NOT TO BE CITED WITHOUT PRIOR
REFERENCE TO THE AUTHOR(S)

Northwest Atlantic Fisheries Organization

Serial No. N4418 **NAFO SCR Doc. 01/40**

SCIENTIFIC COUNCIL MEETING – JUNE 2001

Distribution of Greenland Halibut and By-catch Species that Overlap the 200-mile Limit Spatially and in Relation to Depth – Effect of Depth Restrictions in the Fishery.

by

D. W. Kulka

Department of Fisheries and Oceans
P O Box 5667, St. John's, Newfoundland, Canada A1C 5X1

Abstract

It is thought that measures currently in operation in the NAFO Regulatory Area are not adequate for the protection of the juvenile fish. The largest fishery in the NRA and thus the one of greatest concern is that directing for Greenland halibut. As well, the need to reduce by-catch of any species in the Greenland halibut and other fisheries has been noted. Because of the range of depths currently fished, the Greenland halibut fishery not only focuses on the juvenile component of the population but also takes significant by-catch. Information on the distribution of Greenland halibut including distribution of undersized (below 35 cm, the Canadian minimum landing size) and mature and immature components of the population is presented. The paper also elaborates on the distribution of thirteen other commercial species that occur in the NRA, those that may be taken as by-catch in the directed Greenland halibut or other NRA fisheries, including those that overlap the Southeast Shoal. Based on fall survey data, the analyses take the form of biomass partitioning by depth ranges and mapping the distribution of each species and spatial analyses employing GIS. The survey data suggest that restricting fishing effort to depths exceeding 700 m will significantly reduce the proportion of undersized Greenland halibut and also marginally increase proportion of mature fish taken. Relative amounts of some species of by-catch will be reduced. Other will increase.

INTRODUCTION

Establishment of an Exclusive Economic Zone or EEZ obligates interested parties in addressing issues of extended rights of ownership and management responsibilities of fish resources, as detailed in the Convention of the Law of the Sea (Anon 1982). When stocks straddle international zones, the Convention suggests that states exploiting the resource should seek to agree upon measures necessary to ensure the conservation of those resources. For NAFO (Northwest Atlantic Fisheries Organization), part of its responsibilities of ensuring sustainable fisheries is the formulation and implementation of conservation measures for the purpose of maintaining viability of stocks for which they are responsible. Since 1977, when Canada established its 200 mile limit (formally referred to the EEZ) NAFO responsibilities have focused on stocks that straddle that border (Fig. 1).

STACTIC (the Standing Committee on International Control) a Committee of NAFO has indicated that in part, the measures currently in operation in the NAFO Regulatory Area (NRA) were felt to be inadequate for the protection of the juvenile fish. Scientific Council also noted the need to reduce exploitation of juvenile fish. The largest fishery in the NRA and thus the one of greatest concern is that directing for Greenland halibut (*Reinhardtius hippoglossoides*). As well, the Joint Scientific Council/Fisheries Commission WG on Implementation of the Precautionary Approach recommended that for the three stocks considered in their report, Div. 3LNO yellowtail flounder (*Limanda ferruginea*), Div. 3NO cod (*Gadus morhua*), and 3LNO American plaice (*Hippoglossoides plattesoides*), steps be taken to minimize the catch of juveniles. They also indicated the need to reduce by-catch of any species in the Greenland halibut and other fisheries to the lowest possible level.

Because of the range of depths currently fished, the Greenland halibut fishery in the NRA not only focuses on the juvenile component of the population but also takes significant by-catch. Yellowtail flounder, cod, American plaice and thorny skate, among other species have been regularly recorded from the Greenland halibut (and other fisheries) in the NRA. Cod and American plaice are restricted species (under moratorium) in Canadian waters and the NRA given their current low abundance.

Related to questions on fish sizes as well as amounts of by-catch taken in the Greenland halibut (and other) fisheries, for 2000 the Scientific Council was requested by Fisheries Commission to evaluate:

1. Whether the current measures, with minimum size, mesh size and requiring vessels to move from areas where high percentages of undersized fish (less than 35 cm in length) are caught, allow for the continued rebuilding of the stock in the presence of the current fishery.
2. The biomass of Greenland halibut available to the commercial fishery over the whole distribution area of this species, in depth strata of 0 - 99 m, 100 - 199 m, 200 - 299 m, 300 - 399 m, 400 - 599 m, 600 - 799 m and 800 - 1,000 m.

It was further specified that separate values should be provided for:

a) Fish above and below the length of 50% maturity.

b) Fish above and below the current minimum landing size.

The Fisheries Commission of NAFO reiterated the request for scientific advice on management in 2002 (FC Doc. 00/20) as follows:

a) Evaluate the distribution of the fishable biomass of the main commercial species of fish in relation to depth (in 100 m intervals). Separate values should be provided for a) for fish above and below the length of 50% maturity and b) for fish above and below the current minimum landing size.

b) Evaluate the likely future medium-term development for Greenland halibut in 2+3KLMNO (and 2 other species) under the following assumed constraint:

   Closure of targeted Greenland halibut fishery in depths less than 200, 500 and 800 meters or any other depths considered appropriate. These cases, which will have to make a reasonable assumption on the redirection of effort so removed onto the remaining depth strata, should be compared with evaluation of current fishing practices.

While the proposal for a depth restriction was aimed at protecting juvenile Greenland halibut, it was thought that reductions in by-catch of other groundfish species, including yellowtail flounder, cod and American plaice could also be realized by constraining the Greenland halibut effort to deep water. In addition, a Canadian proposal for a closure of the Southeast (SE) Shoal to directed fishing for Greenland halibut, thorny skate (*Raja radiata*), roundnose grenadier (*Coryphaenoides rupestris*) and roughead grenadier (*Macourus berglax)* and yellowtail flounder was also presented to NAFO.

The above proposed measures are aimed at promoting conservation of the resources straddling the 200 mile limit. While the Precautionary Approach indicates that even when there is doubt, fisheries managers should err on the side of caution, wherever possible, it is clearly more appropriate to base conservation related decisions on sufficient supporting information. With this in mind, the purpose of this paper is to address the juvenile fish, by-catch and effect on the fishery issues raised by the Fisheries Commission. Information on the distribution of Greenland halibut including distribution of undersized and mature vs. immature components of the population is presented. Expected affects on the fishery are examined. The paper also elaborates on the distribution of thirteen other commercial species that occur in or adjacent to the NRA, those that may be taken as by-catch in the directed Greenland halibut or other NRA fisheries, including those that overlap the Southeast Shoal. Based on fall survey data and Canadian commercial data, the analyses take the form of biomass partitioning by depth ranges and mapping the distribution of each species, spatial analyses employing GIS (Geographical Information System). Surveillance boarding information is used to define current fishing practises in the NRA with respect to depth and (Canadian) fisheries data is used to look at fish size and catch rates with respect to depth.

METHODS

Annual stratified random trawl surveys of groundfish resources have been conducted during fall (autumn) in the Newfoundland Region since 1977. From the fall of 1995 onward the surveys have covered the offshore areas of Div. 2J, 3K, 3L, 3N, and 3O employing a Campelen shrimp trawl. The stocks examined in this paper partially or wholly overlap this area and Canada's 200 mile limit crosses Div. 3L, 3N and 3O over fishable areas. Survey coverage of Div. 3M and 2GH were added in 1996, as well as inshore coverage of Div. 3KL in 1997. It is this recent period since 1995 that the Campelen gear was deployed and this analysis focuses on these years. It was thought to be an appropriate period for the study to best reflect current and near future conditions as many of the stocks in the area have been relatively stable in terms of their spatial distribution since the mid-1990's.

The survey design is stratified random (pre-determined strata), with allocation of sets proportional to stratum area within a Division, and a minimum of 2 sets in all strata. Survey coverage generally occurred from mid September to mid December, although the 1995 survey actually extended into January 1996. The Campelen trawl was towed for 15 minutes at a speed of 3.0 knots, and SCANMAR equipment was used to monitor and record trawl performance. Sampling effort ranged from a total of 486 sets in 1995 to 904 in 1996. Survey coverage varied somewhat among years, partly due to design and partly due to other influences (weather, breakdowns, etc.). For example, a full survey of Div. 3M was done in 1996, but only the deep strata along the west and northern part of Flemish Cap were surveyed in subsequent years. Coverage in Div 2GH, inshore 3KL, and deepwater 3NO tends to be less consistent than for the core area of 2J3KLNO.

For this analysis, only successful surveys sets with minimal or no damage were chosen. Catches from sets that differed from the standard distance towed of 0.75 nautical miles were adjusted to this value. Fig. 2 shows how the set data are distributed by depth. Survey design is elaborated in Doubleday (1981). All analyses are performed on the entire surveyed area (2G-3O). As well, analyses are performed on a focussed area of interest, a window comprising the eastern Grand Banks where the 200 mile limit crosses the banks (portions of 3LNO). Data from the fall surveys were used for the analysis. Spring data were not used in the main analyses as they did not cover the deeper portions of the eastern edge of the Grand Bank, the main area of concern. However, spring data were used to compare to the fall to examine if there was any s easonal differences in the distribution of Greenland halibut.

Distribution maps (density surfaces showing where fish were more abundant by darkening grey shades) of each species of fish were produced using potential mapping in SPANS, a GIS (Anon 1997). Details of the mapping method are elaborated in Kulka (1998). To determine biomass at depth (biomass within each depth interval described below), the calculation used is very similar to the STRAP method (Smith and Somerton 1981) employing areal expansion. The technique overlays the survey set values of local density (kg per standard tow) on a surface depicting bottom depth intervals. The primary difference between the two techniques is that the GIS analyses using the depth zones as strata were not dependant on the pre-specified strata as required for STRAP calculations. Rather, the set data were post stratified and pooled into the following depth intervals: 0-50, 51-100, 101-150, 151-200, 201-250, 251-300, 301-350, 351-400, 401-450, 451-500, 510-600, 601-700, 701-800, 801-900, 901-1000, 1001-2000 m. The result was a larger number of sets per strata (average 47 sets per depth interval per year) for use in the density and biomass calculations. Mean catch per tow in each stratum adjusted to area of the stratum, summed over all strata yields an estimate of biomass, similar to STRAP. The depth categories used in this analysis are more detailed than specified in the request for information on distribution by depth zones originating from STACTIC. However, the depth interval data can be combined as required.

For Greenland halibut, the data from 1995-1999 were examined for each year separately in terms of density (kg per tow), and relative biomass partitioned by depth zones (expressed as percent of biomass in relation to biomass at all depths). Distribution was also mapped for each year as described above. Given that similar patterns were observed among years, the data were pooled to give an averaged view of the recent (1995-1999) distribution. The pooled approach was als o used for the other species listed below.

Greenland halibut were measured for length for each of the survey sets where they were captured. Based on these length data, the biomass of Greenland halibut was also compartmentalized in two ways:

a) that proportion of the surveyed population above and below 70 cm (approximate length at 50% maturity per Morgan and Bowering (2000) who indicated length at 50% maturity was 57-61 cm and 74-82 cm for males and females respectively) and

b) above and below 35 cm. The value 35 cm as listed in Scientific Council Report was used in this analysis to represent minimum landing size. However, it was noted that the NAFO minimum landing size listed in Conservation and Enforcement Measures, FC Doc 00/1 is 30 cm. As such, the results based on 35 cm were compared to 30 cm with respect to proportion of fish above/below those values.

The Campelen trawl used for surveys was inefficient at capturing large (greater than 70 cm) Greenland halibut (fish greater than 70 cm were almost absent in the survey catches). Almost no individuals over 70 cm were captured by the survey gear (refer to Fig. 10 which shows that size of fish in commercial gears, particularly longline and gillnet is substantially different than in research gear). Thus, length measurement data from the Canadian commercial fisheries, gillnet, longline and otter trawl was used to examine the distribution of the larger fish with respect to depth. Data from all areas was compared to fisheries in 3LNO and the pattern in average sizes caught at depth was found to be very similar regardless of area. Thus, data from all areas was used in the analysis.

Canadian fishery officer boarding information, specifically set location was used to examine the spatial distribution of the fisheries in the NRA. This information comprising 3,504 sets constituted a subset of the total fishing effort. By methods similar to those described above, fishing set locations for 1995-1999 were overlaid over the depth contours. Effort location was delineated by a count of sets that occurred within depth interval. The analysis assumes that the set data collecting during the boarding were spatially representative of the complete fishery.

The distribution of thirteen species commonly taken as by-catch with the Greenland halibut fishery and/or comprise other directed fisheries in the area (known to be fished or comprise a significant by-catch on the Grand Banks) were examined in relation to Greenland halibut: cod, American plaice, yellowtail flounder, roughead grenadier and roundnose grenadier, thorny skate, white hake (*Urophysis tenuis,* difficult to distinguish from red hake), haddock (*Melanogrammus* aeglefinus), monkfish (*Lophius americanus*), spotted wolffish (*Anarhichas denticulatus*), striped wolffish (*Anarhichas lupus*), redfish (*Sebastes sp.*), witch (*Glypocephalus cynoglossus*) were also analysed for distribution and biomass at depth. Red hake (*Urophysis chus*) was noted as a species commonly taken in the NRA fisheries. However, there may be some confusion as to species since red hake rarely if ever occurs in the NRA (Scott and Scott 1988) and based on survey data. Red hake records may be mis-identified threebeard silvery rockling (*Gaidrosarus ensis*) a similar looking deep-water species with a reddish colouration. Rockling has not been included in the analysis.

These species comprise the most common commercially valuable species straddling the 200 mile limit plus the most common expected by-catch. Using the same fall survey data for 1995-1999 pooled, distribution maps were produced for both the entire surveyed area and an eastern Grand Bank window, the portion of NAFO Div. 3LNO overlapped the 200 mile limit. Percent of relative biomass at depth (depth intervals specified above) was calculated for each species and compared to Greenland halibut. A ratio of catch of each by-catch species to catch of Greenland halibut at depth summed and scaled a range of 0 (no overlap) to 1 (most overlap) was used illustrate overlap of each species with Greenland halibut. The effect of fishing in a full depth range (0-2000 m) was compared to fishing restricted to depths greater than 700 m.

Information from the commercial fishery was used to define current fishing practices and to evaluate the impact of depth restrictions. Data on fishing positions collected by Canadian fisheries officers during surveillance boarding from 1995 to 1999 was mapped and analysed with respect to depth. Data from the 1995-1999 Canadian Greenland halibut fishery (otter trawls, longlines and gillnets) were used to examine catch rates and fish size at depth fished.

RESULTS AND DISCUSSION

In interpreting the information on distribution presented in this paper, three limitations in the survey data must be considered:

1) This analysis is based on the fall period, Sept.-Dec. the only time when surveys cover the entire study area. Also, the spring survey does not cover the deeper waters of the Flemish Pass, the primary area of concern. Most historic analyses of Greenland halibut distribution use this survey (i.e. Bowering 2000). For Greenland halibut, spring survey data (1996-1999 combined) was compared to the fall data (1995-1999). The comparison was done for NAFO Div. 3LNO, the areas covered during both surveys and the primary

area of concern for this analysis. The data from spring 1995 were not used as they were derived from a different survey gear (Engel). Fig. 3, indicates that Greenland halibut distributes similarly both by depth (upper panel) and spatially (lower panel) between those two periods. The only significant difference in the two distributions is the presence of higher concentrations in the northeast tip of the Nose of the Grand Bank. As noted above, the spring survey does not cover the deeper waters of the Flemish Pass as extensively as in the fall, thus the smaller proportion of biomass shown in the spring percent biomass within the 1000-2000 m category. Greenland halibut are not known to undergo seasonal movements although they undergo movement to deeper water over the period of their life cycle (Morgan and Bowering 2000). Thus, the fall data are used to represent annual distribution.

For the other species examined in this paper, similar fall/spring comparisons were not carried out. However, where available, past analyses were examined to see if those species were known to undergo seasonal movements and thus might affect the conclusions with respect to all times of the year. Cod undergo an inshore/offshore migration (Lilly et al. 2000) and thus their presence in the Greenland halibut fishery might be expected to be relatively greater during the fall/winter period when they are further offshore. Thorny skate undergoes a limited bank/slope migration. Kulka and Mowbray (1998) noted that this species tends to migrate to deeper waters during the winter and spring. Although still largely concentrated at shallow depths at all times of the year, a small component of the population was observed to shift into depths of 600-900 m. Skate by-catches in the Greenland halibut fishery on the slope therefore were observed to be only slightly higher during the winter/spring period from fishery officer boarding data for vessels fishing for Greenland halibut in the NRA. American plaice not previously observed to undergo seasonal movements (based on tagging data) were observed at greater depths on the slope of the Grand Bank in the early 1990's than in past years during the winter/spring period (Inglesias *et al*. 1996). However, it appears that the bulk of the population does not undergo a seasonal movement. White hake (Kulka and Mowbray 1999), monkfish, spotted and striped wolffish (Kulka and Deblois 1996) do not move to any degree with the seasons on the Grand Bank. Yellowtail flounder, haddock and redfish, witch, roughead and roundnose grenadier are also not known to undergo substantial seasonal movements. Thus, with the exception of cod, skate and plaice (the latter two with minor seasonal differences), the fall distributions presented in this paper provide a reasonable representation of the distribution of the various species during all seasons within the years presented.

2) The surveys do not cover the entire depth range of the distribution for a number of species analysed, including Greenland halibut. Fig. 2 shows that between 1995 and 1999, less than 1% of survey sets occurred at depths exceeding 1400 m (10% executed at depths greater than 1000 m). The deepest survey set prosecuted was 1470 m. The calculation of biomass uses area (km^2) between 1000 and 2000 m thus assuming (for species that occurred at those depths: Greenland halibut, roundnose grenadier, roughead grenadier, redfish, witch, plaice, skate) average density is the same from 1000-1470 m as for 1470-2000 m. As well, the depth plots for Greenland halibut, roundnose grenadier, roughead grenadier (refer to middle panel, Fig. 8, 12l, 12m) are truncated on the right side of the axis suggesting that a significant portion of the stock may fall outside of the surveyed area. The other species examined appeared to be nearly completely sampled in terms of their depth range.

3) The Campelen survey trawl rarely captures Greenland halibut greater than 70 cm. In part, it relates to selectivity in terms of size of fish used (refer to Fig. 11 for comparison of fish sizes taken in the various commercial gears and the survey gear) but also the survey does not cover depths in excess of 1400 m. Otter trawls in general are more selective of smaller fish. Greenland halibut do not mature until they approach this size (smaller for males and larger for females as specified by Morgan and Bowering 2000). Thus the gear used for research surveys does not account for a large portion of the mature portion of the population. To examine distribution of the mature component of the population, length data from the commercial fisheries for three gear types, gillnet longline and otter trawl was used (refer to Fig. 11). Thus, the analyses using Campelen survey data pertain largely to the immature portion of the population only.

Greenland halibut

Information on distribution presented in this paper is based on combined 1995-1999 fall survey data. Before pooling across years (i.e. if variation in the distribution of Greenland halibut was minimal among years), annual data were examined for each of 1995 to 1999 for the entire survey area covering NAFO Div. 2G to 3O (Fig. 1). Both the spatial distribution (Fig. 4) and density and biomass at depth (Fig. 5) showed a high degree of consistency among years. Areas of high density were confined to deep channels and to the shelf edge in all years. Greenland halibut along the shelf edge tended to be most dense in the same locations year after year. With respect to density (average kg per tow) at depth, a similar bi-modal pattern was observed across years except for 1995. In that year, the deep mode was somewhat shallower (600-700 m). However, this difference was largely the result of part of the study area not being surveyed in that year rather than a variation in distribution. For biomass, the pattern was also consistent across years. Biomass was concentrated at similar depths. These findings indicate that for the years 1995 and 1999, distribution of Greenland halibut was spatially consistent. Thus, the survey data for Greenland halibut from 1995-1999 were pooled to produce an averaged representation of the distribution.

Fig. 6, map of the pooled data shows that Greenland halibut distributes primarily along the shelf edge and in the deep channels. The Grand Bank topography differs from the more complex Northeast Nfld and Labrador Shelf in that it comprises a large, relatively flat and shallow bank. Fifty-four percent of the area of the Grand Bank occurs between 51-150 m compared to only 22% over the entire survey area. Thus there is less available habitat on the Grand Bank (lack of deep channels) compared to the banks to the north. As well, lower densities (kg per tow) of Greenland halibut encountered in the 300-600 m range on the Grand Bank compared to the areas to the north may be because of very cold bottom temperatures that cover much of the upper half of the bank (see Kulka and Mowbray 1999). Less than 5% of the biomass of Greenland halibut was found to distribute where bottom temperatures were less than 0.5^0 C. About 40% of Div. 3L-3O is covered by temperatures in this range in the fall. Thus, Greenland halibut in Div. 3L-3O are restricted largely to the slope areas around the periphery of the bank. The largest area of slope waters occur to the northeast in the Flemish Pass and adjacent areas (north of 45^0 lat). This is where most of the Greenland halibut is found in the NRA and where a substantial portion of the fishery (boardings data indicates about 63%) occurs. North of 45^0, the area outside of 200 miles extends over about 50,000 km^2 and there 50% of the area falls between 700 and 2000m bottom depth. This area straddles the border between NAFO Div. 3L and 3M.

Fig. 7 illustrates how Greenland halibut distribute by depth zones for NAFO Div. 2G-3O and for 3L-3O. The upper panel shows that the majority, 61% (70%) of the total area ($km^{2)}$ occurs at depths less than 250 m in Div. 2G-3O (3L-3O). Greenland halibut on the other hand is concentrated at depths greater than 250 m. In Div. 2G-3O (3L-3O), 95% (92%) occurs at depths greater than 250 m, 69% (78%) in greater than 400 m and 27% (49%) in greater than 1000 m. The highest catch rates were observed within the ranges of depths peaking at 350-500 m and at 700-900 m in both Div. 2G-3L and 3L-O.

Comparing the middle and lower panels of Fig. 7 indicates substantial differences in how the species distribute with respect to its density compared to biomass. This is because of the differences in extent of area contained within each depth range given that biomass is a function of area and density. Surveyed locations occurred only as deep as 1470 m thus calculation of biomass for the 1001-2000 m zone assumes a density of fish at depths greater than 1470 m. As indicated earlier, the patterns described above largely represent the immature component of the population of Greenland halibut. The mature portion of the population tends to be concentrated in the deepest part of the range of the species. Catch per hour and catch petr5 set from the Canadian commercial otter trawl fishery (Fig. 8) shows that Greenland halibut increase in density (as reflected by increasing catch rate) with depth. Catch per hour was observed to increase from about 2.5 t in 700 m to about 6 t at 1200 m. Data from Russian vessels fishing in Div. 3L in the NRA in 2000 corroborates this trend. Savvatimsky and Gorchinsky (2000) reported that proportion of Greenland halibut in the directed commercial catches in the NRA increased from near zero at 500 m to about 80% at 900 m.

Fig. 9 provides a spatial representation of the proportion of fish in the survey catches (by number) less than 35 cm. The black area delineates where on average less than 20% of the fish in the survey catches were smaller than 35 cm. The catches fall largely outside of the 700 m contour over the entire area surveyed. Catches with predominantly small fish (less than 35 cm) occur on the bank mainly inside 400 m regardless of location. Fig. 10a, panel A, a scatter plot of proportion of Greenland halibut less than 35 cm in each set shows two distinct clouds of points across depth. Where depths were less than 700 m, on average, 74% of the fish in the samples were less than 35 cm in length. In greater than 700 m the proportion was less than 8%. Fig. 10, panel b shows that the average proportion of fish less than 35 cm within depth zones is fairly constant down to about 400 m then declines with increasing depth, both in terms of weight and numbers. The numbers are slightly lower for Div. 3L-3O given that there are relatively fewer small fish in this area. At depths exceeding 1000 m, fish less than 35 cm are largely absent in the catches regardless of area. Fig. 10, panel b also indicates that average size of fish increased with depth from about 0.25 kg in depths less than 350 m to greater than 1 kg in depths greater than 1000 m. Fig. 10, panel c shows that 95% of fish were less than 35 cm over 2G-30 and 68% over Div. 3L-3O (1995-1999). At depths greater than 700 m, proportion less than 35 cm was 39 (2G-3O) and 20% (3L-3O).

As indicated in under Methods and reported above, the value 35 cm as listed in Scientific Council Report was used in this analysis to represent minimum landing size. However, it was noted that the NAFO minimum landing size in Conservation and Enforcement Measures, FC Doc 00/1 is 30 cm. As such, the results based on 35 cm were compared to 30 cm with respect to proportion of fish above/below those values. Fig. 10b, panel A shows that at depths exceeding 700 m the proportion (by number) of fish under 30 cm in length was 0.036 compared to 0.077 for fish under 35 cm. Panel B shows that the trend for both the entire survey area (2G-3O) and 3L-3O is very similar with the proportion below 30 cm being about 20% lower for than for proportion below 35 cm. Length composition data from the Russian, Spanish and Portuguese directed fisheries for Greenland halibut in 1998-2000 shows that only a very small proportion, 1.6% of fish were less than 30 cm (Igashov 2001). These fisheries were reported to have taken place at depths largely exceeding 700 m.

Scientific Council was requested to evaluate fish above and below the length of 50% maturity. However, data from Campelen survey gear cannot be used to address this issue because catchability of fish exceeding 70 cm, approximate size at 50% maturity (Morgan and Bowering 2000) is close to zero. Average size at depth from the Campelen gear falls below what is captured by commercial otter trawl and other commercial gears ranging from 21 cm at 200 m to 50 cm at 1300+ m.

To examine the distribution of the mature portion of the population, length data from commercial gears was used. Fig. 11 shows that longlines and gillnets have a much higher selectivity for the larger Greenland halibut than otter trawls. Average size in the catch was observed to increase with depth from about 35 cm for otter trawls and 45 cm for gillnets at 200-250 m to 52 cm (otter trawls) and 67 cm (gillnets) at 1200+ m. Longlines fished over a narrower range and on average took sizes slightly smaller than the gillnets. Percent of the catch less than 70 cm was close to 100% at depths shallower than 700 m. Beyond that depth, proportion of the larger fish increased slightly for otter trawls and rapidly for gillnet and longlines. Igashov (2001) showed very few Greenland halibut greater than 70 cm in the directed catches of Russia, Spain and Portugal during 1998-2000. At the greatest depths fished, 45% of the fish from gillnets exceeded 70 cm. Thus, even with otter trawl gear as is used in the fishery for Greenland halibut in the NRA, fishing at greater depths will result in larger fish in the catch.

By-catch species

A variety of species are taken as by-catch in the Greenland halibut fishery and in directed fisheries in the vicinity of the Grand Banks. Figure 12a-c (distribution maps) and Fig.13 a-m (biomass and density at depth, also refer to Fig. 15) illustrate how the common by-catch species distribute in relation to Greenland halibut for the entire area surveyed (Div. 2G-3O). The species are ordered by their pattern of distribution with respect to depth, shallow to deep. Figure 12 shows that haddock, monkfish and white hake, found mainly on the southwest slope of the Grand Bank do not overlap spatially with Greenland halibut in the NRA.

The remaining 10 species occur on the eastern side of the Grand Bank and may be expected to occur as by-catch with the Greenland halibut fishery to varying degrees. Of these, yellowtail flounder and cod distribute mainly on the tail of the bank. For the three most shallow species observed, yellowtail, thorny skate and haddock, more than 99%, 85%, and 67% of biomass respectively was distributed in less than 150 m. No yellowtail were recorded in depths greater than 100 m and as noted above, haddock does not occur on the NRA. Thus overlap of these species with Greenland halibut is expected to be null or minimal. Thorny skate although distributed primarily at depths less than 150 m was also found at low concentrations as deep as 1,100 m.

American plaice and cod were also observed to have a majority of their biomass (75% for both species) in less than 150 m although high densities of both species were also observed in the mid-range of depths. For plaice, the density distribution was bi-modal with a deep peak occurring at 800-900 m at nearly the same magnitude as that observed in the shallow area. However, given the small area contained within the 800-900 m range, this translates into only a minor component of the biomass. Fishing activity at this depth range, it would be expected to capture plaice particularly during the fall/winter period (Inglesias et *al*. 1996). Gorchinsky (2001) reported that from the directed fishery for Greenland halibut in the NRA, plaice was a common by-catch in the 600-1000 m range averaging about 1-4% of the catch depending on depth. If the biomass of presently depressed stock were to increase, by-catch of this species could also increase. The density distribution of cod was also bi-modal but with a peak at 300-350 m. Below this depth, it comprised only a small part of the biomass. Historically (prior to the early 1990's), cod would have been much more densely distributed in the northern portion of the NRA at much greater depths during the fall/winter.

Four other species redfish, spotted wolffish, striped wolffish, and witch were observed to distribute in a wide range of depths generally peaking in the mid-range of surveyed depths (Fig. 13b). White hake (Kulka and Mowbray 1999) and monkfish (Kulka and Miri 2000) are warm water species and thus are restricted to the western part of the bank outside of the NRA. The peak of biomass observed at 101-150 m for these two species corresponds with a warm body of water on the SE Shoal and the peaks at 301-350 m (white hake) and 351-400 m (monkfish) correspond to the warm bottom waters on the SW slope of the Grand Bank. The two wolfish species distributed similarly over a wide range of depths (51-700 m) with biomass peaking at 300 m. They were most densely aggregated in the deep channels on the banks as well as along the shelf edge. Striped wolfish varied from spotted in that a shallower mode was observed at 101-150 m. This corresponded to a concentration of striped wolfish just west of the SE Shoal comprising primarily juvenile fish as reported by Kulka and Deblois (1996). Redfish, also widely distributed by depth (101 to about 1400 m) has a complex and variable distribution throughout the year (D. Power pers. comm.). The greatest biomass was spread over the 251-500 m range. Witch occurred commonly over all depths surveyed. A shallow (51-150 m) mode corresponded to a concentration of witch in Div. 3NO along the southwest slope of the Grand Bank. In the fall, this comprised the majority (63%) of the biomass. Although witch was considerably denser at depths between 601 and 900 m, the biomass was relatively small in that area.

Three species were observed to be predominantly distributed in deep water along the slope or in the deeper parts of the channels on the shelf: Greenland halibut, roughead grenadier and roundnose grenadier. For the grenadiers, the density distributions were uni-modal and 70% of the biomass for roughead and 90% for roundnose was observed to fall within depths exceeding 1000 m.

Table 1 lists by depth categories, percent of biomass at depth for the species examined. Figure 13 (upper panel, shallow species, middle panel, mid or wide range species and lower panel, deep species) and Figure 14, upper panel compares how the species distribute in relation to depth. As previously indicated (refer to Fig. 12) haddock, monkfish and white hake, found mainly on the southwest slope of the Grand Bank do not overlap spatially with Greenland halibut in the NRA. For the species that overlap spatially (i.e. occur in the NRA), the shallow species, yellowtail, skate, plaice and cod distribute largely at depths less than 200 m suggesting minimal overlap with Greenland Halibut if the fishery is restricted to depths exceeding 700 m. The largest portion of grounds in the NRA where depths are less than 200 m is on the tail of the Grand Bank, an area not associated with Greenland halibut concentrations. Small amounts of skate and plaice might be expected in some sets exceeding 700 m but at much lower amounts than in shallower depths. This was observed to be the case for skate where by-catch rates in the Greenland halibut fishery are observed to be about 15 kg per hour in slope waters at certain times of the year (Kulka and Mowbray 1999). Canadian fishery observers have recorded plaice as deep as 900 m in the Greenland halibut fishery. However, amounts are small at theses depths. The mid-range species, redfish, the two wolfish and witch overlap to a greater extent than the shallow species since they cover a broader range of depths. Some overlap with Greenland halibut would be expected even with a fishery restricted to 700+ m although a reduction in by-catch levels would be expected since a substantial proportion of the biomass of each these species is found at less than 700 m. Overlap at the greatest depths (700+ m) occurs primarily with roundnose and roughead grenadier.

Fig. 15, lower panel shows relative overlap of each species with Greenland halibut comparing unrestricted fishing vs. fishing confined to depths exceeding 700 m. A ratio of percent catch of each of the by-catch species to percent catch of Greenland halibut at depth scaled to a range of 0 (no overlap) to 1 (most overlap) is used to illustrate overlap of each species with Greenland halibut. Assuming that the survey data would reflect species composition in the commercial catches, the effect of fishing in depths restricted greater than 700 m (light bars) effectively reduces proportion of by-catch of some species while increasing others. For species that occur in the NRA, yellowtail flounder, cod, and striped wolfish would be virtually eliminated from the catches. Redfish, plaice, witch and spotted wolfish by-catch would be reduced. Skate would increase slightly and the grenadiers would show the largest increase. By-catch of other non-commercial deep-water species not dealt with in this paper such as black dogfish (*Centroscyllium coelepis*) and silver rocking (*Gaidropsarus argentatus*), would also likely increase with increasingly greater depths fished.

Figure 16, upper panel shows 3,504 fishing locations in the NRA based on information collected by Canadian fisheries officers from 1995-1999. It is a subset (proportion unknown) of the entire fishing effort during that period collected during boardings. If these sets are representative of the entire fishery, this map indicates that the majority of fishing effort in the NRA straddles the shelf break, primarily in deep water. The sets that occur on the tail of the banks at 51-100 m are directing for thorny skate, not Greenland halibut. Figure 16 lower panel shows distribution of sets with respect to depth. Eighty-one percent of the sets were observed to occur at depths greater than 700 m. These set positions represent starting positions. Actual tow trajectories may result in a wider range of depths fished than indicated by the data Even so, this sample of the fishing activity in the NRA suggests that restricting the Greenland halibut fishery to greater than 700 m would in effect mean a relative minor change in the fishing strategy.

CONCLUSIONS

Regulatory organizations such as NAFO are responsible for implementing measures that promote sustainable fisheries and maintain viability of stocks. While the Precautionary Approach indicates that even when there is doubt, fisheries managers should err on the side of caution, wherever possible, it is clearly more appropriate to base conservation related decisions on sufficient supporting information. In relation to the Greenland halibut fishery in the NRA, this analysis suggests that confining the effort to depths greater than 700 m will promote conservation of the resources straddling the 200 mile limit.

Restricting fishing to depths greater than 700 m will result in:

a) increased average size of Greenland halibut taken in the fishery. In particular, proportion of undersized fish (less than 30/35 cm) will be reduced thus protecting juvenile Greenland halibut.
b) a wider mix of ages taken in the catches, resulting in a lower fishing mortality for younger age groups.
c) a decrease in by-catch of a number of commercially important species including several under moratorium (increase for the grenadiers and other deep water species).
d) no significant (negative) impact on catch rates (commercial catches from adjacent areas and catch composition in the NRA fisheries suggest that there would be an increase in catch rate with increasing depth).
e) little affect on current fishing practices in the NRA since the majority of effort in recent years already occurs outside of 700 m.

Thus restricting the Greenland halibut effort to greater than 700 m would appear to be positive for the population with minimal impact on the fishery. It is recommended that further and more detailed data from the fishery in the NRA be analysed to confirm what was observed from this analysis in terms of age structure of the catch, catch rate of Greenland halibut and by-catch mix.

References

Anon 1969. Report of the midterm Meeting of the Standing Committee on Regulatory Measures. ICNAF Com Doc. 69/2 Ser. No. 2150.

Anon 1978. The biology, distribution and state of exploration of shared stocks in the North Sea area. ICES Cooperative Res. Rep. No. 74.

Anon 1982. United Nations Convention on the Law of the Sea. Third United Nations Conference on the Law of the Sea. Oct. 1982.

Anon, 1997. SPANS. Ver. 7 Spatial analysis system. Reference Manual. Tydac Research Inc. 3rd Edition.

Anon 1999. Report of the Working Group on Allocation of Fishing Rights to Contracting Parties of NAFO and chartering of vessels between contracting parties. NAFO/GC Doc. 00/4 Ser. No. N4137 22p.

Anon 2000. Report of the Working Group on Allocation of Fishing Rights to Contracting Parties of NAFO. NAFO/GC Doc. 99/2 Ser. No. N4290 22p.

Anon 2000 Conservation and Enforcement Measures. FC Doc. 00/1.

Bowering W. R. 2000. Trends in the distribution, biomass and abundance of Greenland halibut (*Reinhardtius hippoglossoides*) in NAFO Subarea 2 and Divisions 3KLMNO from Canadian research vessel surveys during 1978-99. NAFO Res. Doc. 00/12 Ser. No. N4234 42p.

Doubleday, W.G., 1981. Manual on groundfish surveys in the Northwest Atlantic. NAFO Sci. Counc. Stud. No. 2.

Gorchinsky, K.V. 2001. Bathymetrical distribution of American plaice by-catches in the diretected fishery for Greenland halibut, thorny skate and beaked redfish in NAFO Divisions 3LMNO in January-July 2000. NAFO Res. Doc. 01/18 Ser. No. N4386 6p.

Igashov, T. M. 2001. Comparative analysis of length-age composition of Greenland halibut (*Reinhardtius hippoglossoides)* from the commercial catches taken by Russia, Spain and Portugal in the Flemish Pass (Divisions 3LM) in 1998-2000. NAFO Res. Doc. 01/12 Ser. No. N4381 5p.

Inglesias, S., J. Paz and E. de Cardenas 1996. Occurrence of American plaice (Hippoglossoides platessoides) at non-habitual depths in the Northwest Atlantic, 1990-93. NAFO Sci. Coun. Stud. 24 91-95.

Kulka, D. W 1998. SPANdex - SPANS geographic information system process manual for creation of biomass indices and distributions using potential mapping. DFO Atl. Fish. Res. Doc. 98/60 28p.

Kulka, D. W. and E. M. Deblois 1996. Non traditional groundfish species on Labrador Shelf and Grand Banks – Wolfish, Monkfish, White Hake and Winter Flounder. DFO Atl. Fish. Res. Doc. 96/97 49p.

Kulka, D. W. and F. K. Mowbray 1998. The status of thorny skate (*Raja radiata*), a non-traditional species in NAFO Divisions 3L, 3N, 3O and 3Ps. DFO Atl. Res. Doc. 98/131 70 p.

Kulka, D. W. and F. K. Mowbray 1999. The status of White Hake (*Urophycis tenuis*), a non-traditional species in NAFO Divisions 3L, 3N, 3O and Subdivision 3Ps. DFO Atl. Fish. Res. Doc. 99/132 5xp.

Kulka D. W. and C.M. Miri The status of Monkfish (*Lophius americanus*) in NAFO Divisions 2J, 3K, 3L, 3N, 3O and Subdivision 3Ps. DFO Atl. Fish. Res. Doc. 2001/004 40p

Lilly, G. R., P. A. Shelton, J. Brattey, N.G. Cadigan, E. F. Murphy and D. E. Stansbury 2000. An assessment of the cod stock in NAFO Divisions 2J+3KL. DFO Atl. Fish. Res. Doc. 00/063 40p.

Morgan, M.J. and W. R. Bowering 2000. Maturity at age and size of Greenland halibut (*Reinhardtius hippoglossoides*) and geographic distribution of spawning fish. DFO Atl. Res. Doc. 00/06 15 p.

Scott, W. B. and M. G. Scott 1988. Atlantic fishes of Canada. Can Bull. Fish. Aquat. Sci. No 219 Univ. Tor. Press 731 pp.

Savvatimsky, P.I. and K.V. Gorchinsky 2001. By-catch of grenadiers in directed fishery for Greenland halibut in Divisions 3LMN and size, age and sex composition of roughead grenadier in 2000. NAFO Res. Doc. 01/9 Ser. No. N4375 12p.

Smith, S. J. and F. H. Page 1996. Association between Atlantic cod (*Gadus morhua*) and hydrographic variables: Implications for the management of the 4VsW cod stock. ICES J. Mar. Sci. 53:597-614.

Smith, S. J. and G. D. Somerton. 1981. STRAP: A user-oriented computer analysis system for groundfish research vessel survey data. Can. Tech. Rep.Fish. Aquat. Sci. 1030:iv + 66p.

Table 1 – Percent of biomass at depth for Greenland halibut and 13 other species that occur as by-catch or area taken as directed fisheries in the area.

Species	0-50	51-100	101-150	151-200	201-250	251-300	301-350	351-400	401-450	451-500	501-600	601-700	701-800	801-900	900-1000	1001-2000
Yellowtail	48.4%	51.5%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Haddock	1.0%	31.6%	34.3%	4.4%	23.7%	2.3%	2.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Striped wolfish	0.4%	17.2%	4.7%	7.1%	16.9%	30.9%	16.3%	3.7%	1.6%	0.9%	0.1%	0.2%	0.0%	0.0%	0.0%	0.0%
Monkfish	0.0%	0.0%	23.6%	17.8%	7.2%	6.5%	12.9%	17.6%	0.0%	9.6%	3.3%	1.5%	0.0%	0.0%	0.0%	0.0%
Cod	22.8%	46.2%	6.0%	4.0%	4.5%	4.1%	6.6%	2.3%	1.9%	0.9%	0.5%	0.2%	0.1%	0.0%	0.0%	0.0%
White hake	2.0%	15.1%	18.9%	7.0%	8.2%	7.7%	30.8%	3.1%	0.8%	4.6%	0.8%	0.5%	0.0%	0.0%	0.0%	0.4%
Thorny skate	35.6%	44.9%	4.9%	1.4%	1.7%	2.0%	2.5%	1.8%	2.3%	1.3%	0.5%	0.5%	0.2%	0.1%	0.1%	0.2%
Redfish	0.0%	0.0%	7.5%	2.9%	4.3%	17.3%	11.3%	12.9%	12.0%	13.3%	6.6%	10.1%	0.8%	0.1%	0.6%	0.2%
Spotted Wolfish	0.0%	0.8%	2.9%	10.7%	18.5%	20.4%	12.3%	18.3%	7.5%	3.2%	0.8%	2.6%	0.7%	0.2%	0.4%	0.5%
American plaice	9.0%	47.0%	18.6%	5.1%	4.9%	2.1%	3.5%	1.4%	3.0%	1.0%	0.9%	0.7%	0.8%	1.5%	0.2%	0.2%
Witch	0.7%	39.0%	23.6%	2.0%	3.5%	1.5%	1.1%	1.0%	2.6%	3.3%	4.4%	5.0%	3.9%	4.2%	2.4%	1.8%
Greenland halibut	**0.0%**	**0.6%**	**0.4%**	**0.9%**	**3.2%**	**6.4%**	**8.5%**	**11.2%**	**20.6%**	**6.4%**	**4.6%**	**2.3%**	**2.7%**	**3.0%**	**2.4%**	**26.7%**
Roughead grenadier	0.0%	0.0%	0.0%	0.1%	0.1%	0.9%	1.5%	0.9%	2.1%	2.4%	3.4%	3.8%	2.7%	5.7%	6.7%	69.8%
Roundose grenadier	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.1%	0.1%	0.3%	1.2%	2.3%	2.7%	3.1%	90.0%

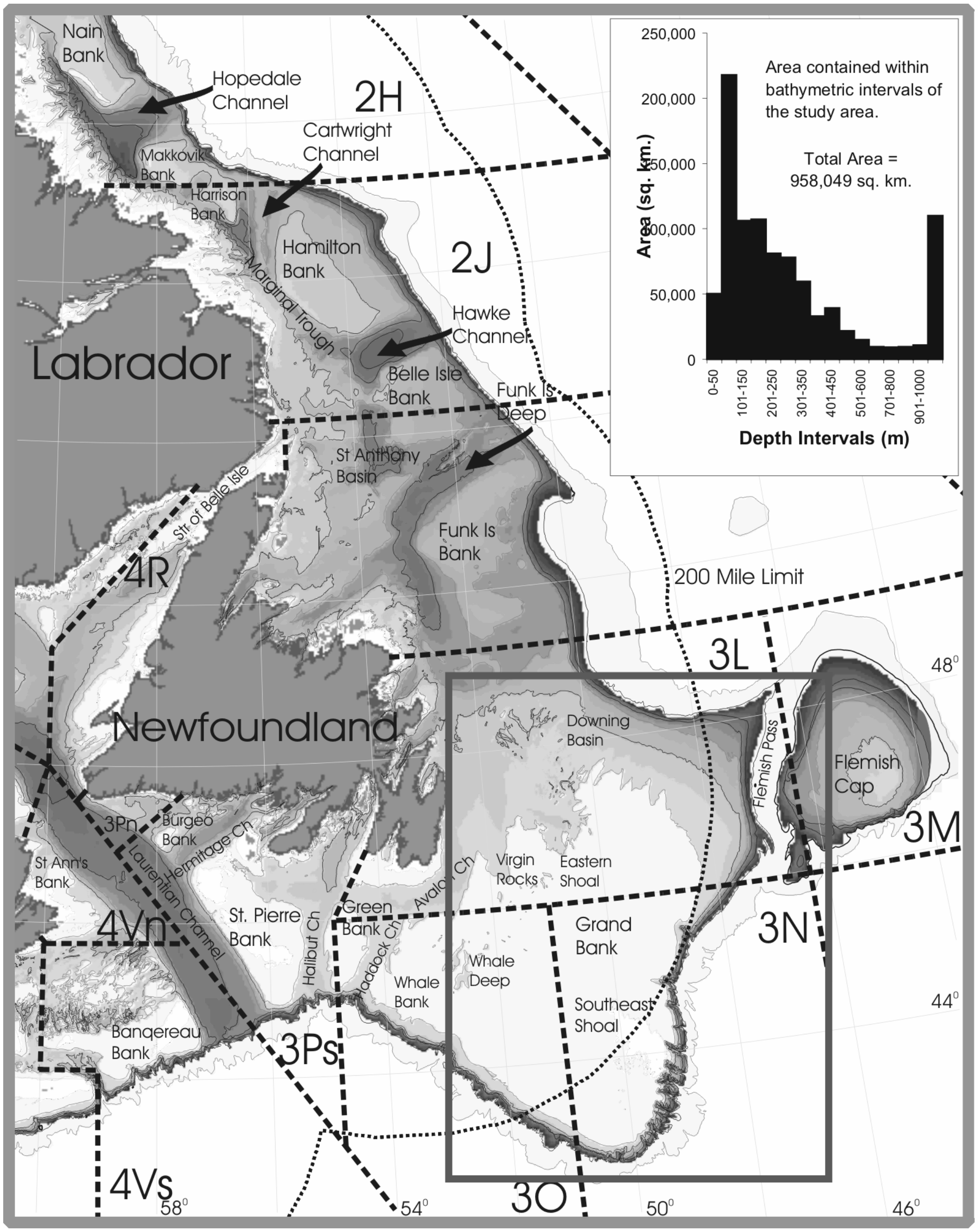
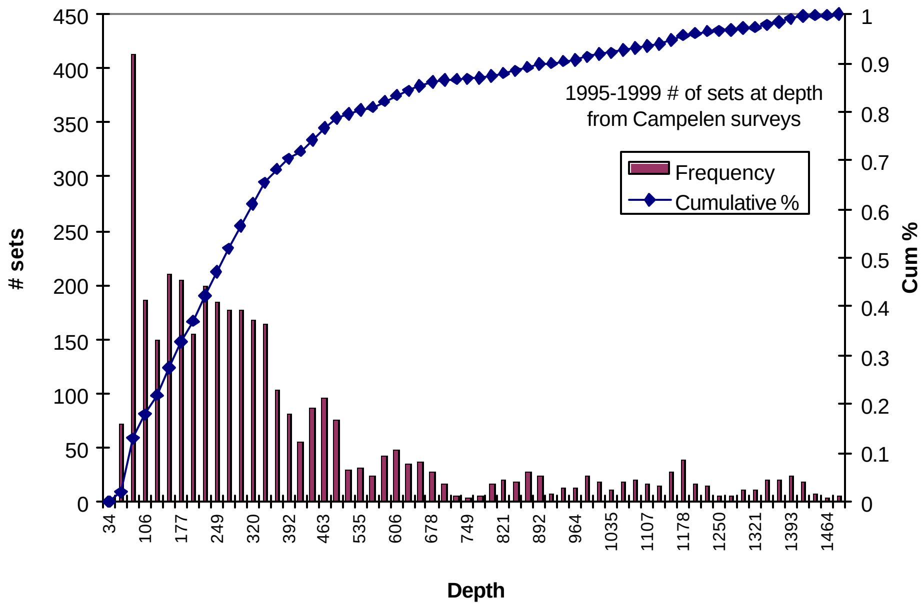


Figure 1. Study area showing the depth strata used in the analysis. Box illustrates the area of concern where the 200 mile limit overlaps the Grand Bank.



	1995	1996	1997	1998	1999	All years
Count of sets	486	904	810	813	744	3,757

Figure 2. Distribution of research survey sets by depth from 1995-1999 and count of sets by year.

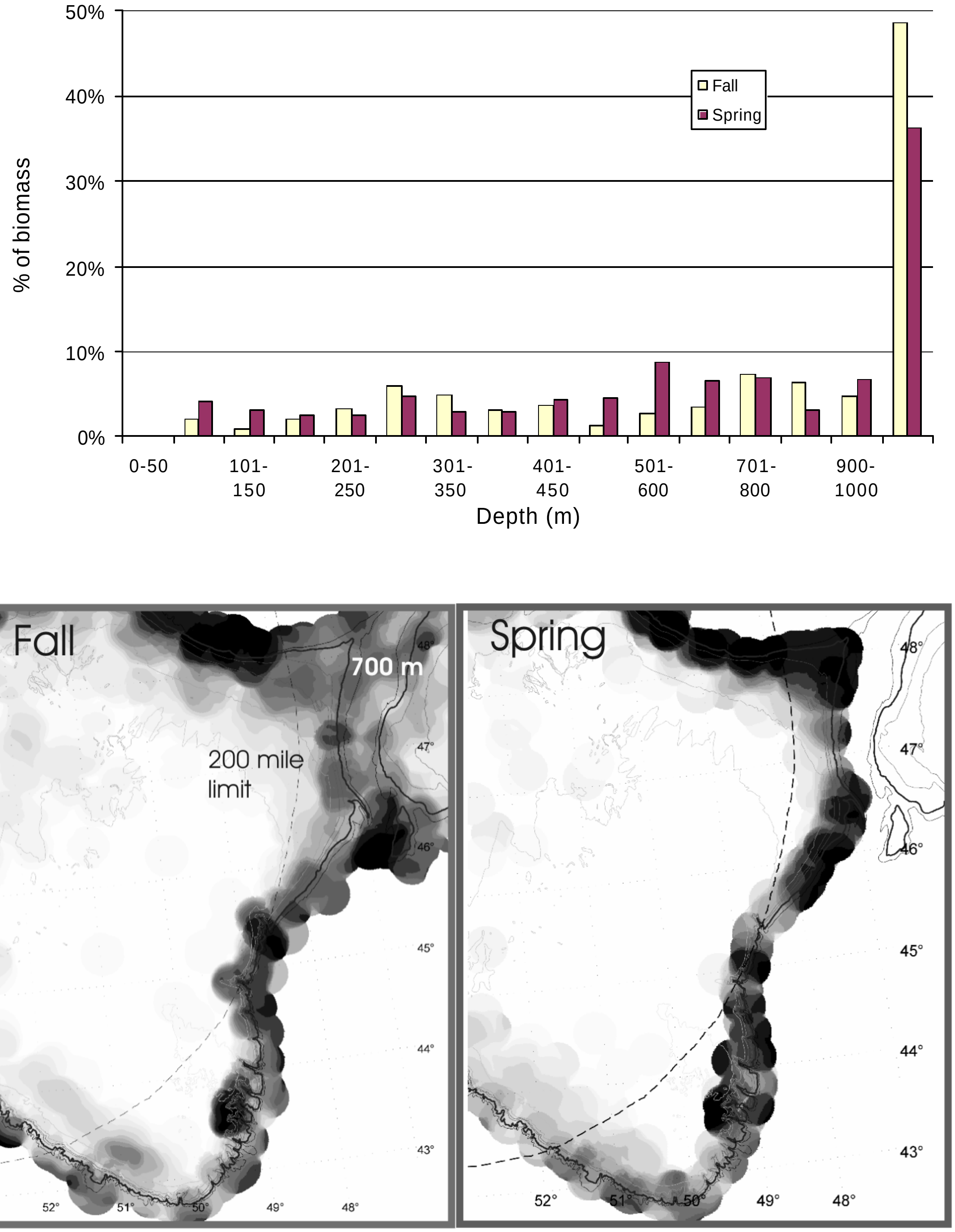


Figure 3. Comparison of biomass at depth between fall (1995-1999) and spring (1996-1999) for Greenland halibut for the overlapping area 3LNO. Upper panel compares % biomass at depth, lower panel shows spatial distribution. 1995 data were not used for the spring because in that year, a different gear (Engels) was used.

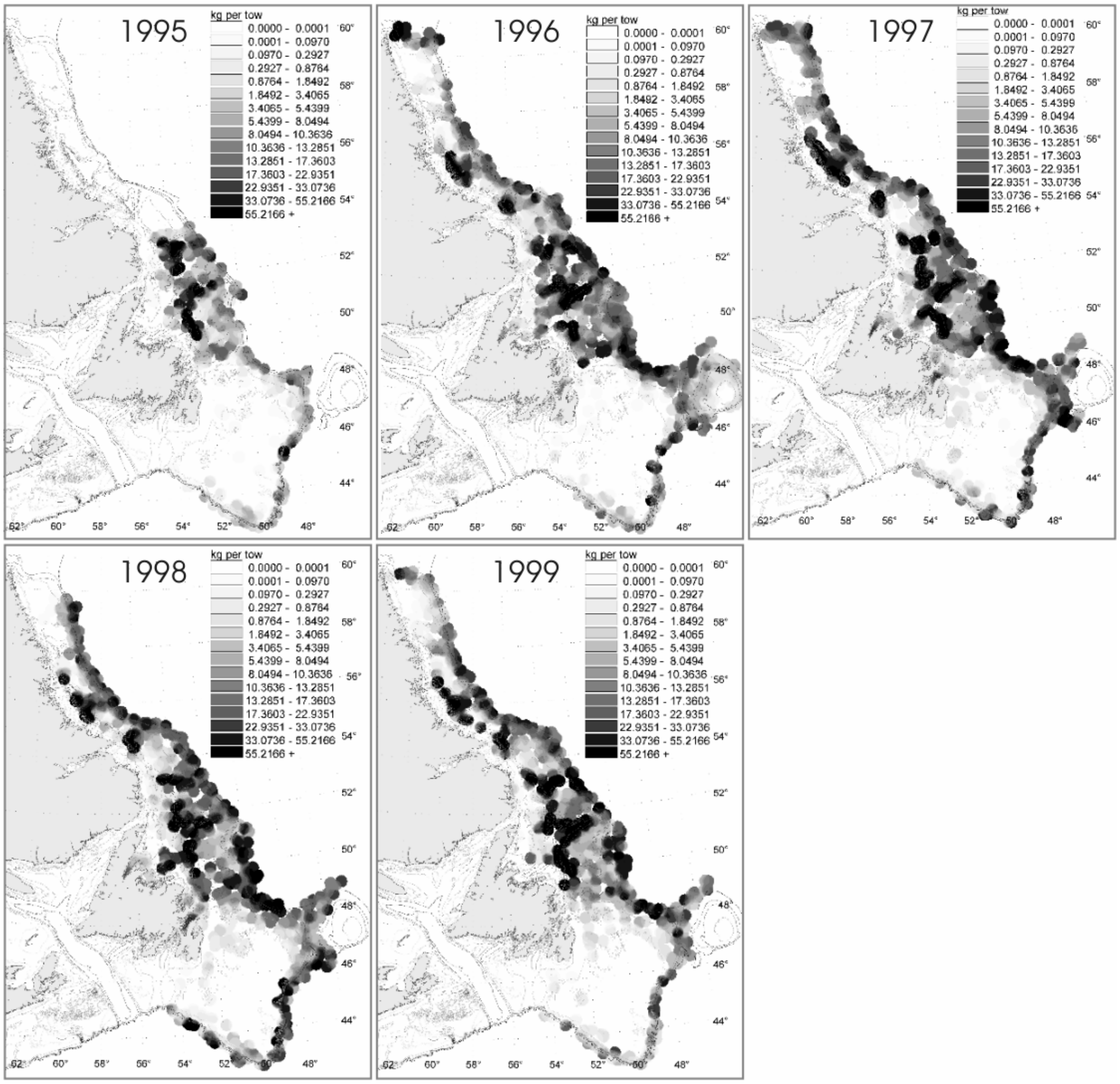


Figure 4. Annual distribution maps of Greenland halibut, 1995-1999 based on fall surveys. Scale is increasing density reflected by kg per standard tow.

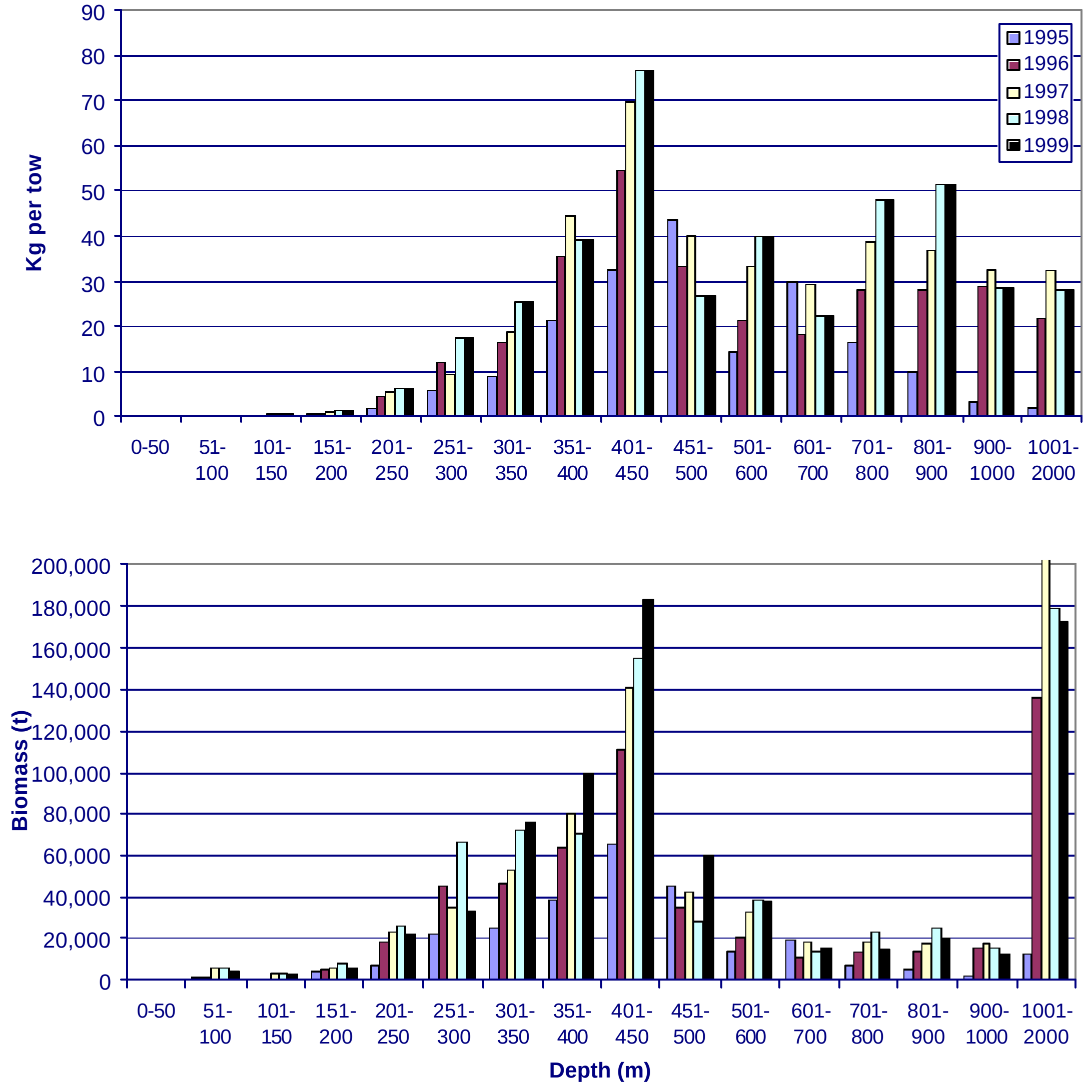


Figure 5. Annual distribution of Greenland halibut by depth, 1995-1999: Upper panel - density (average kg per tow by depth range); Lower panel – biomass (t) by depth range.

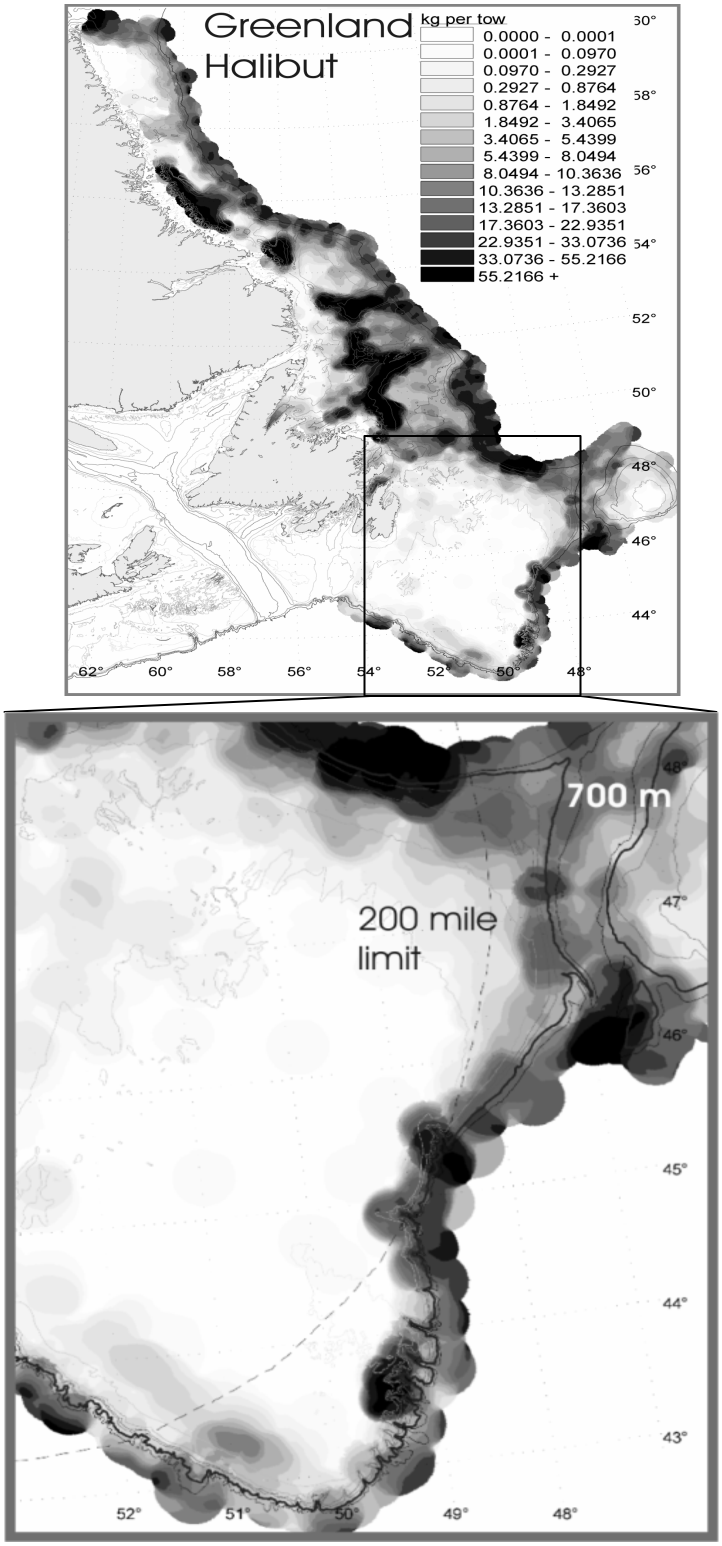


Figure 6. Distribution of Greenland halibut based on fall surveys. Upper figure shows the entire surveyed area. Lower figure shows the are of concern where the 200 mile limit crosses the Grand Bank. 700 m contour is thick line, 200 mile limit is dashed.

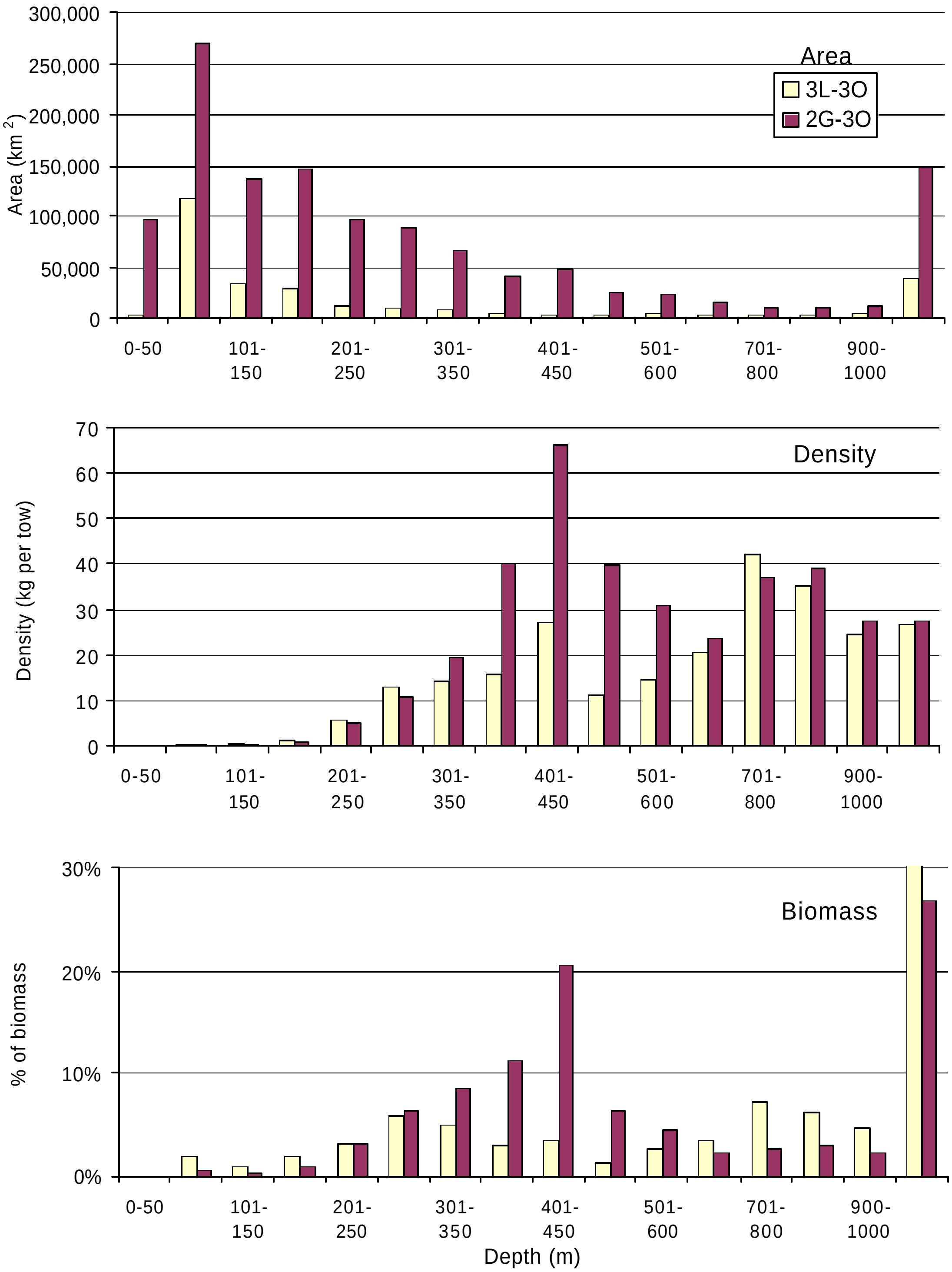


Figure 7. Distribution of Greenland halibut by depth, 1995-1999 for NAFO Div. 2G-3O, dark bars ands 3L-3O, light bars: Upper panel - available area (km^2 by depth range); Middle panel - density (average kg per tow by depth range); Lower panel – biomass (t) by depth range.

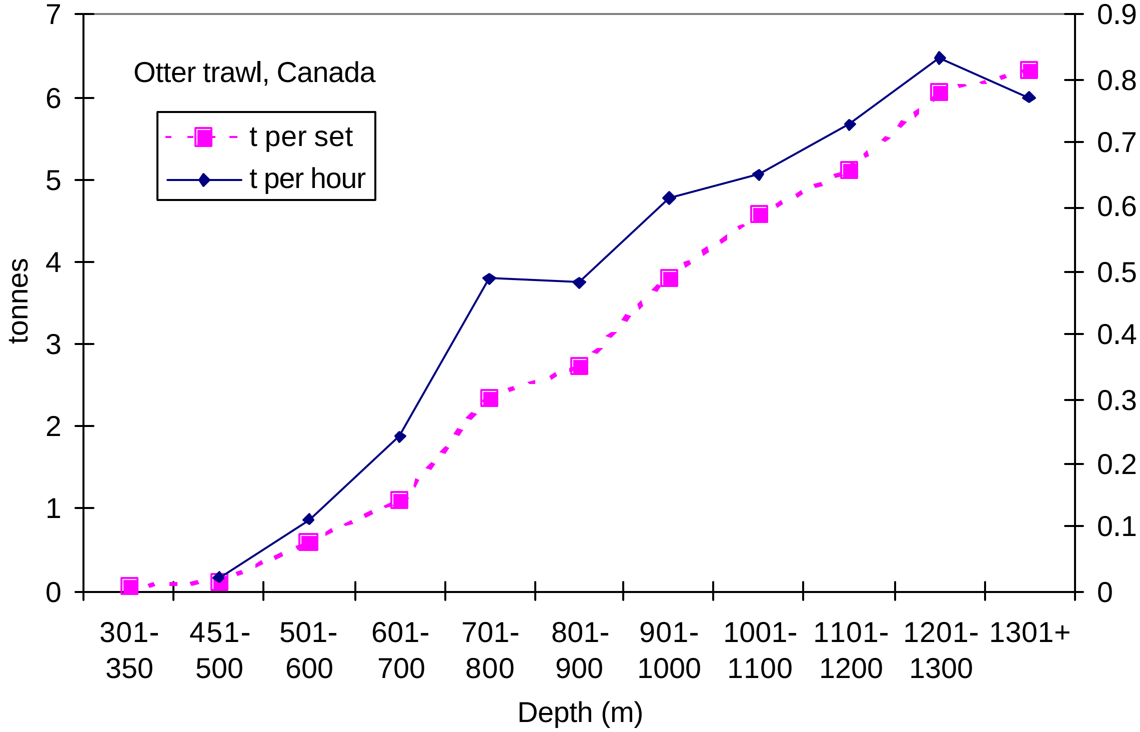


Figure 8. Catch rate in t per hour and t per set for Greenland halibut based on the Canadian fishery inside the 200 mi limit, 1995-1999.

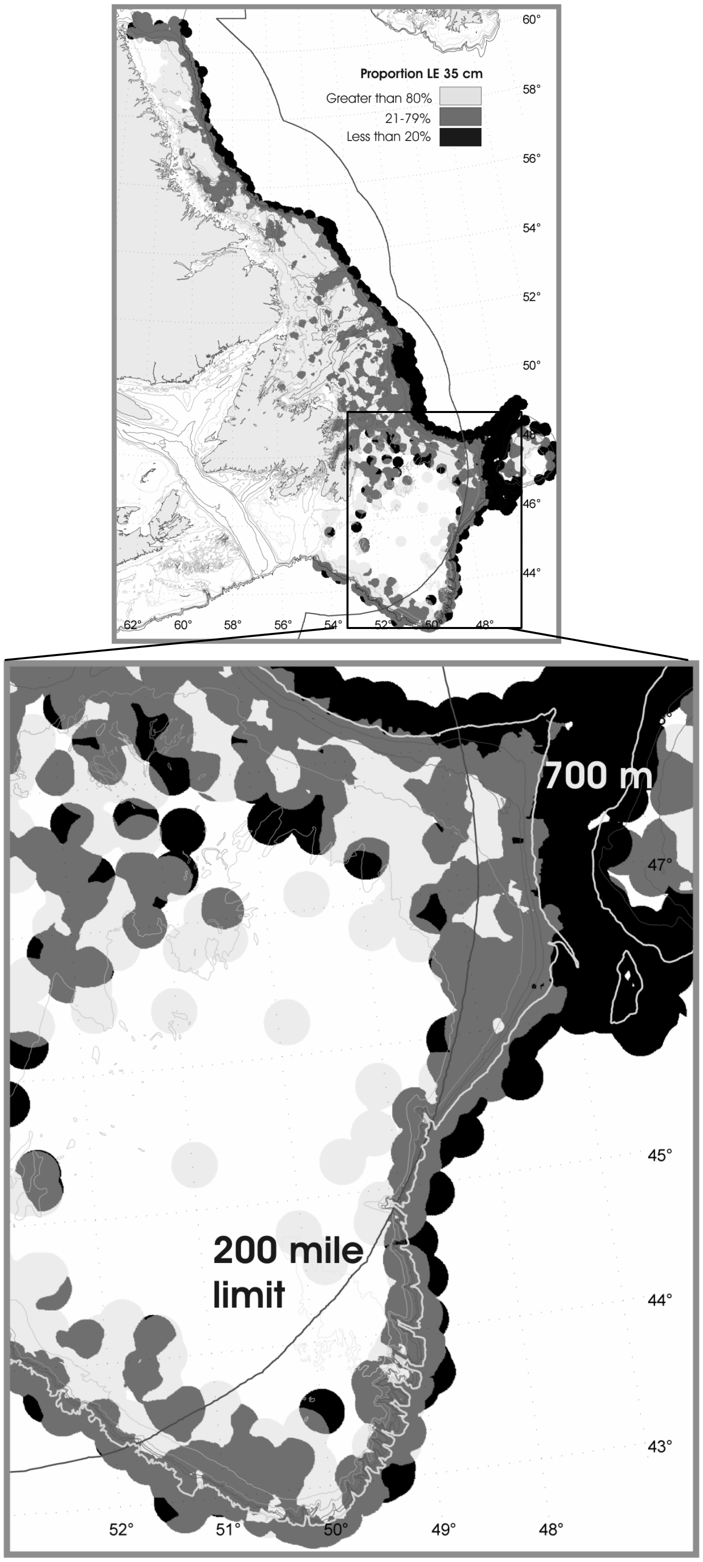


Figure 9. Distribution of proportion of Greenland halibut less than35 cm. Upper figure shows the entire surveyed area. Lower figure shows the are of concern where the 200 mile limit crosses the Grand Bank. 700 m contour is thick light gray line, 200 mile limit is solid black.

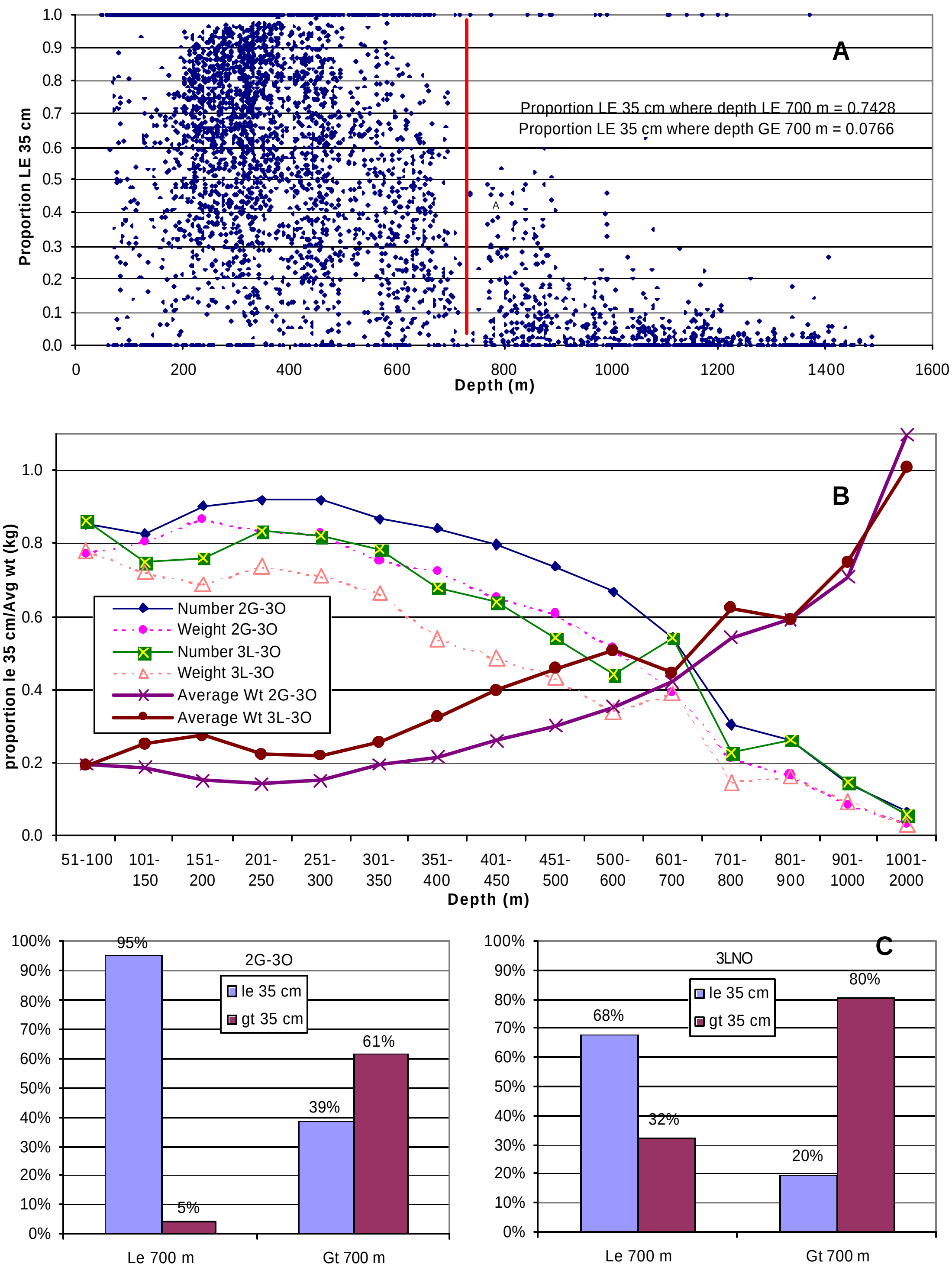


Figure 10. Biomass at depth for Greenland halibut categorized by minimum size fish, under 35 cm vs. over 35 cm. Panel A shows set by set proportion less than 35 cm (2G-3O). Panel B proportion less than 35 cm

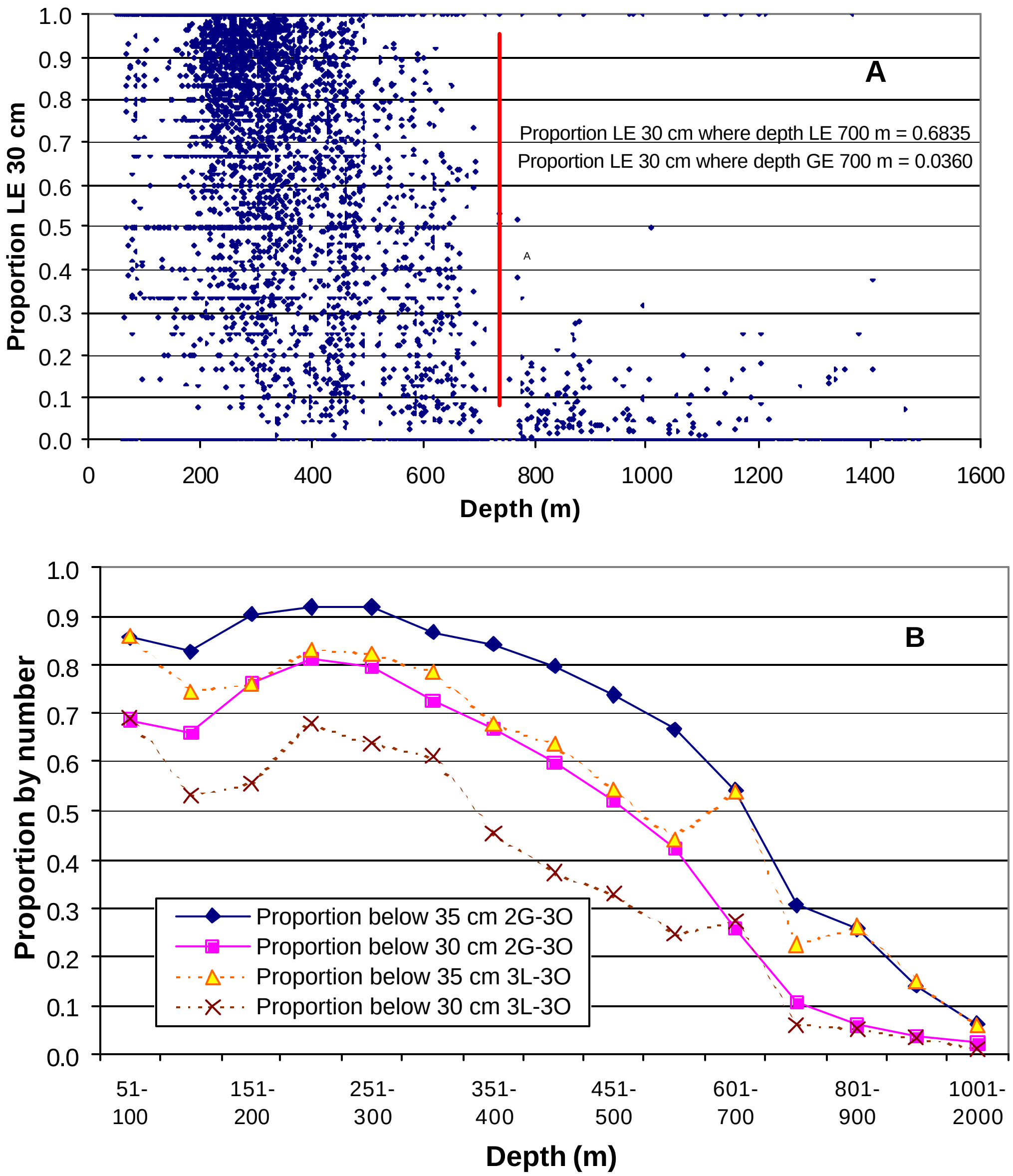


Figure 10b. Proportion Panel A shows set by set proportion less than 30 cm (2G-3O). Panel B shows proportion of number of Greenland halibut at depth, less than 35 cm vs. less than 30 cm, 2G-3O and 3L-3O.

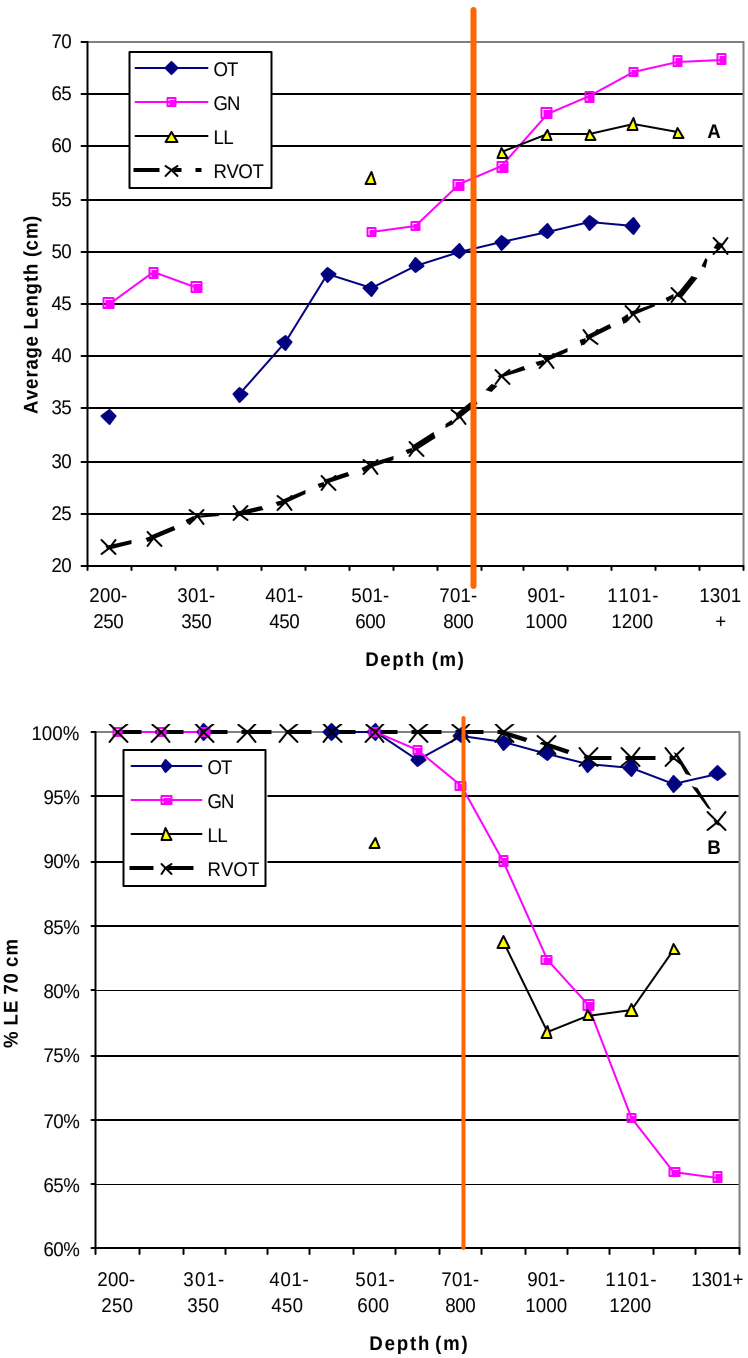


Figure 11. Size of Greenland halibut at depth caught in commercial fishing gears OT – otter trawl, GN – gillnet and LL - longline and RVOT – survey (Campelen) trawl, 1995-1999. Panel A shows average length by depth interval. Panel B shows percent of fish less than 70 cm by depth interval.

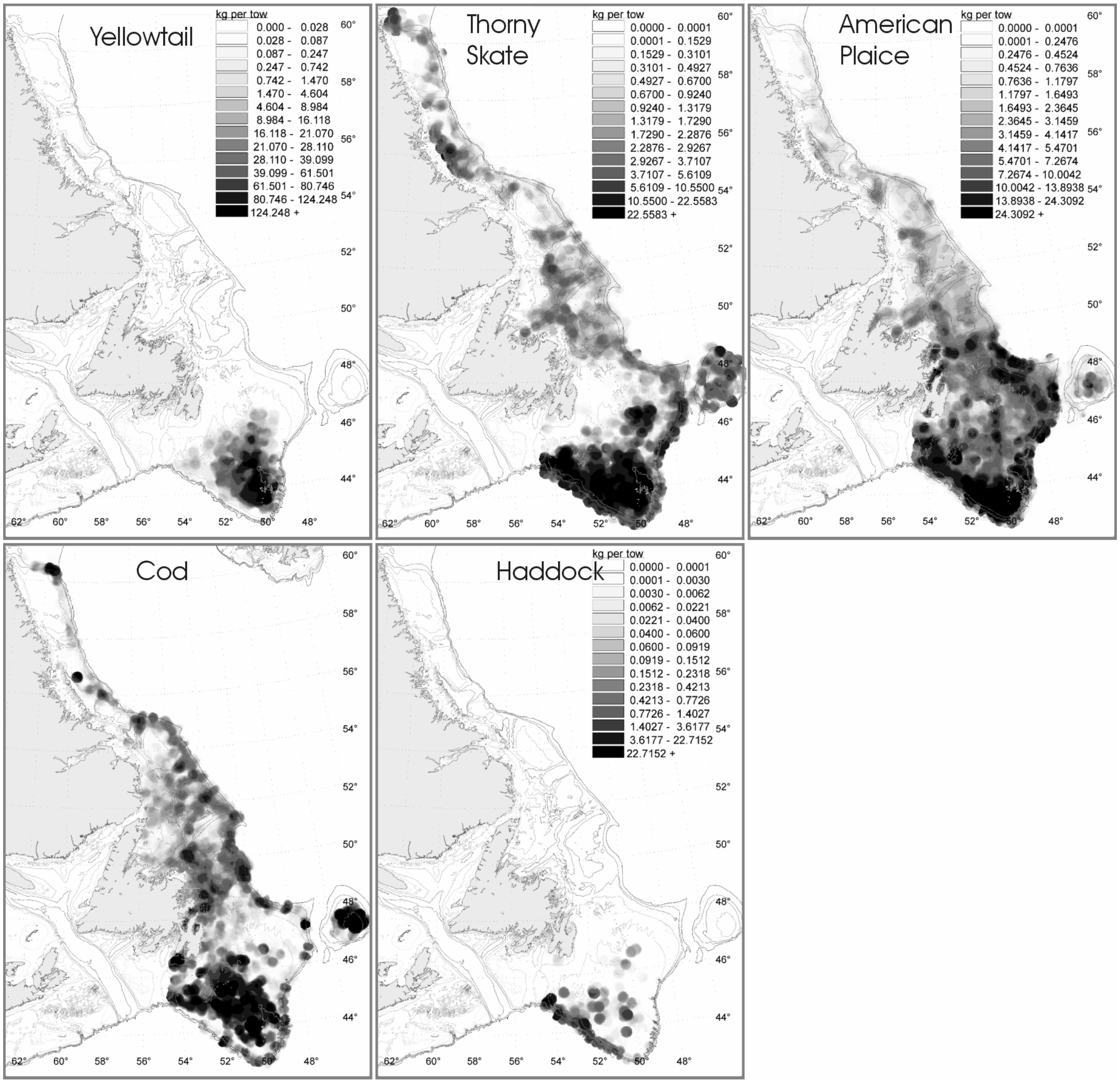


Figure 12a. Spatial distribution of species classified as shallow (predominantly distributed in less than 250 m) based on fall survey data pooled over 1995-1999. Darker areas denote denser concentrations.

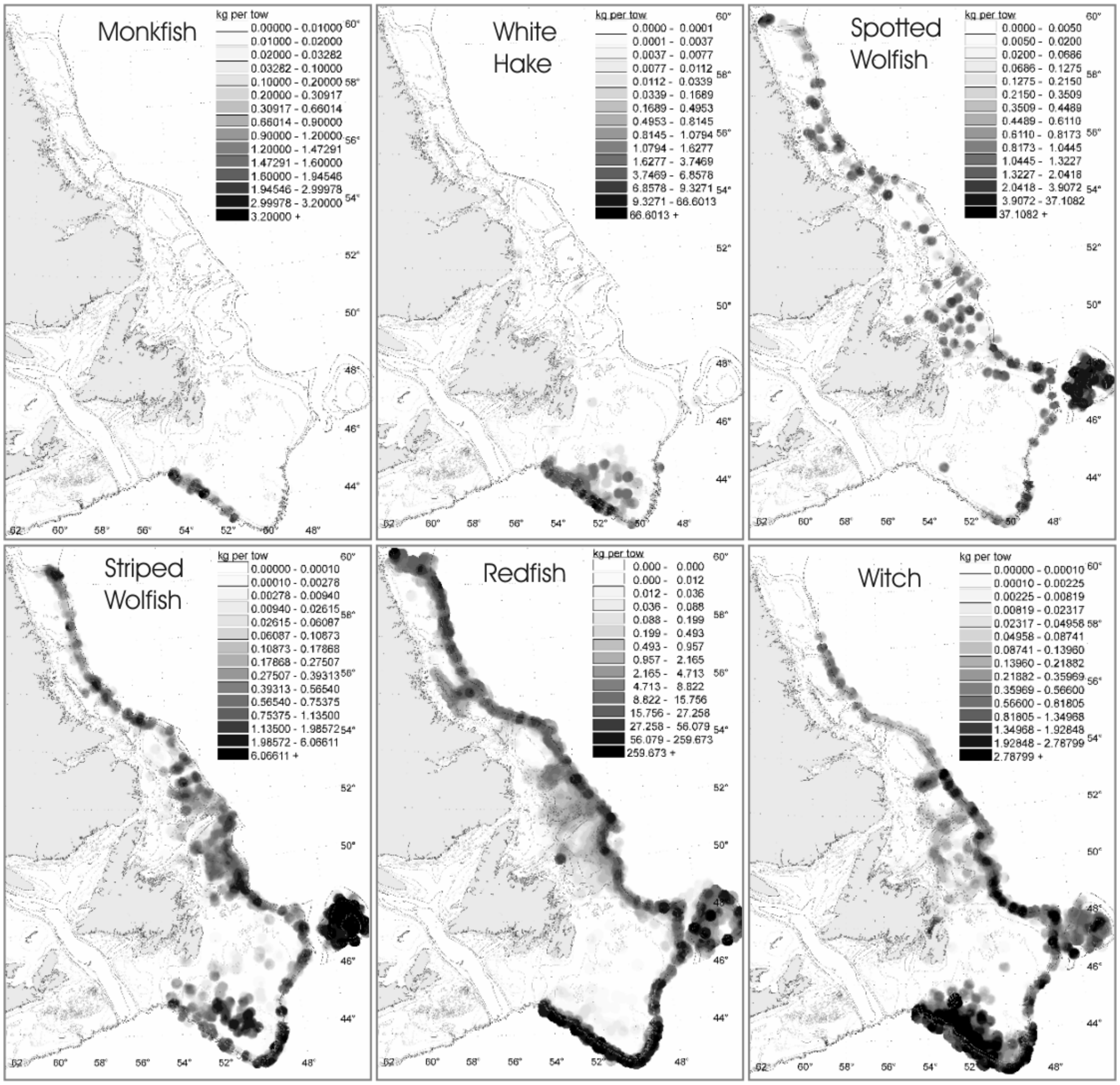


Figure 12b. Spatial distribution of species classified intermediate (distributed over a wide range of depths primarily between 250and 900 m) based on fall survey data pooled over 1995-1999. Darker areas denote denser concentrations.

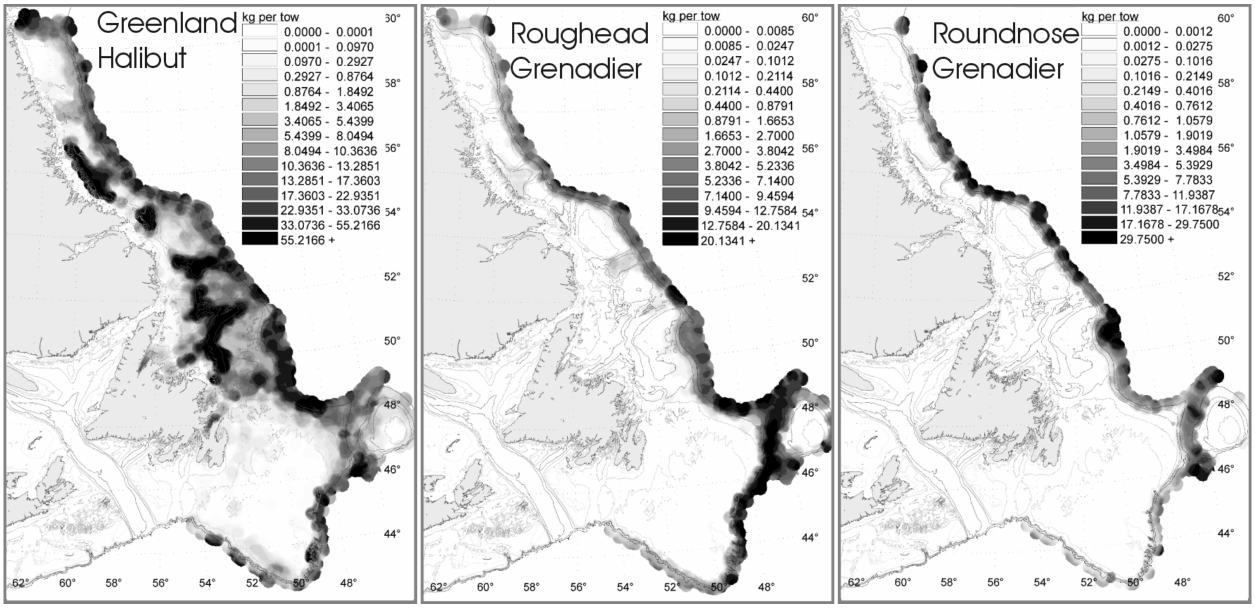


Figure 12c. Spatial distribution of species classified as deep (predominantly distributed in more than 800 m) based on fall survey data pooled over 1995-1999. Darker areas denote denser concentrations.

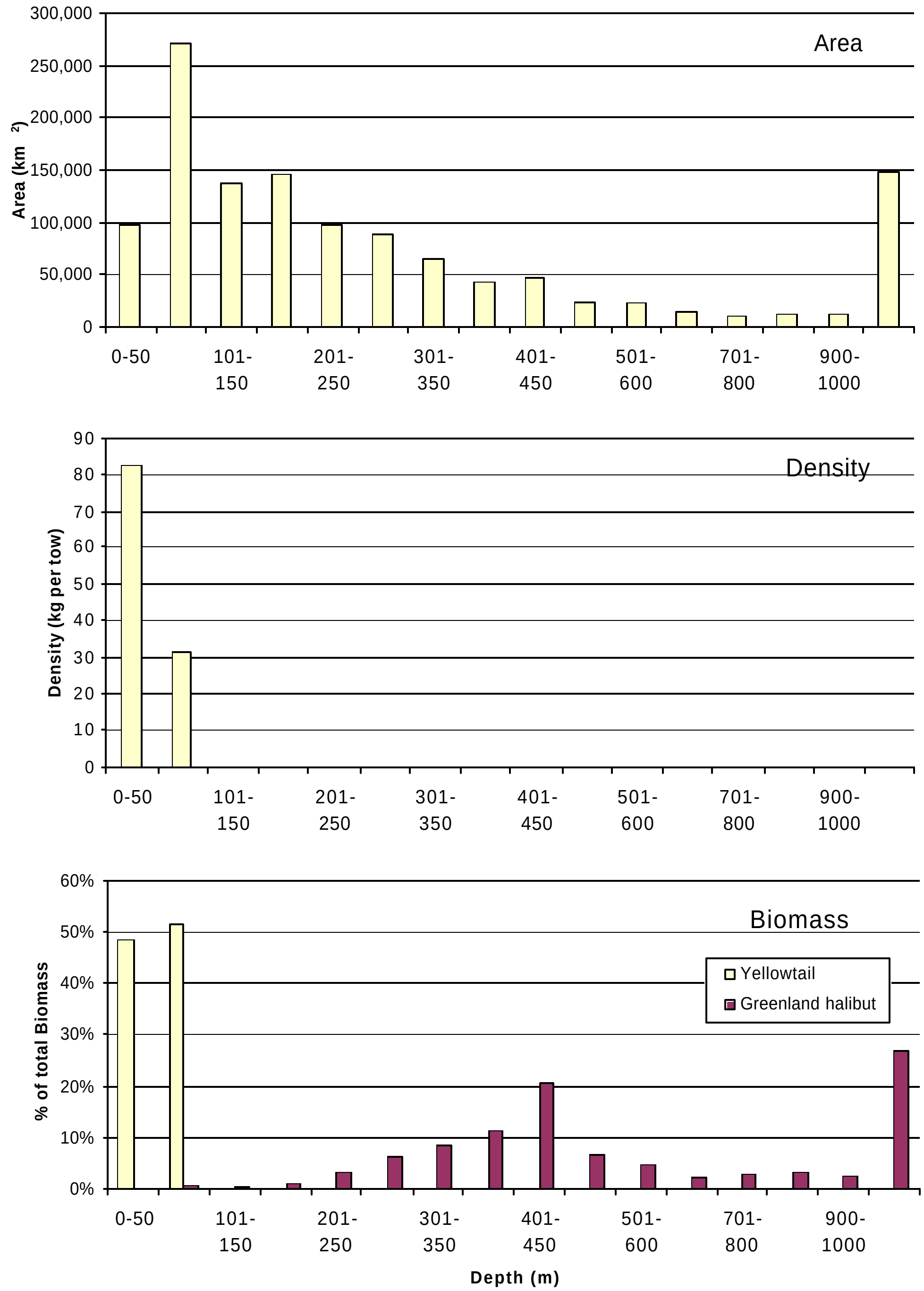


Figure 13a. Distribution of yellowtail flounder by depth: Upper panel - available area (km^2 by depth range); Middle panel - density (average kg per tow by depth range); Lower panel – biomass (t) by depth range.

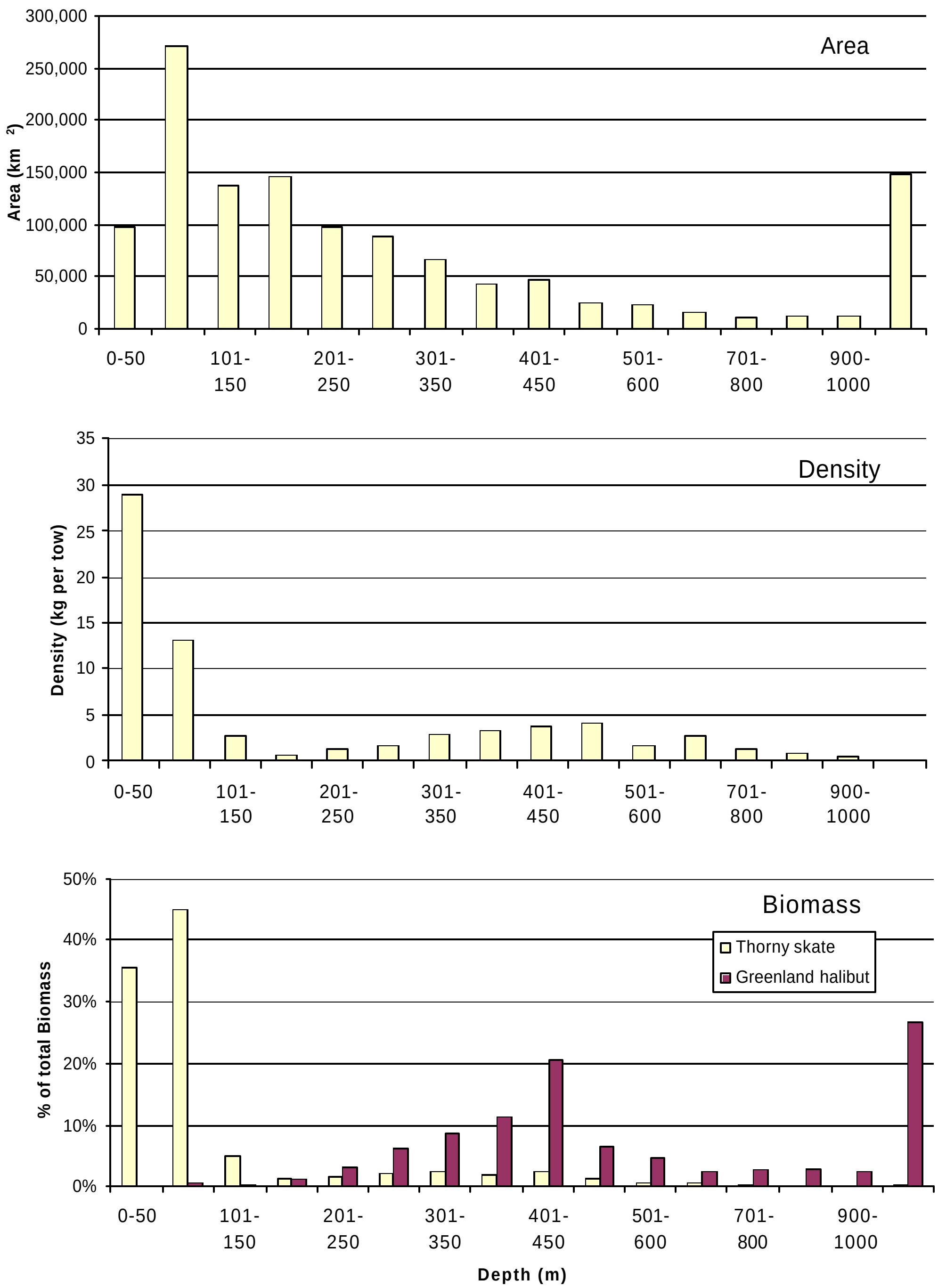


Figure 13b. Distribution of thorny skate by depth: Upper panel - available area (km2 by depth range); Middle panel - density (average kg per tow by depth range); Lower panel – biomass (t) by depth range.

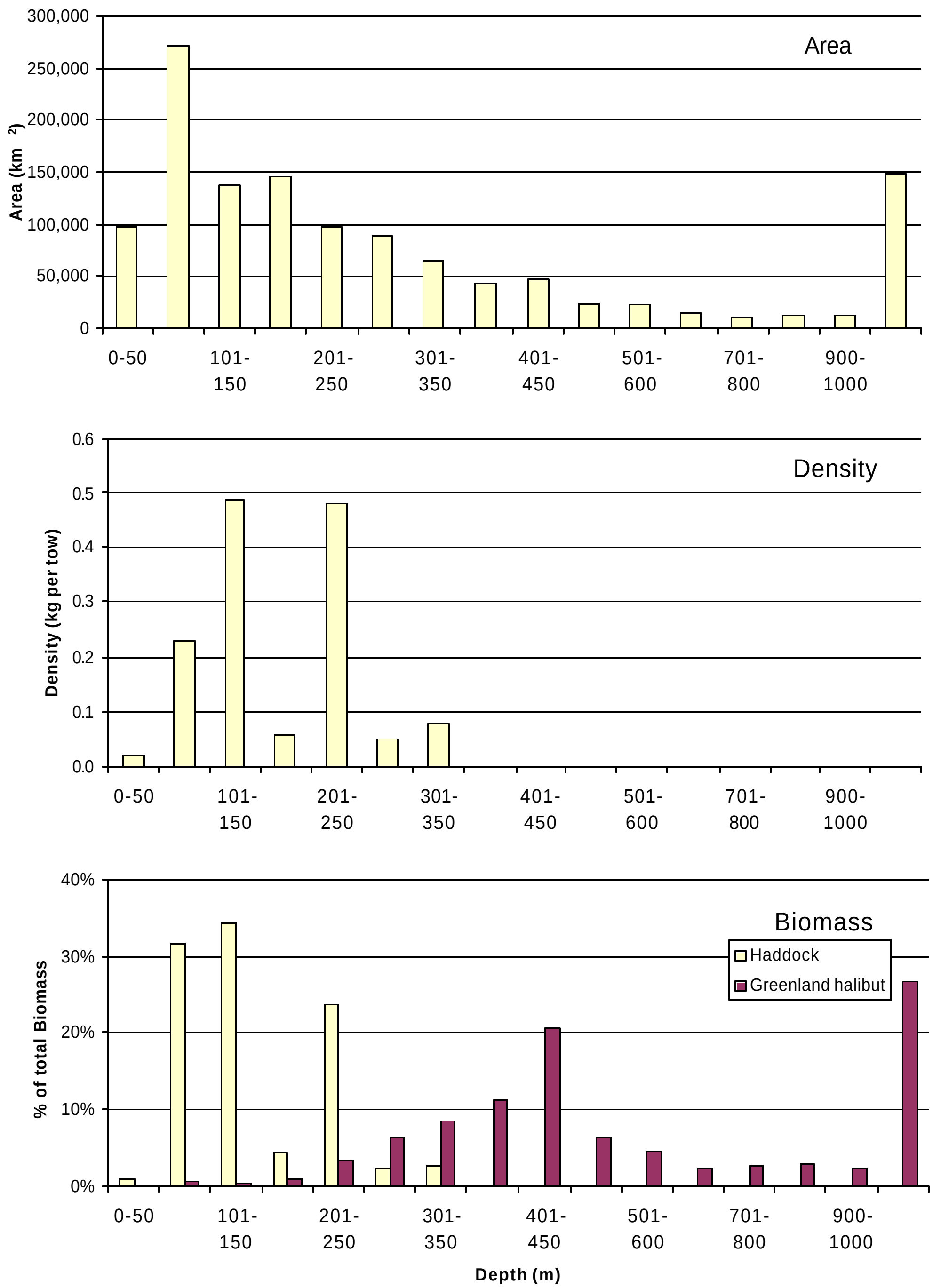


Figure 13c. Distribution of haddock by depth: Upper panel - available area (km2 by depth range); Middle panel - density (average kg per tow by depth range); Lower panel – biomass (t) by depth range.

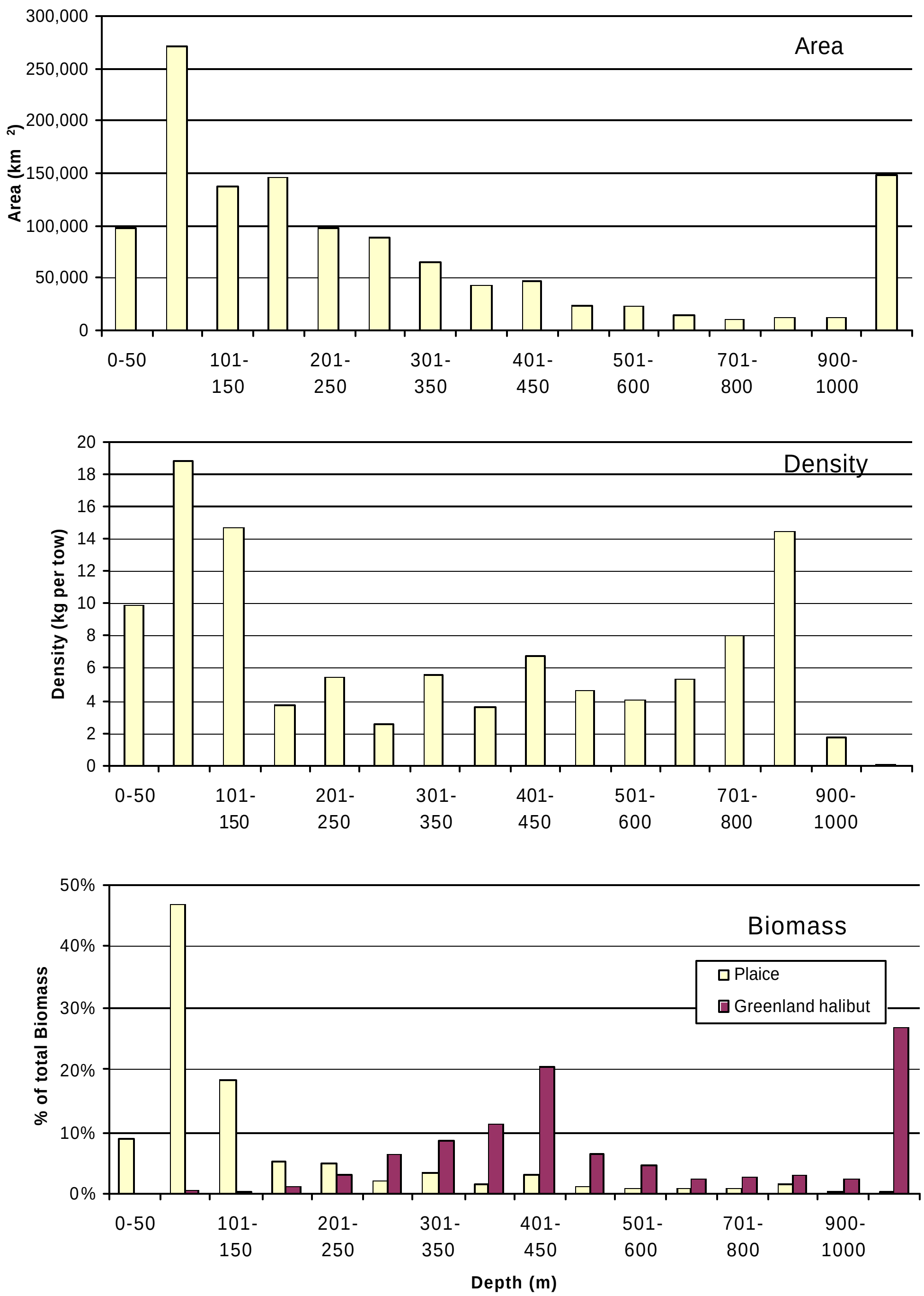


Figure 13d. Distribution of American plaice by depth: Upper panel - available area (km2 by depth range); Middle panel - density (average kg per tow by depth range); Lower panel – biomass (t) by depth range.

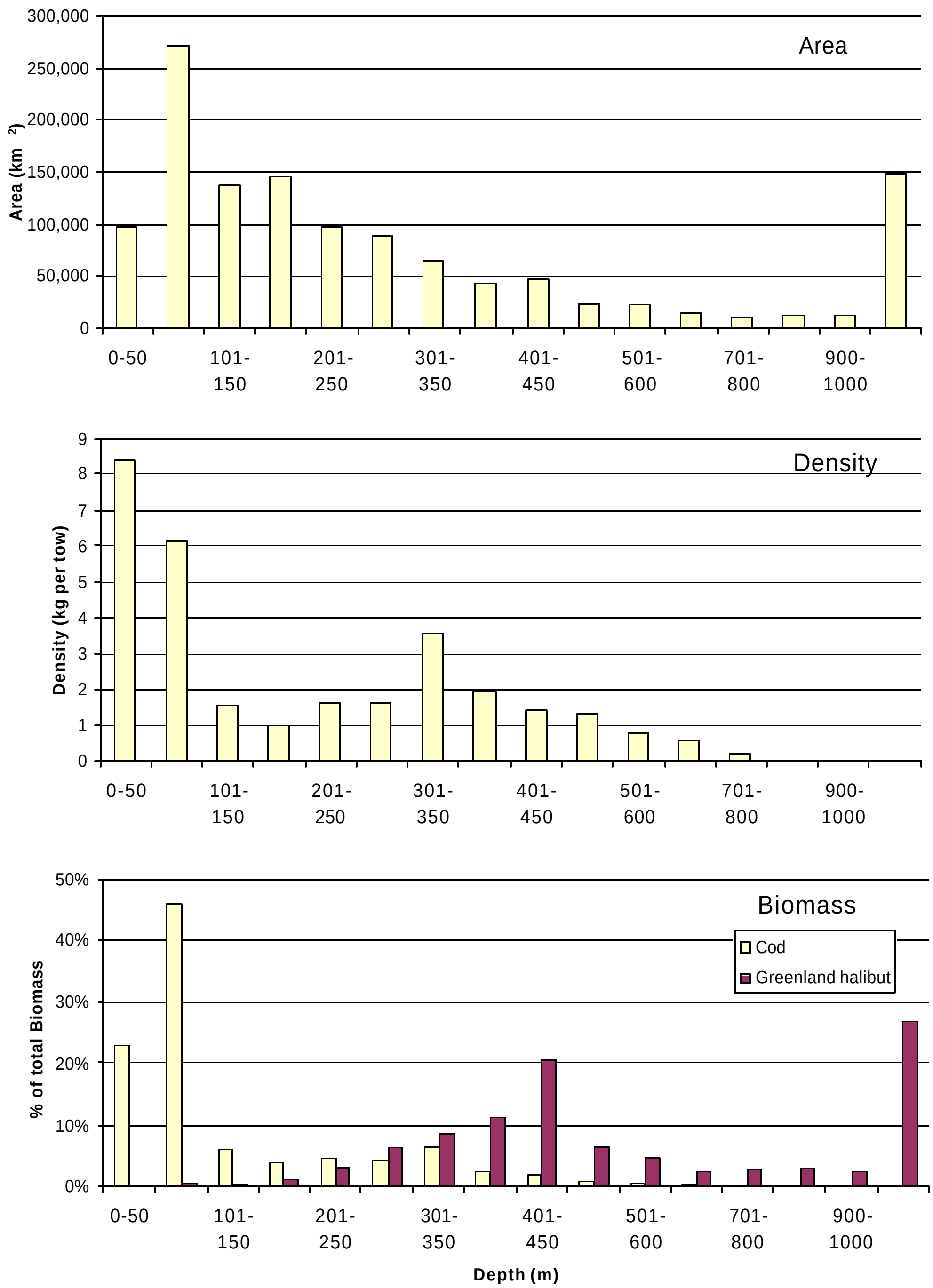


Figure 13e. Distribution of cod by depth: Upper panel - available area (km^2 by depth range); Middle panel - density (average kg per tow by depth range); Lower panel – biomass (t) by depth range.

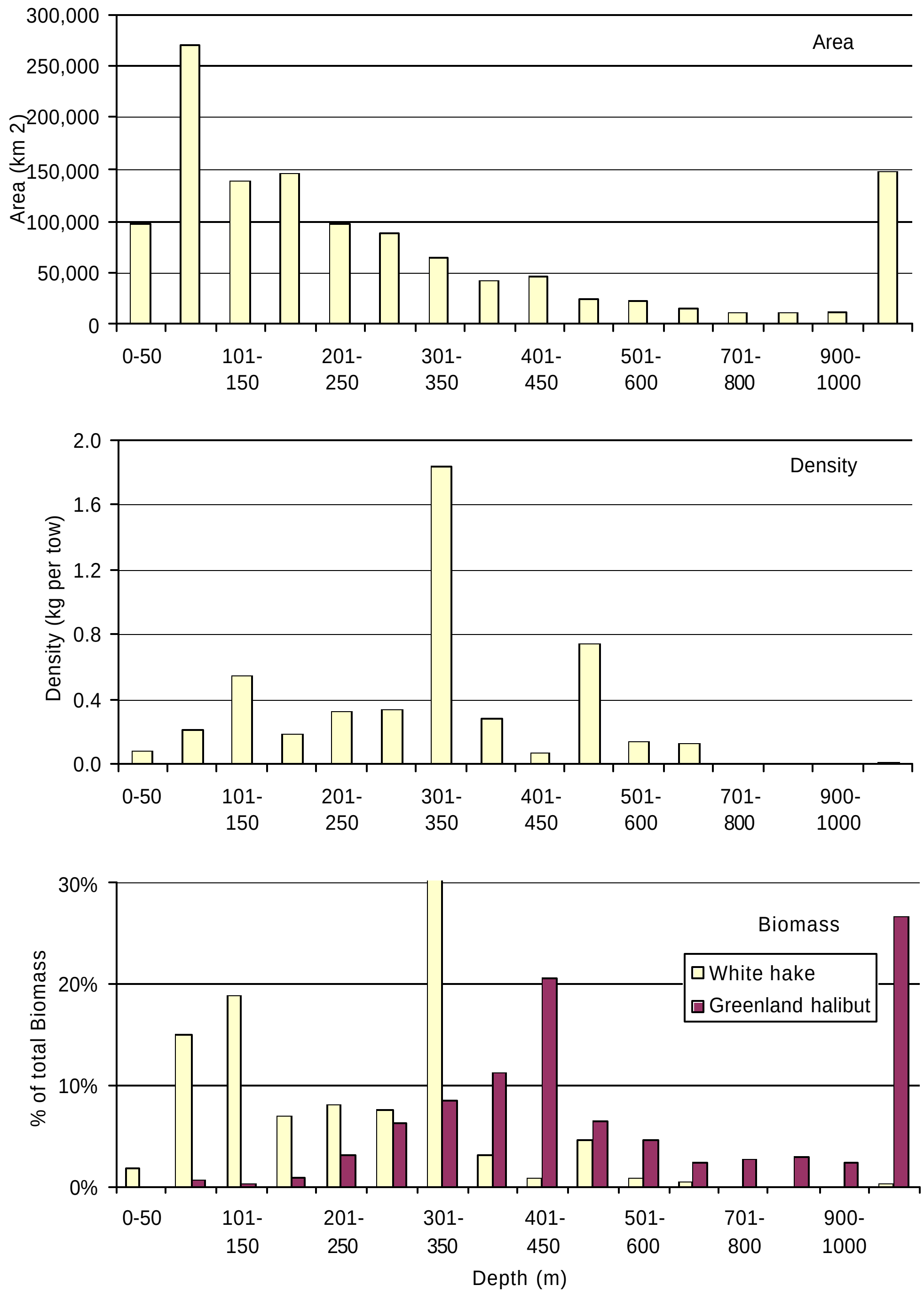


Figure 13f. Distribution of white hake by depth: Upper panel - available area (km^2 by depth range); Middle panel - density (average kg per tow by depth range); Lower panel – biomass (t) by depth range.

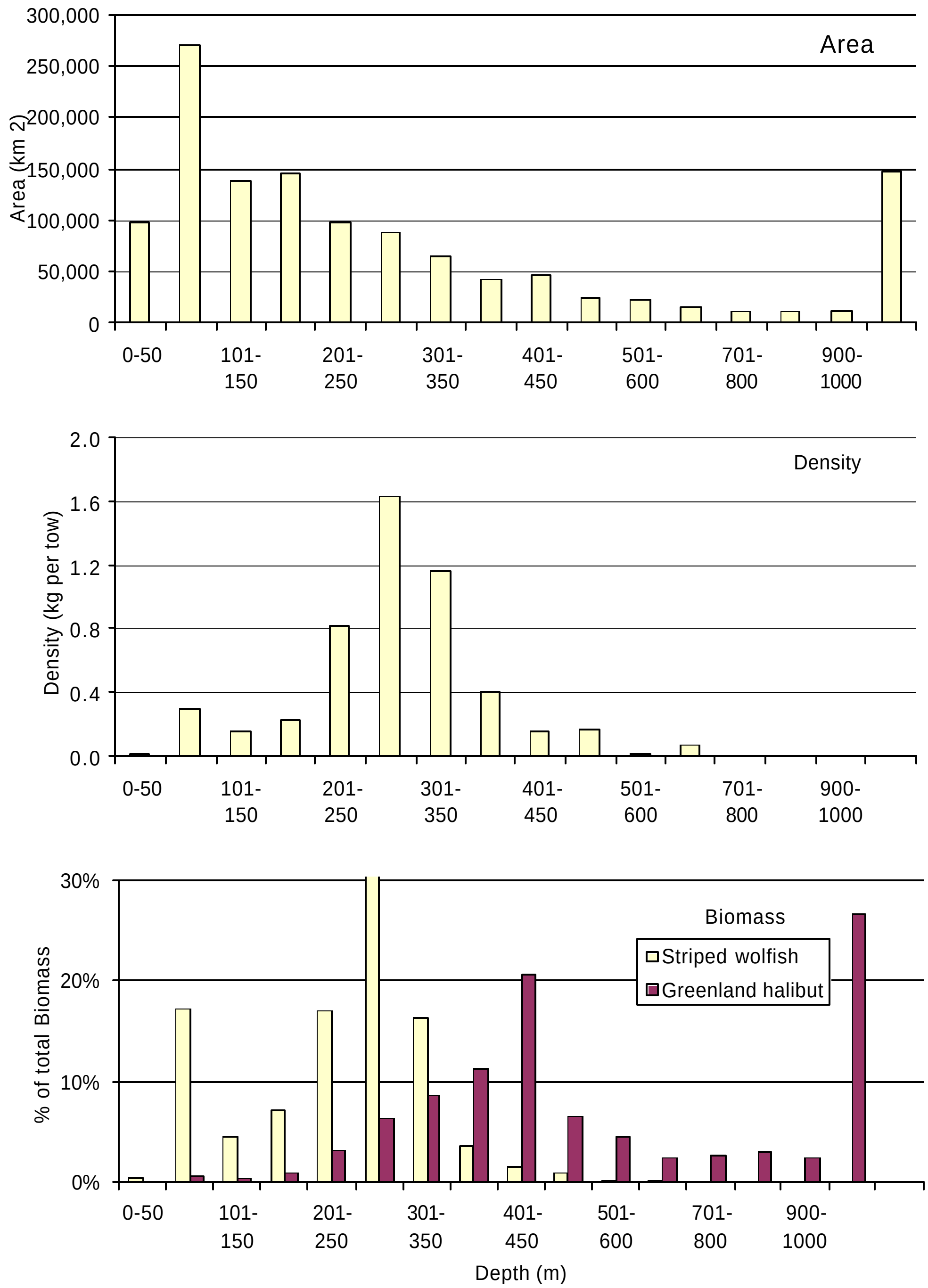


Figure 13g. Distribution of striped wolfish by depth: Upper panel - available area (km^2 by depth range); Middle panel - density (average kg per tow by depth range); Lower panel – biomass (t) by depth range.

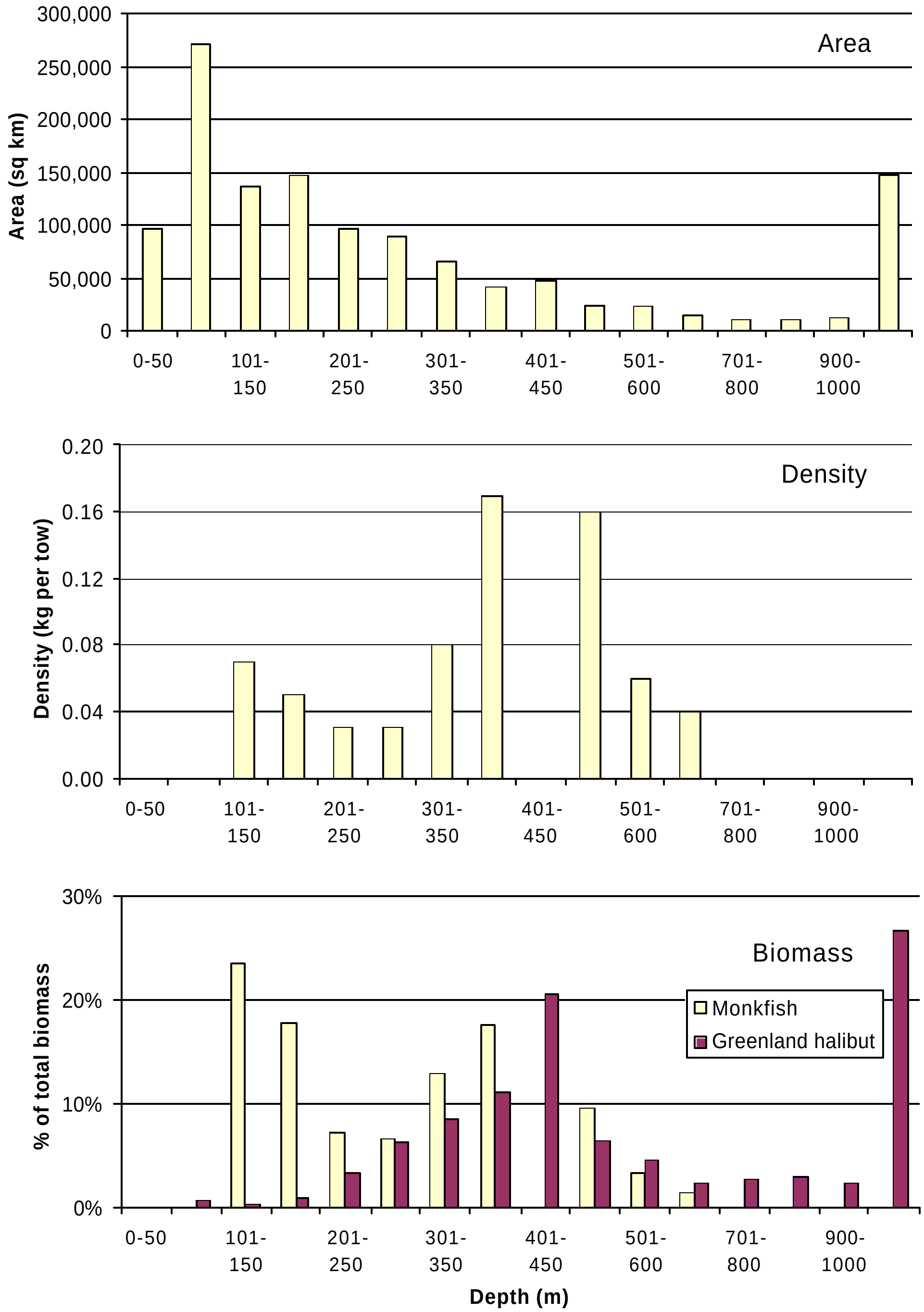


Figure 13h. Distribution of monkfish by depth: Upper panel - available area (km^2 by depth range); Middle panel - density (average kg per tow by depth range); Lower panel – biomass (t) by depth range.

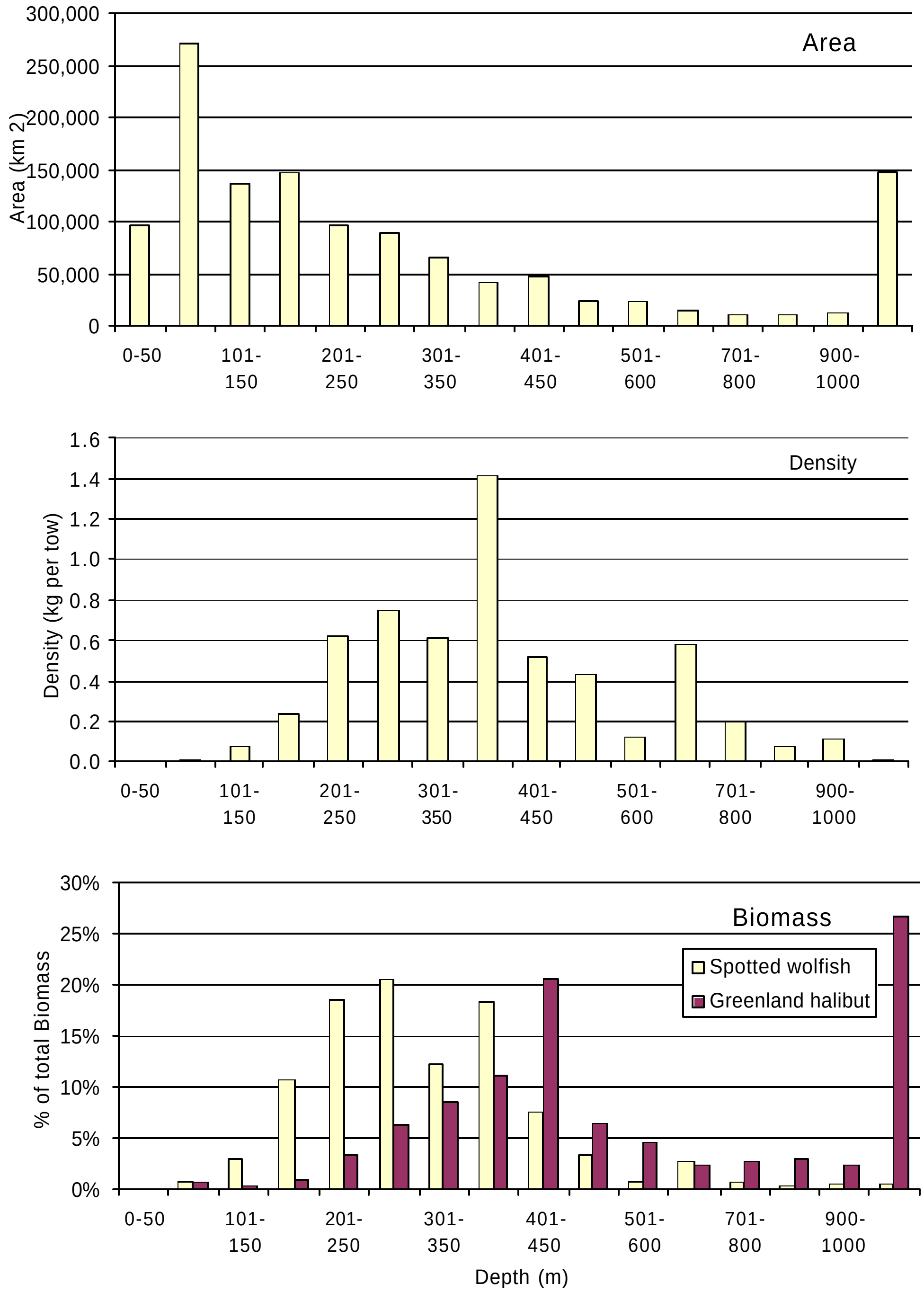


Figure 13i. Distribution of spotted wolfish by depth: Upper panel - available area (km^2 by depth range); Middle panel - density (average kg per tow by depth range); Lower panel – biomass (t).

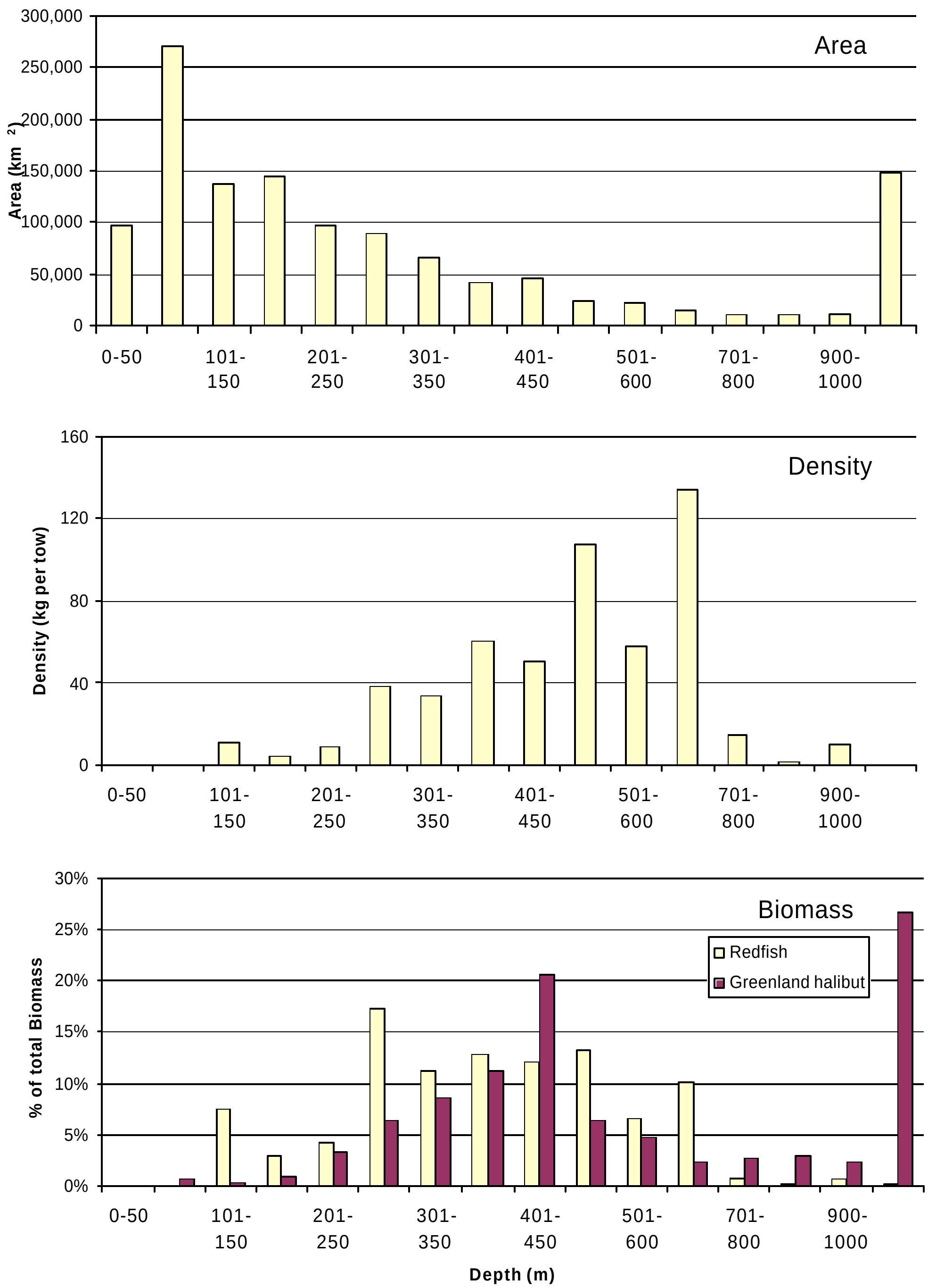


Figure 13j. Distribution of redfish by depth: Upper panel - available area (km^2 by depth range); Middle panel - density (average kg per tow by depth range); Lower panel – biomass (t).

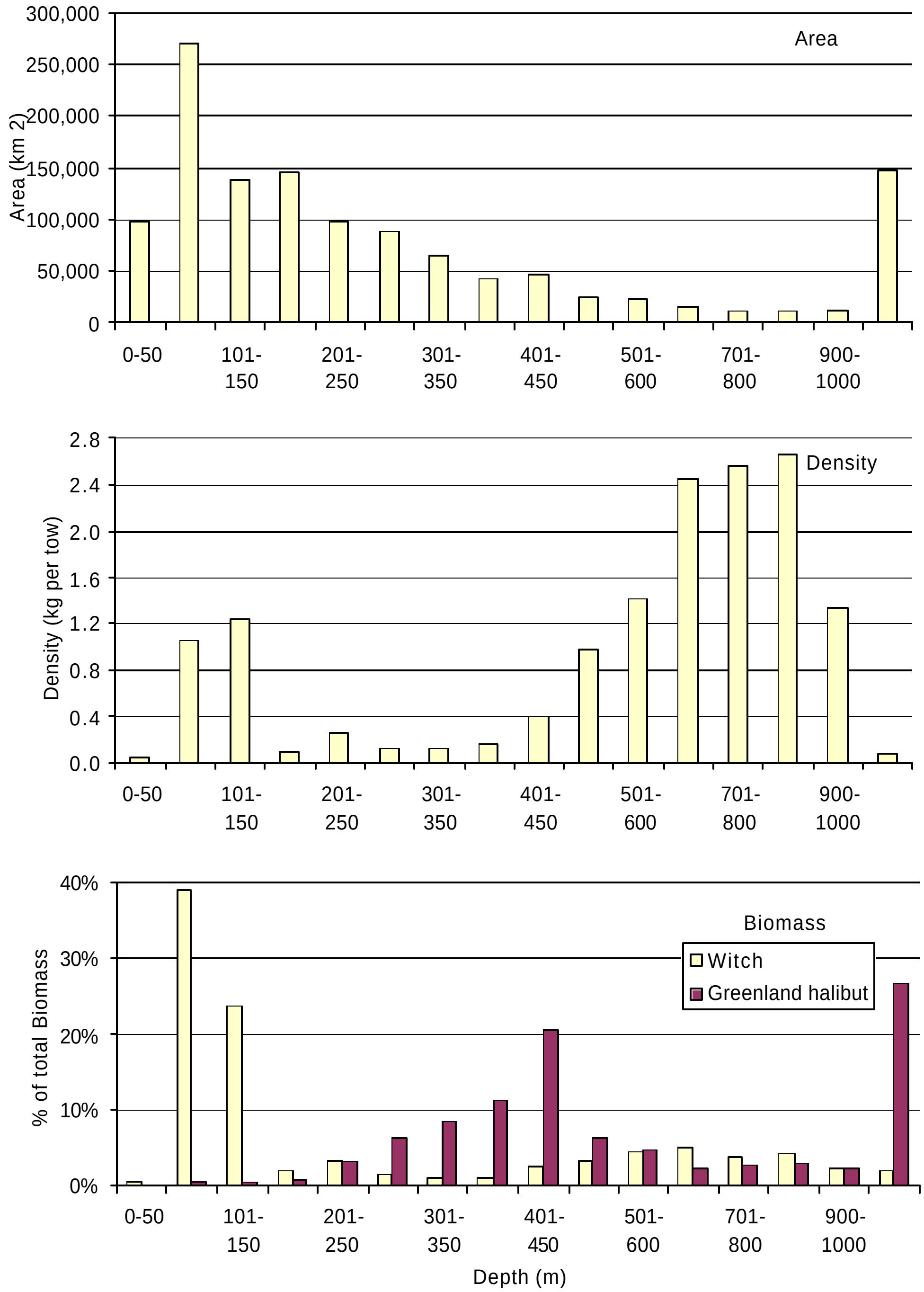


Figure 13k. Distribution of witch by depth: Upper panel - available area (km^2 by depth range); Middle panel - density (average kg per tow by depth range); Lower panel – biomass (t)

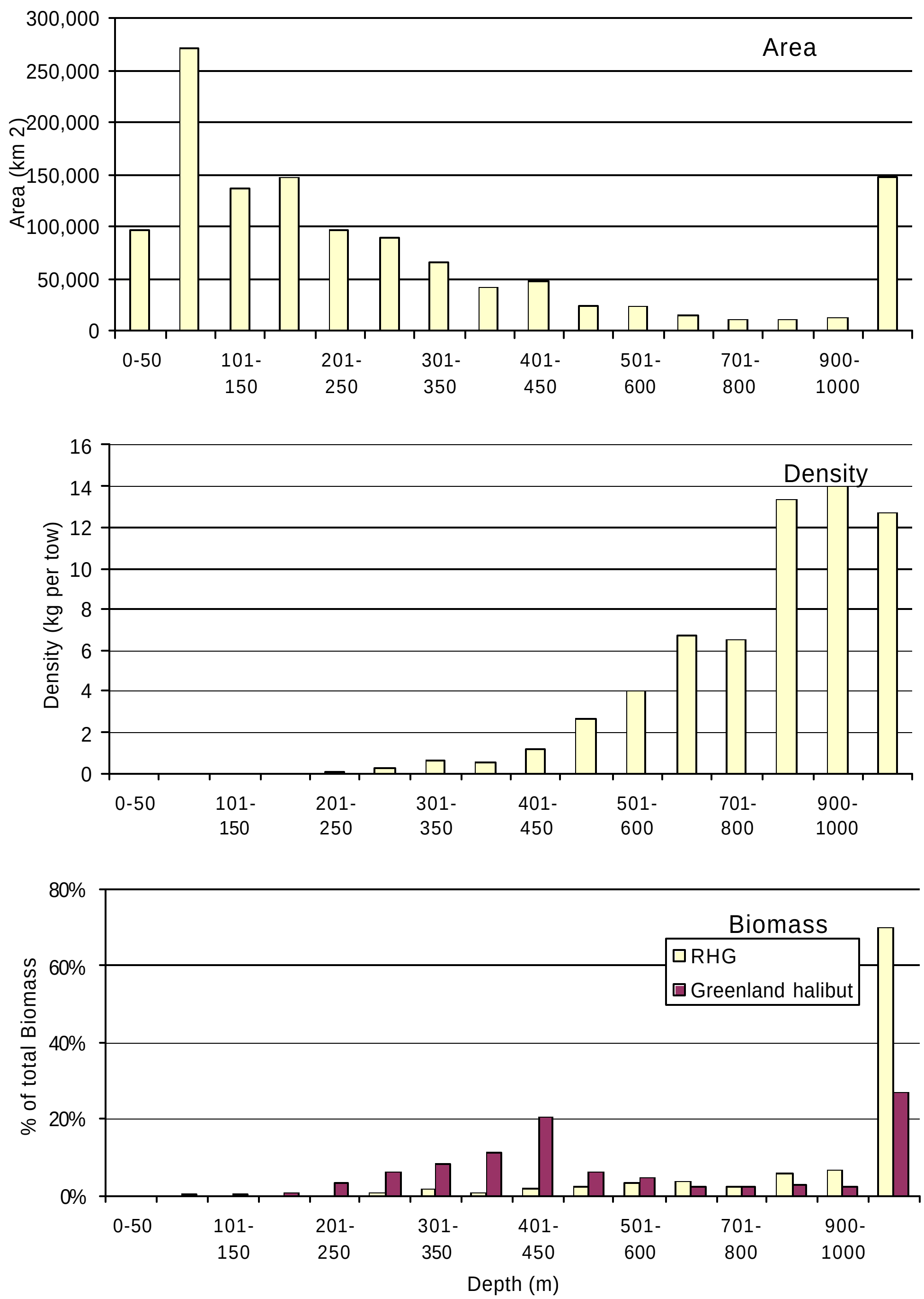


Figure 13l. Distribution of roughead grenadier by depth: Upper panel - available area (km^2 by depth range); Middle panel - density (average kg per tow by depth range); Lower panel – biomass (t).

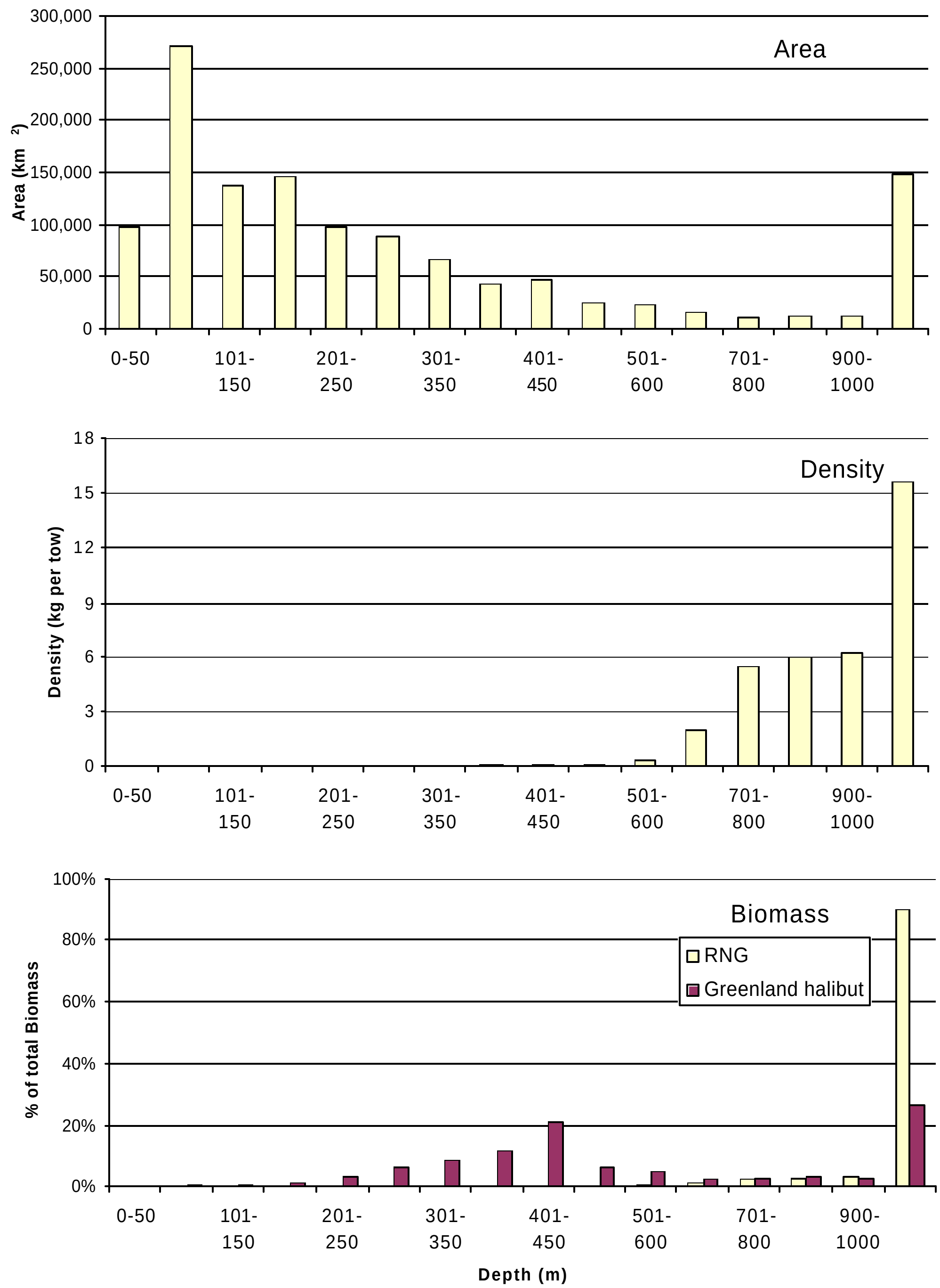


Figure 13m Distribution of roundnose grenadier by depth: Upper panel - available area (km^2 by depth range); Middle panel - density (average kg per tow by depth range); Lower panel – biomass (t)

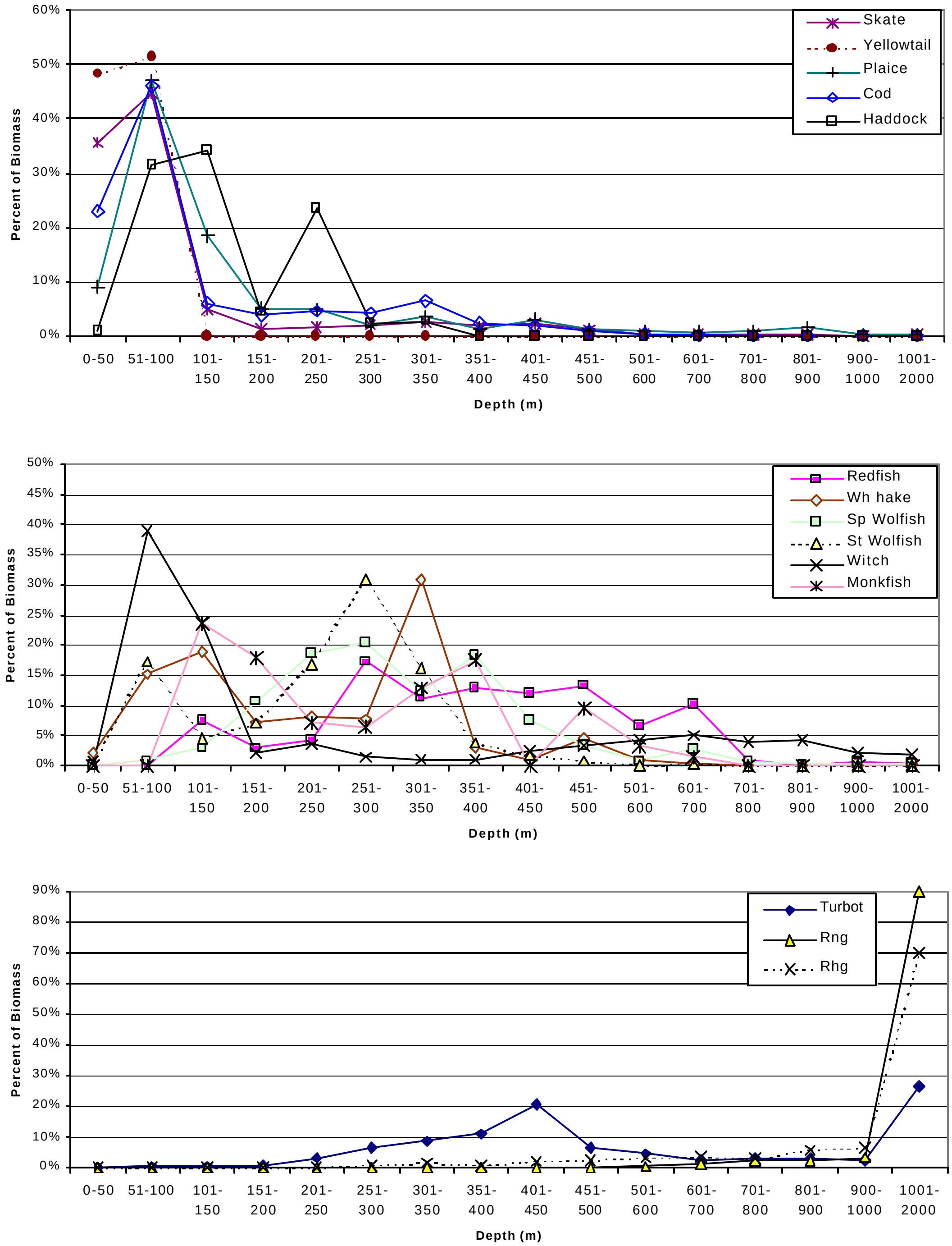


Figure 14. Summary of percent of biomass at depth. Species are grouped into shallow (upper figure), intermediate (middle) and deep (lower) categories.

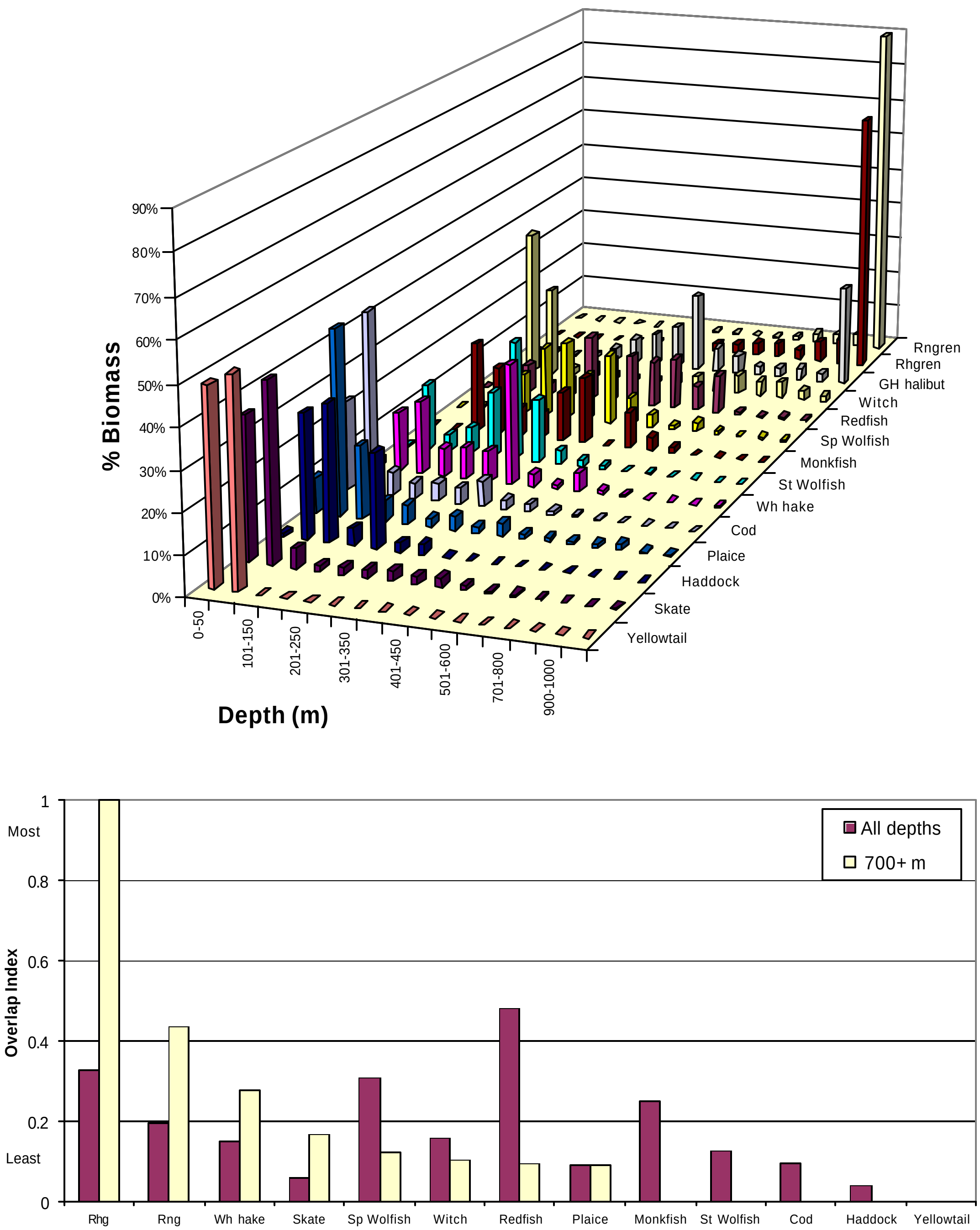
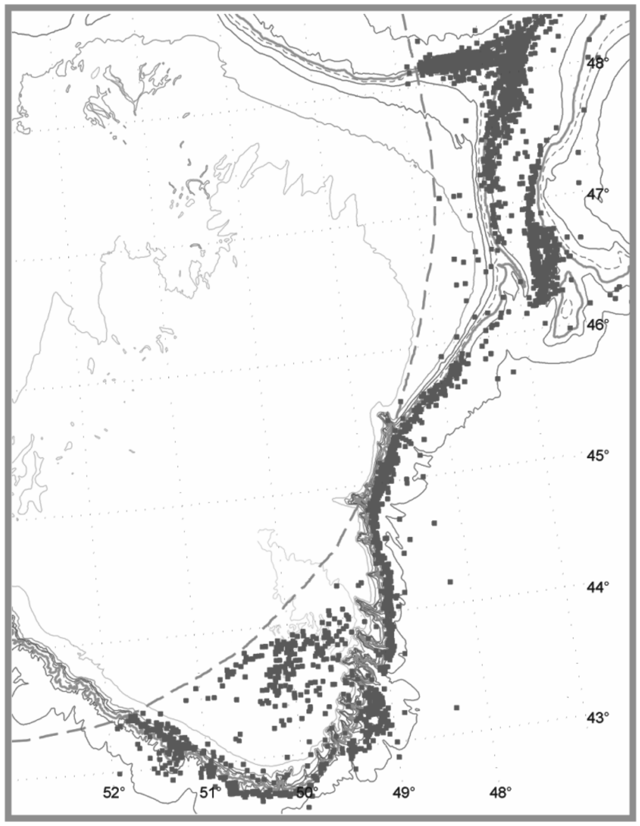


Figure 15. Upper panel compares percent biomass at depth. Lower panel compares degree of overlap of selected by-catch species across all depths vs. depths greater than 700 m. Species are placed in order of their depth distribution for areas greater than 700 m.



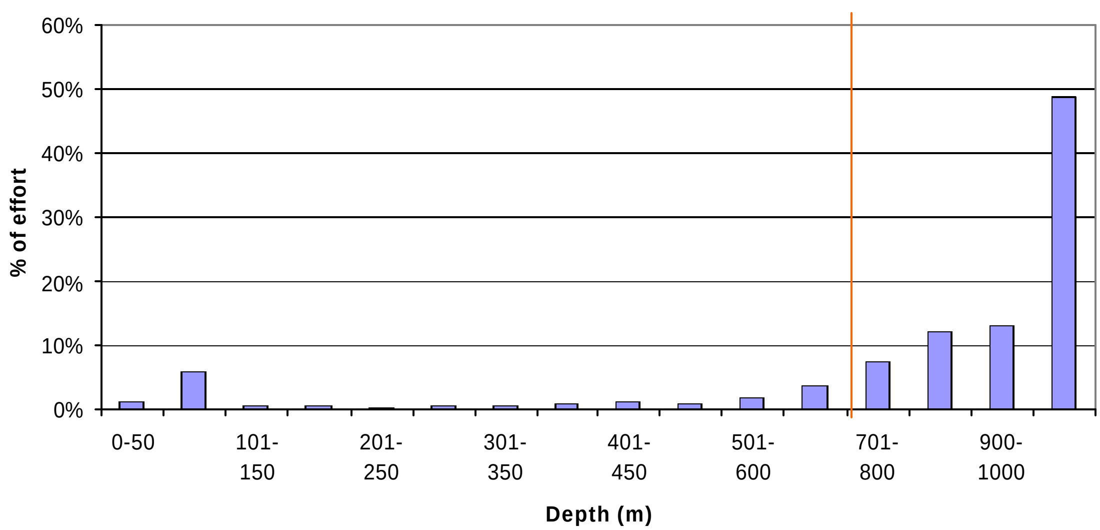


Figure 16. Fishing effort in the NRA based on information collected from boardings 1995-1999, by Conservation and Protection (Canada). Upper panel shows a map of the distribution of the sets. The lower panel shows distribution by depth range.