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Plankton and Nekton of the Northeast Newfoundland Shelf and Grand Banks in 1997

by

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Abstract

A comprehensive broad-scale survey of temperature, plankton, and nekton of the marine pelagic environment was carried out for the fourth consecutive year during late summer 1997. The study area covers inshore and offshore waters from southern Labrador to the southern Grand Banks. Spatial and annual (1994-97) effects accounted for significant variation in all 22 variables examined. Area differences were larger and generally associated with latitudinal or inshore/offshore clines. Mean surface temperatures during the 1997 survey ranked third behind those of 1994 and 1996, both of which were relatively warm. In 1997 the mean total zooplankton biomass and that of the smallest size fraction was significantly greater than that of the 3 previous. Total nekton was dominated by capelin and squid, and catch rate of Arctic cod decreased each year of the survey. Mean total nekton biomass was higher than in 1996 but not significantly different from any other year. Capelin catch rate (age 1-2) in 1997 was similar to that of 1996 and 1995, all three years ranking below 1994. The abundance of pelagic 0-group Atlantic cod increased slightly in 1997, reversing a trend of decreasing abundance in recent years. Species groups that occurred mainly on the Northeast Newfoundland Shelf were relatively abundant in 1997, whereas 2 species that occur mainly on the Grand Banks tended in be less abundant in 1997. The statistical results confirm numerically the visual observations from the contoured data and will form the basis to monitor changes in the marine pelagic environment in the Newfoundland Region in the future.

Résumé

Un relevé détaillé et élargi de la température, du plancton et du necton de l'environnement pélagique marin a été effectué, pour la quatrième année consécutive, à la fin de l'été 1997. La zone étudiée englobe les eaux côtières et hauturières, du sud du Labrador au sud des Grands Bancs. Des effets spatiaux et annuels (1994-1997) expliquaient la variation significative des 22 variables étudiées. Les écarts entre zones étaient plus importants et généralement liés à des variations ayant trait à la latitude ou à la zone de passage eaux côtières - eaux hauturières. Les températures de surface moyennes notées au cours du relevé de 1997 venaient au troisième rang après celles de 1994 et de 1996, deux années où elles étaient relativement élevées. En 1997, la biomasse moyenne totale du zooplancton et celle de la fraction des plus petites tailles étaient significativement plus élevées que celles des trois années précédentes. Le necton total était dominé par le capelan et le calmar, et le taux de capture du saïda franc a diminué à chaque année du relevé. La biomasse moyenne totale du necton était plus élevée qu'en 1996, mais ne différait pas de façon significative de celle d'aucune autre année. Le taux de capture du capelan (âges 1-2) en 1997 était semblable à celui de 1996 et de 1995, mais les taux de ces trois années étaient inférieurs à celui de 1994. L'abondance des morues de l'Atlantique pélagiques du groupe 0 a légèrement augmenté en 1997, ce qui renverse la tendance à la baisse notée au cours des dernières années. Les groupes d'espèces que l'on retrouvait surtout sur le plateau nord-est de Terre-Neuve étaient relativement abondants en 1997, mais deux espèces que l'on rencontre surtout sur les Grands Bancs étaient moins abondantes. Les résultats statistiques confirment numériquement les observations visuelles des données en courbes de niveau et serviront de référence pour le suivi des changements de l'environnement pélagique marin dans la Région de Terre-Neuve.

Introduction

Anderson and Dalley (1997) initially described the marine pelagic environment off Newfoundland and Labrador (NAFO Divisions 2J3KLNO) for the late summers of 1994 and 1995. Information was presented from a single annual comprehensive broad scale multispecies survey. The survey was originally designed to measure the abundance of pre-recruit Atlantic cod during the pelagic juvenile fish stage, and to measure the pre-recruit abundance of Northwest Atlantic capelin at the larval stage (0-group) and as one year old capelin (1+). In addition, it was designed as a multispecies measure of the state of the pelagic ecosystem. The purpose was to provide a baseline with which results of future surveys could be compared in order to understand short and long term variations in the pelagic environment. The survey was conducted again in 1996 and results were compared to those of the first 2 surveys (Dalley and Anderson 1997).

The purpose of this document is to describe the temperature, plankton and nekton biomass and structure (particularly pelagic O-group fish) in this large zoogeographic area during late summer in 1997. Temperature, various measures of plankton and nekton biomass, and nekton species, or groups of species, are statistically examined for differences among years (1994, 1995, 1996 and 1997) and also for spatial patterns throughout the large zoogeographic area surveyed.

Materials and Methods

The 1997 survey was carried out from August 11 - 29, approximately 8 days earlier than in 1996. The mid day of the survey was day 233 of the year. This compares to survey mid days of 241, 257 and 241 for the 1994, 1995, and 1996 surveys respectively. The RV Teleost (70 stations) covered the northern part of the survey area and the RV W. Templeman (78 stations) the southern portion in 1997. The standard sampling protocol at each station included: 1) a Seabird-25 CTD (Conductivity / Temperature / Depth) profile, with flourometry,was obtained to a maximum of 500m depth or within ~ 5m of bottom where depth was less than 500m., 2) a standard double oblique bongo tow to 100m, and 3) a 30 min IYGPT (International Young Gadoids Pelagic Trawl) tow that slowly oscillated between 20 to 60m depth. The study area, survey design, sampling gear, and methods are described in Anderson and Dalley (1997). Since a complete ichthyoplankton sort was not carried out on the bongo samples distribution and abundance data is presented for capelin and herring only. Catch rates of these 2 species were estimated by subsampling catch from the right side of the bongos at sea. In 1996 and 1997 the right bongo net was of 505 micron mesh and the left side 232 micron, whereas in 1994 and 1995 mesh size on both sides was 333 micron. Consistent with the previous 2 years one half of the total plankton biomass from the left side of the bongo was filtered into 3 size categories: >2mm, 1-2mm, and <1mm, dried for 24 hours at ~ 75°C, and weighed to the nearest milligram.

Distribution of variables throughout the large spatial area was examined by dividing it into seven smaller areas (Figure 1). The smaller areas were based on predominant geographical features (eg., banks), closeness to shore, and latitude. Seven areas were consistently sampled all four years. Notation used in the document for the 7 areas is as follows.

1) ISN or the inner Northeast Newfoundland (NE) Shelf, northern portion,
2) BIBI or Belle Isle Bank in the northern NE shelf, offshore portion,
3) ISS or the inner NE shelf, southern portion,
4) FIBI or Funk Isle Bank, the southern NE shelf, offshore portion.
5) INSH denotes all of the large inshore bays and stations within ~ 54km of shore
6) NGB the northern Grand Banks and
7) SGB the southern Grand Banks.

An analysis of variance was carried out with the variables examined (eg., temperature, zooplankton biomass, total nekton biomass, species, or groups of species abundance) as the dependent variable. The main effects, area and year, serve as independent variables. The general linear models or GLM (SAS Institute Inc.1989) were run to include interaction between the two main effects, area and year. If the interaction term was not significant, the model was rerun without interaction. Areas and years were ranked from highest to lowest for each variable. An a posteriori Studentized Maximum Modulus (GT2) test was performed to indicate significant differences ($P<0.05$) between areas and years, for each dependent variable. All biological variables were standardized to the volume of water filtered and logged_{10} prior to the analysis of variance.

Results

In this section the 1997 data for each variable is presented using contour plots. This is followed by the results of the analysis of variance of 28 means (7 areas x 4 years) for the variable, indicating the total variability accounted for by the model, and that attributable by each of the main effects. R^2 and percent explained variation are used interchangeably. Specific statements made regarding significant differences between areas and years are based on the results of the GT2 test.

During the 1997 survey there was a latitudinal cline in surface temperatures (Figure 2, left panel) with warmer water in the southern areas and a tendency for slightly warmer surface water in the bays than adjacent latitudes on the shelf. The area and year GLM model with surface temperature accounted for the highest R^2, (0.84) of all variables examined (Table 1).

Although both main effects were significant, variation in temperature attributable to area was much greater than that of year. Considering all years mean temperature on the southern Grand Bank was warmer than that of all other areas. There was no difference in mean temperature on the northern Grand Bank and that of the inshore area. Both were warmer than the southern portion of the inner Northeast shelf and Funk Isle Bank which in turn were warmer than the northern areas (ISN, BIBI) of the shelf. There was a significant difference in mean temperature each year of the survey, ranking as follows: 94>96>97>95.

There was a weaker cline in temperatures at 50m (Figure 2, right). Warmest water was again over the southern Grand Banks with the inshore ranking next, although relatively warm water occurred at some stations near the shelf break. R^2 for the model was 0.48 and both independent variables contributed significantly to variation in temperature at 50m, area again more so than year (Table 1). The temperature at SGB was warmer than the inshore which was warmer than mean temperature at 50m in each of the other 5 areas. Mean temperature at 50m was warmer during the surveys of 1995 and 1996 than 1997 and 1994. Mean temperature at 50m in 1997 ranked third of the 4 years.

Consistent with the results of other recent surveys total zooplankton biomass in 1997 (Figure 3 and 4), was again highest in the north. Total mean weights ranged from 1.8 - 23.5 mg/m3. Highest weights were obtained at stations near the shelf edge in the north and the lowest weights on the eastern portion of the Grand Banks. R^2 for the model was 0.51, both area and year were significant, area much more than year (Table 1). The four most northern areas ranked highest and were not significantly different from each other but had significantly higher weights than NGB, which had higher weights than SGB. The inshore was not different from the southern Northeast shelf (ISS and FIBI). Total weights were higher inshore than on the Grand Banks. Mean total zooplankton weights were significantly higher in 1997 than the other 3 years.

Mean weights of the largest size fraction ranged from 1.0 - 5.6 mg/m3 with distribution being more variable than the other fractions (Figure 3, right). R^2 for the model was 0.26, interaction of the two main effects was not significant, and area accounted for over 3x as much variation as year (Table 1). Although there was a general trend from north to south there was no significant difference in mean weights in the 4 northern areas, all of which had significantly higher weights than the Grand Banks. There was no difference in mean weight of the largest size fraction from the inshore and from NGB. Mean weight of this fraction was significantly higher in 1995 than any of the other 3 years of which 1997 ranked highest, second overall.

Mean weights of the mid size (1-2mm) fraction ranged from 0.2 to 7.5 mg/m3. Highest weights again occurred in the northern areas and lowest on the Grand Banks (Figure 4, left). R^2 for the model was 0.58, both effects were significant, and area accounted for ~40x more variation than year (Table 1). Mean weights in the two most northern areas were greater than the 2 southern areas of the NE shelf, except there was no difference in mean weights of the two inner areas. Mean weights in all the northern areas were higher than weight on the Grand Banks. Weights inshore were higher than on the Grand Banks but were not different than on Funk Isle Bank area. Although the weights of the mid size fraction ranked highest in 1997, there was no difference in overall mean weights for the 4 years.

Overall, distribution of weights of the smallest size fraction was somewhat similar to that of the mid-size fraction in 1997 (Figure 4, right). Highest weights occurred near the shelf edge in the north, and lowest weights on the southern Grand Banks. The model explained 62% of the variation, but in contrast with the other plankton size fractions and all other variables year accounted for ~2x more variation than area (Table 1). There was no significant difference in mean weights amongst the 4 northern areas or the inshore, all of which had higher mean weights than the Grand Banks. Overall mean weights of the smallest zooplankton size fraction were significantly higher in 1997 than 1996, both being greater than 1994 and 1995 which were not different. One would expect a higher mean weight of this size fraction in the 2 most recent years as a result of the finer mesh used on the during these years. However, since similar mesh was used in 1996 and 1997, the increase in mean weight in 1997 compared to1996 is not a function of mesh size.

Distribution of capelin larvae estimated from bongo subsamples (Figure 5, left) indicates 1997 was similar to other recent years in that distribution was mainly coastal with highest densities nearshore. Capelin spawn on beaches and the distribution represents dispersal from the nearshore habitats. The distribution of capelin larvae appeared, however, to be more restricted to the coast in 1997 than other recent years. This may be a function of the fact that the 1997 survey was ~ 8 days earlier than that of 1996. However, there was no notable difference in size of capelin in 1997 which ranged from 4-18mm with the modal length of 10m (Figure 5, left). This compares with mean lengths of 9.9, 10.7, and 8.9 in the 1996, 1995 and 1994 surveys respectively (Anderson and Dalley 1997).

Herring larvae (7 only) occurred in 3 bongo sets, all of which were inshore during the 1997 survey. (Figure 5, right). Distribution is similar to other recent years with catch rates higher than in 1996 but lower than in 1994 and 1995. Lengths range from 10-30mm.

The distribution of total nekton biomass, including jellyfish, from the IYGPT (Figure 6, left) indicates, as in previous years, highest biomass in the inshore and inner NE shelf. The R^2 for the model was 0.25, both effects were significant and area accounted for ~7-8x more variation than year (Table 1). Taking all years together mean weight inshore was not significantly greater than mean weight on the southern or northern portions of the inner NE shelf. The southern Grand Banks ranked lowest but biomass there was not different from the northern Grand Bank. Biomass on the Northern Grand Bank ranked lowest of a group of areas that were not significantly different, including the inner NE shelf, Funk Isle Bank and Belle Isle Bank. The mean weight in 1997 ranked second to 1995 and was significantly greater than 1996, but not 1994.

Distribution of nekton biomass, with jellyfish removed (Figure 6, right), indicates greatest biomass on the southern portion of the NE shelf, particularly one station in White Bay, with smaller weights north and south of this general area. R^2 for the model was 0.29. Similar to the model with jellyfish, both effects were significant, area explaining much more variation than year (Table 1). Considering all years (3 only), there was no significant difference in biomass on the 4 northern areas, which was greater than that on the Grand Banks. Mean weight inshore, without jellyfish, was significantly less than ISN but not less than the other 3 northern areas, and greater than SGB, but not NGB. This ranking compared with the ranking with jellyfish indicates that the greatest biomass of jellyfish occurred in the inshore. Mean wet weights without jellyfish in 1997 ranked second between 1995 and 1996 and was not significantly different from either year.

Approximately 120,000 fish were taken in the IYGPT in the1997 survey. The most abundant fish was juvenile capelin, constituting 85.7% of all fish caught and occurring in 39.3% of the stations (Table 2). This capelin predominance is consistent with 1994 and 1996, and is the highest relative abundance of any fish over the four years. In 1995, when capelin abundance was the lowest of the 4 years, Arctic cod ranked first. During the 1994 and 1996 surveys Arctic cod ranked second, whereas in 1997 it ranked third. In 1997 squid, which occurred in 65% of the sets, ranked second. Species groups that occurred in approximately half the stations included sculpins, alligatorfish, and seasnails followed by blennies, wolffish and sand lance.

Pelagic capelin (age 1-2) were distributed throughout the inshore portion of the survey area and throughout much of the offshore, particularly the northern Grand Bank (Figure 7, left). This is slightly more extensive than capelin distribution in 1996, especially near the coast of Labrador and further onto the southern Grand Bank. Capelin were absent from most of the offshore portions of the NE shelf and the southern Grand Bank. A relatively low proportion of the variability (R^2=0.2) in capelin catch rates was accounted for by the GLM model. Interaction of the main effects was not significant and that attributable to area was ~8x that of year (Table 1). Over the 4 years, highest mean catch rate occurred on the Northern Grand Bank, which was not significantly greater than that of the inshore. Both were significantly greater than the catch rate in the other 5 areas. The mean catch rate in 1997 ranked second to, but was not different from that of 1994. Lowest catch rate occurred in 1995. The mean catch rate in 1994 was significantly higher than 1996 and 1995, but not higher than that of 1997. The relative proportion of age 1's to age 2's is indicated by the relative size of the 2 modes in the length frequency distribution. Information on year class strength of capelin, estimated from these surveys, is presented annually at the regional capelin assessment meeting. (e.g., Anderson and Dalley 1997)

Distribution of sand lance, another pelagic species, in 1997 (Figure 7, right), was similar to that of 1996 and was restricted primarily to the Grand Banks, with additional low catch rates occurring near the coast of southern Labrador and at several sets near the center of the survey area. High catch rates at some stations near the edge of the Grand Bank suggests that sand lance distribution may extend beyond the survey area. R^2 for the model was 0.24, mostly attributable to area, and that explained by year was not significant (Table 1). Over all years mean catch rates were highest on SGB which was not significantly higher than that of NGB. Mean catches of both SGB and NGB were higher than all the other areas. The inshore was intermediate in catch rate between areas constituting the inner and outer NE shelf which ranked last. Overall mean catch rate of sand lance in 1997 ranked last, behind 1995, 1994 and 1996. The smallest of two modes in the length frequency distribution (40-80mm) correspond to 0-group whereas the large mode corresponds to fish of several ages probably up to age 4-5 years (Winters 1981).

The distribution of pelagic 0-group cod in 1997 (Figure 8, left) was more extensive than in 1996, when cod were practically absent from the NE Shelf, Notre Dame, Trinity and Conception Bays. Low catch rates also occurred on SGB and a single station on NGB. Highest catch rates in 1997 occurred inshore, particularly in Bonavista Bay but were present in all bays. The model explained 33% of variation in catch rate of pelagic 0-group cod. Both main effects were significant and area accounted for approximately 2x more variation than year (Table 1). Over the 4 years mean catch rate was highest inshore but this area was not significantly greater than mean catch rate on the inner southern shelf. These 2 areas had significantly higher catch rate than the others, except ISS not greater than BIBI. BIBI ranked highest of the others and NGB the lowest. Catch rate was significantly lower each year from 1994 to 1996. Mean catch rate in 1997 ranked between that of 1995 and 1996 and was not significantly different from that of either year. Lengths of cod ranged from 22-54mm. Further information on pelagic 0-group cod from these surveys, is presented annually at the regional cod assessment meeting. (e.g. Anderson et al. 1998)

Distribution of Arctic cod in 1997 (Figure 8, right) was similar to that of 1996 with highest catch occurring in the more northern inshore portion of the survey area (ISN), decreasing toward the shelf edge and with decreasing latitude to NGB, where catches were low. Lengths in 1997 ranged from ~20-60mm. In the model both main effects contributed significantly in explaining ~45% of variation in catch rate (Table 1). Area accounted for ~4x more variation than year. Considering all years highest mean catch rate occurred on ISN which was not significantly higher than that of the inshore or ISS. Mean catch rate in these 3 areas was significantly higher than the others. There was no difference in catch rates on FIBI, BIBI and NGB, all of which (except NGB) had higher catch rates than SGB. There has been a decrease in the mean catch rate of Arctic cod each year of the surveys, such that 1997 ranks lowest. Arctic cod ranked 1st in relative abundance in 1995, 2nd in 1996 and 3rd in 1997. Catch rate was significantly higher in 1994 than each of the 3 following years. Mean catch rate in 1997 was significantly lower than that of 1994 and 1995, but not 1996.

Redfish distribution in 1997 was similar to that of 1996, in that they occurred in two distinct areas, one on the NE shelf and one on the southern Grand Bank (Figure 9, left). Lengths of redfish ranged from 15-40mm in 1997. The overall GLM model, although significant, explained relatively little variability in catch rate (R^2=0.08) and only the area effect was significant (Table 1). Considering the 4 years SGB had the highest mean catch rate, but this was not significantly higher than that of FIBI, ISS and the inshore. The northern Grand Bank and the inner NE shelf rank lowest. Although there was no significant difference in overall mean catch rate over the 4 years 1997 ranked lowest with 1995 the highest, followed by 1994 and 1996.

White hake (Figure 9, right), a relatively warm water species, occurred in only 2 stations on SGB in 1997. The model explained 25% of the variation in catch rate and area accounted for over 3-x that of year (Table 1). The interaction factor in the model was relatively high indicating shifts in distribution between years. Considering all 4 years the mean catch rate was significantly higher on the SGB than all other areas. Overall mean catch rate in 1997 ranked third and was not significantly different from 1994 and 1995. Highest mean catch rate occurred in 1996, which was a relatively warm year, and was significantly higher than that of the other 3 years.

Shannies and blennies, as in 1996, were restricted to the northern portion of the survey area including the northern bays (Figure 10, left). The group made up of 4 species has a tri-modal length distribution, which is probably attributable to different spawning times and/or growth rates of different species. The model had an R^2 of 0.35, and the area effect contributed approximately 2x that of year (Table 1). Mean catch rates over the 4 years were significantly higher in the two areas constituting the inner NE shelf. These areas had significantly higher catch rates than the other 5 areas. Mean catch rates were significantly higher in 1997 than the other 3 years 1996 ranking second, followed by 1994 and 1995.

Sculpins constitute another mainly northern group made up of approximately 13 species. In 1997 distribution (Figure 10, right) was mostly restricted to the area north of the northern Grand Bank with several low catches occurring on the SGB. Lengths ranged from approximately 25-80mm. The model explained approximately half the variation in catch rates. Both main effects were significant with area accounting for 2x the variation as year (Table 1).

The interaction factor was also relatively high for sculpins. Over the 4 years the highest mean catch rate occurred on ISN which was significantly greater than that of ISS, which had significantly higher catch rates than the other 5 areas. Catch rate on Belle Isle Bank was higher than the Grand Banks but not higher than Funk Isle Bank, or the inshore. Catch rate in 1996 ranked highest but was not significantly different than that of 1997. Catch rate in 1996 and 1997 were significantly higher than the 2 earlier years of which 1995 ranked lowest.

Unidentified squid, in 1997 were distributed similarly to 1996 (Figure 11, left) mainly in the northern half of the survey area with highest catch rates occurring near the edge of the NE shelf. There was a distinct distribution with relatively low catch rates on the southern Grand Bank. R^2 for the model was 0.49, both main effects contributed significantly, area approximately 6x that of year, with again a relatively large interaction factor (Table 1). Over the 4 years mean catch rate of squid was highest on ISN which had significantly higher catch rates than all other areas except Belle Isle Bank. The inshore and the Grand Banks had significantly lower catch rates than the other 4 areas. Overall mean catch rate in 1997 was not significantly lower than that of 1995 which ranked highest. The catch rate in 1997 was significantly higher than that of 1996 but not that of 1994.

Several species of seasnails of the family Liparidae were also distributed mainly in the northern half of the survey area (Figure 11, right). Highest catch rates occurred near the coast of southern Labrador and along the Great Northern Peninsula of Newfoundland. Sporadic low catches were taken on the Grand Banks. Lengths of seasnails ranged from 20-50mm. The model explained ~ 37% of variation in catch rates, both main effects were significant, that of area ~6x that of year (Table 1). Considering all 4 years the northern inner NE shelf ranked highest but catch rates there were not significantly higher than those of the southern inner shelf. These 2 areas had significantly higher catch rates than all other areas, except the southern inner shelf was not greater than the inshore. The Grand Banks ranked lowest.

Two more groups of predominantly northern pelagic juvenile fish, alligatorfish (3 species of Family Agonidae) and 2-3 species of less abundant Wolffish (Anarhichus sp.) had similar distributions in 1997 (Figure 12). Alligatorfish (left panel) had highest catch rates on the southern portion of the NE shelf, which was similar to the 1996 distribution, except that highest catch rates occurred further east on the shelf in 1996. There was a distinct distribution of low catches on the southern Grand Bank. Length range of alligatorfish in 1997 was ~29-47mm. The model explained 38% of the variation in catch rate over the 4 years, but only the area effect was significant (Table 1). ISS ranked highest and was not significantly different from FIBI and ISN, all three of which had higher catch rates than inshore and BIBI, except ISN was not higher than inshore. The catch rate on the Grand Banks was lower than all other areas. Although there was no significant difference over the 4 years catch rate of alligatorfish ranked highest in 1997 (97>95>96>94).

Wolffish were distributed throughout the NE Shelf , with highest catch occurred at a station on the inner, southern portion (Figure 12, right). Relatively high catch rates occurred throughout the outer portion of the NE shelf. There was again a distinct distribution on the southern Grand Banks. Lengths of wolffish ranged from ~42-82mm with 2-3 modes in the distribution. R^2 for the model was 0.28, both effects were significant, with variation attributable to area ~6x that of year (Table 1). Over all years highest mean catch rate occurred on Funk Isle Bank and catch rate on FIBI, BIBI and ISS was significantly higher than that of the other areas, except there was no difference between ISS and ISN. Catch rate on NGB ranked last behind that of SGB. Of the 4 years wolffish abundance also ranked highest in 1997 but was not significantly higher than 1996. Mean catch rate was higher in 1997 than 1994 or 1995, but 1996 was not different than 1994.

Only 2 species of flatfish, American plaice and turbot, had significant catches in 1997. American plaice (Figure 13, left) was mostly restricted to the inshore, with highest catch rate in Bonavista Bay. Lengths ranged from ~15-38mm. The model explained 18% of the variation and only the area effect was significant. Over the 4 years mean catch rate was highest inshore. The inshore was not greater than that from ISN but was significantly higher than all other areas. Mean catch rate was highest in 1997 and lowest in 1996. Mean catch rate in 1997 was significantly higher than 1995 and 1996 but not 1994.

Highest catch rates of turbot in 1997 occurred over Belle Isle and Funk Isle Banks with sporadic occurrences inshore, over ISN and the Grand Banks (Figure 13, right). Lengths were distributed in 2 groups (probably corresponding to age 0 and age 1) and ranged from ~57-153mm. R^2 for the model was 0.40, both main effects were significant, and variability attributable to area was higher than that for year (Table 1). Over the 4 years mean catch rate on BIBI was significantly higher than all other areas. ISS and ISN had significantly higher catch rates than the inshore, NGB and SGB, but FIBI was not different from either group. Mean catch rate of turbot in 1997 ranked between that of 1994 and 1996 but was not different from either. Mean catch rate all three years was significantly lower than that of 1995.

In many cases the interaction term, although statistically significant, was small in relation to the area effect, in particular (Table 1). For some variables however interactions were relatively high compared with the year effect, as determined by the partial R^2. These include, in particular, white hake and squid and indicates shifts in distribution between years.

Discussion

Results of analysis of variance indicated that in the overall model there was a statistically significant ($P<0.0001$) relationship between all variables examined during the 1997 survey, and geographic area and/or year of survey (Table 1). The partial F-value attributable to area was significant for all variables and the partial F-value attributable to year was significant in 18 of the 22 cases; sand lance, redfish, American plaice, and alligatorfish being the exceptions. Geographic area accounted for much more variation in mean temperature than did annual differences particularly at 0m. Area accounted for more variation in total zooplankton biomass and total nekton biomass than did year, but year rather than area, accounted for more variation in biomass of the smallest (< 1mm) size fraction of zooplankton. Area rather than year accounted for more variation in mean catch rate of all 14 fish species/groups examined. The interaction of the two main effects in the analysis of variance was significant in all relationships except that for the large zooplankton size fraction, nekton wet weights, capelin and redfish, but in most cases the partial F-value attributable to interaction was low compared to the main effects, white hake being the exception. (Table 1).

In comparison to the three previous years surface temperatures during the survey in 1997 were significantly higher than 1995 but lower than 1994 and 1996, both of which were relatively warm years. In contrast, mean temperatures at 50m in 1995 and 1996 were higher than 1997 and 1994.

The mean total zooplankton biomass from the bongos was significantly higher in 1997 than in the 3 previous years, which were not significantly different. Mean biomass of the largest size fraction was higher in 1995 than the other 3 years, which were not different and of which 1997 ranked highest. Mean biomass of the mid-size zooplankton fraction was not significantly different among years, but 1997 ranked first followed by 1996. Biomass of the smallest size fraction was significantly greater in 1997 than any other year. The mean total nekton biomass, with or without jellyfish, ranked second to but was not significantly different from1995, which ranked first. In terms of zooplankton and nekton, biomass in 1997 was then relatively high in comparison to the 3 previous years.

Of the two pelagic fish species that were examined, capelin (age 1-2) ranked relatively high (2^{nd}), whereas sand lance ranked lowest of the 4 years (that did not differ significantly). Mean catches of pelagic 0-group Arctic cod were significantly lower in 1995 and 1996 than 1994. This trend continued in 1997 with the lowest mean catch of the series. Catch rate in 1997 was not, however, significantly different than that of 1996. Catch rate of Atlantic cod decreased significantly in 1995 and again in 1996. However, catches increased slightly in 1997 such that it was not different from either 1995 or 1996, but mean catch rate of cod all three years was significantly lower than that of 1994. Catch rate of redfish ranked lowest in 1997, whereas catch rate of white hake was significantly lower than 1996, when white hake had the most extensive distribution of the 4 years. Six groups of relatively abundant species (including blennies, sculpins, squid, seasnails, alligatorfish and wolffish) were consistently more abundant on the Northeast Newfoundland Shelf than on the Grand Banks. Blennies, sculpins and seasnails were more confined to the inner shelf waters whereas wolffish were more predominant over the offshore banks. Squid were more abundant in the northern areas, whereas alligatorfish tended to be more abundant over the southern portion of the NE shelf. Three of the groups (blennies, alligatorfish and wolffish) ranked first in mean catch rate in 1997, and the other three groups ranked second in mean catch rate of the 4 years. These groups taken together indicate that 1997 was relatively productive in relation to other recent years on the NE shelf. In contrast to this sand lance and white hake which were mainly confined to the Grand Banks, ranked lowest of the 4 years. Of the 4 species of flatfish that have occurred over the survey area, abundance of pelagic 0-group yellowtail and witch is so low and occurrence sporadic that no annual or spatial relationships existed in the data. Of the other two flatfish species, which also had relatively low catch rate, American plaice ranked highest of the 4 years and turbot ranked second lowest.

With the addition of the 1997 data spatial patterns are more evident and some temporal patterns are emerging, albeit for a relatively short time series. A pattern of decreasing abundance and spatial contraction of pelagic cod during the 1st 3 years changed direction in 1997. Although distribution of Arctic cod has not obviously contracted there has been a decline in catch rates each year of the survey.

This survey is a baseline to monitor changes in the pelagic environment. It is an attempt to increase our understanding of annual variability in the marine ecosystem and ocean conditions in the Newfoundland Region. As this knowledge increases, we improve our understanding of recruitment to commercial fish stocks utilising these ecosystems. Coupled with this will be an increase in precision to predict recruitment from O-group surveys.

Acknowledgements

We thank the officers and fishing crew of the W. Templeman and the Teleost for their excellent co-operation and expertise at sea in carrying out the survey. Technical staff that participated at sea, including D. Davis, A. Murphy, E. McDonald, G. Redmond and D. Gillet and P. Eustace are thanked for their assistance in carrying out the sampling program. D. Davis is thanked for data processing and production of figures. Doug Swain commented constructively on an earlier draft.

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Table 1. Results of analysis of variance carried out on variables measured during the 1994-1997 pelagic 0-group surveys. Year and geographic area are used as dependent variables. Shown are the maximum and minimum means by area, for each variable, the R-squared explained by the model, the overall F-value and associated probability, as well as the partial R-squared (and probability) associated with each independent variable. The partial R-squared and probability attributable to interaction of the two main effects is also shown, if the interaction factor was significant.

Dependent Variable	Min mean	Max mean	r^2	Overall F-value / prob	Partial R^2 Area / Prob.	Partial R^2 Year / Prob.	Interaction factor
°C 0m	7.3	18.0	0.84	78.22 0.0001	0.59 (.0001)	0.07 (.0001)	0.10 (.0001)
°C 50m	-1.3	3.1	0.48	13.25 0.0001	0.29 (.0001)	0.10 (.0001)	0.07 (.0001)
Zootot	1.8	23.5	0.51	15.53 0.0001	0.38 (.0001)	0.06 (.005)	0.04 (.0245)
Zoo >2	1.0	5.6	0.26	15.72 0.0001	0.20 (.0001)	0.06 (.0001)	N.S.
Zoo 1-2	0.2	7.5	0.58	20.25 0.0001	0.39 (.0001)	0.01 (.0035)	0.04 (.0002)
Zoo <1	0.4	11.3	0.62	23.81 0.0001	0.15 (.0001)	0.36 (.0001)	0.04 (.0071)
Nekton1 with	1.54	17.37	0.25	15.61 0.0001	0.23 (.0001)	0.03 (.0011)	N.S.
Nekton2 w/0	1.08	13.77	0.29	16.31 0.0001	0.27 (.0001)	0.02 (.0074)	N.S.
Capelin	0	140.4	0.20	11.33 (.0001)	0.17 (.0001)	0.02 (.0204)	N.S.
Sand lance	0	7.0	0.24	4.51 (.0001)	0.14 (.0001)	0.01 (.2139)	0.08 (.0036)
Atlantic cod	0	1.2	0.33	7.08 (.0001)	0.16 (.0001)	0.08 (.0001)	0.10 (.0001)
Arctic cod	0	65.9	0.45	12.18 (.0001)	0.33 (.0001)	0.08 (.0001)	0.07 (.0001)
Redfish	0	5.9	0.08	4.05 (.0001)	0.07 (.0001)	0.01 (.1474)	N.S.
White hake	0	0.26	0.25	4.93 (.0001)	0.07 (.0001)	0.02 (.0183)	0.15 (.0001)

Table 1. Continued .....

Dependent Variable	Min mean	Max mean	r^2	Overall F-value / prob	Partial R^2 Area / Prob.	Partial R^2 Year / Prob.	Interaction factor
Blennies	0	2.72	0.33	7.10 (.0001)	0.16 (.0001)	0.08 (.0001)	0.10 (.0001)
Sculpins	0	18.9	0.50	14.74 (.0001)	0.22 (.0001)	0.11 (.0001)	0.17 (.0001)
Squid	0.5	22.2	0.49	14.16 (.0001)	0.31 (.0001)	0.05 (.0001)	0.10 (.0001)
Seasnail	0.25	5.1	0.37	8.67 (.0001)	0.23 (.0001)	0.04 (.0001)	0.10 (.0001)
A.plaice	0	0.38	0.18	3.19 (.0001)	0.08 (.0001)	0.01 (.2846)	0.08 (.0065)
Turbot	0	0.53	0.40	9.78 (.0001)	0.20 (.0001)	0.12 (.0001)	0.13 (.0001)
Alligatorfish	0	2.25	0.38	8.99 (.0001)	0.27 (.0001)	0.00 (.8690)	0.11 (.0001)
Wolffish	0	0.27	0.28	5.66 (.0001)	0.19 (.0001)	0.03 (.0007)	0.07 (.0039)

Table 2. Relative overall abundance and incidence of occurrence of dominant fish species caught in the IYGPT during the pelagic 0-group survey in 1997.

Species	Scientific Name	No. Caught	Relative Abundance(%)	Incidence(%)
Capelin	Mallotus villosus	101958	85.7	39.3
Squid	Cephalopoda	5235	4.4	65.3
Arctic cod	Boreogadus saida	3722	3.1	54.0
Sand lance	Ammodytes sp.	1742	1.5	27.3
Sculpins	Cottidae	1347	1.1	48.7
Alligatorfish	Agonidae	1166	1.0	50.0
Shannies Blennies	Stichaeidae	1138	0.1	40.0
Seasnails	Liparus sp.	1081	0.9	48.0
Lanternfish	Myctophidae	975	0.8	2.7
Wolffish	Anarhichus sp.	153	0.1	34.0
Atlantic cod	Gadus morhua	120	0.1	20.7
Redfish	Sebastes sp.	97	0.1	18.7

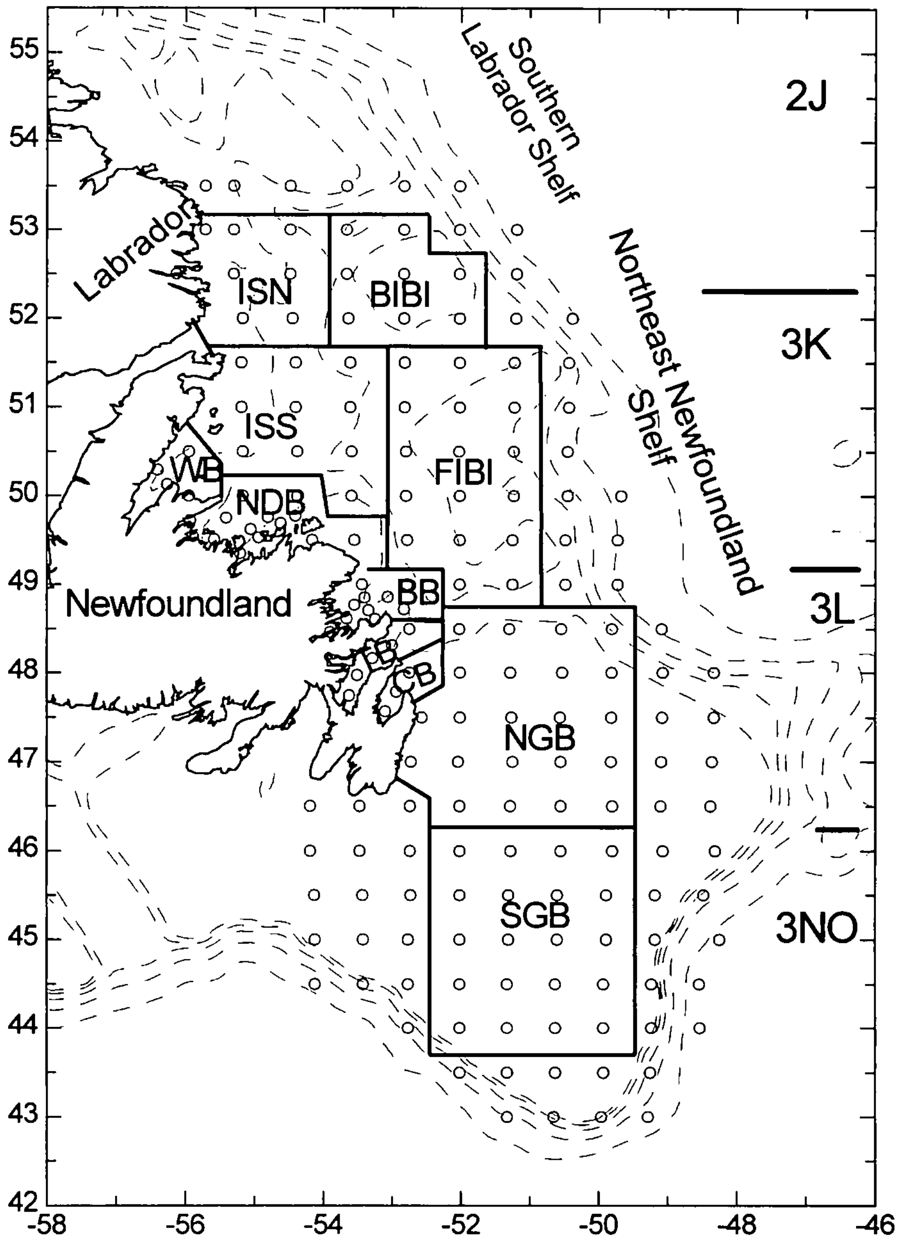

Figure 1. Survey area showing stations sampled during the 1997 pelagic 0-group survey on the southern Labrador shelf, Northeast Newfoundland Shelf, and Grand Banks. Each of the seven subareas are indicated. (ISN = inner shelf, northern; BIBI = Belle Isle Bank; ISS = inner shelf, southern; FIFI = Funk Island Bank; INSH = inshore; NGB = Northern Grand Bank; SGB = Southern Grand Bank).

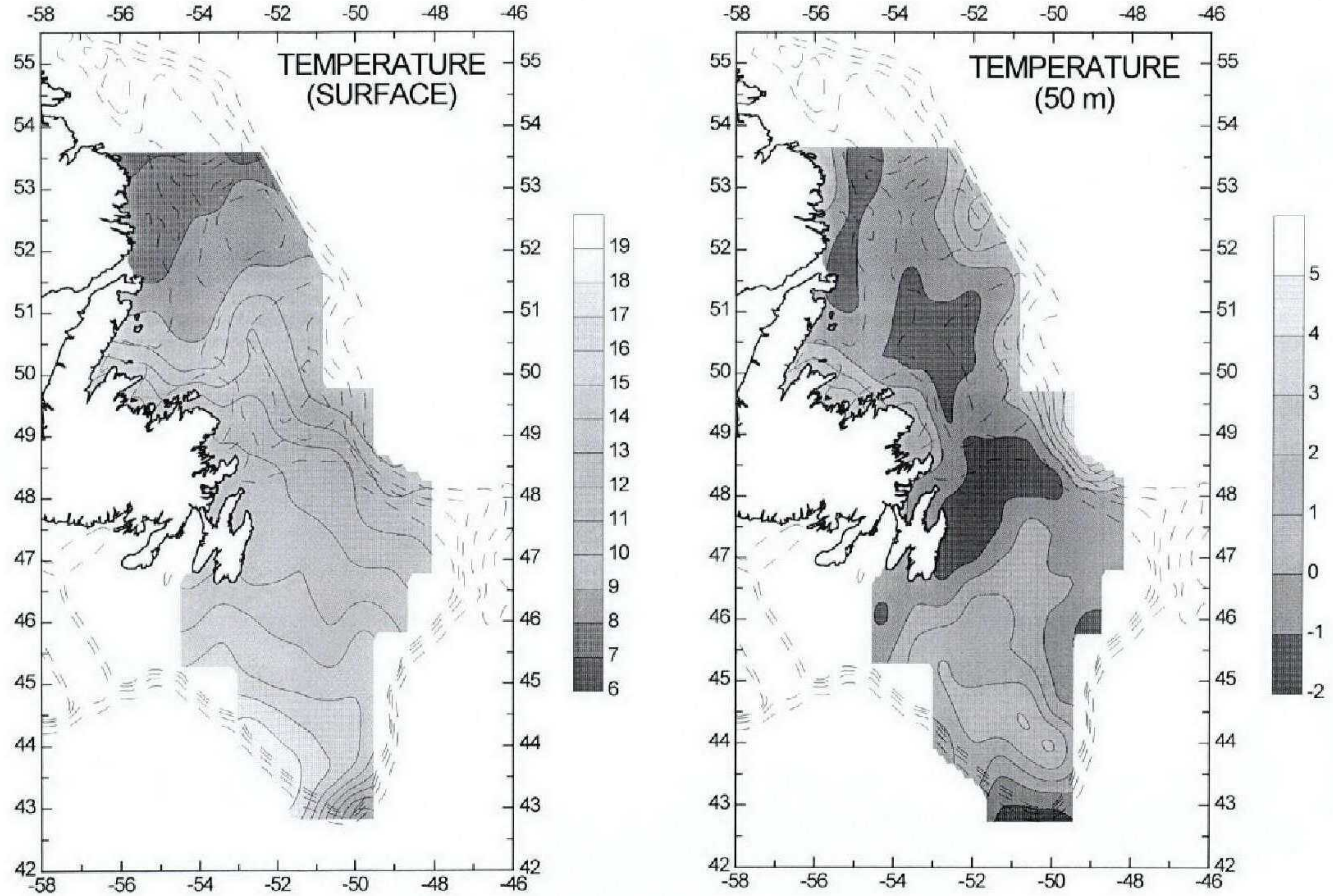

Figure 2. Distribution of surface tempertures (degrees C), left panel, and temperatures at 50m, during the 1997 pelagic 0-group survey in NAFO Divisions 2J3KLNO.

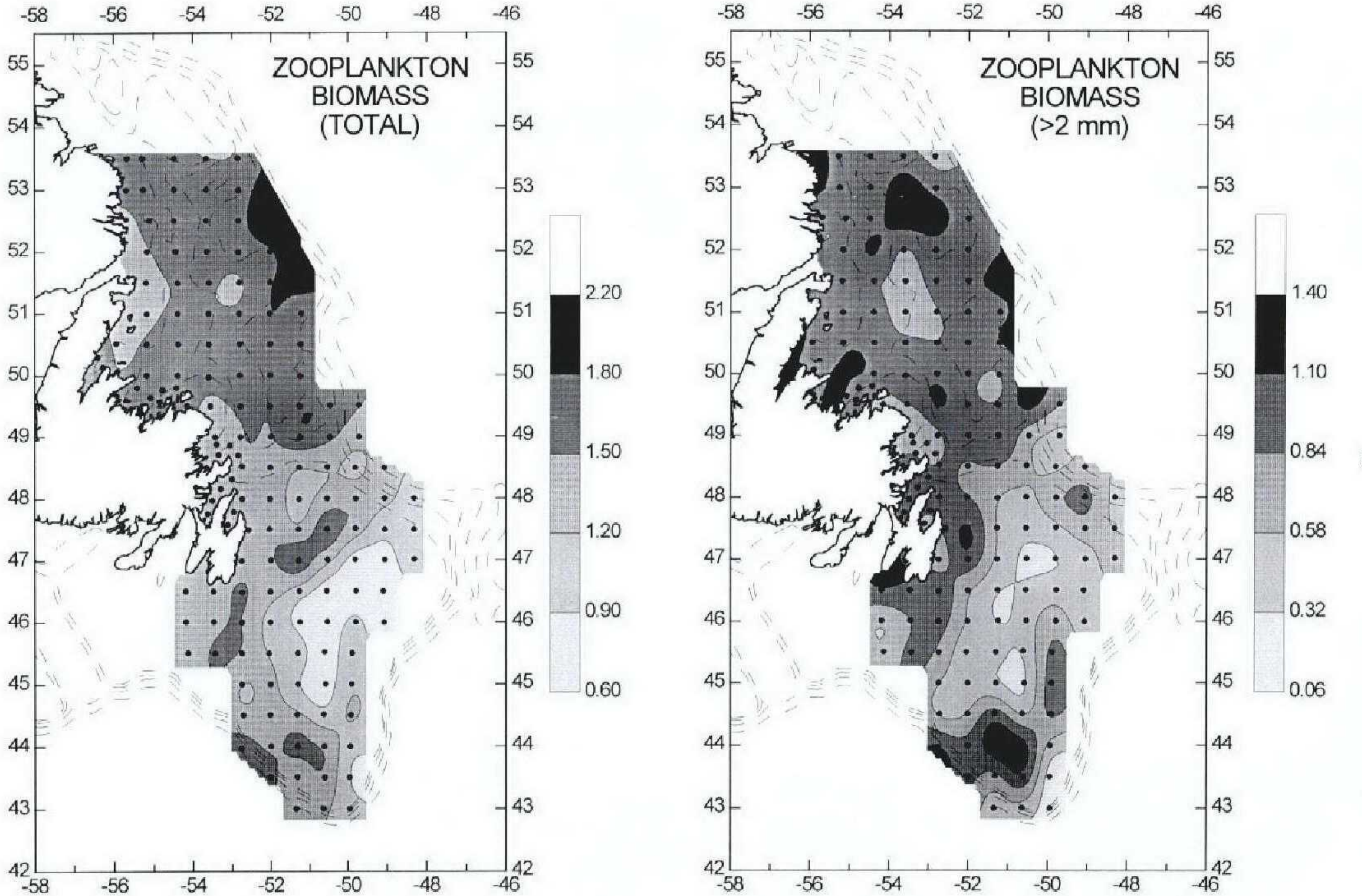

Figure 3. Distribution of total invertebrate zooplankton biomass (mgDW/m^3), left panel, and for the large size fraction (>2mm), caught in the bongos during the 1997 pelagic 0-group survey in NAFO Divisions 2J3KLNO.

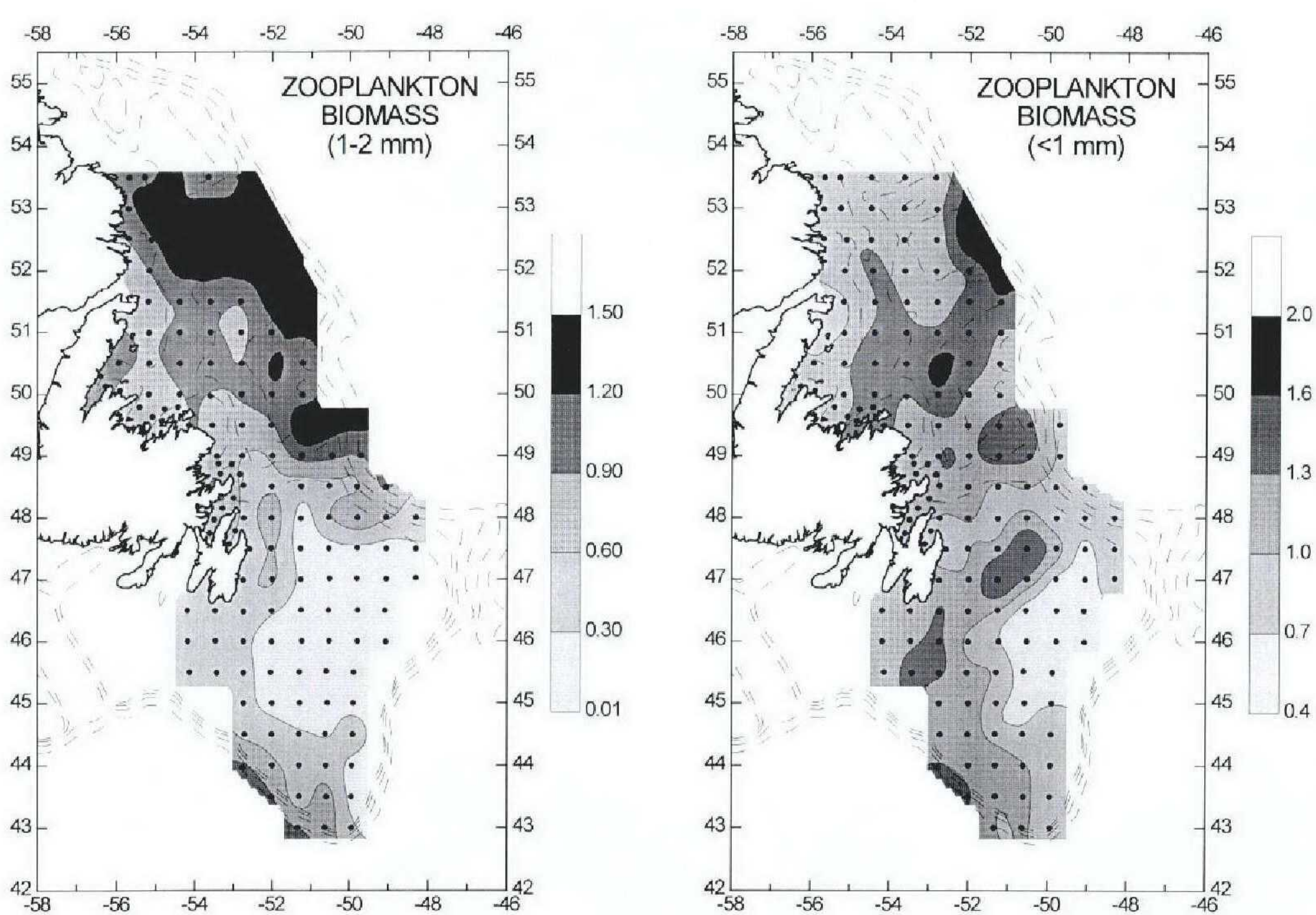

Figure 4. Distribution of the midsize fraction (1-2mm) of invertebrate zooplankton biomass (mgDW/m^3), left panel, and for the small size fraction (<1mm), caught in the bongos during the 1997 pelagic 0-group survey in NAFO Divisions 2J3KLNO.

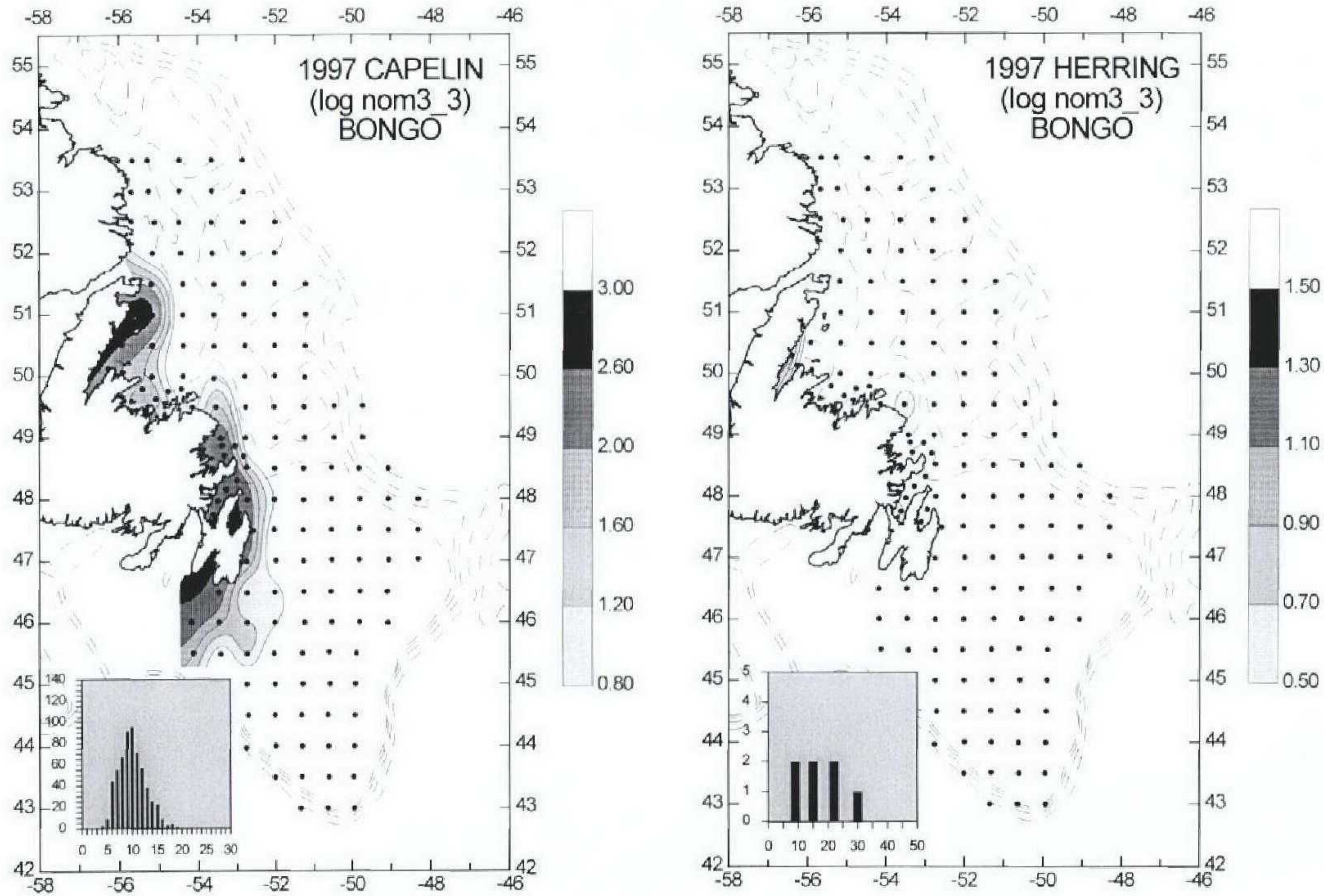

Figure 5. Distribution of capelin larvae (log_10 number 10^3 /m^3), left panel, and herring larvae, right panel, from the bongos during the 1997 pelagic 0-group survey in NAFO Divisions 2J3KLNO.

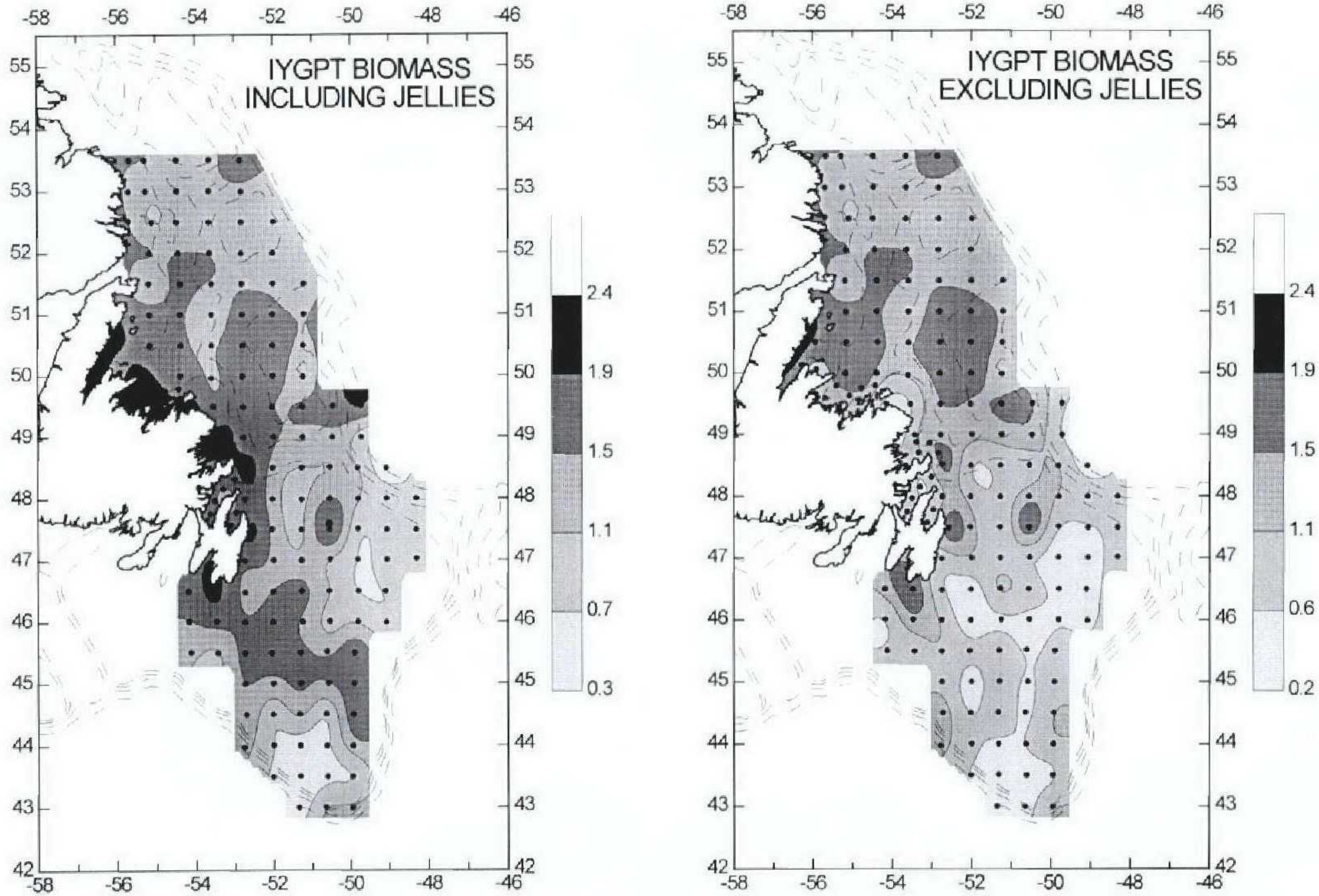

Figure 6. Distribution of total nekton biomass (kgWW/m^3) with jellyfish included, left panel, and without jellyfish, right panel, freom the IYGPT during the 1997 pelagic 0-group survey in NAFO Divisions 2J3KLNO.

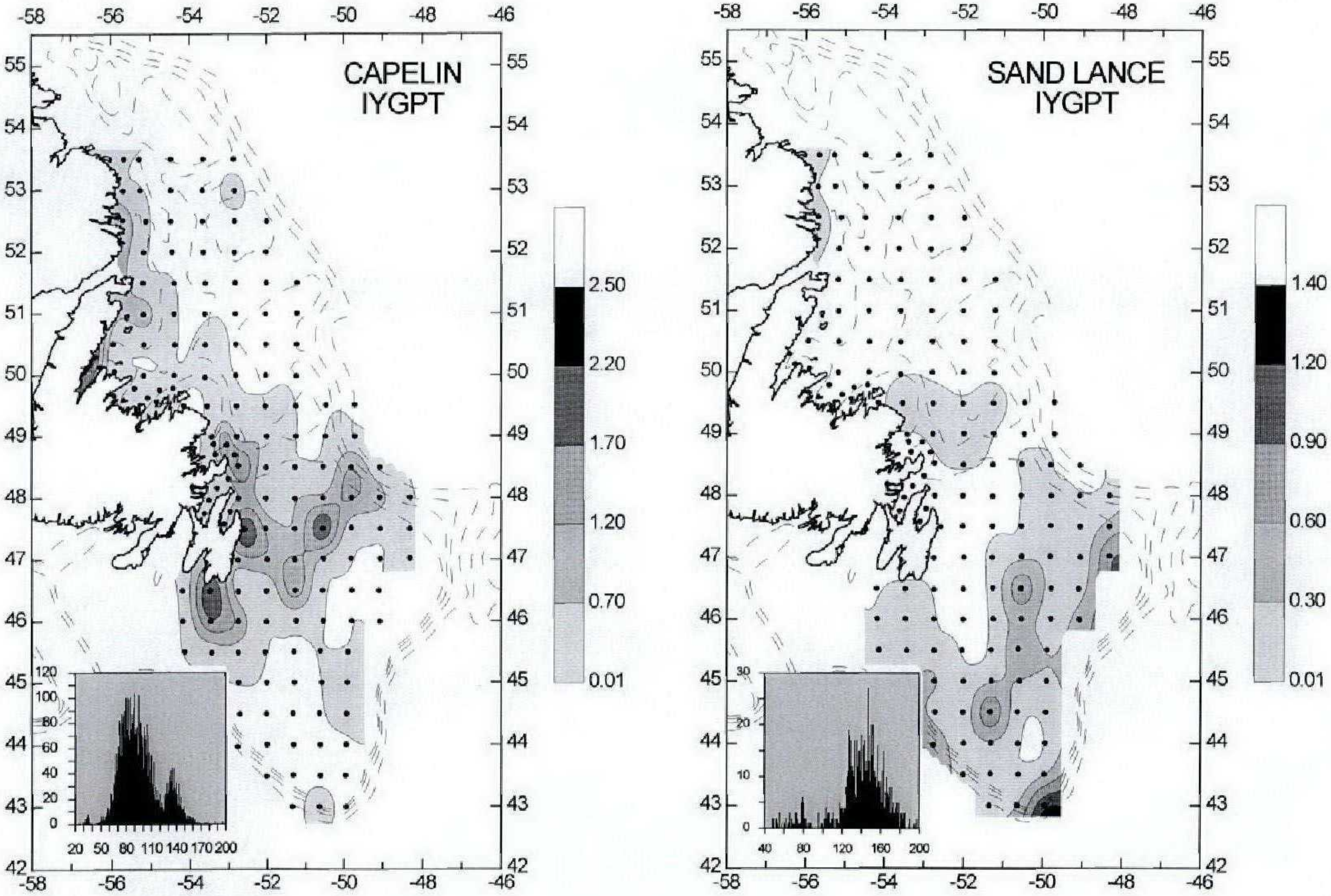

Figure 7. Distribution of capelin (log_10 number 10^4 /m^3), left panel, and sand lance, right panel, from the IYGPT during the 1997 pelagic 0-group survey in NAFO Divisions 2J3KLNO. Length frequency distribution (mm) of animals captured is shown in the bottom left hand corner of each panel.

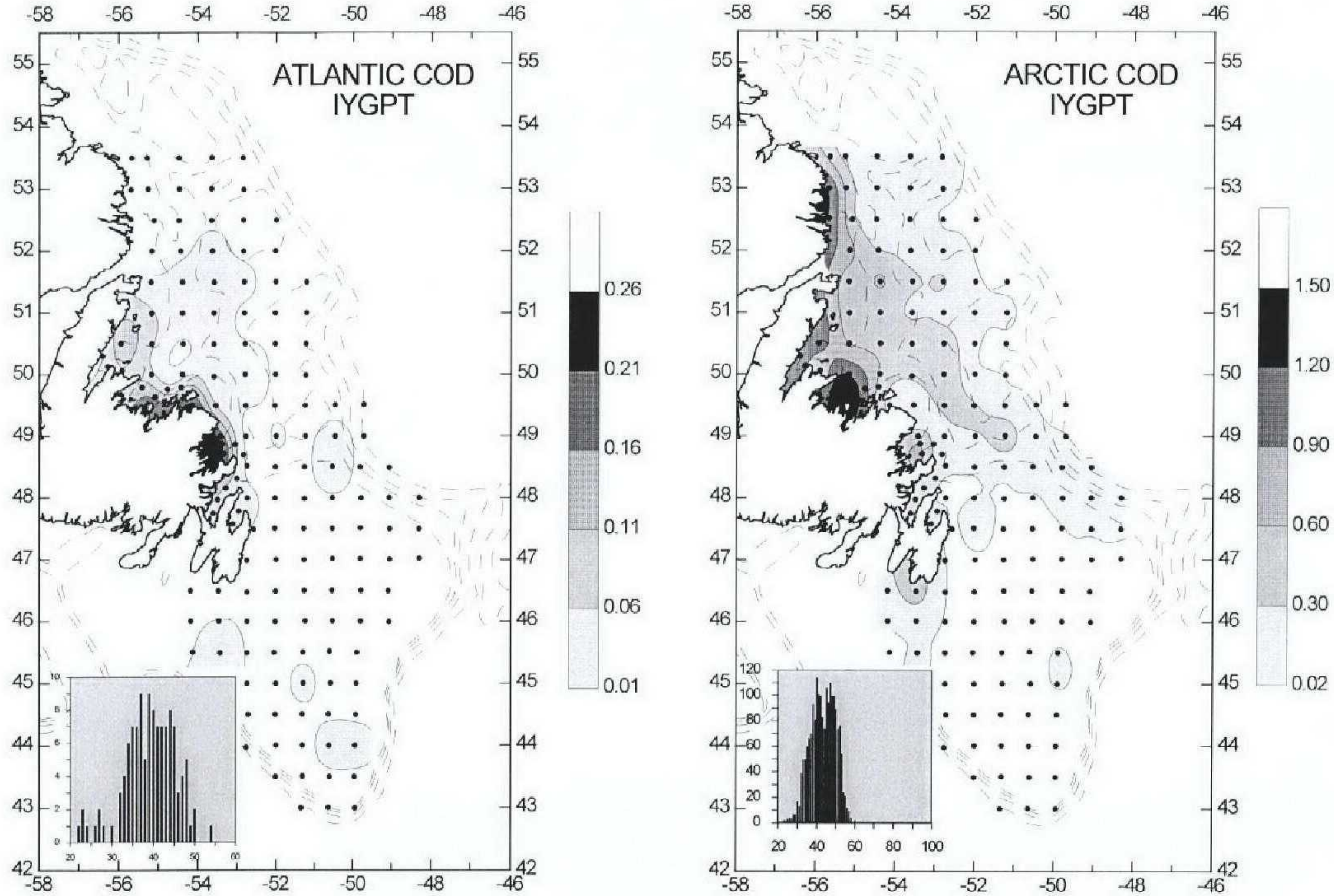

Figure 8. Distribution of pelagic 0-group cod (log_10 number 10^4/ m^3) left panel and Arctic cod, right panel, from the IYGPT during the 1997 pelagic 0-group survey in NAFO Divisions 2J3KLNO. Length frequency distribution (mm) of animals captured is shown in the bottom left hand corner of each panel.

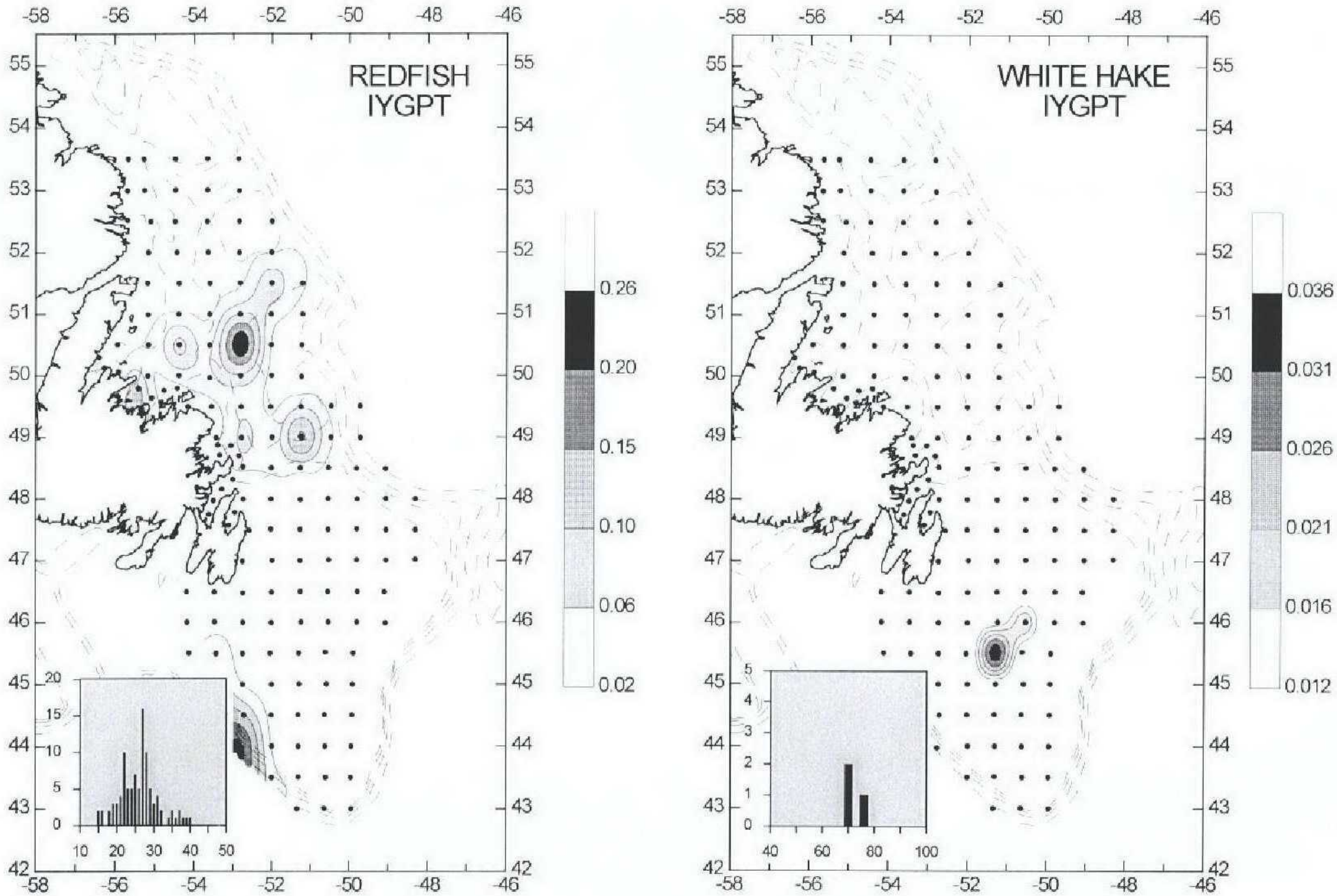

Figure 9. Distribution of redfish (log_10 number 10^4 /m^3), left panel, and white or common hake, right panel, from the IYGPT during the1997 pelagic 0-group survey in NAFO Divisions 2J3KLNO. Length frequency distribution (mm) of animals captured is shown in the bottom left hand corner of each panel.

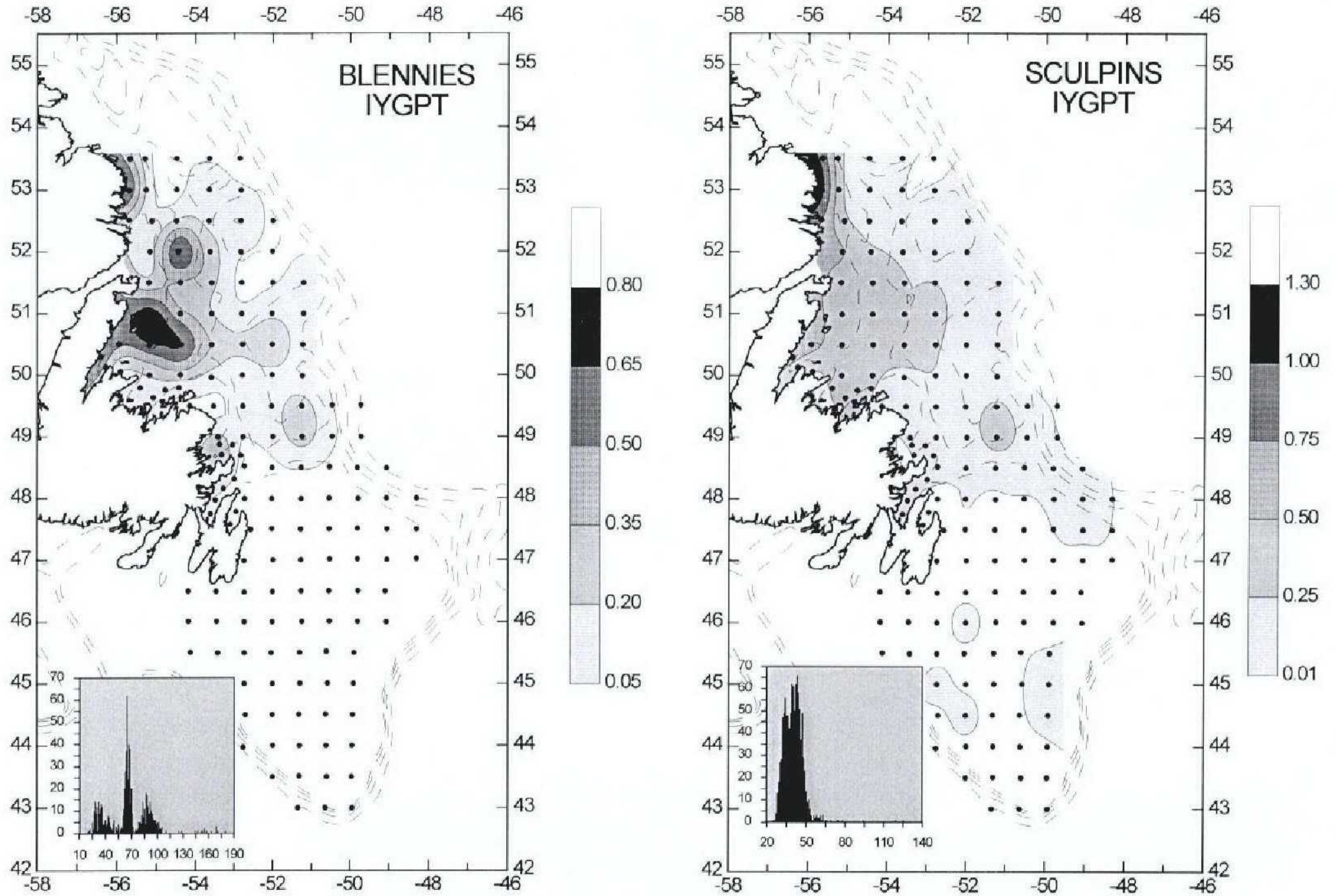

Figure 10. Distribution of blennies (log_10 number 10^4 /m^3), left panel, and sculpins, right panel, from the IYGPT during the 1997 pelagic 0-group survey in NAFO Divisions 2J3KLNO. Length frequency distribution (mm) of animals captured is shown in the bottom left hand corner of each panel.

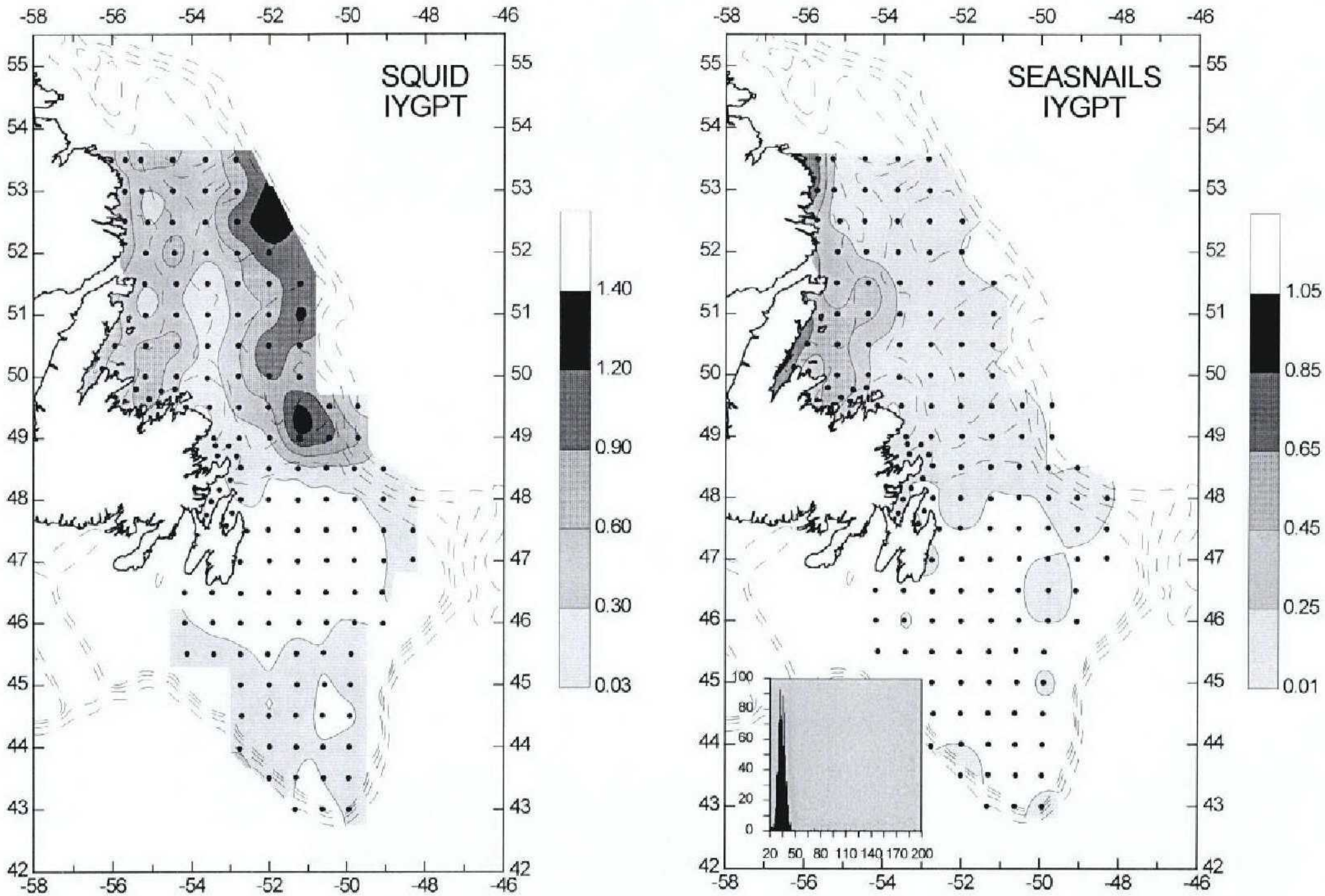

Figure 11. Distribution of squid (log_10 number 10^4 /m^3), left panel, and seasnails, right panel, from the IYGPT during the 1997 pelagic 0-group survey in NAFO Divisions 2J3KLNO. Length frequency distribution (mm) of animals captured is shown in the bottom left hand corner of each panel.

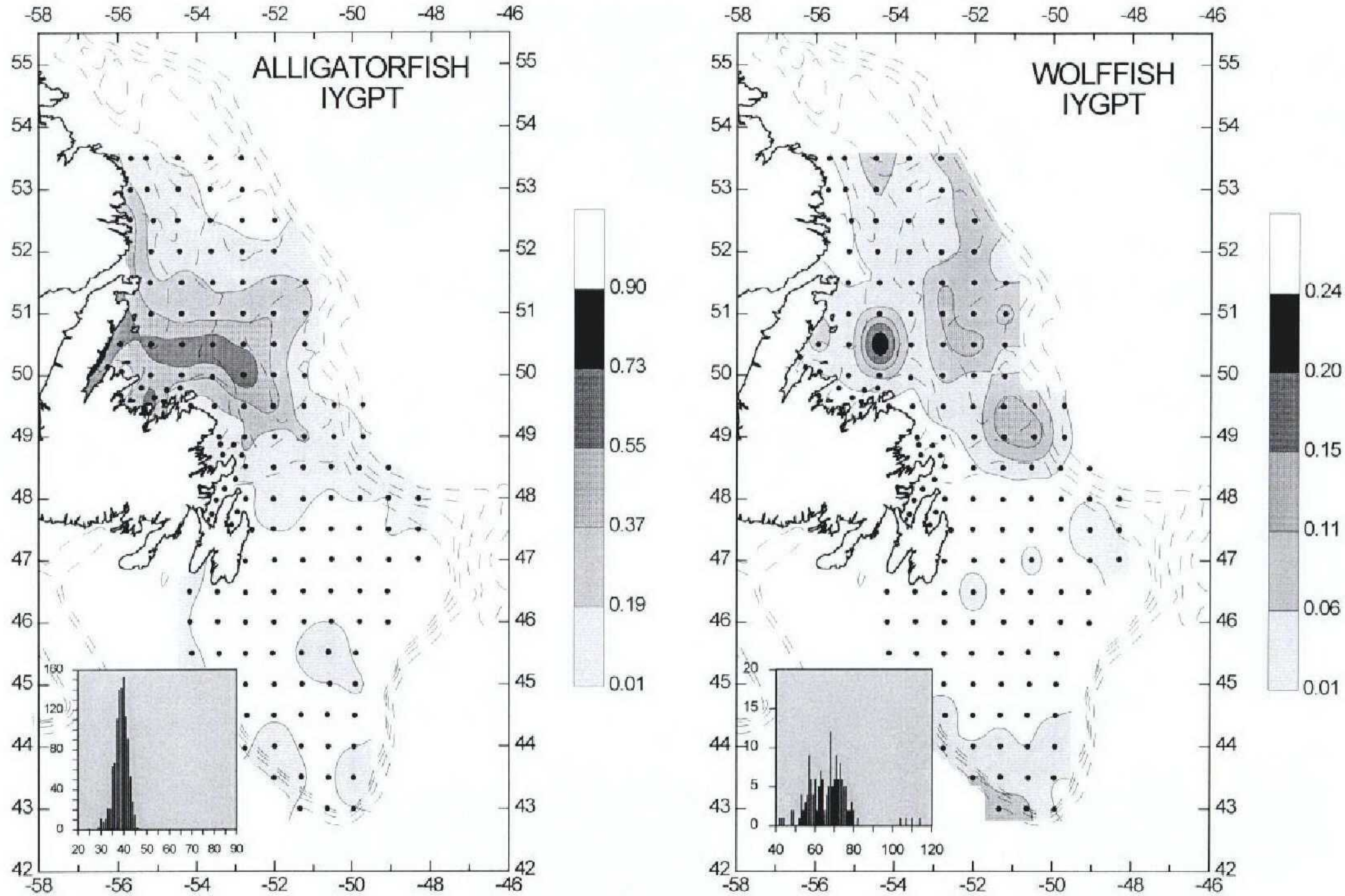

Figure 12. Distribution of alligatorfish (log_10 number 10^4 /m^3), left panel, and wolffish, right panel, from the IYGPT during the 1997 pelagic 0-group survey in NAFO Divisions 2J3KLNO. Length frequency distribution (mm) of animals captured is shown in the bottom left hand corner of each panel.

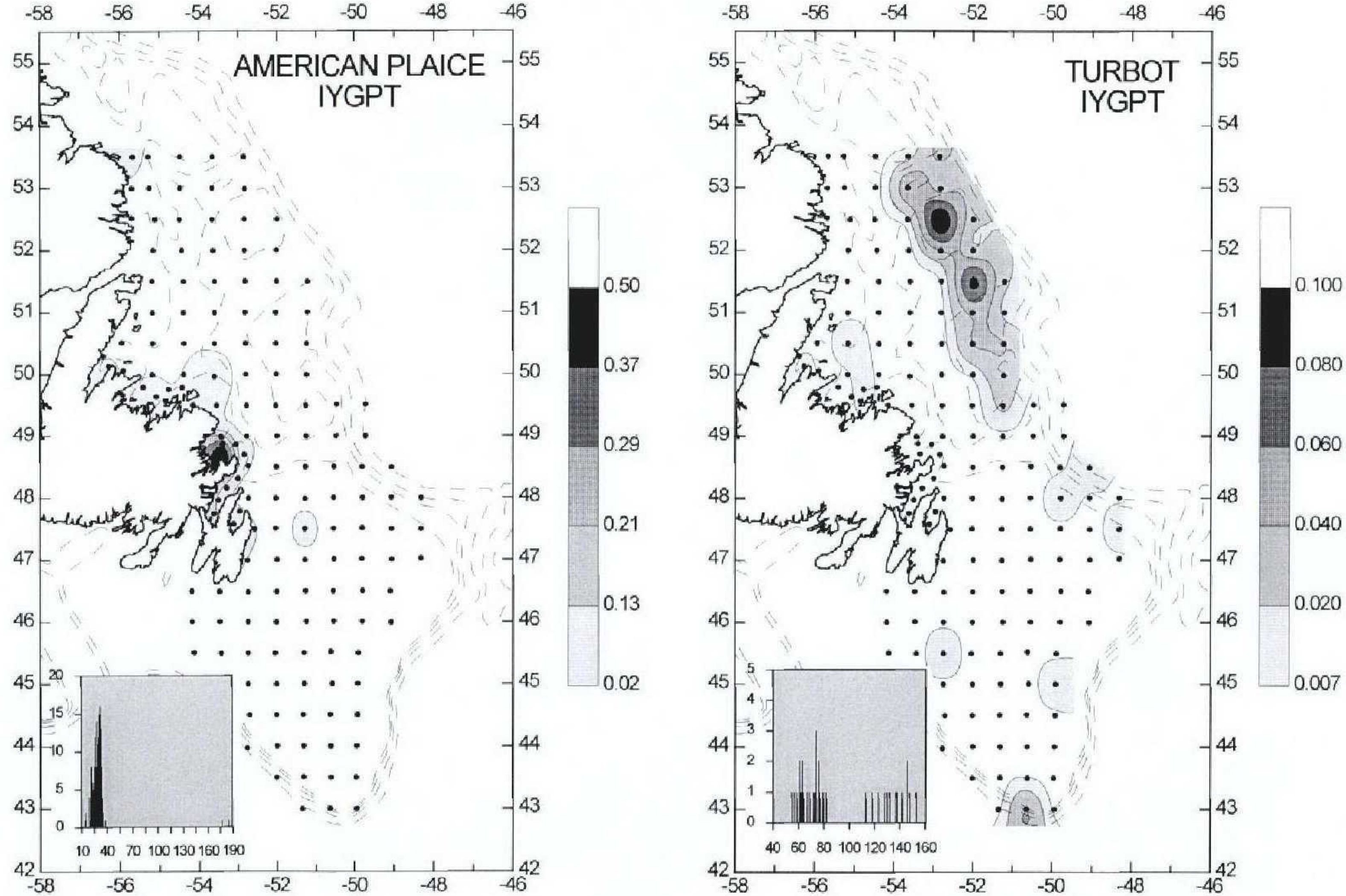

Figure 13. Distribution of American plaice (log_10 number 10^4 /m^3), left panel and turbot, right panel, from the IYGPT during the 1997 pelagic 0-group survey in NAFO Divisions 2J3KLNO. Length frequency distribution (mm) of animals captured is shown in the bottom left hand corner of each panel.