for minimizing bycatch by shifting from areas where cod and plaice were more abundant (from deeper to shallower locations) was successful.

Although the fishery was exploited solely by otter trawl, gear configurations were not consistent among vessels or over time. Size of mesh in the codend varied throughout the 1998 fishery. As specified in the Conservation Harvesting Plan, the regulated minimum mesh size was 145 mm diamond. Fig. 9, lower panel shows that the actual mesh sizes used by the 9 vessels participating in the fishery ranged from 145 to 155 mm but as described below, effect of mesh size on catch rate and bycatch was confounded by spatial differences in distribution (varying density) of the various species even within Grounds. The different mesh sizes used appeared to have little effect on catch rate of yellowtail. Although catch rate for the 151-152 mm category was about 29% higher than for other sizes, this was because of an interaction with spatial variation in the distribution of yellowtail with respect to effort location. The vessels using 151 and 152 mm mesh fished the majority of their sets where yellowtail was more dense, particularly on Ground 4 (catch rates in these area was high at these locations for all mesh sizes). Other vessels using the other mesh sizes fished across all the grounds more evenly.

With respect to bycatch taken with the different mesh sizes, the 145-146 mm range captured the highest bycatch of plaice, 147-148 mm the lowest, thereafter increasing with mesh size. For cod, the bycatch levels fluctuated without trend. As previously indicated, the 9 vessels in the fishery using different mesh sizes did not fish at the same locations. As for yellowtail catch rate, the differences in bycatch rate among mesh sizes observed for both cod and plaice were confounded by spatial variation in densities of fish being fished with different mesh sizes. For example, almost double the number of sets employing 147-150 mm mesh (the mesh sizes with the lowest bycatch rates) were fished in Ground 1 where on average, bycatch rates of both cod and plaice were lower than elsewhere. Even within a ground, bycatch rate varied independent of mesh size used. Thus, within the 145-155 mm range used by the fleet in the 1998 yellowtail fishery, it appears that size of mesh used had little affect on the composition in the catches. Location fished was the apparently the most important factor influencing the catch rate of yellowtail or the bycatch levels of plaice or cod.

For the 1998 yellowtail fishery, a 5% ceiling was imposed on the bycatch of cod and plaice (refer to the section on the Fishery under the Introduction). As a result, the vessels participating in the yellowtail fishery employed a gear modification in the form of a rigid grate (industry initiative) with vertically oriented bars as described by Hickey et *al*. (1995). It was used for most of the sets as an attempt to reduce bycatch of cod and also plaice. Spacing of the vertical bars in the excluder grate varied among vessels and also changed over time for some vessels. In order to avoid exceeding the ceiling on bycatch, captains of the vessels not only shifted fishing location but also voluntarily modified their gear by placement of sorting grates near the codend. Figure 10 describes the effect of employing the sorting grate (left panel) and effect of different bar spacings (right panel) on catch rates of yellowtail, plaice and cod. Sets completed without a grate were few, only 86 of 1,665 sets observed. However Fig. 10, left panel shows that the catch rates of yellowtail, plaice and cod were lower where the grate was used. The effect on plaice and cod was substantially greater. While average yellowtail catch per hour was lower, 69% of the rate achieved when not employing a grate, plaice and cod rates were proportionately even more reduced; 36% (plaice) and 30% (cod) of the rate observed without a grate. Employment of a grate also likely affected catch composition. as with different bycatch in relation to mesh size used, bycatch levels observed with respect to different bar spaces was also likely confounded by differences in spatial distribution of the various species. However, an examination of catch rates of yellowtail, plaice and cod for sets immediately preceding and proceeding sets where no grate was used (spatially and temporally contiguous sets) showed that catch rate was higher in the majority of cases without the grate. This analysis suggests that using a grate was affective in reducing bycatch of cod and also plaice while affecting yellowtail catch rates to a lesser extent.

Fig. 10, right panel shows that different bar spacings within the range of 76 to 151 mm catch rates of the three species fluctuated without trend suggesting that different bar spacings even within the wide range used had little effect on the catch rates.

Length and Age Composition

Fisheries and Oceans, Resource Allocation landing records indicated that 3,795 t or 99% of the large vessel Canadian allocation was taken. It is this number that is used in the calculation of removals (numbers at length and numbers at age) in this section.

Length frequencies of commercial catches of yellowtail are illustrated in Figure 11 for Ground 1, Fig. 12 for Ground 2 and Fig. 13 for Ground 3&4 as well as for all Grounds combined. 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 38.3 cm and a range of 15 to 57 cm. Males averaged 36.5 cm, females 39.5 cm. Table 4, listing fish length statistics and numbers of fish caught by ground by month and as well, Fig. 14 indicate that mean and mode of males and females was consistent over time for each ground. However, the range of both males and females became increasingly restricted by about 10-12 cm between Aug. and Nov., particularly for Ground 2. There is no apparent change in gear configuration or fishing pattern over time that might have caused narrowing of the range of yellowtail taken. Thus, it appears likely that the range of lengths of fish available to the gear were becoming narrower over time, particularly on Ground 2.

Fig. 15 illustrates spatial patterns in fish size. The lower left panel shows that average length of fish caught differed substantially among areas fished. The smallest fish averaging 36.8 cm were encountered on Ground 2 while the largest fish averaging 39.6 cm were taken on Ground 3&4. Fish taken on Ground 2 were substantially smaller for two reasons. The average size of males and females were about 1 and 2 cm smaller respectively on Ground 2 compared to Ground 1 and 3&4 (Fig. 16). Secondly, a difference in ratio of males to females taken on Ground 2 (0.990) vs. Ground 1 (0.541) and 3&4 (0.581) contributed to the smaller average length of the catch from Ground 2. Considering that average size of males was about 3 cm less than for females, the much higher proportion of males on Ground 2 was the main reason for small average size of the fish taken from this area. A higher male to female ratio (above 1 and as high as 1.28 in 1995) has been observed for the research survey catches since 1984 (Walsh et al. 1998). The substantially lower ratio of males taken in commercial gear compared to survey gear and substantial differences observed among commercial fishing grounds illustrates not only the differences in selectivity of sex between different gears but also the spatial variation in the distribution of males and females. These patterns and differences suggest that interpretation of spatial information on sex composition and size on must be done with caution.

Figure 15 also shows distribution of proportion of fish below 3 cut-off lengths, below 26 cm, 30 cm and 40 cm for Grounds 1 and 2. Sampling from Ground 3&4 was limited to two samples only, not sufficient to examine spatial size related patterns. These cutoffs are related to management and scientific issues as follows: 26 cm - the length below which yellowtail are considered to be juveniles aged 1-4 (Brodie et al., 1998), 30 cm - for monitoring purposes, yellowtail were considered undersized if less than 30 cm according to the Conservation Harvesting Plan, and 40 cm – ages 1 to 7, the large majority of ages (excluding fish considered to be “large” from industry grid surveys (Walsh et al., 1999).

The area with the largest proportion of fish less than 26 cm i.e. where juvenile fish comprised greater than about 1.5% of the catch occurred sporadically throughout much of Ground 1 but not on Ground 2. Further, the highest levels of juveniles in the catches were observed at the southern extent of Ground 1. This area borders on the northwest edge of the nursery ground as reported by Walsh (1992) where one would expect the greatest proportion of juveniles to occur. Similarly, the largest proportions of fish below 30 cm (comprising greater than 15% of the catch) were taken on the southern part of Ground 1. Moderate amounts (about 3-15% of the catch) were taken on the most of the rest of Ground 1 and the eastern part of Ground 2. There was a substantial difference in the proportion below 40 cm between Ground 1 and Ground 2 where much lower proportions were observed on Ground 1. This indicated that a greater proportion of older fish (age 8+) were removed from Ground 1 than from Ground 2. Thus the range of sizes caught (presumably because of a greater spread of sizes available to the gear) was greater on Ground 1. Fig. 14 also shows that this wider spread of sizes in the catch was observed for both the male and the female components. Fig. 17 showing the percent (upper panel) and numbers of fish (lower panel) taken in each of the cutoff categories by ground further illustrates the differences by ground. Fig. 18 indicates that there was no relationship between these cut-off categories and mesh size used. This suggests that there were actual differences in size composition of the schools among fishing grounds rather than the differences being related to mesh size used.

Over time, Fig. 19 shows that average length of fish caught on Ground 1 was consistent over time whereas average length increased steadily from the start of the fishery in Aug. until the end of Sept. from 36.8 to 38.5 cm on Ground 2. Average length based on limited (2) samples from the last part of Oct. for Ground 2 was lower compared to Sept. Percent below 26 and 30 cm showed no trend for Ground 1 but tended to decrease over time during Aug. and Sept. for Ground 2 while percent below 40 cm showed little change. Thus, the spatial and temporal variation in size of fish and proportion by sex observed for the commercial catches suggests a complex and dynamic population structure within the confines of the commercial fishing grounds.

The age composition of the commercial catches is summarized in Fig. 20a-c (right panel percent, left panel total numbers) by sex, by ground, by quarter of the year. The data were analysed by ground rather than NAFO Division given that the grounds were not spatially distinct by division. The dividing line between Div. 3N and 3O was close to Ground 1 and overlapped Grounds 2-4. On Ground 1, quarter 3, 91% of the catch comprised ages 6-8. This was the case for both males and females although a larger proportion of females (57.1% females, 15.5% males) were age 8. Similarly for the 4th quarter on Ground 1, 92% and 95% of males and females respectively comprised ages 6-8 and again a larger proportion of females (39.5% females, 10.9% males) were age 8. For Ground 2, quarter 3, 89.6% of males and 93.7% of females comprised ages 6-8. As for Ground 1, on Ground 2, a larger proportion of females (32.8% females, 6.1% males) were age 8. Similarly, for the 4th quarter on Ground 2, 92% and 95% of males and females respectively comprised ages 6-8 and a larger proportion of females (39.5% females, 10.9% males) were age 8. Based on only 2 samples, the pattern on Ground 3&4 was very similar, dominated by ages 6-8 with a larger proportion of age 8 females compared to males.

Thus, age composition was very similar among grounds. In total, it is estimated that just over 7.3 million fish were removed from the population during the 1998 fishery, 0.9% of the numbers of fish estimated by Walsh et *al*. (1998) from fall research survey in Divisions 3N and 3O. Of this 7.3 million fish caught, 66% were taken from Ground 1, 30% from Ground 2 and 4% from Ground 3&4. Females were more abundant in the catches comprising 60.5% of the total number of individuals caught. The most common year class was for males was age 6 at 46.3% of the catch and age 7 (44.9%) for females.

One of the stated management objectives for the 1998 fishery was to fish the population after spawning was complete. Yellowtail examined for maturity during the first two weeks of the fishery showed that a large majority, 99% for males and 97.6% for females were either partly spent or spent (Fig. 21). This indicated that the management objective had been achieved.

Conclusions

Intense monitoring of the re-emerging 1998 yellowtail fishery in the form of nearly full coverage by fishery observers facilitated a detailed examination of the fishery. In terms of meeting both management and commercial objectives, analyses of the observer data indicate that the 1998 limited fishery for yellowtail can be considered a success. 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), bycatch of plaice and cod was minimized (due to the localized fishing and employment of a sorting grate), small fish (less than 30 cm) constituted only a very small proportion of the catch (using codend mesh ranging from 145 to 155 mm) and the period of the fishery concentrated on a post-spawning fish. Unlike past years, the 1998 fishery was truly a directed fishery 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 have suggested that bycatch 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 the 1998 fishery, the only location fished that yielded both high yellowtail catch rates and also a level of bycatch that led to an apparent restriction of effort was Ground 4, spatially speaking a minor ground. While the existence of other (un-fished) yellowtail concentrations is likely, fishing activity being limited to the 1998 grounds did not appear to negatively affect the ability of the fleet to sustain good catch rates. Based on historic patterns, it seems likely that if the fishing effort in 1998 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, bycatch of cod and plaice would have been higher. Within the bounds of the 1998 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 remained fairly constant during the first half of the fishery then increased steadily during the last half.

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Table 1a. Catch and catch rates of yellowtail, by-catch rates, average depth and gear parameters by month and ground for the 1998 yellowtail fishery.

		Month				
Ground		8	9	10	11	Total
1	# of sets	377	378	422	27	1,203
	Yellowtail catch (t)	703	692	1,071	105	2,571
	Avg chr yellow	0.672	0.591	0.882	1.487	0.738
	Avg chr plaice	0.038	0.029	0.020	0.102	0.030
	Avg chr cod	3.960	13.335	6.612	0.055	23.963
	Avg depth	54.9	54.3	53.8	53.1	54.3
	Avg codend (mm)	147.2	148.3	149.4	149.9	148.4
	Avg grate space (mm)	121.8	110.7	118.5	121.0	117.1
2	# of sets	213	292	5		511
	Yellowtail catch (t)	421	597	9		1,027
	Avg chr yellow	0.961	0.708	0.577		0.812
	Avg chr plaice	0.039	0.046	0.066		0.043
	Avg chr cod	2.766	2.811	0.014		5.591
	Avg depth	70.4	70.7	71.2		70.6
	Avg codend (mm)	147.4	148.2	149.0		147.9
	Avg grate space (mm)	109.3	110.6	125.0		110.2
3&4	# of sets	42	21			63
	Yellowtail catch (t)	181	16			197
	Avg chr yellow	1.219	0.313			0.912
	Avg chr plaice	0.099	0.101			0.100
	Avg chr cod	3.544	0.750			4.294
	Avg depth	72.4	68.7			71.1
	Avg codend (mm)	153.1	149.1			151.7
	Avg grate space (mm)	89.0	99.3			98.6
All	# of sets	632	692	427	27	1,777
Grounds	Yellowtail catch (t)	1,305	1,304	1,080	105	3,795
	Avg chr yellow	0.805	0.632	0.878	1.487	0.766
	Avg chr plaice	0.042	0.039	0.021	0.102	0.036
	Avg chr cod	10.270	16.896	6.626	0.055	33.847
	Avg depth	61.3	61.7	54.0	53.1	59.6
	Avg codend (mm)	147.6	148.3	149.4	149.9	148.3
	Avg grate space (mm)	117.2	110.4	118.5	121.0	114.9

Table 1b. Catch and catch rates of yellowtail, bycatch rates and average depth by month for the 1998 fall research survey.

	Month			
	10	11	12	Total
# Sets	126	171	101	398
Avg wt of yellowtail	24.74	3.39	0.01	9.29
Avg number of yellowtail	88.3	8.1	0.0	31.4
Avg number of plaice	73.9	51.7	15.5	49.5
Avg number of cod	3.4	0.8	0.3	1.5
Avg depth	193.3	229.2	877.4	382.3

Table 2. Landings and biological sampling coverage of the Canadian fishery for yellowtail, by fishing ground, by month in 1998. 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	Number Otoliths
G1	August	703	9.602	1.4%	72	8,856	831
	September	692	14.560	2.1%	102	13,081	208
	October	1,071	15.070	1.4%	108	14,035	493
	November	105	1.090	1.0%	8	1,048	37
G2	August	421	5.332	1.3%	44	5,800	272
	September	597	10.080	1.7%	78	10,099	393
	October	9	0.252	0.3%	2	280	32
	November	0	0				
G3&4	August	181	0	0%			
	September	16	0.497	3.1%		513	0
	October	0	0				
	November	0	0				
All Grounds	August	1,305	14.934	1.1%	116	14,656	1,103
	September	1,304	25.306	1.9%	184	23,693	601
	October	1,080	15.322	1.4%	110	14,315	525
	November	105	1.090	1.0%	8	1,048	37

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

Table 3. 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%	0.00%	0.000
Redfish	1	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.000
Sea urchin	1	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.000
Lanternfish	1	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.000
Cusk	1	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.001
Silver hake	1	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.001
Sponges	1	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.001
Sabinea sp	1	0.00	0.01	0.01	0.00%	100.00%	0.00%	0.002
Starfish	3	0.00	0.01	0.01	0.00%	100.00%	0.00%	0.001
Squid (Illex)	7	0.00	0.01	0.01	0.00%	100.00%	0.00%	0.000
Spiny dogfish	4	0.00	0.01	0.01	0.00%	100.00%	0.00%	0.001
Lumpfish	10	0.00	0.03	0.03	0.00%	100.00%	0.00%	0.001
Northern wolfish	7	0.02	0.03	0.05	40.00%	60.00%	0.00%	0.002
Spotted wolfish	1	0.05	0.00	0.05	100.00%	0.00%	0.00%	0.015
Monkfish	6	0.04	0.02	0.06	66.67%	33.33%	0.00%	0.003
Cnidaria	9	0.00	0.07	0.07	0.00%	100.00%	0.00%	0.002
Capelin	39	0.00	0.07	0.07	0.00%	100.00%	0.00%	0.001
White hake	18	0.09	0.00	0.09	100.00%	0.00%	0.00%	0.002
Sandlance	126	0.00	0.16	0.16	0.00%	100.00%	0.00%	0.000
Toad crab	180	0.00	0.93	0.93	0.00%	100.00%	0.02%	0.001
Haddock	63	0.39	0.01	0.40	97.50%	2.50%	0.01%	0.002
Eelpouts	139	0.16	0.29	0.45	35.56%	64.44%	0.01%	0.001
Snow crab	257	0.00	0.93	0.93	0.00%	100.00%	0.02%	0.001
Striped wolfish	133	1.46	0.00	1.46	100.00%	0.00%	0.03%	0.004
Halibut	79	1.69	0.02	1.71	98.83%	1.17%	0.04%	0.007
Turbot	3	1.92	0.00	1.92	100.00%	0.00%	0.05%	0.275
Sea raven	474	5.58	2.46	8.04	69.40%	30.60%	0.19%	0.006
Sea cucumber	366	0.00	10.16	10.16	0.00%	100.00%	0.24%	0.009
Witch	1,234	14.56	0.02	14.58	99.86%	0.14%	0.34%	0.004
Sculpins	900	32.76	6.00	38.76	84.52%	15.48%	0.91%	0.010
Skates	1,611	9.45	84.28	93.73	10.08%	89.92%	2.21%	0.019
Cod	1,298	98.93	0.00	98.93	100.00%	0.00%	2.33%	0.025
Plaice	1,704	175.92	0.00	175.92	100.00%	0.00%	4.15%	0.034
Yellowtail	**1,707**	**3,794.00**	**1.13**	**3,795.13**	**99.97%**	**0.03%**	**89.43%**	**0.738**
Total		4,137.02	106.65	4,243.67				

1. Weights recorded as 0 are values less than 10 kg.
2. Percent of catch recorded as 0 are less than 0.01%
3. T per hour are average catch rate for sets where that particular species was captured.

Table 4 - Summary statistics for length measurements of yellowtail sampled from the 1998 fishery.

	Sex	Month	Catch Wt.	Set Wt.	Length (cm) Mean	Std Dev.	Min	Max	Mode	Number of Fish
Ground 1										
	Male	Aug.			36.6	4.21	20	51	37	507,693
	Female				39.1	5.44	17	56	40	774,655
	Total		702,758	70,555	38.1	5.14	17	56	38	1,282,348
	Male	Sept.			37.0	3.89	20	50	38	464,682
	Female				39.6	4.74	20	56	41	800,348
	Total		691,657	95,455	38.7	4.62	20	56	38	1,265,030
	Male	Oct.			36.6	4.14	15	53	38	673,171
	Female				39.5	4.58	20	57	41	1,354,166
	Total		1,071,344	155,396	38.6	4.65	15	57	38	2,027,337
	Male	Nov.			36.8	3.82	25	47	39	55,502
	Female				39.4	4.30	25	53	38	152,669
	Total		105,293	18,557	38.7	4.34	25	53	38	208,171
	Male	All			36.7	4.08	15	53	38	1,701,048
	Female				39.5	4.78	17	57	41	3,081,838
	Total		2,571,052	339,963	38.5	4.73	15	57	38	4,782,886
Ground 2										
	Male	Aug.			34.9	3.64	19	48	36	438,973
	Female				36.9	4.36	21	54	37	494,149
	Total		421,438	46,540	35.9	4.16	19	54	37	933,122
	Male	Sept.			36.1	2.98	22	49	37	622,176
	Female				38.6	3.76	22	52	39	594,474
	Total		596,779	77,995	37.3	3.60	22	52	38	1,216,650
	Male	Oct.			36.2	2.69	29	44	37	14,010
	Female				37.8	3.50	29	45	40	7,593
	Total		9,045	1,648	36.8	3.15	29	45	37	21,603
	Male	All			35.7	3.29	19	49	37	1,075,159
	Female				37.9	4.10	21	54	39	1,096,216
	Total		1,027,262	126,183	36.8	3.88	19	54	37	2,171,375
Ground 3										
	Male	Sept.			37.2	3.71	25	46	35	115,154
	Female				41.1	4.76	26	52	41	197,914
	Total		16,015	2,485	39.6	4.82	25	52	41	313,068
	Male	All			37.2	3.87	25	46	35	115,154
	Female				41.1	4.86	26	52	41	197,914
	Total		196,687	2,485	39.6	4.90	25	52	41	313,068
All Grounds										
	Male	All			36.5	3.75	15	53	37	2,891,361
	Female	All			39.5	4.58	17	57	40	4,375,968
	Total	All	3,795,001	468,631	38.3	4.50	15	57	39	7,267,329
									Avg Wt	0.5222 kg

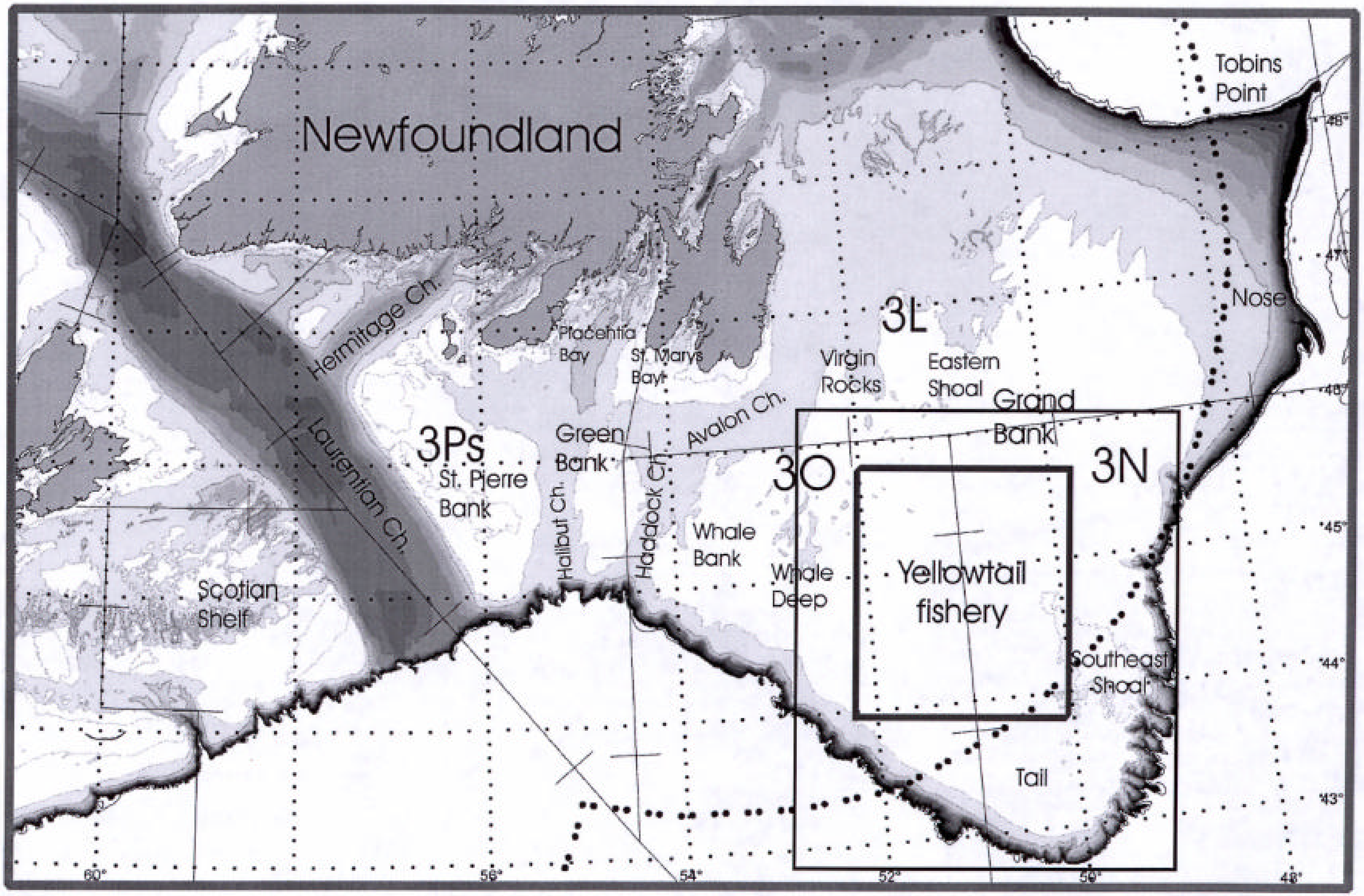
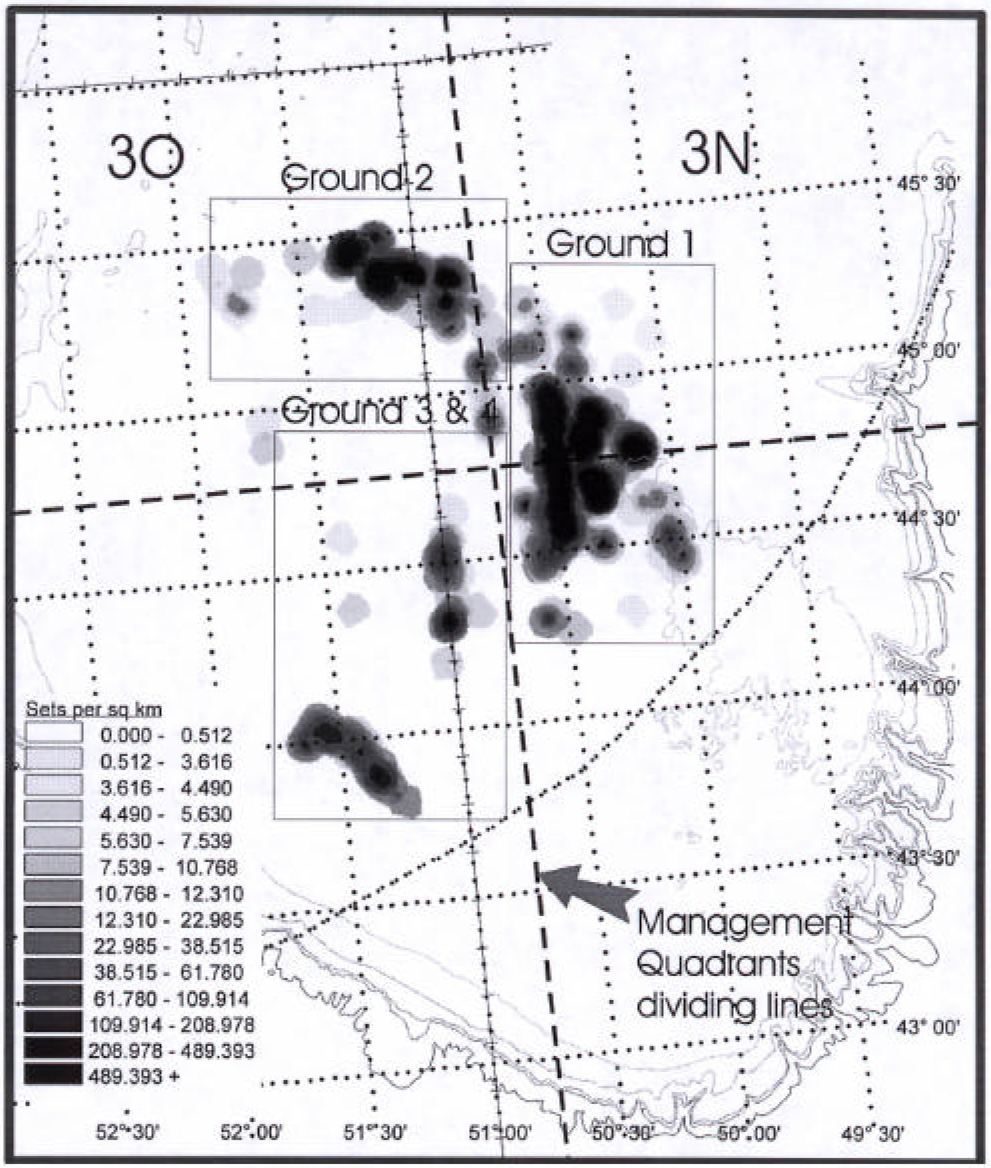


Figure 1. Features of the Grand banks showing NAFO Divisions, the 200 mile limit, specific locations and bathymetry (0 to 450 m by 50 m then 500 to 1000 m by 100m). The inner box illustrates the extent of the 1998 yellowtail fishery. The outer box shows the area illustrated in subsequent map figures.



	Fishing Grounds	1	2	3 & 4	All	Catch/Effort	
	% of Effort	67.7%	28.9%	3.5%		1,777	Total Sets
	Avg Depths fished (m)	54	71	72	61		
	Months Fished	8-11	8-10	8-9	8-11		Yellowtail
Yellowtail	Mean t per hour	0.739	0.8124	0.9404	0.7658	3,795 t	Total Catch
	Min t per hour	0	0.0747	0.0729	0		
	Max t per hour	3.3612	2.1025	2.2376	3.3612		
	% of Catch	67.7%	27.1%	5.2%			
							Plaice
Plaice	Mean t per hour	0.030	0.043	0.038	0.037	176 t	Total Catch
	Min t per hour	0.000	0.000	0.000	0.000	4.2	% of total catch
	Max t per hour	0.263	0.579	0.154	0.579		
							Cod
Cod	Mean t per hour	0.021	0.012	0.018	0.020	99 t	Total Catch
	Min t per hour	0.000	0.000	0.000	0.000	2.3	% of total catch
	Max t per hour	0.500	0.391	0.154	0.574		

Figure 2. Fishing grounds for yellowtail flounder in 1998. Darker grey shades denote more densely fished areas. Solid line boxes delineate fishing grounds. Dashed lines delineate managem,ent quadrants. Refer to Fig. 4 for a description of catch rates within fishing density classes.

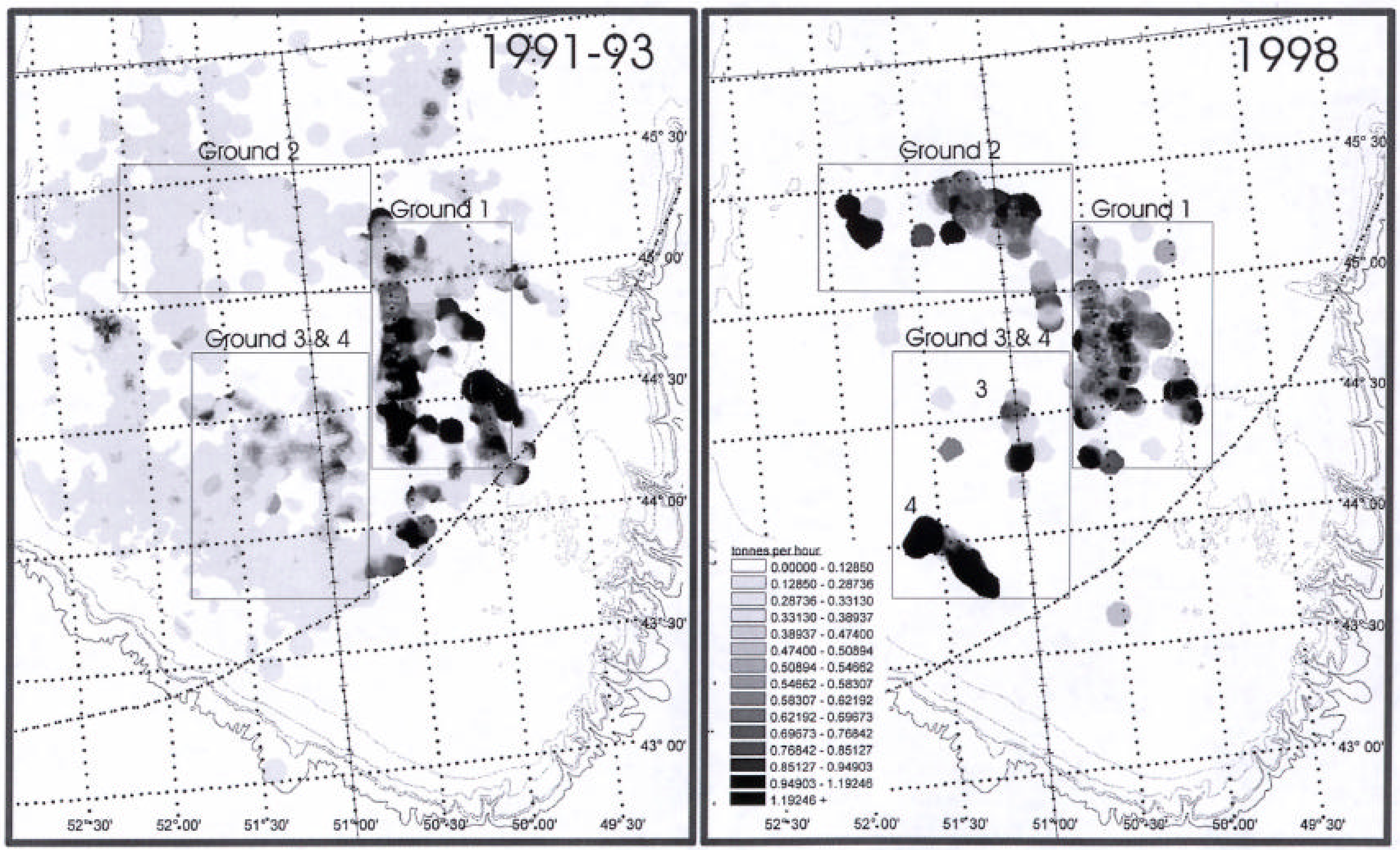


Figure 3. Comparison of the density (catch per hour) from the fishery for yellowtail in 1998 vs. 1991-1993 on the Grand Banks. The two figures use the same scale of fish density shown in the 1998 panel.

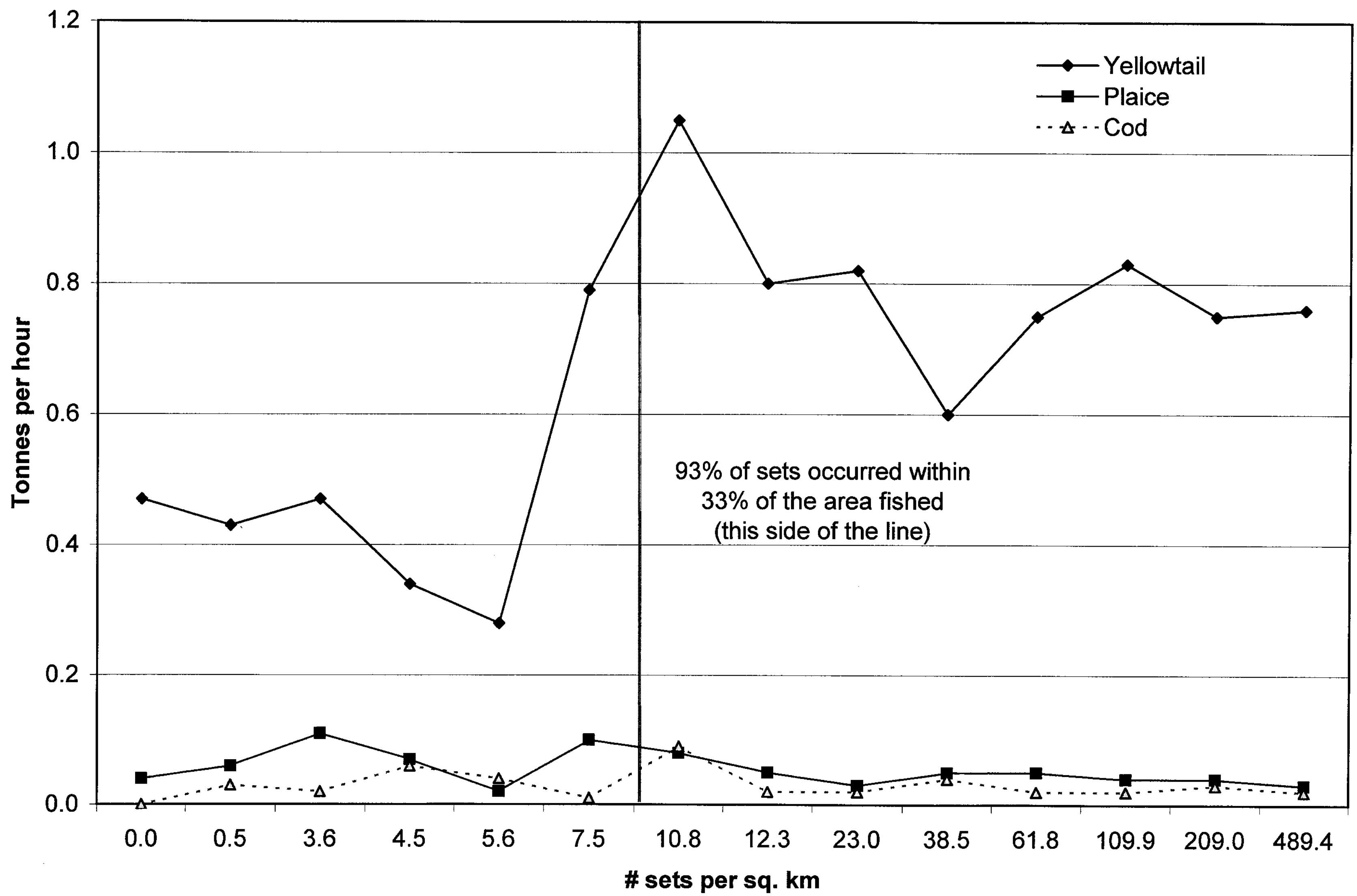


Figure 4. Catch rate of yellowtail and plaice by-catch with fishing density classes

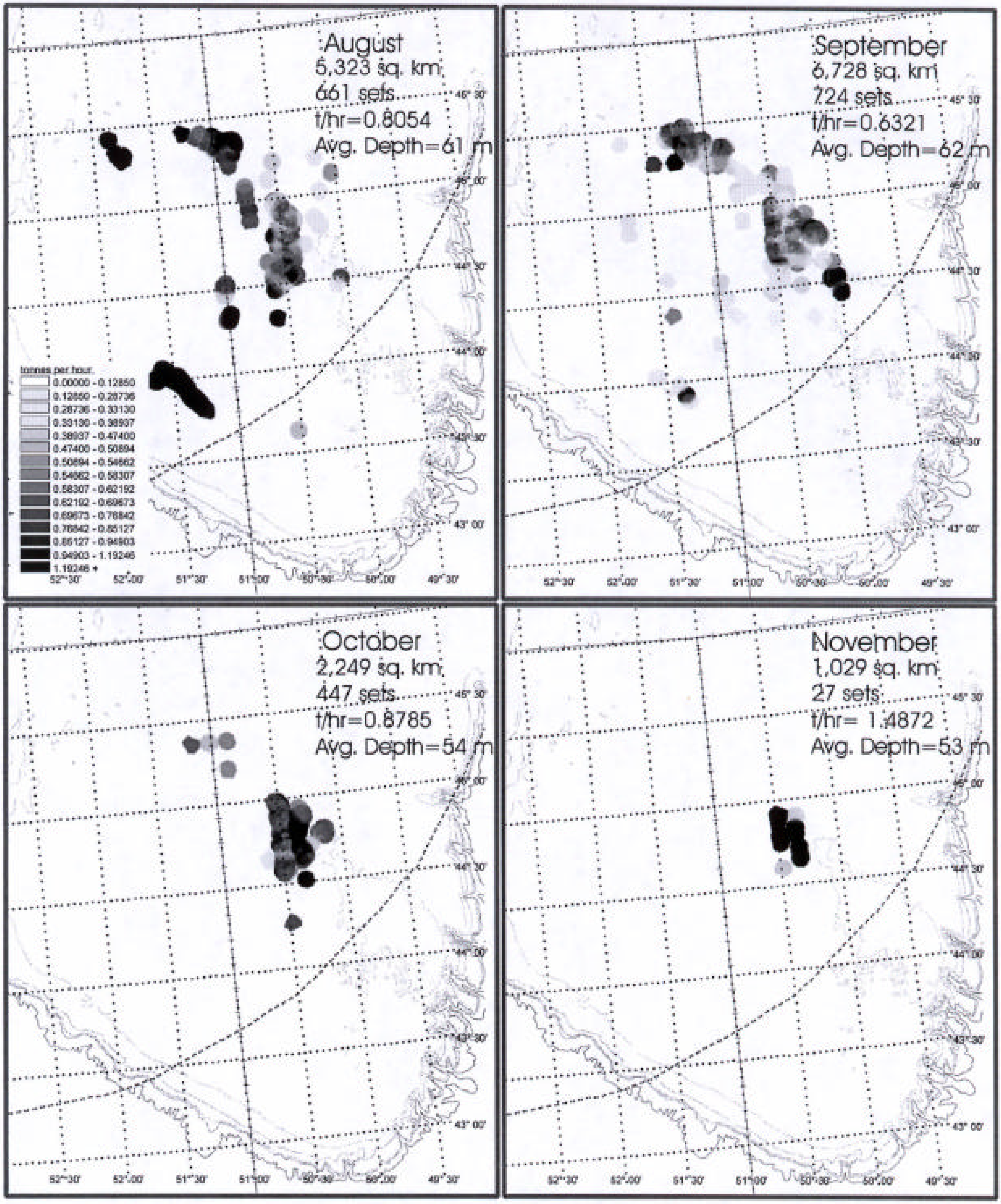


Figure 5. Monthly densities of yellowtail in the 1998 Grand Banks fishery. Extent of grounds, effort, catch rate and depth are illustrated.

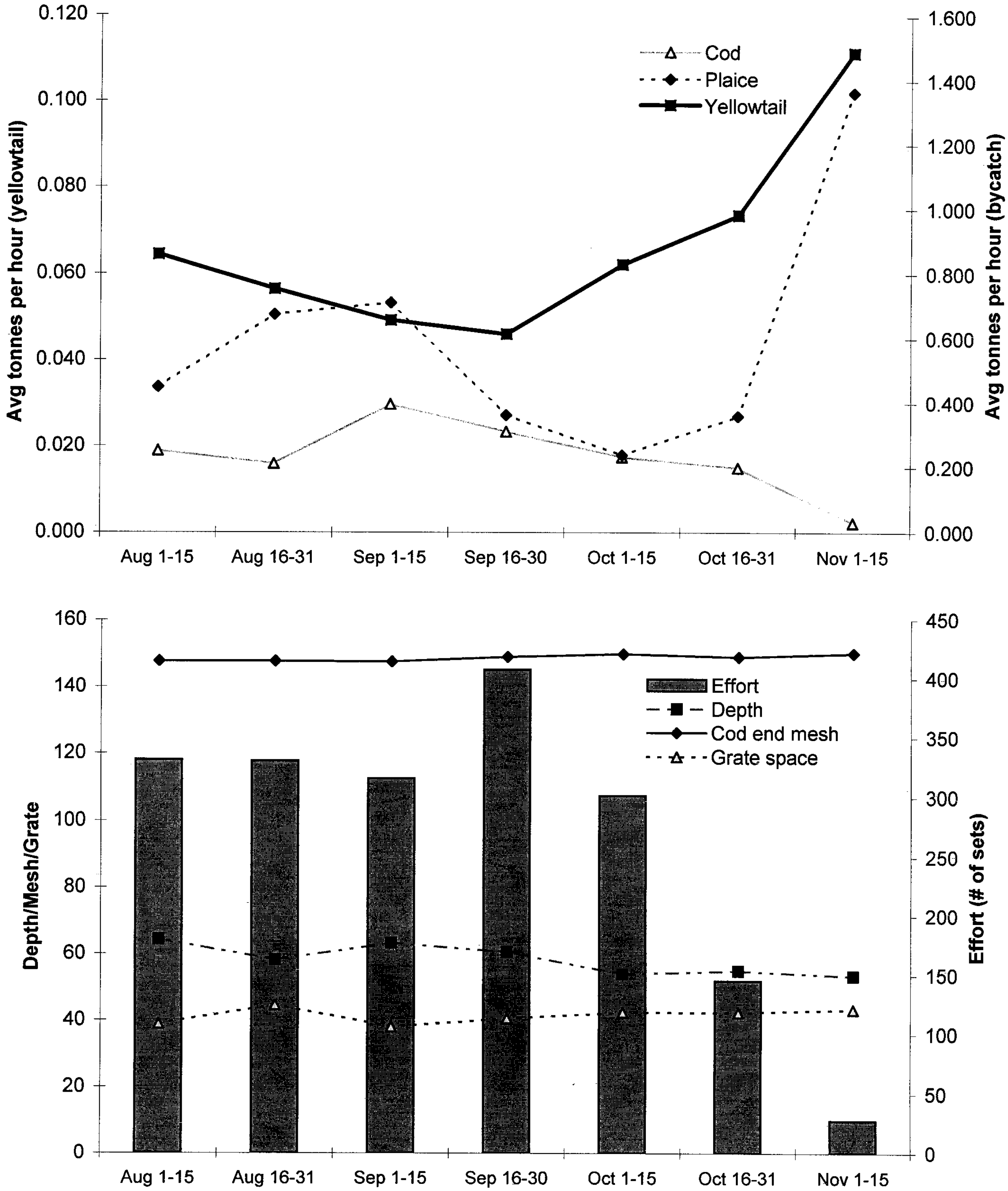


Figure 6. Biweekly patterns in catch, effort and fishery parameters for yellowtail and bycatch of plaice and cod in the 1998 yellowtail fishery.

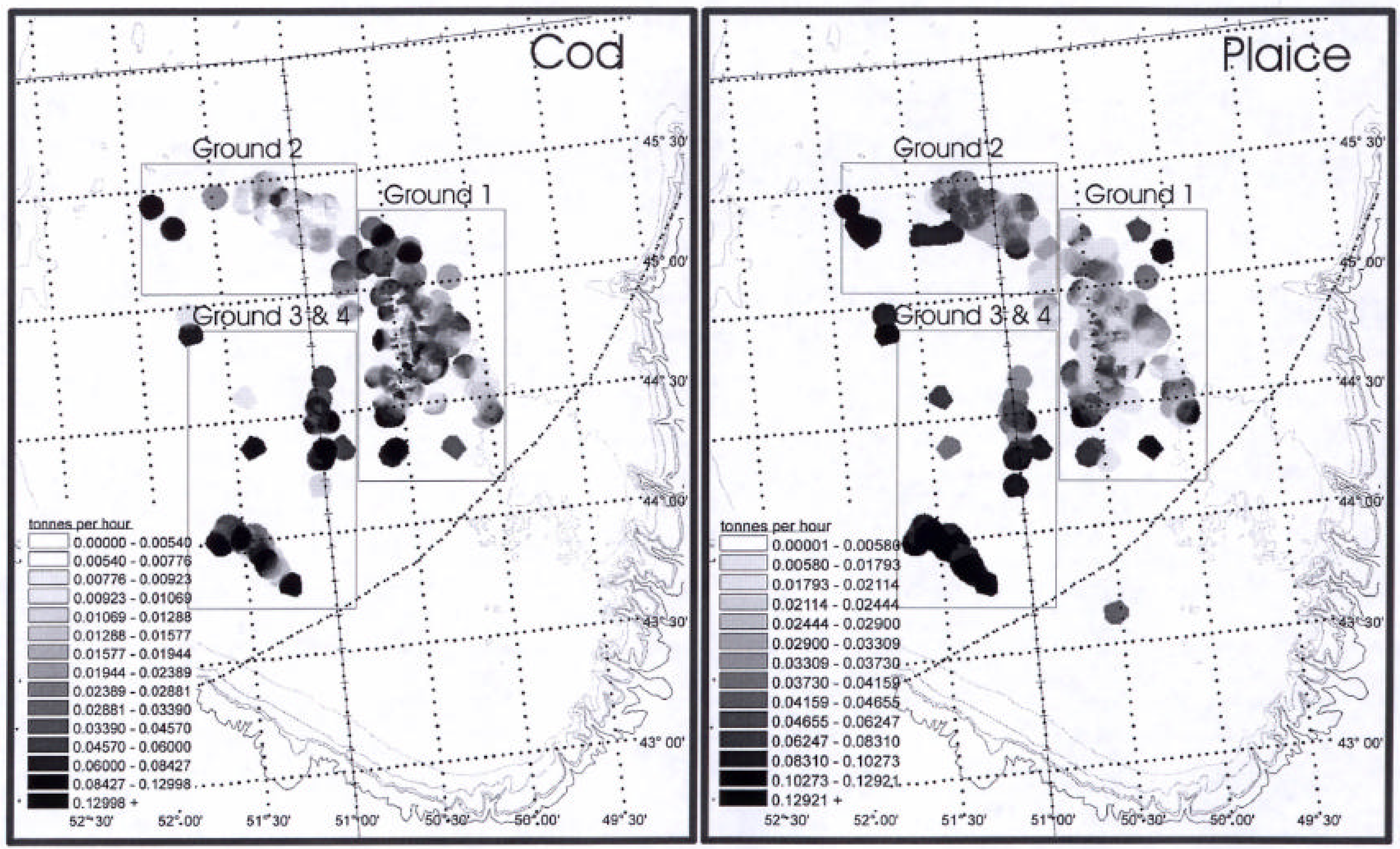


Figure 7. Distribution of bycatch of cod and American plaice in the 1998 yellowtail fishery. Different scales are used for the two different species due to substantially different catch rates.

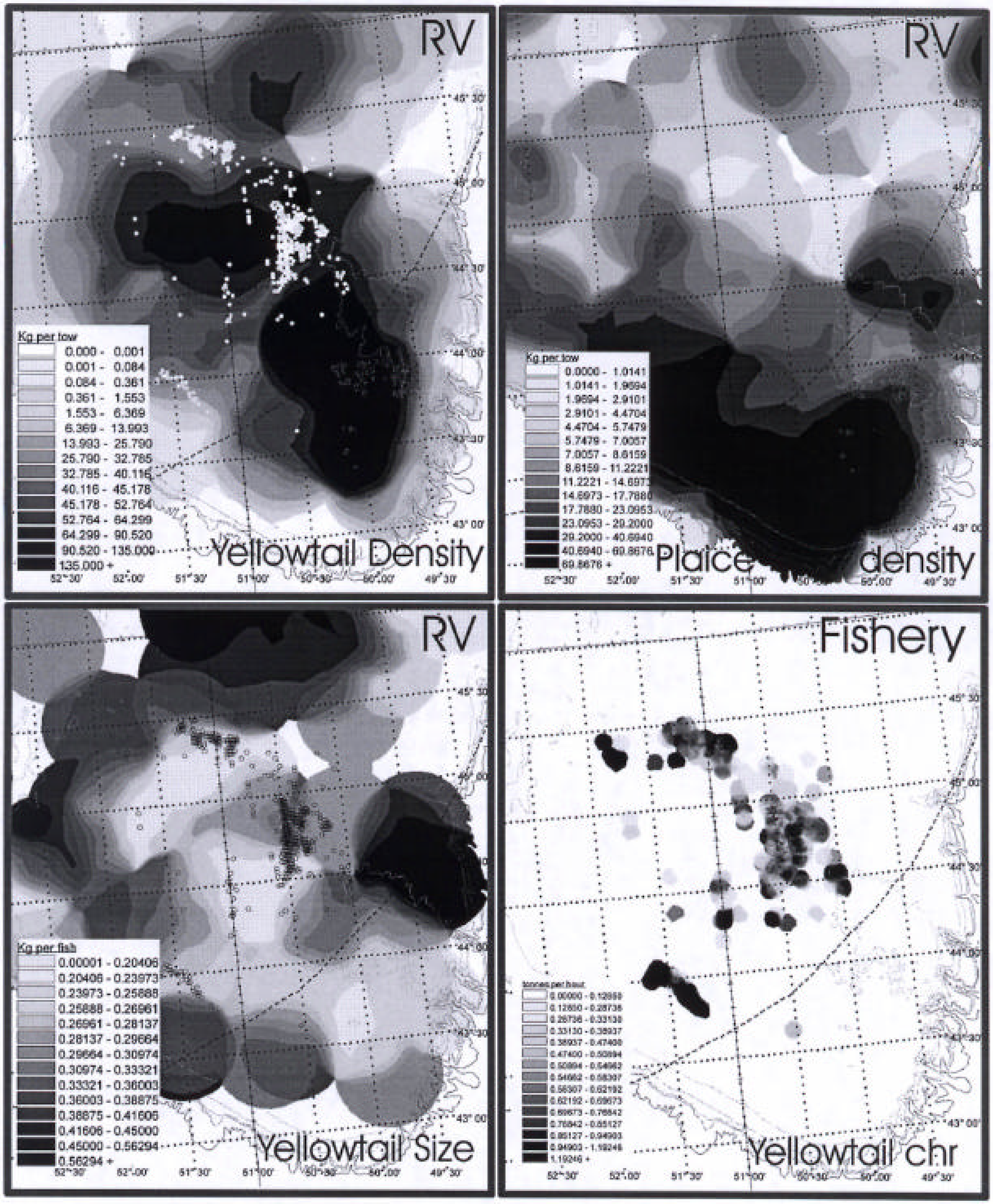
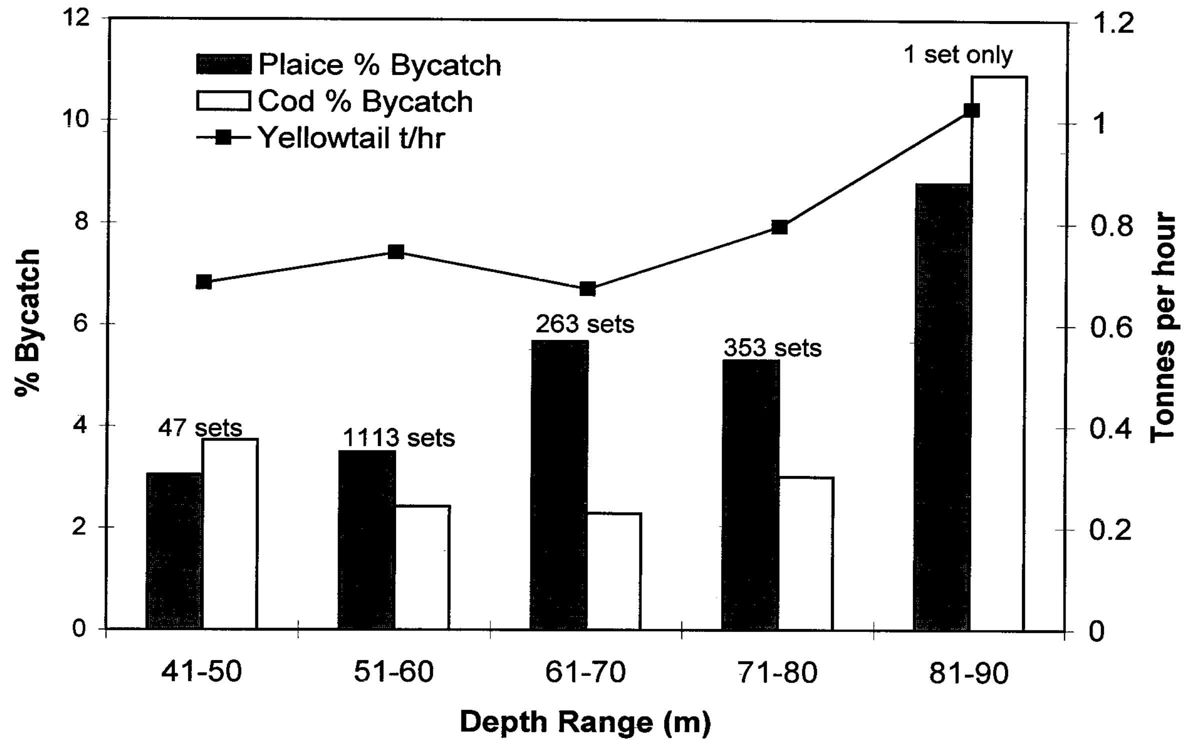


Figure 8. Distribution of yellowtail from the 1998 directed fishery (lower right panel) in comparison with density distribution (upper left) and size (lower left) of yellowtail and plaice density distribution (upper right) from the 1998 fall research surveys. White points in the fish density panel and open black circles in the fish size panel are fishing set locations for the 1998 commercial fishery.



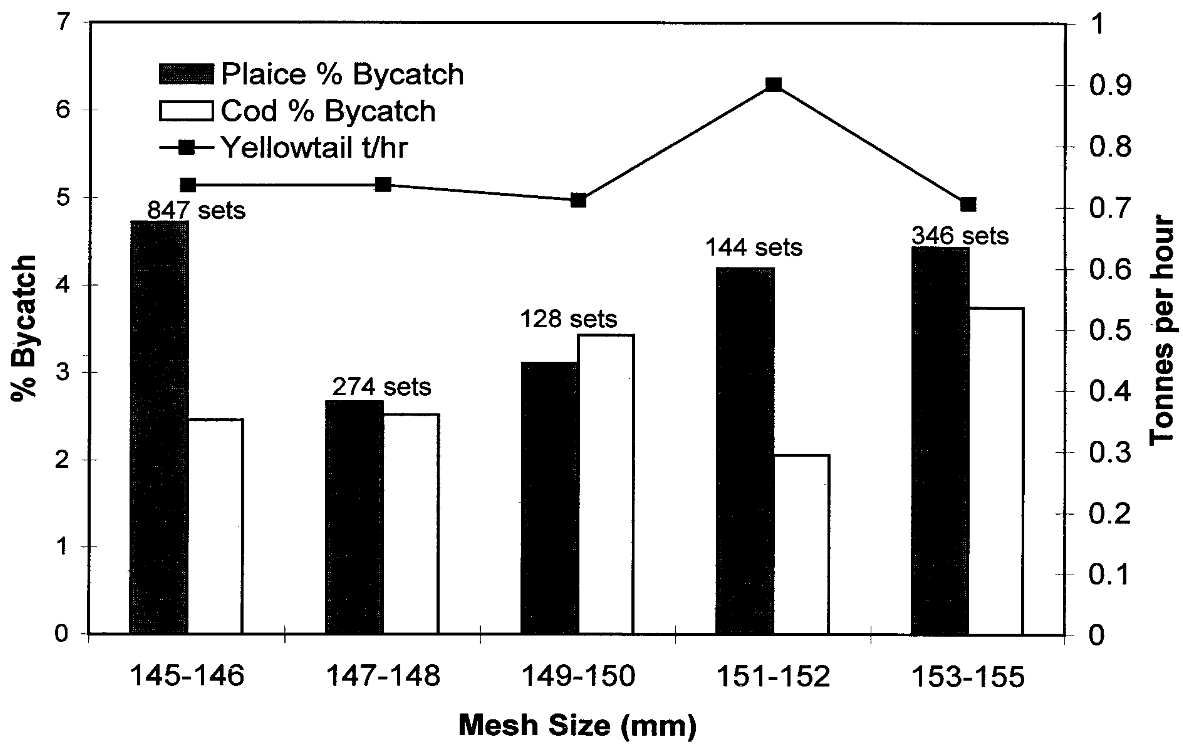


Figure 9. Catch rate of yellowtail and percent bycatch of plaice and cod by depth ranges (upper panel and by mesh size (lower panel).

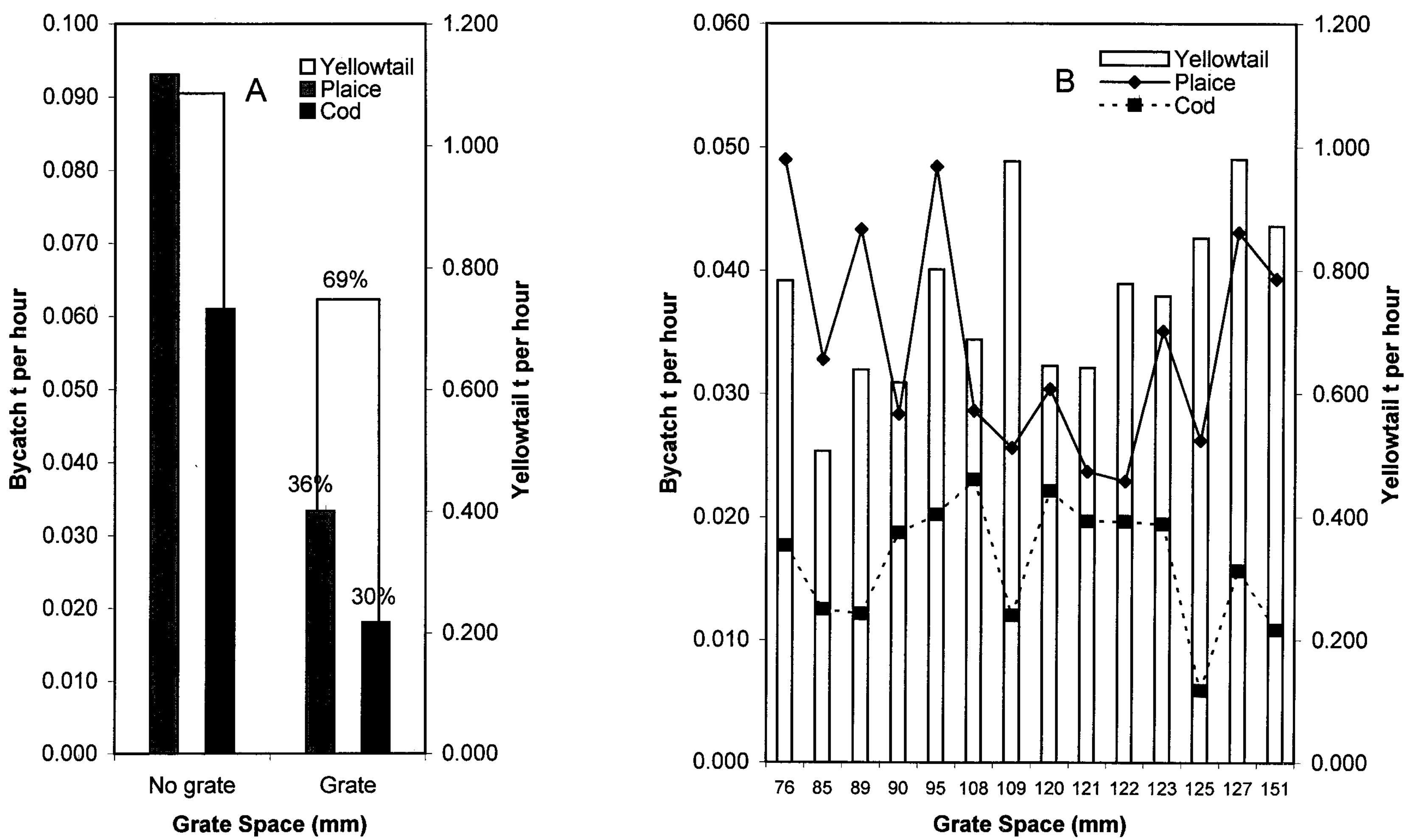


Figure 10. Effect of using a sorting grate on the catch rates of the directed species, yellowtail and bycatch of plaice and cod. Panel A shows grate vs no grate. Panel B shows effect of grate spacing.

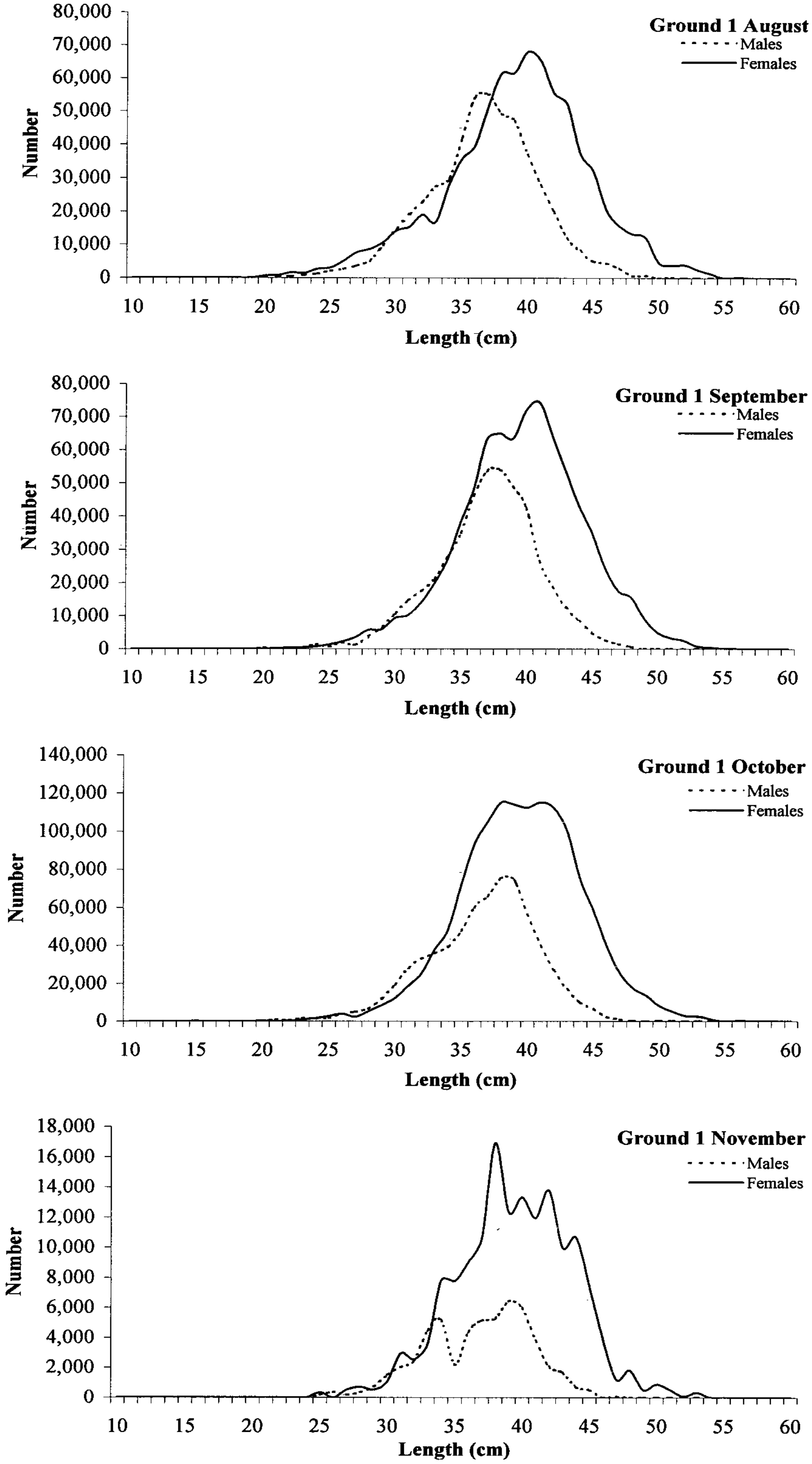


Figure 11. Sexed length frequency distributions by month for ground 1 yellowtail catches. Refer to Fig. 2 for location of grounds.

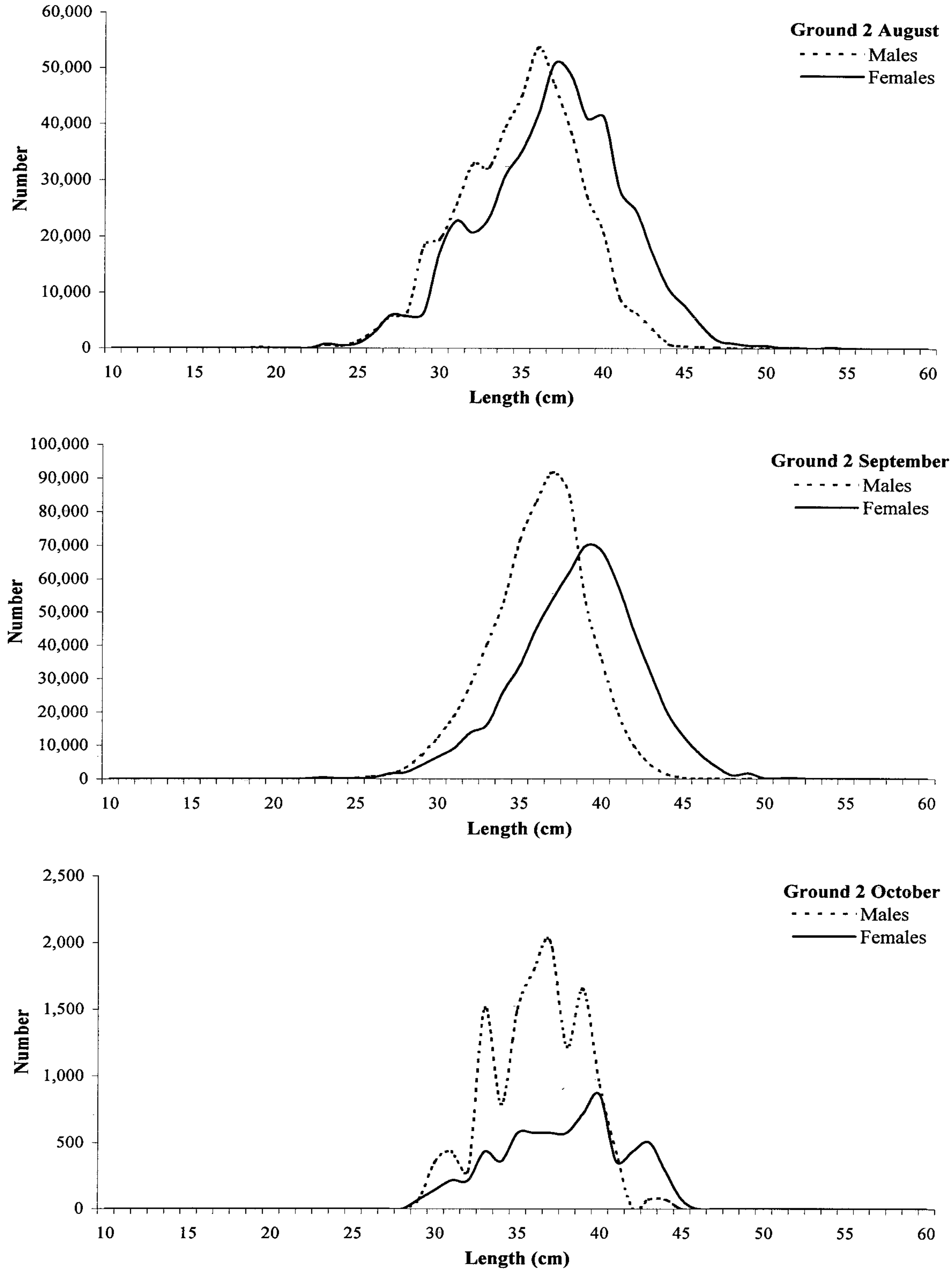


Figure 12. Sexed length frequency distributions by month for ground 2 yellowtail catches. Refer to Fig. 2 for location of grounds.

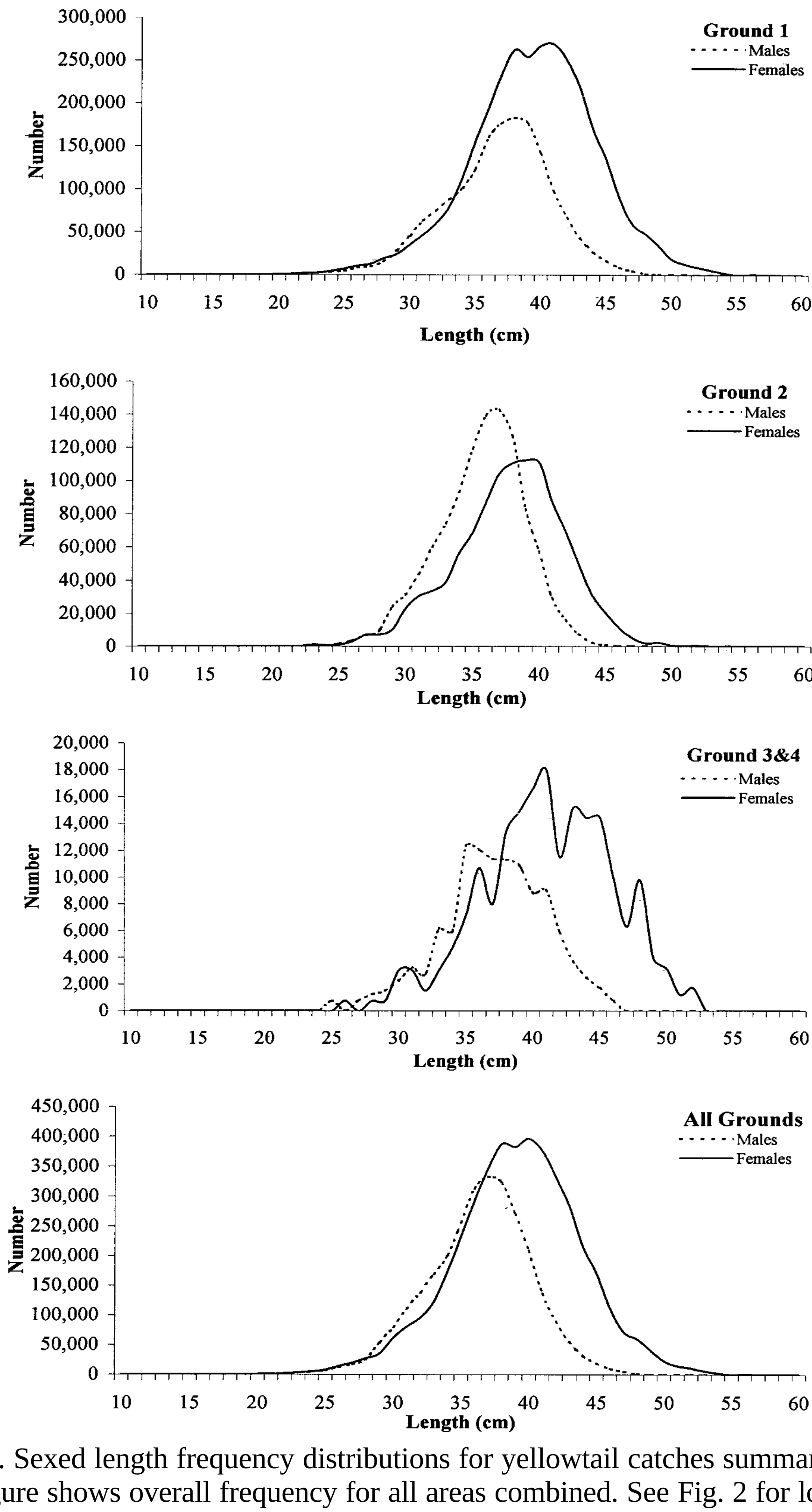
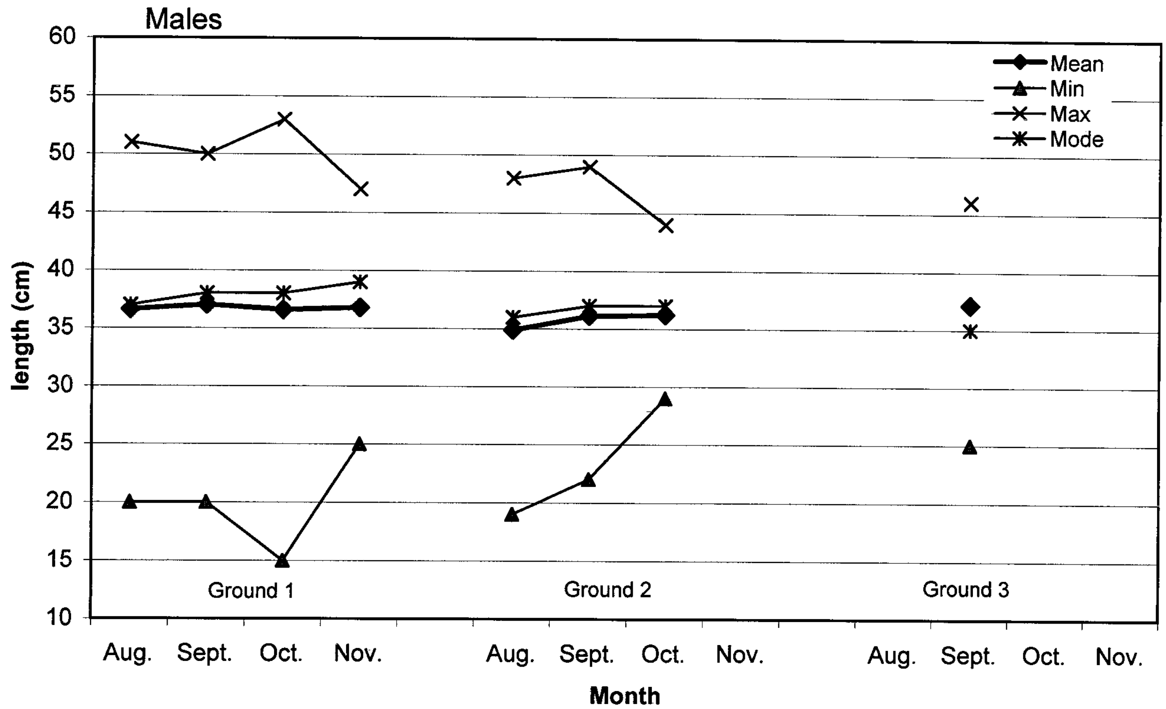


Figure 13. Sexed length frequency distributions for yellowtail catches summarized by ground. Lower figure shows overall frequency for all areas combined. See Fig. 2 for location of grounds.



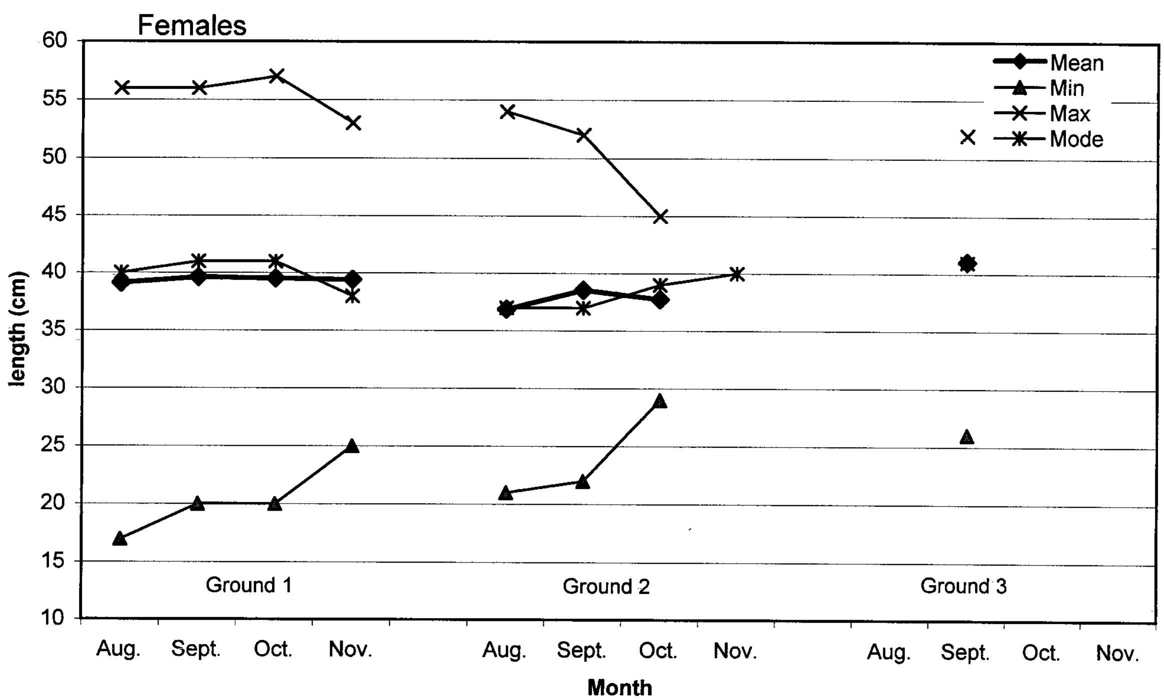


Figure 14. Temporal trends in mean, minimum, maximum and mode lengths of yellowtail from the 1998 fishery by fishing ground.

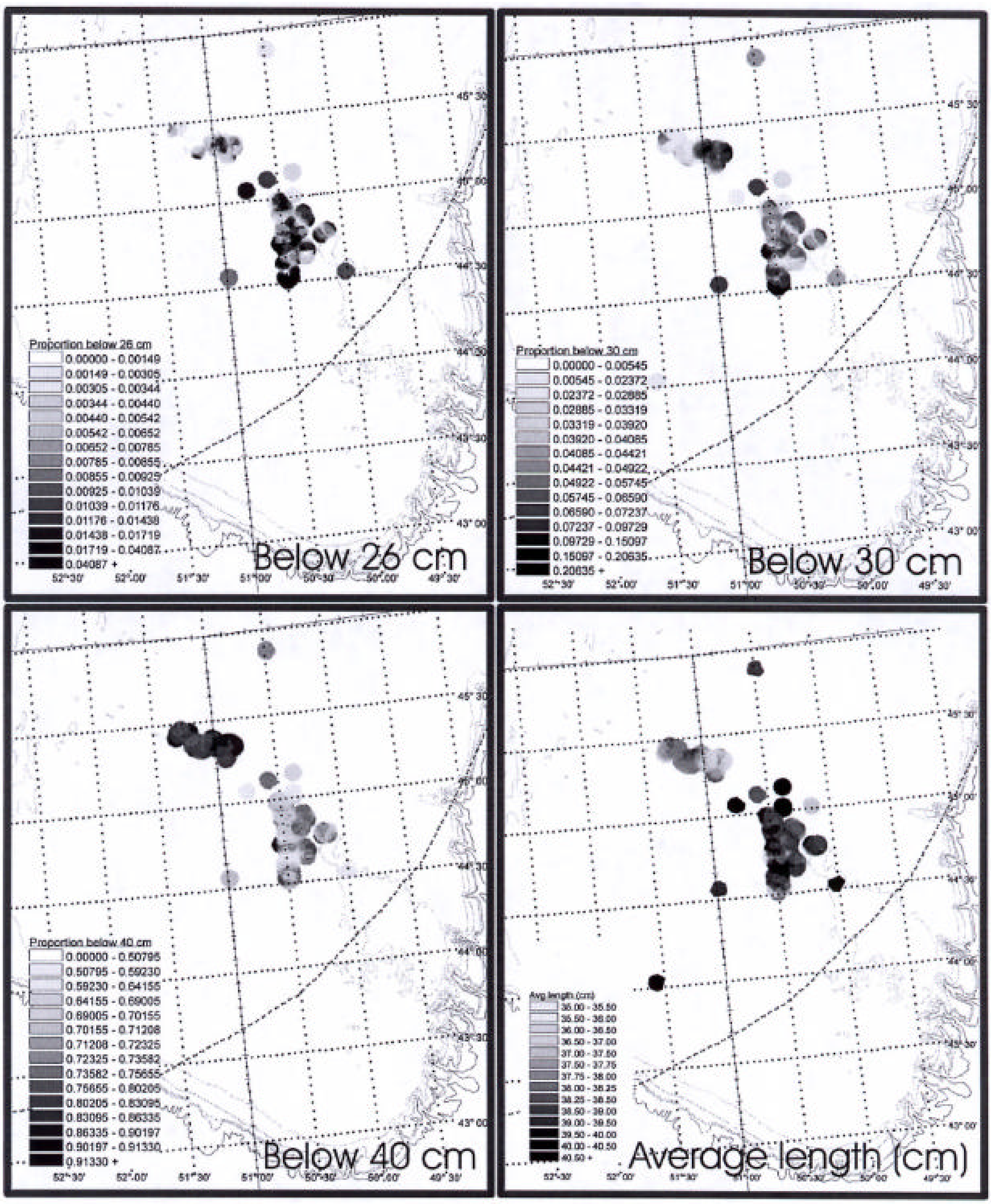
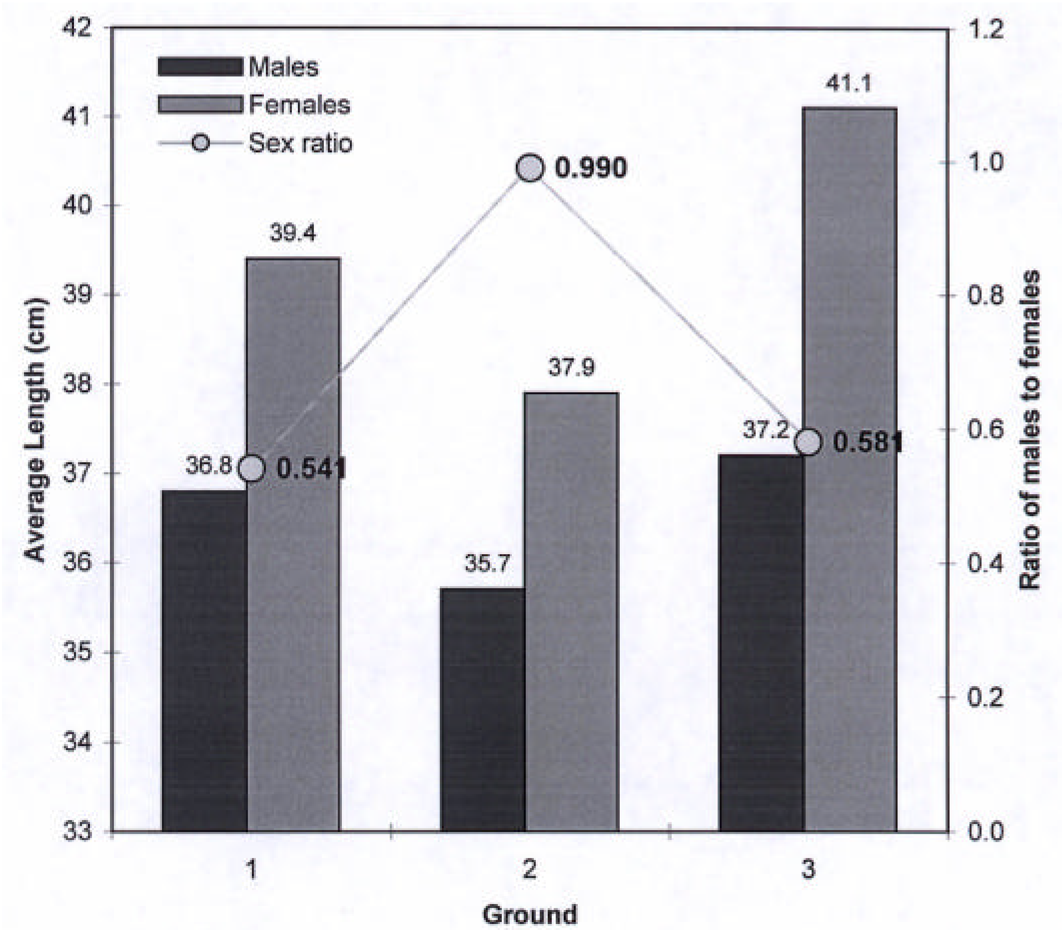
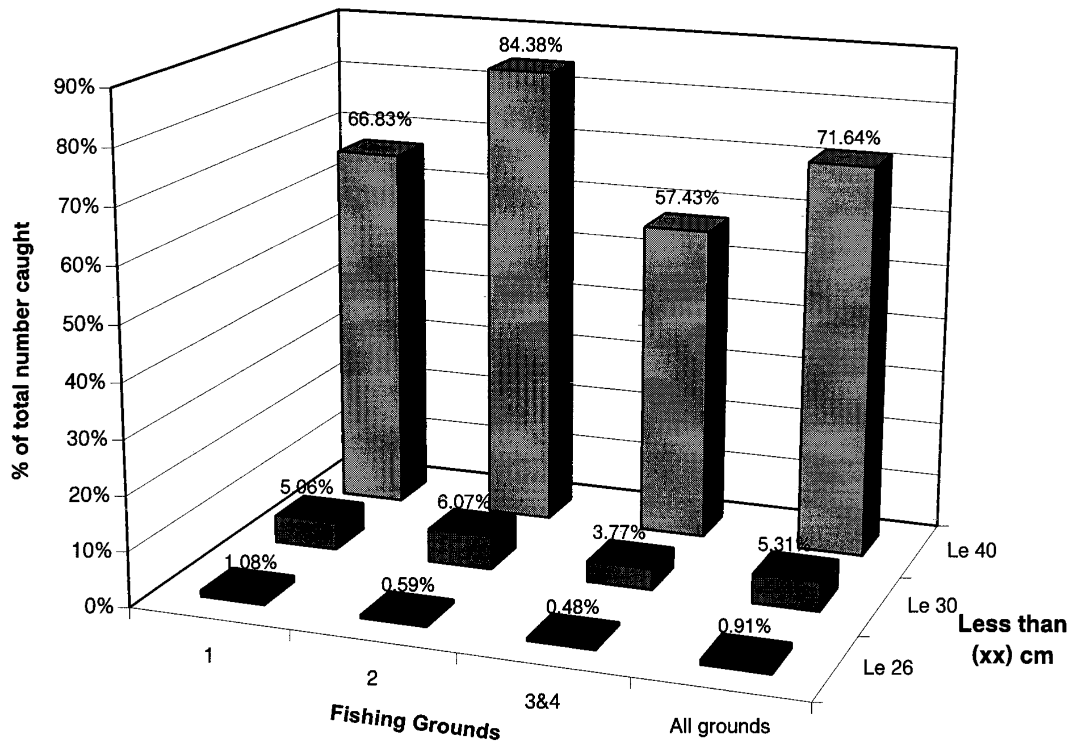


Figure 15. Proportion of fish below 26 cm, juveniles (upper left panel), below 30 cm, minimum acceptable landing size (upper right), below 40 cm, ages 1 to 7 (lower left) and average length (lower right).



Sex		Ground 1	2	3	Total
Males	Avg Length	36.8	35.7	37.2	36.5
	Number	1,682,704	1,076,126	114,950	2,873,781
Females	Avg Length	39.4	37.9	41.1	39.5
	Number	3,112,887	1,087,091	197,914	4,397,892
Both	Avg Length	38.5	36.8	39.6	38.3
	Number	4,795,591	2,163,216	312,865	7,271,672
	Sex Ratio	**0.541**	**0.990**	**0.581**	**0.653**

Figure 16. Average length, numbers of fish caught and sex ratio by fishing ground for the 1998 yellowtail fishery.



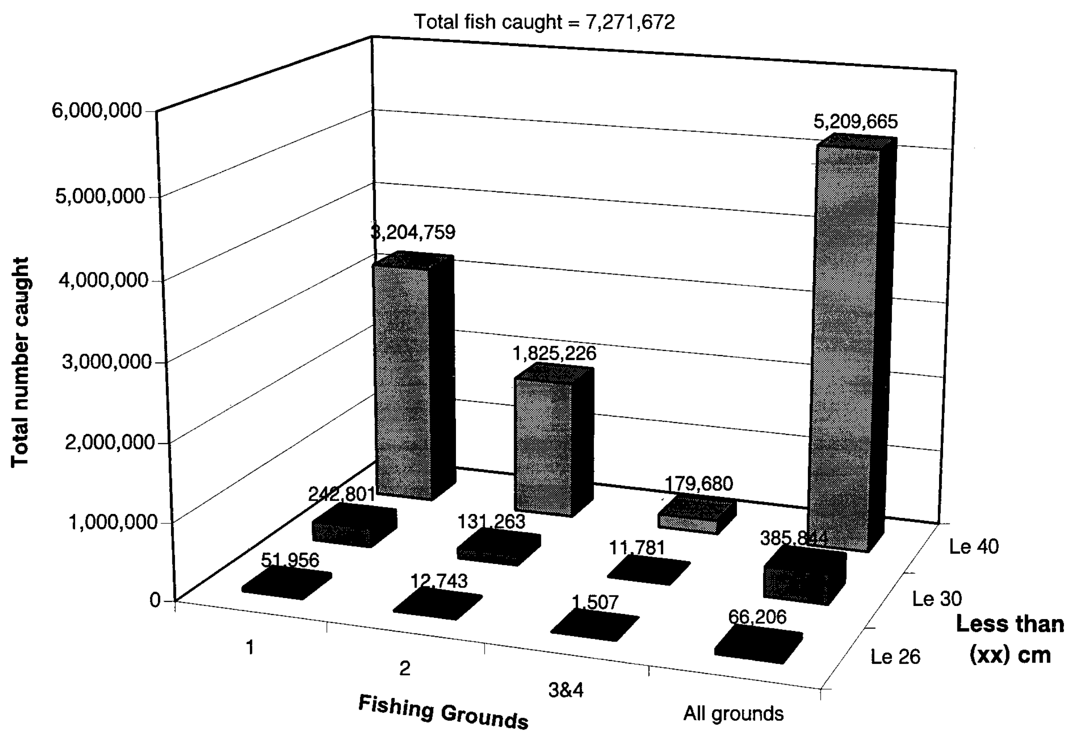
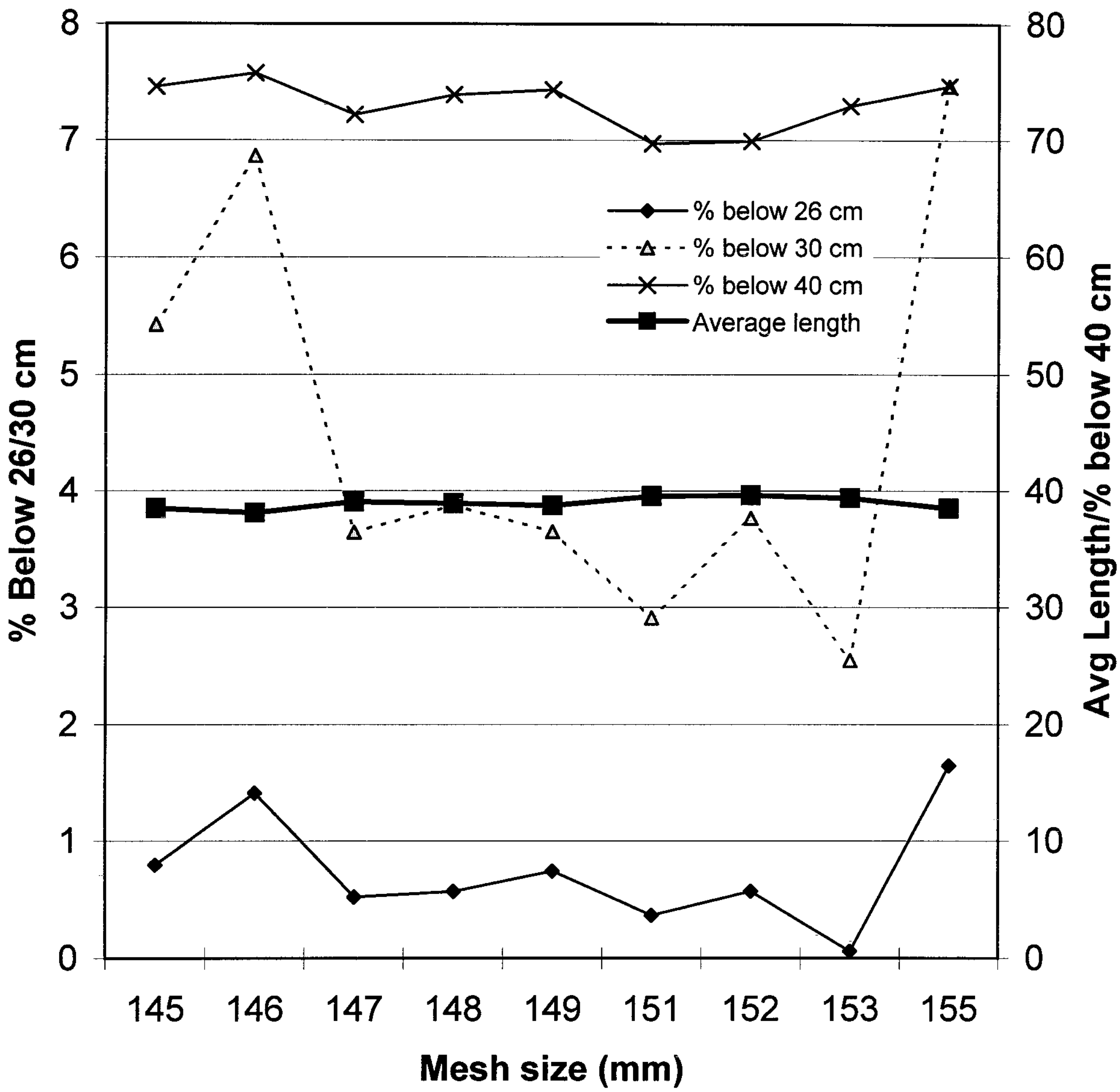
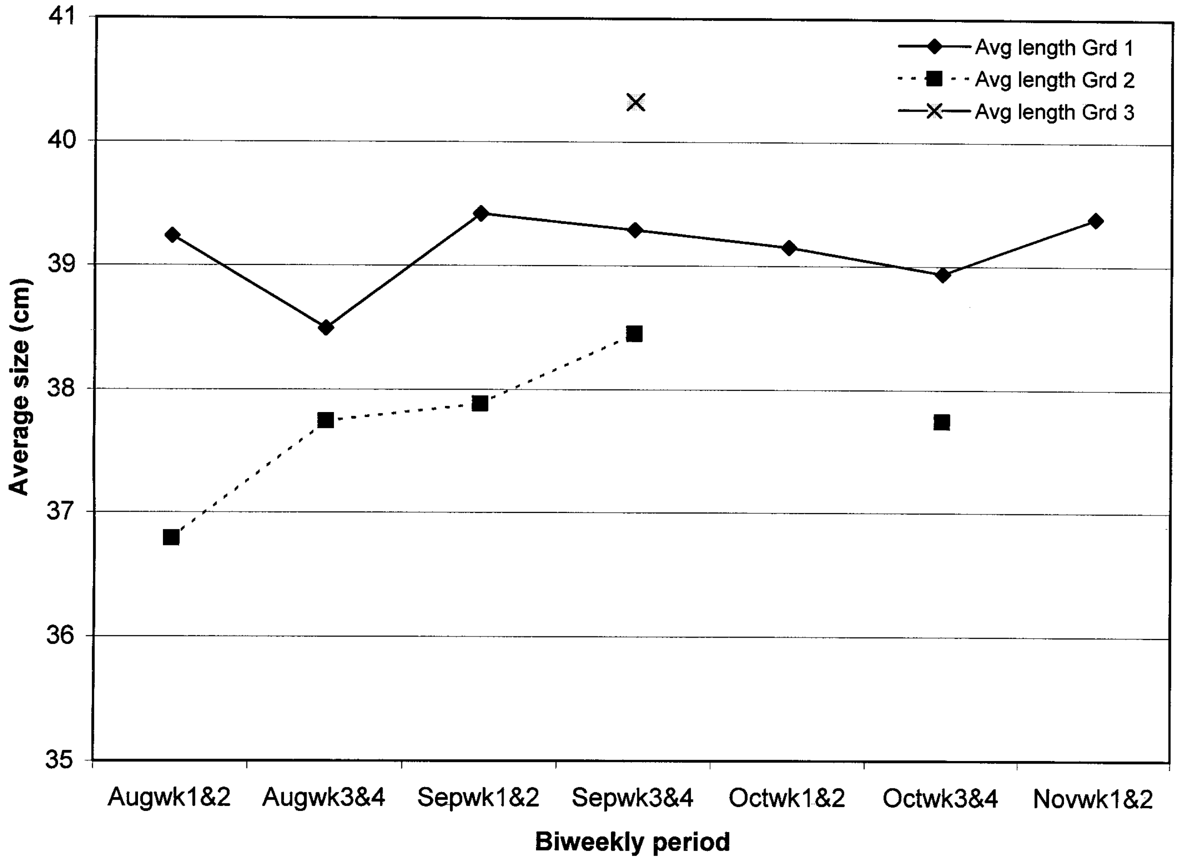


Figure 17. Percent (upper) and number (lower) of fish taken in the 1998 yellowtail fishery within range of sizes specified on the Z axis.



Mesh Range (mm)	145-149	151-153	155	Avg.
Count	296	62	60	418
Average length	38.66	39.50	38.50	38.71
% below 26	0.81	0.33	1.65	0.89
% below 30	4.69	3.07	7.47	5.19
% below 40	74.15	70.86	74.66	73.93

Figure 18. Relationship between average length, % below of yellowtail 26 cm, % below 30 cm, % below 40 cm and mesh sizes used for catching yellowtail in the 1998 fishery.



Ground		Augwk1&2	Augwk3&4	Sepwk1&2	Sepwk3&4	Octwk1&2	Octwk3&4	Novwk1&2	All
1	# samples	16	56	38	64	68	40	8	290
	Avg length Grd 1	39.24	38.49	39.42	39.29	39.15	38.94	39.39	39.07
	Proportion LE 26 cm	0.0134	0.0178	0.0094	0.0063	0.0083	0.0124	0.0064	0.01
	Proportion LE 30 cm	0.0719	0.0760	0.0454	0.0395	0.0440	0.0553	0.0341	0.05
	Proportion LE 40 cm	0.7065	0.7098	0.6560	0.7083	0.7103	0.7027	0.6877	0.70
2	# samples	34	10	38	40		2		124
	Avg length Grd 2	36.79	37.74	37.89	38.45		37.75		37.75
	Proportion LE 26 cm	0.0098	0.0120	0.0031	0.0010		0.0000		0.00
	Proportion LE 30 cm	0.0955	0.0671	0.0403	0.0231		0.0319		0.05
	Proportion LE 40 cm	0.8821	0.8051	0.8282	0.8038		0.8596		0.83
3	# samples				4				4
	Avg length Grd 3				40.32				40.32
	Proportion LE 26 cm				0.00				0.00
	Proportion LE 30 cm				0.04				0.04
	Proportion LE 40 cm				0.60				0.60
All	# samples	50	66	76	108	68	42	8	418
	Avg length	37.57	38.38	38.65	39.02	39.15	38.88	39.39	38.69
	Proportion LE 26 cm	0.0110	0.0169	0.0062	0.0043	0.0083	0.0119	0.0064	0.01
	Proportion LE 30 cm	0.0880	0.0746	0.0428	0.0333	0.0440	0.0542	0.0341	0.05
	Proportion LE 40 cm	0.8259	0.7242	0.7421	0.7398	0.7103	0.7102	0.6877	0.74

Figure 19. Average size, % below 26, 30 and 40 (table only) over biweekly time periods in the 1998 yellowtail fishery.

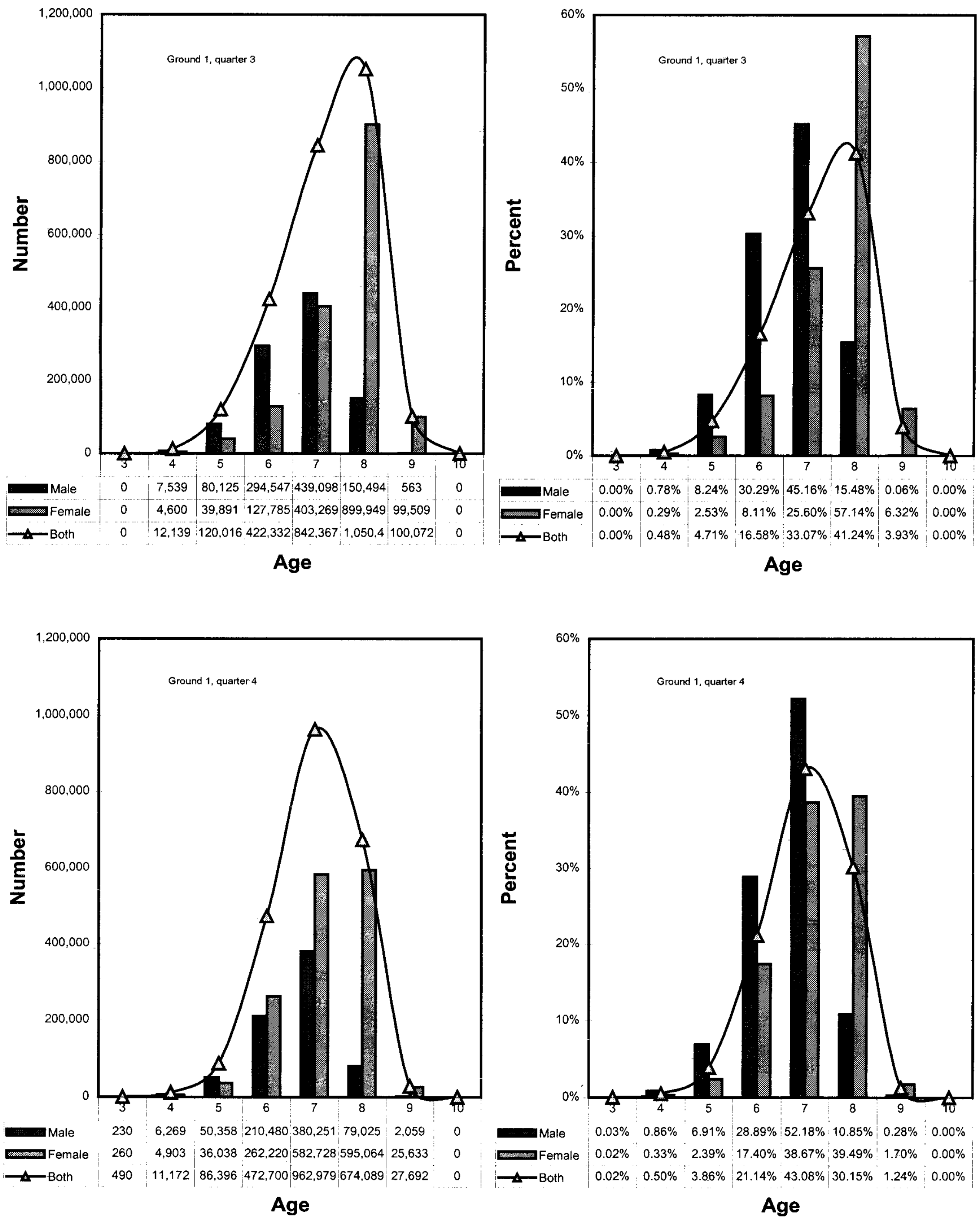
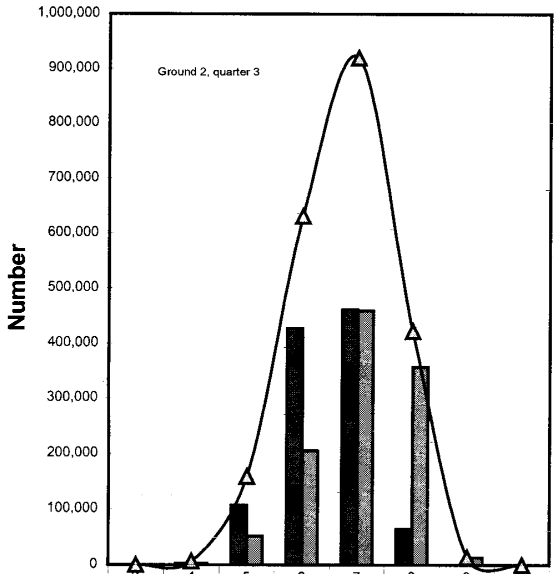
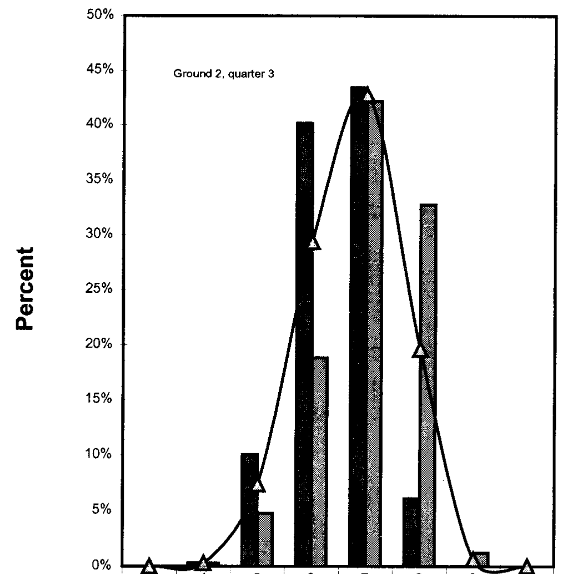


Figure 20a. Numbers (left) and percent (right) of yellowtail at age taken from the 1998 directed fishery in NAFO Divisions 3N and 3O.



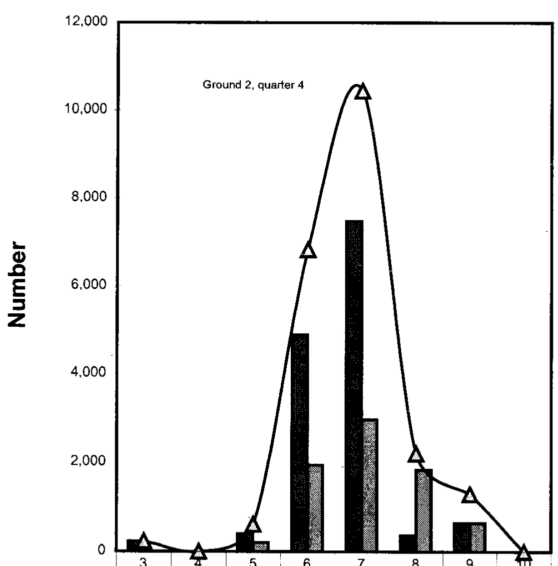
	3	4	5	6	7	8	9	10
Male	0	3,132	106,565	426,180	460,562	64,477	233	0
Female	11	3,246	51,700	204,726	458,867	356,748	13,325	0
Both	11	6,378	158,265	630,905	919,430	421,226	13,558	0

Age



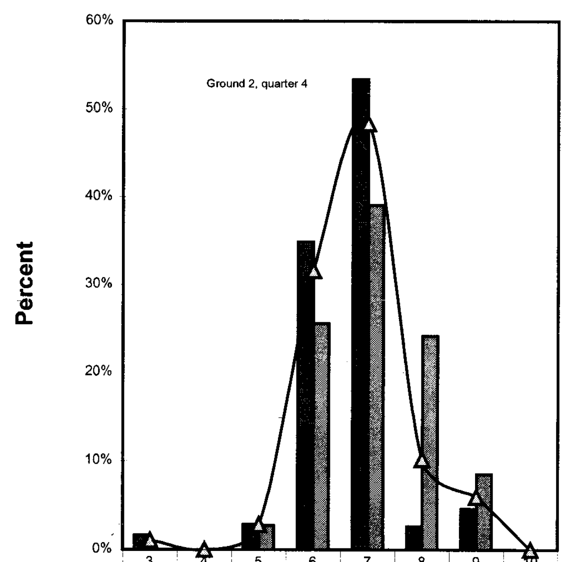
	3	4	5	6	7	8	9	10
Males	0.00%	0.30%	10.04%	40.16%	43.40%	6.08%	0.02%	0.00%
Females	0.00%	0.30%	4.75%	18.81%	42.15%	32.77%	1.22%	0.00%
Both	0.00%	0.30%	7.36%	29.35%	42.77%	19.59%	0.63%	0.00%

Age



	3	4	5	6	7	8	9	10
Males	230	0	401	4,887	7,479	368	646	0
Females	0	0	209	1,941	2,966	1,832	646	0
Both	230	0	609	6,827	10,445	2,200	1,292	0

Age



	3	4	5	6	7	8	9	10
Males	1.64%	0.00%	2.86%	34.88%	53.38%	2.62%	4.61%	0.00%
Females	0.00%	0.00%	2.75%	25.56%	39.06%	24.13%	8.51%	0.00%
Both	1.06%	0.00%	2.82%	31.60%	48.35%	10.18%	5.98%	0.00%

Age

Figure 20b. Numbers (left) and percent (right) of yellowtail at age taken from the 1998 directed fishery in NAFO Divisions 3N and 3O.

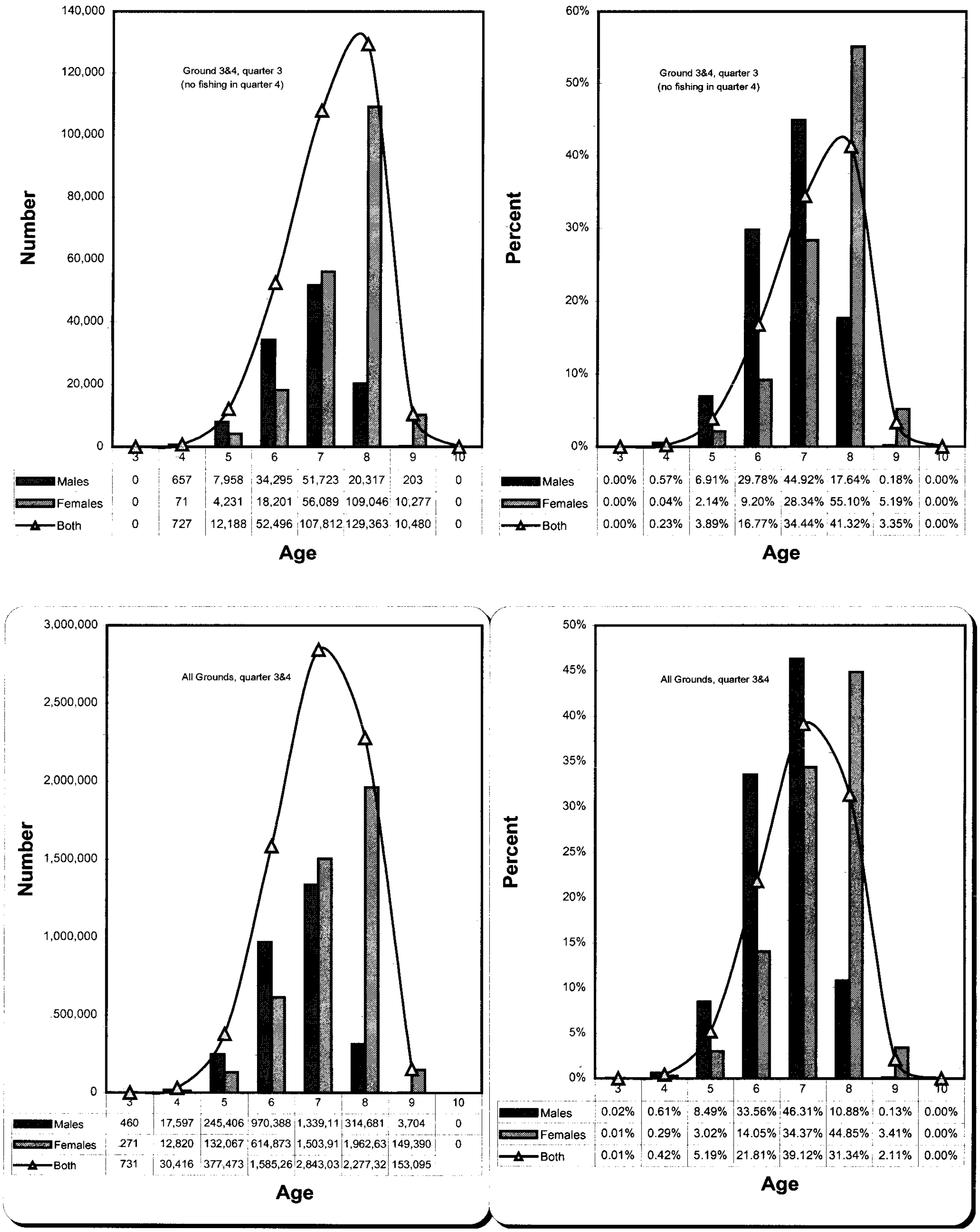


Figure 20c. Numbers (left) and percent (right) of yellowtail at age taken from the 1998 directed fishery in NAFO Divisions 3N and 3O.

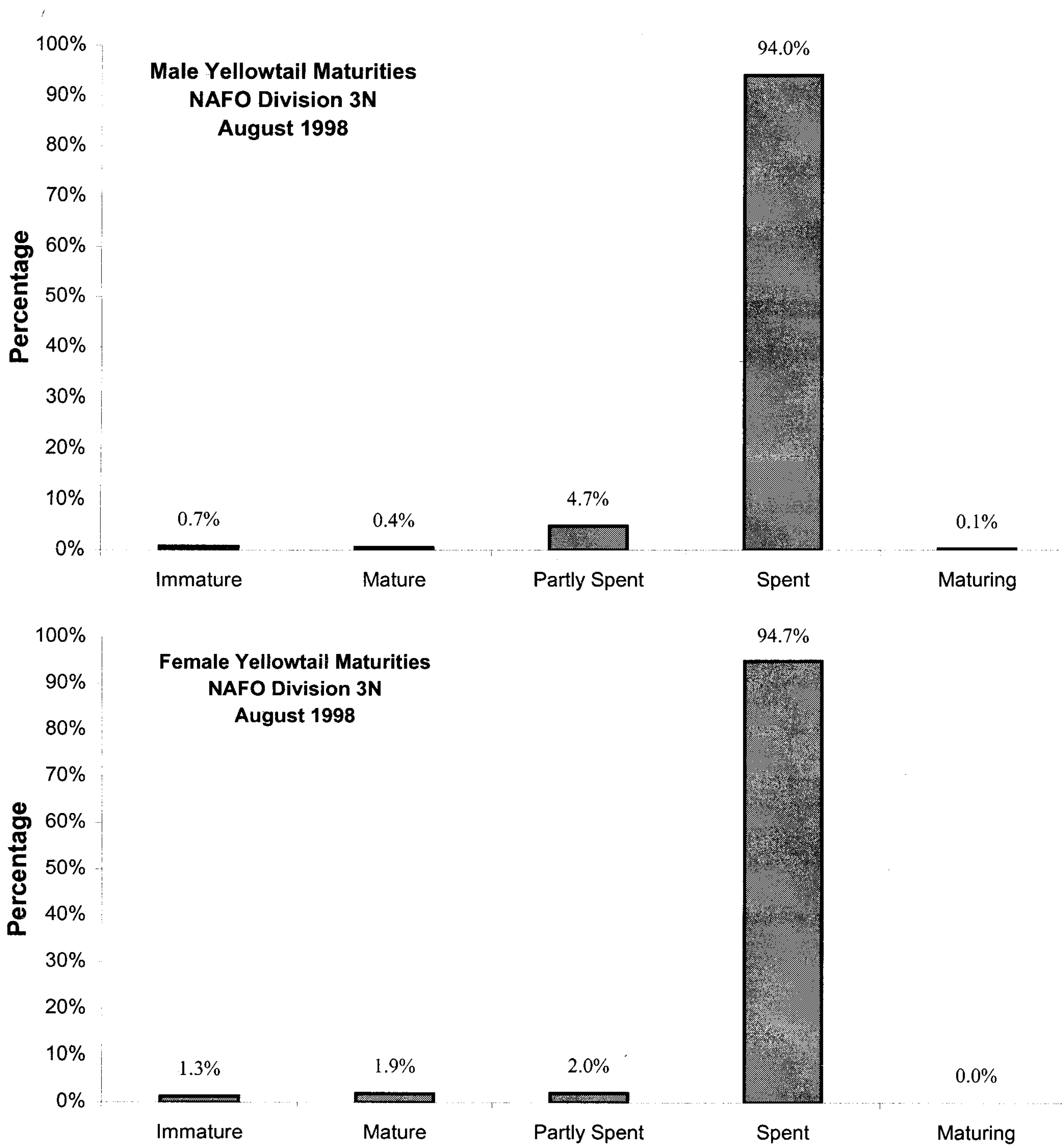


Figure 21. Maturity stages of yellowtail caught in the first two weeks of the 1998 directed fishery.