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Plankton and Nekton of the Northeast Newfoundland Shelf and Grand Banks in 1998

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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 fifth consecutive year during late summer 1998. The study area covers inshore and offshore waters from southern Labrador to the southern Grand Banks (NAFO Divisions 2J3KLNO). Spatial and/or annual (1994-98) effects accounted for significant variation in all variables examined. Area differences were larger and generally associated with latitudinal or inshore/offshore clines. Mean surface temperatures during the 1998 survey ranked in the middle of the 5 years behind 1994 and 1996, but warmer than 1997 and 1995. There was a large body of relatively warm water on the Grand Bank in 1998 with cooler water to the south. In 1998 biomass of the smallest zooplankton size fraction ranked second behind that of 1997 and was significantly higher than 1996, 1995 and 1994. The mid size fraction ranked highest and was not significantly greater than any year, except 1994. The largest size fraction ranked second last but was significantly less than any other year. In 1998 capelin larvae were more widely distributed than any other year, extending as far north as sampling occurred on the Labrador coast and also on the Southeast Shoal. Capelin and sand lance dominated total nekton. Mean catch rate of Arctic cod, which decreased the previous 3 years in succession, ranked third in 1998 following diel adjustments. Mean total nekton biomass (including jellyfish) was significantly higher than any other year in 1998. After adjusting for daynight difference capelin (mostly age 1-2) catch rate in 1998 ranked lowest and was significantly lower than all years except 1995. The mean catch rate of pelagic 0-group Atlantic cod was also the highest since 1994 as a result of relatively high catch rates on the Grand Bank and not the more northern areas. Six species groups that occurred mainly on the Northeast Newfoundland Shelf were all less abundant than they were in 1997, whereas species that occur mainly on the Grand Banks tended to be more abundant in 1998.

Résumé

Un relevé détaillé à grande échelle de la température, du plancton et du necton du milieu pélagique marin a été effectué pour la cinquième année consécutive à la fin de l'été 1998. La zone d'étude comprenait les eaux côtières et hauturières s'étendant du sud du Labrador au sud des Grands Bancs (divisions de l'OPANO 2J3KLNO). Les effets spatiaux et (ou) annuels (1994-1998) expliquaient une partie significative de la variation de toutes les variables examinées. Les écarts régionaux étaient importants et généralement associés aux zones de transition en latitude ou à celles entre les eaux côtières et hauturières. Les températures moyennes de surface au moment du relevé de 1998 se situaient au centre de la gamme des cinq années, en deçà de celles de 1994 et 1996, mais supérieures à celles de 1997 et 1995. On a noté la présence d'une importante masse d'eau relativement chaude sur le Grand Banc en 1998, mais l'eau était moins chaude au sud. En 1998, la biomasse de la fraction du plus petit zooplancton venait en deuxième après celle de 1997 et était significativement plus importante que celles de 1996, 1995 et 1994. Celle de taille intermédiaire était la plus élevée et n'était pas, à l'exception de celle de 1994, significativement plus importante que celle d'aucune autre année. La fraction de plus grande taille était la deuxième dernière et significativement inférieure à celle de toute autre année. En 1998, la répartition des larves de capelan était plus étendue que celle de toute autre année et s'étendait aussi loin au nord que les prélèvements effectués sur la côte du Labrador et le Southeast Shoal. Le capelan et le lançon dominaient le necton total. Le taux de capture moyen de la morue polaire, qui avait diminué de façon successive au cours des trois années précédentes, se situait au troisième rang en 1998, après correction pour les variations nycthémérales. La biomasse moyenne du necton total (incluant les méduses) était significativement supérieure à celle de toute autre année en 1998. Après correction pour les écarts entre le jour et la nuit, le taux de capture du capelan de 1998 (surtout des individus d'âge 1 ou 2) était le plus faible de la série et, à l'exception de 1995, significativement inférieur à ceux de toutes les années. Le taux de capture moyen de la morue pélagique du groupe 0 était aussi le plus élevé depuis 1994, cela à cause de taux de capture relativement élevés sur le Grand Banc mais non dans les zones plus au nord. Six groupes d'espèces se rencontrant surtout sur le plateau nord-est de Terre-Neuve étaient aussi moins abondants qu'en 1997, mais les espèces se trouvant surtout sur les Grands Bancs avaient tendance à être plus abondantes en 1998.

Introduction

Large scale comprehensive surveys of the marine pelagic environment off Newfoundland and Labrador (NAFO Divisions 2J3KLNO) have been carried out during late summer since 1994 (Anderson and Dalley 1997; Dalley and Anderson 1997, 1998). The survey was originally designed to measure the abundance of pre-recruit Atlantic cod during the pelagic juvenile fish stage. Also an independent measure of pre-recruit abundance of Northwest Atlantic capelin at the larval stage (0-group) and as one-year-old capelin (1+) was sought. In addition, it was designed as a multispecies measure of the state of the pelagic ecosystem and changes in it. We wanted to provide a basis to compare results of future surveys, in an effort to understand short and long-term variations in the pelagic environment. This environment harbours prerecruit stages of numerous commercial and non-commercial fish species and invertebrates, in addition to older life history stages of pelagic species as capelin and sand launce.

The survey was undertaken for a fifth consecutive year in August/September 1998. The purpose of this document is to describe the temperature, plankton and nekton biomass and structure of this large zoogeographic area during 1998, in relation to the 4 previous years. Day/night variability in catch rates of 23 biological variables is examined each year of the survey. Following adjustments for any diel variability, these variables, along with 2 temperature measures, are statistically examined for differences among years (1994, 1995, 1996, 1997, and 1998) and also for spatial patterns throughout the large zoogeographic area surveyed.

Materials and Methods

The 1998 survey was carried out from August 24 until September 10. The mid-day of the survey was day 244 of the year. This compares to survey mid days of 241, 257, 241 and 233 for the 1994, 1995, 1996 and 1997 surveys respectively. Thus, the 1998 survey was approximately 11 days later than 1997 and 3 days later than 1996. The RV Teleost (67 stations) covered the northern part of the survey area and the RV W. Templeman (65 stations) the southern portion in 1998. The standard sampling protocol at each station included: 1) a Seabird-25 CTD (Conductivity / Temperature / Depth) profile, with flourometry to a maximum 500m depth, or within ~ 5m of bottom where depth was less, 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 to 1998 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 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^{o}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) INSH denotes all of the large inshore bays and stations within ~ 54km of shore. In 1998 stations within Bonavista Bay were not completed due to an early termination of the Teleost portion of the survey.
2) NGB the northern Grand Banks and
3) ISN or the inner Northeast Newfoundland (NE) Shelf, northern portion,
4) BIBI or Belle Isle Bank in the northern NE shelf, offshore portion,
5) ISS or the inner NE shelf, southern portion,
6) FIBI or Funk Isle Bank, the southern NE shelf, offshore portion.
7) SGB the southern Grand Banks.

A daynight variable was created to determine if diel differences existed in catch rates. Sets with mid-times between sunrise and sunset were classified as day, those between sunset and sunrise as night. Sunrise and sunset were determined each day of the survey using tables provided by Environment Canada. An analysis of variance was carried out for each variable, each year, with catch rate as the dependent variable and daynight and area as independent variables. If the mean day and night catch rates were significantly different ($P<0.05$), catch rates of the light condition with the lower mean were adjusted upward according to its ratio of the higher mean.

Once biological variables with significant diel differences in catch rates were adjusted, another analysis of variance was carried out on all 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 procedure or GLM (SAS Institute Inc.1989) was 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 standardised to the volume of water filtered and logged_{10} prior to the analysis of variance

Results

Temperature, and distribution and abundance data for the 1998 survey is presented using contour plots covering the whole zoogeographic range for each variable examined. The results of the analysis of variance of 35 means (7 areas x 5 years) are presented for each variable, indicating the total variability accounted for by the model, and that attributable to each of the main effects (Table 2). 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.

Consistent with previous years there was a latitudinal cline in surface temperature from southern Labrador to the northern Grand Bank (Figure 2, left panel) with warmer water to the south and a tendency for slightly warmer surface water in the bays than adjacent latitudes on the shelf. However, in 1998 this north to south cline did not continue to the southern Grand Bank as it did during previous years and mean surface temperature on the northern Grand Bank (15.2^{O}C) was higher than that of the southern Grand Bank (13.5^{O}C). This is indicated by the large light area over the northern Grand Bank in the figure. South of the warm water there was a cline of decreasing temperature until relatively cool water occurred on the southern edge of the survey area. The GLM model for surface temperature had the highest R^2 (0.82) of all variables examined (Table 2). 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 2 most northern areas (ISN, BIBI) of the shelf. There was a significant difference in mean temperature each year of the survey such that 94>96>98>97>95, noting that 1998 was mid range of the previous 5 years.

There was a weaker cline in temperatures at 50m (Figure 2, right). Unlike the surface warmest water at 50m in 1998 was located over the southern Grand Banks, with the inshore ranking second. As in previous years 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, area again more so than year (Table 2). Mean temperature at 50m was warmer during the surveys of 1995 and 1996 than the other 3 years. Mean temperature at 50m in 1998, like surface temperature, ranked in the middle. Although mean surface temperature ranked warmest in 1994, mean temperature at 50m ranked coldest in 1994, but was not significantly different from 1997 or 1998.

Results of analysis of variance of mean catch rates of biological variables between day and night indicated much variability between day and night catch rates (Table 2). Biomass of the large and mid-size zooplankton fractions was consistently significantly greater during night sets than day sets all years. There was significantly more of the small-size fraction taken at night during 1994 and 1995 only. The total wet biomass of nekton, with jellyfish, showed no difference in daynight catches during the first four years but significant more was caught at night during the 1998 survey. Without jellyfish there was a significantly greater biomass caught at night during each of the past three surveys. There was a significant difference in daynight catches of alligatorfish and Atlantic cod in 1994 only, when more were taken in the day. Significantly more Arctic cod were taken at night in 1998 only, there being no difference in other years. There was no difference in day and night catches of haddock in 1998, the only year they were caught. Capelin were variable amongst years. In 1994 the mean catch was higher at night, but not significantly. From 1995 to 1998 there were significantly more, ranging from 6.9 to 291.5 times, taken at night. Catch rates of blennies were significantly higher, ranging from 5.7 to 55.5 times higher, at night all years except 1995. There was no significant difference in day and night catch rate of sculpins from 1994 to 1996. However, in 1997 there were significantly more taken during the day, whereas in 1998 there were more taken at night. During 1994 and 1997 there was no diel difference in catch rates of seasnails whereas during the other three years catch rate was from 2.8 to 6 times higher at night. There was no significant difference in day and night catch rates of squid during 1994 and 1995, but during the three most recent years catch rate was 2.2 –3.5 times greater at night. There was a significant difference in catch rate of turbot each year of the survey. In 1994 7.6 times more were caught during the day wheareas during the 4 most recent years there from 1.7 to 7.8 times more caught caught at night. Wolffish exhibited daynight differences in catch rate in 1998 only when 5 times more were caught at night. American plaice, hake, redfish, sand launce, witch flounder and yellowtail did not have any significant daynight differences in catch rate and have not had catch rates adjusted for any year.

Consistent with the results of previous years surveys total zooplankton biomass in 1998 (Figure 3 and 4), was highest on the Northeast Newfoundland Shelf. Highest biomass was obtained at stations well in, as opposed to near the shelf edge, where the highest biomass occurred in 1997. Consistent with 1997 the lowest weights occurred on the eastern portion of the Grand Banks. Total mean biomass ranged from 289.3 – 6452.7 mg/m2. R^2 for the model was 0.49, both area and year were significant, area accounting for more variation (Table 2). The four most northern areas ranked highest and were not significantly different from each other, but BIBI and ISN was higher than the inshore. The inshore was not different from the southern Northeast shelf (ISS and FIBI). All five areas had significantly higher biomass than NGB, which was higher than SGB. Mean total zooplankton biomass was significantly higher in 1997 and 1998 than the other years and was significantly higher in 1995 and 1996 than 1994. The year of lowest zooplankton biomass (1994) coincided with the year of highest mean surface temperature.

Highest concentrations of the large zooplankton size fraction occurred on the central and northern portions of the NE shelf (Figure 3, right), the distribution being less patchy than that of 1997. Mean weights ranged from 163.9-2168. /m2. R^2 for the model was 0.38 and area accounted for more variation (Table 2). There was a general trend of decreasing weights from north to south with no significant difference in mean biomass in the 4 northern areas or the inshore, all of which had significantly higher biomass than the Grand Banks. Mean biomass of this large size fraction was significantly higher in 1995 than any of the other 4 years of which 1998 ranked the lowest.

Mean weights of the mid-size (1-2mm) fraction ranged from 37.1 to 2646.0 mg/m2. Highest biomass again occurred in the northern areas and lowest occurred on the Grand Banks (Figure 4, left). R^2 for the model was 0.60, both effects were significant, and area accounted for more variation than year (Table 2). Highest mean biomass occurred in BIBI which was significantly higher than all other areas except ISN. Mean weights in all the northern areas were higher than weights on the Grand Banks. Weights inshore were higher than on the Grand Banks but were not less than on Funk Isle Bank area. Although the mean biomass of the mid size fraction ranked highest in 1998, there was no significant difference in mean weights for any of the 4 most recent years, all having higher biomass than in 1994.

Distribution of weights of the small-size fraction indicated more of an inshore/offshore cline (Figure 4, right). Highest biomass generally occurred inshore rather than near the shelf edge as in 1997 and relatively large catches were taken on the southern portion of the Grand Bank. The highest concentration occurred at a station located between Fogo Island and coast of the Island. The model explained 60% of the variation, but in contrast with the other plankton size fractions, and all other variables, annual variation was greater than geographic variation (Table 2). Over the 5 years there was no significant difference in biomass amongst the 4 northern areas or the inshore, all of which had higher biomass than the Grand Banks. Overall mean weights of the smallest zooplankton size fraction were significantly higher in 1997 than 1998 which was higher than 1996, all three being higher than in 1995 and 1994, which were not different. One would expect a higher mean weight of this size fraction in the 3 most recent years as a result of the finer mesh used on the bongo codends during these years. However, since similar mesh was used in each of the three most recent years, the differences in mean weight in these years is not gear related. No difference was detected in the biomass of the small size fraction between night and day sets.

Capelin spawn inshore on beaches and their late summer larval distribution represents dispersal from the nearshore habitats. The distribution of capelin larvae during the 1998 survey, estimated from bongo subsamples, was similar to other recent years being mainly coastal. In contrast to other recent years however the distribution was more extensive in the north to the coast of Labrador. Also for the first year since the 2-ship survey was started, capelin larvae were distributed on the southern Grand Bank. This distribution is distinct from that of larvae spawned inshore and represents the first year we have observed spawning products from the Southeast Shoal capelin spawning stock. Also, in contrast to the distribution in 1997, that of 1998 was dispersed further offshore, especially in the area of the Northern Grand Bank. Also in the Notre Dame Bay area, highest densities did not occur at stations nearest shore, but at those further off, (Figure 5, left) indicating significant dispersal from the nearshore spawning relative to 1997. The 1997 survey was ~ 8 days earlier than that of 1996 whereas the 1998 survey was 3 days later than 1996, 11days later than 1997. This is reflected in the larger size of capelin in 1998, which ranged from 4-25mm with the mean length of 11.7mm (Figure 5, left). This compares with mean lengths of 10.0, 9.9, 10.7, and 8.9 in the 1997, 1996, 1995 and 1994 surveys respectively (Anderson and Dalley 1998).

As in previous years distribution of herring larvae (4 only) was quite restricted and occurred in 3 bongo sets only, all of which were close to inshore. Two were taken near Fogo Island and one near the Avalon Peninsula. (Figure 5, right). Distribution is similar to other recent years with catch rates similar to 1996 and 1997, but lower than in 1994 and 1995. Lengths range from 16-20mm.

The distribution of total nekton biomass, including jellyfish, from the IYGPT (Figure 6, left) indicates highest concentrations on the central portion of the northern Grand Bank and portions of the Northeast Shelf. This, particularly with high weights in the southern portion of the survey area, differs from other years in that the north/south cline is not as evident. The R^2 for the model was 0.34, both effects were significant, area accounting for much more variation than year (Table 2). Similar to last year's analysis, when all years are considered, mean weight inshore ranked highest and was not significantly greater than mean weight on the southern or northern portions of the inner NE shelf (ISS and ISN). The southern Grand Banks ranked last and was significantly lower than all other areas except the northern Grand Bank. The overall mean biomass ranked highest in 1998 and was significantly greater than all other areas1996 but not the other years. Nekton biomass was greater in night sets compared to day sets.

Distribution of nekton biomass, with jellyfish removed (Figure 6, right), indicates greatest biomass on the central portion of the NE shelf, and at several stations on the Grand Bank. As with jellies, the north to south cline in weights evident in previous years is not as obvious in 1998. R^2 for the model was 0.26. Similar to the model with jellyfish, both effects were significant, area explaining much more variation than year (Table 2). Considering all years (4 only), there was no significant difference in biomass of the 4 northern areas, which was greater than that on the Grand Banks. Mean biomass inshore was significantly less than the 2 northern areas nearer shore but was not less than the two offshore areas of the NE shelf. Weights inshore ranked higher but were not significantly greater than SGB or NGB. The greater difference in weights between the two measures indicates that the greatest biomass of jellyfish occurred in the inshore and on the northern Grand Bank. This ranking compared to the ranking with jellyfish indicates that the greatest biomass of jellyfish occurred in the inshore. Mean wet weights without jellyfish in 1998 ranked second behind 1995 and was not significantly different from any year. Nekton biomass, with jellies, was higher in night than day catches.

Approximately 106,400 fish were taken in the IYGPT in the1998 survey (Table 3) compared to ~120000 in 1997. Like 1997 the most abundant fish was juvenile capelin. In contrast to 1997, however, capelin constituted only 58% of all fish caught compared to 85.7% in 1997. Nonetheless capelin were more widespread in 1998 occurring in 62.9% of all sets compared to 39.3% in 1997.

For the first year of the survey there was an abundance in 1998 of sandlance (over 13x more than in 1997) ranking second in overall abundance and occurring in 45.5% of the sets. In 1998 Arctic cod ranked fourth compared to first in 1995, second in 1994 and 1996, and third in 1997. Lanternfish ranked third in total number of fish caught in 1998 but occurred in only 3 sets. All but 2 of the 12167 lanternfish were taken at the shelf break at 49.5^{O}N latitude. Squid ranked fifth in total numbers caught in 1998. However, despite the fact that less than one third the total number of squid were caught as in 1997 when they ranked second they were widespread occurring in 69% of the sets compared to 65% in 1997. Species groups that occurred in approximately half the stations included sculpins, alligatorfish, shannies and blennies, sculpins, seasnails, Atlantic cod followed by wolffish, redfish and American plaice.

Similar to 1997 pelagic capelin (mostly age 1-2) were distributed throughout the inshore portion of the survey area as far north as sampled on the Labrador coast, and throughout much of the offshore, particularly the northern Grand Bank (Figure 7, left). 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=0.26) in capelin catch rates was accounted for by the GLM model. Variation attributable to area was much more than that of year (Table 2). Over the 5 years, highest abundance occurred on the Northern Grand Bank, which was not significantly greater than the inshore. Both were significantly greater than abundance in the other 5 areas which were not different. The mean catch rate in 1998, after diel adjustment, ranked last to but was not different from 1995. Highest catch rate occurred in 1996 but it was not significantly greater than 1998 only. The relative proportion of age 1's to older capelin 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 1998)

Over 13 times more pelagic sand lance were captured in 1998 than in 1997. Distribution (Figure 7, right), was similar to that of 1997, being primarily on the Grand Banks, with lower catch rates occurring on the NE shelf to the coast of southern Labrador. Also in contrast to 1997, the distribution of sand lance extended from the Grand Banks to the Avalon Peninsula and into Conception and Trinity Bays. As in 1997 the distribution of high catch rates at some stations near the edge of the Grand Bank suggests that the distribution extends beyond the area surveyed. R^2 for the model was 0.32, mostly attributable to area; and the year effect was significant (Table 2), in contrast to the 1997 results. Over all 5 years mean catch rates were highest on NGB which was not significantly higher than that of SGB. Mean catches of both NGB and SGB were higher than all the other areas, which were not significantly different. The inshore was intermediate in catch rate between areas constituting the inner and outer NE shelf, which ranked last. Overall abundance of sand lance in 1998 was significantly higher than the 4 previous years, which did not differ significantly. The smaller 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 1998 (Figure 8, left) was more extensive than in 1997, and particularly 1996, when cod were practically absent from the NE Shelf, Notre Dame, Trinity, and Conception Bays. For the first year since the survey began relatively high catch rates occurred on the Grand Banks. Highest catch rates in 1998 occurred on the southern Grand Banks. Cod also occurred in each of the bays that were examined, the highest catch rates being in Notre Dame Bay. Catches on the Northeast Newfoundland Shelf were quite low. The model explained 35% of variation in catch rate of pelagic 0-group cod. Both effects were significant (Table 2). Over the 5 years catch rate ranked highest inshore which was significantly higher than all other areas. ISS ranked highest of the others, NGB the lowest. Catch rate was significantly higher in 1994 than any of the years that followed. Mean catch rate in 1998 ranked second and was significantly greater than 1996 but not 1995 or 1997. Lengths of cod ranged from 28-88mm and mean length was the largest of pelagic cod sampled over the 5 years. Further information on pelagic 0-group cod from this survey, is presented annually at the regional cod assessment meeting. (e.g. Anderson et al. 1999)

Total number of Arctic cod was similar to that taken in 1997. Distribution in 1998 (Figure 8, right) was less dispersed than in 1997, being almost exclusively restricted to the northern half of the survey area. Similar to 1997 highest catch rates occurred 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 extremely low. In the model both main effects contributed significantly in explaining ~46% of variation in catch rate (Table 2), the area effect accounting for more variation than year. Considering all years highest mean catch rate occurred on ISN which was higher than catch rate of all areas except the inshore. The inshore which ranked second had higher mean catch rate than all other areas, except ISS. Catch rate was significantly higher on BIBI and FIBI than on the northern or southern Grand Bank, which was lowest. After catch rates were adjusted for diel differences a decrease in the abundance of Arctic cod each year of the surveys was no longer apparent. When 1998 catch rates, which were significantly higher at night, were adjusted 1998 ranked third. There were significantly more in 1994 than any other year. Catch rate in 1995 ranked second, and was significantly higher than 1997, but not higher than 1998 or 1996. Lengths in 1998 ranged from ~25-65mm which is similar to other years.

Redfish distribution in 1998 was similar to other years, occurring in two distinct areas, one on the NE shelf and one on the southern Grand Bank (Figure 9, left). Redfish were also distributed in the northern bays as they were in 1995 and 1997. The overall GLM model, although significant, explained relatively little variability in catch rate (R^2=0.09) and only the area effect was significant (Table 2). Considering all 5 years SGB had the highest mean catch rate and was significantly higher than all other areas except FIBI. The northern Grand Bank and the inner NE shelf rank lowest. There was no significant difference in overall mean catch rate over the 5 years and 1998 ranked in the middle behind 1994 and 1995, but higher than 1996 and 1997. Lengths of redfish ranged from 25-65mm in 1998 which is larger than those caught in 1997. Similar to the length frequency in 1995 there was at least two modes evident in the distribution.

Although distribution of hake (common and/or white) (Figure 9, right), a relatively warm water species, was more extensive than in 1997 (when they occurred in only 2 stations), but was still restricted to the southern Grand Bank. The model explained 25% of the variation in catch rate and area accounted for more than year (Table 2). Overall mean catch rate in 1998 ranked third and was not significantly different from 1994, 1997 and 1995. Highest mean catch rate occurred in 1996 and was significantly higher than that of the other 4 years. Lengths ranged from ~25 to 150mm.

Similar to previous years shannies and blennies were restricted to the northern portion of the survey area including the northern bays (Figure 10, left). Overall catch numbers were down from 1997 and the distribution was less extensive with numerous null catches on the NE shelf. The model had an R^2 of 0.34, and both effects were significant (Table 2). Abundance over the 5 years was significantly higher in the two areas constituting the inner NE shelf (ISS and ISN) than the other 5 areas. Catch rates on the outer portions of the NE Shelf (FIBI and BIBI) were not significantly higher than the inshore but these three areas were higher than the Grand Banks. Mean catch rates were significantly higher in 1997 than all other years, except 1998, which ranked second, followed by 1996, 1994 and 1995. Catch rates were significantly higher in 1998 than in 1995 but not higher than 1996 or 1994. The group is made up of several species and has a tri-modal length distribution (ranging from ~ 25 - 165mm), which is probably attributable to different spawning times and/or growth rates of the different species.

Sculpins constitute another mainly northern group made up several species. In 1998 only one third the total numbers were taken as in 1997, but distribution (Figure 10, right) was similar to 1997, being mostly restricted to the area north of the Grand Bank, but with sporadic low catches occurring on the bank. The model explained 47% the variation in catch rates. Both main effects were significant, area more so than year (Table 2). The interaction factor was also relatively high for sculpins. Over 5 years the highest abundance occurred on ISN which was significantly greater than the other areas. Catch rate on ISS, which ranked second was higher than all others except Belle Isle Bank. Catch rate on the Grand Banks was lowest but not significantly lower than FIBI or the inshore. Catch rate in 1998 ranked behind 1997 and 1996, but was not significantly different from either year. Catch rate during these three years was significantly greater than 1994 and 1995. Lengths ranged from approximately 28 - 60mm with a couple of specimens ranging over 100mm.

Overall catch of pelagic squid (unidentified) in 1998 decreased with 1/3 the number taken as in 1997, but except for a few null catches on the NE shelf squid were distributed similarly to 1997 (Figure 11, left). They were mainly in the northern half of the survey area with highest catch occurring on the central northern portion of the NE shelf. There was also a distinct distribution with relatively low catch rates on the southern Grand Bank. R^2 for the model was 0.50, both main effects contributed significantly, area more so than year (Table 2). Over the 5 years mean catch rate of squid ranked 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 1998 ranked fouth but was not significantly different from 1994 or 1996. Catch rate of squid ranked highest in 1995, was not significantly higher than 1997, but was higher than the other three years.

Several species of seasnails of the family Liparidae were also distributed mainly in the northern half of the survey area (Figure 11, right). However, only 1/5 the number was taken as in 1997, and distribution on the NE shelf was much less continuous than in the past. Highest catch rates occurred near the coast of southern Labrador and in White Bay. Sporadic low catches were taken on the Grand Banks. The model explained ~ 42% of variation in catch rates and both main effects were significant (Table 2). Considering all years the northern inner NE shelf (ISN) ranked highest but catch rates there were not significantly higher than those of the southern inner shelf (ISS). These 2 areas had significantly higher catch rates than all other areas, except the ISN was not greater than the inshore. The Grand Banks ranked lowest but was not significantly less than FIBI. Most seasnails ranged from approximately 25-50mm but there were also some larger specimens extending up to ~165mm which were not observed in previous years.

Another predominantly northern pelagic juvenile fish, alligatorfish (3 species of Family Agonidae), (Figure 12, left panel) were most abundant close to the Labrador coast and on the southern portion of the NE shelf in 1998. This was similar to the 1997 distribution, except that highest catch rates occurred further offshore in 1997. As in 1997, there was a distinct distribution of lower catches on the southern Grand Bank. The model explained 38% of the variation in catch rate over the 5 years, and the area effect accounted for more variation than year (Table 2). In fact the total numbers caught in 1998 which ranked fifth was ~ 75% that of 1997 which ranked second. Considering all years alligatorfish were significantly more abundant on the southern portion of the NE shelf (ISS and FIBI) than all other areas except the northern portion which was similar to the inshore. The catch rate on the Grand Banks was lower than all other areas. Length range of alligatorfish in 1998 was ~28-49mm which was similar to 1997.

Less abundant wolffish, constituting 2-3 species of Anarhichus, were distributed mainly the NE Shelf and shelf edge, but extended as far south as the southern Grand Bank (Figure 12, right). Just over ½ as many fish were taken as in 1997 and distribution, particularly on the NE shelf was less extensive. Highest catch occurred on the central portion of the NE shelf and on the shelf edge on the northern Grand Bank. R^2 for the model was 0.27, both effects were significant, area more so than year (Table 2). Over all years highest abundance occurred on Funk Isle Bank, which was not significantly higher than BIBI and ISS, all three being significantly higher than the other areas. Abundance in the inshore ranked last but was not significantly less ISN or the Grand Banks. Of the 5 years wolffish abundance ranked highest in 1996 but was not higher than any other year except 1995 which was not significantly less than 1994 or 1998 which ranked third. Lengths of wolffish ranged from ~48-100mm with 2-3 modes in the distribution.

The abundance of four species of flatfish was relatively low over the 5 years of the surveys, often with sporadic distribution. In contrast to 1997, when American plaice distribution was mostly restricted to the inshore, in 1998 highest catch rates occurred in a distinct distribution on the southern Grand Bank. (Figure 13, left). The model explained 20% of the variation and as in 1997 only the area effect was significant. Considering all 5 years mean catch rate was highest inshore which was significantly greater than all other areas except the southern Grand Bank. Abundance was lowest on the northern portions of the NE Shelf. Mean catch rate ranked highest in 1998 but not significantly higher than 1997 or 1994. Lowest catch rate occurred in 1996, which was not significantly lower than any year except 1998. Lengths ranged from ~20-60mm.

With a total catch of only 18 in 1998 abundance of turbot in 1998 ranked lowest of the five years. Catch rate in 1995 was significantly higher than the other years. Highest catch rates in 1998 occurred at several locations on the NE shelf and, as in 1997, they occurred sporadically inshore and on the southern Grand Banks (Figure 13, right). R^2 for the model was 0.41, both main effects were significant (Table 2). Over the 5 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. Lengths were distributed mostly in 1 mode (56-88mm) as opposed to 1997 when 2 modes (probably corresponding to age 0 and age 1) were observed.

Although abundance of witch flounder was relatively low in 1998, with a total catch of 40 fish it was higher than that of the 4 previous years. It was distributed in the northern bays as well as on the southern Grand Bank (Figure 14, left panel). The model explained only 17% of variability in catch rate. Although the model indicated that the area effect was significant (P=0.006), the GT2 test indicated no area difference in catch rate. The inshore ranked highest followed by the southern Grand Bank, with BIBI ranking last. The model itself showed no annual effect (P=0.08), but the GT2 test indicated that catch rate in 1998 was higher than the 4 previous years, of which 1996 ranked highest and 1997 lowest. Sizes of witch flounder ranged from 31-60mm and there was no difference in day and night catches.

Over the five years of the survey extremely low numbers of yellowtail flounder have also been taken. In 1998 only four juveniles were taken in 2 stations (Table 3) on the southern Grand Bank. The model explained only 6% of variability and only the area effect was significant. Significantly more were taken on southern Grand Bank and over the years the only other area where they occurred was inshore. Catch rate in 1996 ranked highest ahead of 1994 and 1995. Catch rate in 1998 ranked fourth ahead of 1997.

Pelagic 0-group haddock were observed in 1998 for the first time since the 2-ship survey was started in 1994. They had a fairly extensive distribution on the Grand Banks, mostly on the southern portion but also extending onto the northern Grand Bank (Figure 14, right panel). Lengths ranged from ~73-138mm. Examination of otoliths stratified over the whole length range indicated that all specimens were young of the year.

Summary and Discussion

Results of analysis of variance indicated that in the overall model there was a statistically significant ($P<0.0001$) relationship between all variables (except yellowtail with $P<0.0005$) examined during the 1998 survey, and geographic area and/or year of survey (Table 2). The partial F-value attributable to area was significant for all variables ($P<0.0001$) except haddock ($P<0.0587$) and witch flounder ($P<0.0062$). Variation attributable to year was significant ($P<0.05$) in all but 6 cases; midsize zooplankton, capelin, redfish, American plaice, witch, and yellowtail flounder being the exceptions. As noted abundance of the flatfish species was low all years. 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 similar to 1997, annual rather than geographic area, accounted for more variation in biomass of the smallest (< 1mm) size fraction of zooplankton. The partial F-value for area was higher than that for year in all but 3 species/groups examined the small zooplankton size fraction, haddock and seasnails being exceptions. The interaction of the two main effects in the analysis of variance was significant in all relationships except that for the redfish, and yellowtail but in most cases the partial F-value attributable to interaction was low compared to the main effects. (Table 1).

Surface temperatures were notable in 1998 due to the large amount of warm water on the Grand Bank compared to the previous years. In comparison to the four previous years mean surface temperatures during the survey in 1998 were midrange being significantly higher than 1997 and 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 1998, 1997 and 1994.

The mean total zooplankton biomass from the bongos was significantly higher in 1997 and 1998 than in the other 3 years of which 1995 ranked highest and 1994 was lower than the other years. Thus the year of lowest zooplankton biomass coincided with year of lower mean temperatures. Mean biomass of the largest size fraction ranked second last in 1998, but was not significantly less than the higher ranking years. Mean biomass of the mid-size zooplankton fraction was highest in 1998 but was not significantly greater than any year except 1994. Biomass of the smallest size fraction was significantly greater in 1998 than the first 3 years of the survey but was significantly less than 1997. The mean total nekton biomass, with jellyfish, was significantly greater in 1998 than any previous year. In 1998 the largest biomass of jellyfish occurred inshore and on the northern Grand Bank. Without jellyfish, the nekton biomass in 1998 was significantly greater than the previous years. In terms of zooplankton biomass 1998 was relatively normal to high compared to the earlier years. The large size fraction which ranked fourth but was not significantly less than any year. Nekton biomass in 1998 was highest in the time series, with or without jellyfish.

Of the two pelagic fish species that were examined, capelin (age 1-2) ranked relatively low, but not significantly, whereas catch rate of sand lance was significantly higher than any of the previous years (that did not differ significantly). In 1997 a trend of decreasing abundance in mean catch rate of pelagic 0-group Arctic cod was identified. However, in 1998, with diel adjustments mean catch rate ranked in the middle, was significantly lower than the first year of the survey but was not significantly different from any other year. (Without diel adjustments, catch rate of Arctic cod ranked lowest of the 5 years). Catch rate of Atlantic cod decreased significantly in 1995 and again in 1996. Catches increased slightly in 1997 but not significantly over 1996. In 1998 mean catch rate of cod increased again such that it was significantly higher than 1996 but not 1997 but still significantly lower than 1994. The increase in catch rate of pelagic 0-group Atlantic cod in 1998 over 1997 is a result of increased catch rate on the Grand Bank particularly the southern portion, and not due to an increase in Northern cod. Mean catch rate of redfish increased in 1998 over the past two years, ranking third of the 5 years which were not significantly different. Catch rate of hake ranked 3rd overall and was significantly lower than 1996 but not different than the other four years. As noted in 1997 (Dalley and Anderson 1998) six groups of relatively abundant species (including blennies, sculpins, squid, seasnails, alligatorfish and wolffish) were 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. The fact that three of the groups (blennies, alligatorfish and wolffish) ranked first in mean catch rate in 1997, and the other three groups ranked second, together was taken to indicate that 1997 was relatively productive in relation to other recent years on the NE shelf. Results from the 1998 survey tend to reinforce this. In 1998 catch rates of all 6 of these groups were lower than in 1997 statistically lower in the case of squid and seasnails.

It was also noted last year that species, which were mainly confined to the Grand Bank as sand lance and hake, were not abundant in 1997. There were statistically fewer hake than in 1996 and although there was no year effect in the analysis, sand lance ranked lowest of the four years 1997. We describe an environment that appears to contrast with this in 1998. In 1998 there was a significantly higher (13x) catch rate of sand lance as a result of high catch rates on the Grand Bank. Also, for the first time in at least 5 years pelagic 0-group haddock were observed on the Grand Bank, in addition to a significant concentration of pelagic 0-group cod. Redfish were distributed further onto the southern Grand Bank from the southeast and had higher catch rates in 1998 than in 1997. Also for the first year since 1994 we have evidence, from a concentration of larvae, that capelin spawned on the Southeast Shoal of the Grand Bank. Pelagic 0-group American plaice, which have been observed on the Grand Bank in previous years, were restricted in their distribution to the inshore in 1997. In 1998 highest catch rates of American plaice occurred on the southern Grand Bank.

Of the 4 species of flatfish that have occurred over the survey area, abundance of pelagic 0-

group yellowtail and witch remain extremely low and occurrence sporadic. Of the other two flatfish species, which also had relatively low catch rate, American plaice ranked highest of the 5 years and turbot ranked lowest.

With the addition of the 1998 data spatial patterns are more evident and 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 Arctic cod whose range did not obviously contract declined each of the first 4 years of the survey appear to have again levelled off. The ranking of for 1998-catch rate changed from 5th to 3rd as a result of daynight adjustments. The only year with a diel difference for Arctic cod was 1998 when all daytime catch rates were adjusted upward due to the significantly higher mean catch rate at night.

This survey can monitor changes in the pelagic environment. With it our understanding of spatial relationships and annual variability in the marine ecosystem is improving. With each survey our understanding of recruitment to commercial fish stocks utilising these ecosystems should also improve. Coupled with this will be an increase in precision to predict recruitment from O-group surveys.

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References

Anderson, J.T. and E.L. Dalley. 1997a. Nekton of the coastal and shelf waters of Newfoundland. DFO Atl. Fish. Res Doc. 97/124.

Anderson, J.T. and E.L. Dalley. 1997b. Distributions and abundances of pre-recruit capelin (Mallotus villosus) in the Northwest Atlantic (NAFO Division 2J3KLNO), 1991-1996. Chapter 7 in. Anonymous. 1997. Capelin in SA2 + Div. 3KL. DFO Stock Assessment Res. Doc. 97/29.

Anderson, J.T., E.L. Dalley and D.J. Davis. 1998. Year class strength of Northern Cod (2J3KL) estimated from pelagic juvenile fish surveys in the Newfoundland region, 1994-1997. DFO Stock Assessment Res. Doc. 98/11.

Anderson, J.T., E.L. Dalley and D.J. Davis. 1999. Year class strength of Northern Cod (2J3KL) and Southern Grand Banks Cod (3NO) estimated from the Pelagic juvenile fish survey in 1998. DFO Stock Assessment Res. Doc. 99/80.

Dalley, E.L. and J.T. Anderson. 1997. Plankton and nekton of the Northeast Newfoundland Shelf and Grand Banks in 1996 compared to 1994 and 1995. DFO Stock Assessment Res. Doc. 97/120.

Dalley, E.L. and J.T. Anderson. 1998. Plankton and nekton of the Northeast Newfoundland Shelf and Grand Banks in 1997. DFO Stock Assessment Res. Doc. 98/121.

SAS Institute Inc. 1989. SAS/STAT user's guide, release 6.03, SAS Institute Inc., Cary, N.C.

Winters, G.H. 1981. Growth patterns of sand lance, *Ammodytes dubius*, from the Grand Bank. Can. J. Fish. Aquat. Sci. 38: 841-846.

Table 1. Results of analysis of variance carried out to investigate diel differences in catch rates of biological variables measured during the 1994-1998 pelagic 0-group surveys. Daynight and geographic area are used as independent variables. Shown are the mean catches during daylight and darkness, the partial F-value attributable to daynight, and the associated probability. Also shown are the ratios used to adjust the catches where differences are statistically significant. ** indicates that the day catches are larger, otherwise the day catches are adjusted up to the night catches according to the appropriate ratio.

	1994						**1995**				
Dependent Variable	Day mean	Night Mean	Partial F-value	Probability	Night/Day Ratio	Dependent Variable	Day mean	Night Mean	Partial F-value	Probability	Night/Day Ratio
Zoo(all)	849.36	1548.18	23.11	0.0001	1.82	Zoo(all)	1201.29	2045.36	17.25	0.0001	1.70
Zoo(Large)	341.53	636.47	21.61	0.0001	1.86	Zoo(Large)	701.47	1116.24	8.52	0.0043	1.59
Zoo(mid)	325.99	648.78	10.32	0.0019	1.99	Zoo(mid)	290.88	658.14	22.63	0.0001	2.26
Zoo(small)	181.82	262.93	5.32	0.0236	1.45	Zoo(small)	208.93	270.99	5.23	0.0242	1.30
Nekton1	34.201	74.909	0.01	0.9326		Nekton1	46.863	64.288	1.22	0.2721	
Nekton2	n.a.	n.a.	n.a	n.a		Nekton2	30.79	37.41	0.72	0.3988	
Alligatorfish	0.691	0.181	17.1	0.0001	3.82**	Alligatorfish	0.62	0.38	1.81	0.1809	
American plaice	0.02	0.06	2.29	0.1344		American plaice	0.002	0.02	2.84	0.0952	
Arctic cod	10.143	20.33	2.72	0.1035		Arctic cod	8.75	7.018	0.14	0.7095	
Atlantic cod	0.485	0.23	7.21	0.0089	2.11**	Atlantic cod	0.107	0.308	1.91	0.1699	
Blennies	0.022	0.217	48.07	0.0001	9.86	Blennies	0.006	0.176	2.03	0.1576	
Capelin	11.18	108.35	2.68	0.106		Capelin	1.266	8.702	6.85	0.0103	6.87
Haddock	0	0	n.a	n.a		Haddock	0	0	n.a	n.a	
Hake	0.009	0.003	0.87	0.3536		Hake	0.003	0	1.34	0.2492	
Redfish	2.722	0.008	2.53	0.1155		Redfish	0.583	0.198	0.77	0.3812	
Sand launce	1.937	1.975	2.21	0.141		Sand launce	1.125	1.005	0.07	0.7951	
Sculpins	0.124	0.136	0	0.9729		Sculpins	0.17	0.099	0.3	0.5847	
Seasnails	0.154	0.234	1.95	0.1668		Seasnails	0.16	0.453	4.38	0.0387	2.83
Squid	1.651	2.371	1.87	0.1751		Squid	2.644	4.407	0.81	0.3711	
Turbot	0.038	0.005	8.97	0.0037	7.60**	Turbot	0.072	0.122	8.03	0.0056	1.69
Witch Flounder	0.002	0	0.93	0.3379		Witch Flounder	0.002	0.003	0.09	0.7684	
Wolffish	0.035	0.041	3.58	0.0623		Wolffish	0.008	0.026	1.97	0.1634	
Yellowtail	0.002	0.015	2.12	0.1491		Yellowtail	0.001	0.008	1.31	0.2551	

Table 1. (con't)

Dependent Variable	1996 Day mean	1996 Night Mean	1996 Partial F-value	1996 Probability	1996 Night/Day Ratio	Dependent Variable	1997 Day mean	1997 Night Mean	1997 Partial F-value	1997 Probability	1997 Night/Day Ratio
Zoo(all)	1427.9	2298.54	11.94	0.0008	1.61	Zoo(all)	2765.41	3685.53	1.81	0.182	
Zoo(Large)	406.43	1025.6	29.27	0.0001	2.52	Zoo(Large)	480.8	1067.43	30.12	0.0001	2.22
Zoo(mid)	545.85	800.47	7.11	0.009	1.47	Zoo(mid)	589.24	839.38	4.34	0.0397	1.42
Zoo(small)	475.62	472.47	0.78	0.3788		Zoo(small)	1695.37	1778.73	1.2	0.2759	
Nekton1	48.293	52.208	3.69	0.0576		Nekton1	40.265	77	1.75	0.1885	
Nekton2	13.63	44.27	15.11	0.0002	3.25	Nekton2	22.99	55.14	4.61	0.0341	2.40
Alligatorfish	0.444	0.58	0.31	0.5793		Alligatorfish	0.72	0.69	0.38	0.5405	
American plaice	0.003	0.01	1.92	0.169		American plaice	0.03	0.17	1.24	0.2682	
Arctic cod	5.93	2.66	1.43	0.234		Arctic cod	1.7	2.45	0.31	0.5767	
Atlantic cod	0.05	0.02	0.12	0.7289		Atlantic cod	0.05	0.1	0.63	0.4291	
Blennies	0.03	0.39	49.95	0.0001	13.00	Blennies	0.19	1.08	15.62	0.0001	5.68
Capelin	0.26	75.79	11.33	0.0011	291.50	Capelin	2.98	101.66	11.14	0.0012	34.11
Haddock	0	0	n.a	n.a		Haddock	0	0	n.a	n.a	
Hake	0.07	0.015	1.29	0.2582		Hake	0.002	0.001	0.02	0.8884	
Redfish	0.14	0.04	0.87	0.3532		Redfish	0.04	0.04	0.02	0.8961	
Sand launce	0.9	0.13	0.36	0.552		Sand launce	0.08	1.09	3.81	0.0536	
Sculpins	1.99	1.23	0.03	0.8559		Sculpins	0.64	0.33	4.67	0.0331	1.94**
Seasnails	0.27	1.38	11.62	0.001	5.11	Seasnails	0.49	0.61	0.25	0.6207	
Squid	0.62	2.17	53.51	0.0001	3.50	Squid	1.64	3.63	4.98	0.0279	2.21
Turbot	0.01	0.03	6.24	0.0142	3.00	Turbot	0.008	0.03	4.94	0.0284	3.75
Witch Flounder	0.009	0	1.22	0.2719		Witch Flounder	0	0	n.a	n.a	
Wolffish	0.03	0.09	10.41	0.0017	3.00	Wolffish	0.05	0.09	1.14	0.2883	
Yellowtail	0.001	0.03	1.98	0.1623		Yellowtail	0	0.001	1.46	0.2294	

Table 1. (con't)

1998

Dependent Variable	Day mean	Night Mean	Partial F-value	Probability	Night/Day Ratio
Zoo(all)	1668.95	2853.43	22.51	0.0001	1.71
Zoo(Large)	352.68	1032.71	58.34	0.0001	2.93
Zoo(mid)	448.95	870.64	17.73	0.0001	1.94
Zoo(small)	867.33	950.08	1.58	0.2122	
Nekton1	51.982	112.514	18.13	0.0001	2.16
Nekton2	22.69	89.03	22.62	0.0001	3.92
Alligatorfish	0.41	0.49	0.01	0.9256	
American plaice	0.02	0.19	3.81	0.054	
Arctic cod	0.59	4.56	11.34	0.0011	7.73
Atlantic cod	0.13	0.22	1.02	0.3146	
Blennies	0.02	1.11	29.34	0.0001	55.50
Capelin	5.64	64.58	13.51	0.0004	11.45
Haddock	0.06	0.07	0.35	0.5539	
Hake	0.007	0.007	0.01	0.9382	
Redfish	0.13	0.26	0.21	0.6498	
Sand launce	16.89	3.16	1.34	0.2501	
Sculpins	0.05	0.46	17.94	0.0001	9.20
Seasnails	0.03	0.18	8.89	0.0036	6.00
Squid	0.43	1.23	20.37	0.0001	2.86
Turbot	0.002	0.0155	9.33	0.0029	7.75
Witch Flounder	0.02	0.03	0.12	0.7277	
Wolffish	0.01	0.05	11.32	0.0011	5.00
Yellowtail	0	0.005	1.83	0.1793	

Table 2. Results of analysis of variance carried out on variables measured during the 1994-1998 pelagic 0-group surveys. Year and geographic area are used as independent variables. Shown is 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 F-value (and probability) associated with each independent variable. The partial F-value and probability attributable to interaction of the two main effects is also shown, if the interaction factor was significant. Any diel differences in catches have been adjusted prior to the analysis.

Dependent Variable	Min mean	Max mean	r^2	Overall F-value /prob	Partial F Area / Prob.	Partial F Year / Prob.	Interaction factor
°C 0m	7.3	18.0	0.82	67.29 0.0001	264.92 (.0001)	40.59 (.0001)	13.35 (.0001)
°C 50m	-1.3	3.1	0.48	13.41 0.0001	49.00 (.0001)	19.79 (.0001)	2.83 (.0001)
Zootot	289.3	6452.7	0.49	14.28 0.0001	59.59 (.0001)	9.33 (.0001)	1.86 (.0085)
Zoo >2	163.9	2168.1	0.38	8.82 (.0001)	36.55 (.0001)	3.14 (.0144)	1.81 (.0109)
Zoo 1-2	37.1	2646.0	0.60	21.84 (.0001)	111.76 (.0001)	1.49 (.2026)	1.90 (.0065)
Zoo <1	78.5	3129.5	0.60	22.32 (.0001)	37.92 (.0001)	77.13 (.0001)	3.08 (.0001)
Nekton1 with	10.3	188.4	0.34	7.65 (.0001)	16.52 (.0001)	9.8 (.0001)	3.74 (.0001)
Nekton2 w/0	9.2	169.2	0.26	5.34 (.0001)	15.98 (.0001)	3.65 (.0128)	1.75 (.0291)
Capelin	0	1940.7	0.26	5.00 (.0001)	15.93 (.0001)	1.04 (.3840)	2.37 (.0003)
Sand lance	0	39.3	0.32	7.01 (.0001)	20.00 (.0001)	4.44 (.0016)	3.14 (.0001)
Atlantic cod	0	1.2	0.35	7.78 (.0001)	19.10 (.0001)	15.26 (.0001)	3.59 (.0001)
Arctic cod	0	65.9	0.46	12.54 (.0001)	54.34 (.0001)	14.89 (.0001)	2.67 (.0001)
Redfish	0	5.9	0.09	4.91 (.0001)	7.49 (.0001)	0.97 (.4250)	N.S.
Hake	0	0.3	0.25	4.74 (.0001)	7.77 (.0001)	3.06 (.0165)	3.98 (.0001)

Table 2. Continued .....

Dependent Variable	Min mean	Max mean	r^2	Overall F-value / prob	Partial F Area / Prob.	Partial F Year / Prob.	Interaction factor
Haddock	0	0.2	0.16	2.75 (.0001)	2.04 (.0587)	3.41 (.0092)	2.08 (.0021)
Blennies	0	7.8	0.34	7.62 (.0001)	19.61 (.0001)	15.70 (.0001)	3.47 (.0001)
Sculpins	0	18.9	0.47	12.72 (.0001)	35.15 (.0001)	22.46 (.0001)	5.15 (.0001)
Squid	0.03	22.2	0.50	14.69 (.0001)	51.11 (.0001)	11.84 (.0001)	4.85 (.0001)
Seasnail	0	5.1	0.42	10.67 (.0001)	28.34 (.0001)	29.27 (.0001)	4.85 (.0001)
A.plaice	0	0.4	0.20	3.57 (.0001)	6.49 (.0001)	1.88 (.1123)	2.59 (.0001)
Turbot	0	0.7	0.41	10.03 (.0001)	27.57 (.0001)	26.37 (.0001)	5.09 (.0001)
Alligatorfish	.01	2.0	0.38	8.81 (.0001)	36.97 (.0001)	2.99 (.0186)	3.14 (.0001)
Wolffish	0	0.4	0.27	5.41 (.0001)	17.55 (.0001)	4.20 (.0024)	2.72 (.0001)
Witch	0	0.1	0.17	2.88 (.0001)	3.04 (.0062)	2.07 (.0842)	2.54 (.0001)
Yellowtail	0	0.1	0.06	3.21 (.0005)	4.65 (.0001)	1.06 (.3742)	NS

Table 3. Relative overall abundance and incidence of occurrence of dominant fish species caught in the IYGPT during the pelagic 0-group survey in 1998.

Species	Scientific Name	No. Caught	Relative Abundance(%)	Incidence(%)
Capelin	Mallotus villosus	61752	58.0	62.9
Sand lance	Ammodytes sp.	23401	22.0	45.5
Lanternfish	Myctophidae	12167	11.4	2.3
Arctic cod	Boreogadus saida	3906	3.7	58.3
Squid	Cephalopoda	1626	1.5	68.9
Alligatorfish	Agonidae	865	0.8	70.5
Shannies Blennies	Stichaeidae	847	0.8	25.8
Sculpins	Cottidae	458	0.4	47.0
Redfish	Sebastes sp.	310	0.3	16.7
Atlantic cod	Gadus morhua	309	0.3	46.2
Seasnails	Liparus sp.	206	0.2	31.1
American plaice	H. platessoides	165	0.2	21.2
Haddock	M. aeglefinus	114	0.1	14.4
Wolffish	Anarhichus sp.	80	0.1	23.5
Witch flounder	G. cynoglossus	40	<0.1	9.8
Greenland halibut	R. hippoglossoides	18	<0.1	9.8
Hake	Urophysis	14	<0.01	6.8
Yellowtail	Limanda ferruginea	4	<0.01	1.5

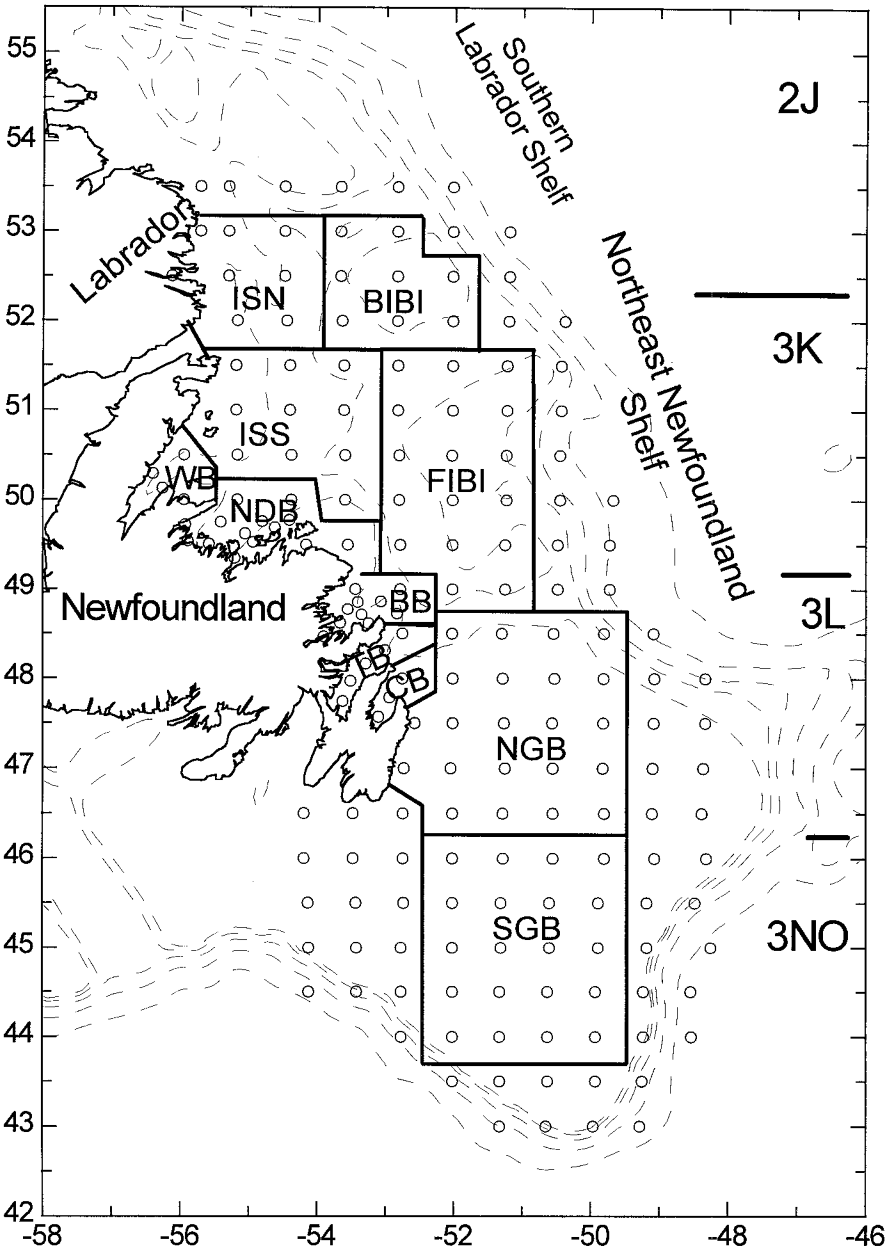

Figure 1. Survey area showing stations sampled during the 1998 pelagic 0-group survey on the southern Labrador shelf, Northeast Newfoundland Shelf, and Grand Banks. Each of the seven subareas are indicated. (ISN = inner shelf, northern; BIBI = Belle Isle Bank; ISS = inner shelf, southern; FIFI = Funk Island Bank; INSH = inshore; NGB = Northern Grand Bank; SGB = Southern Grand Bank).

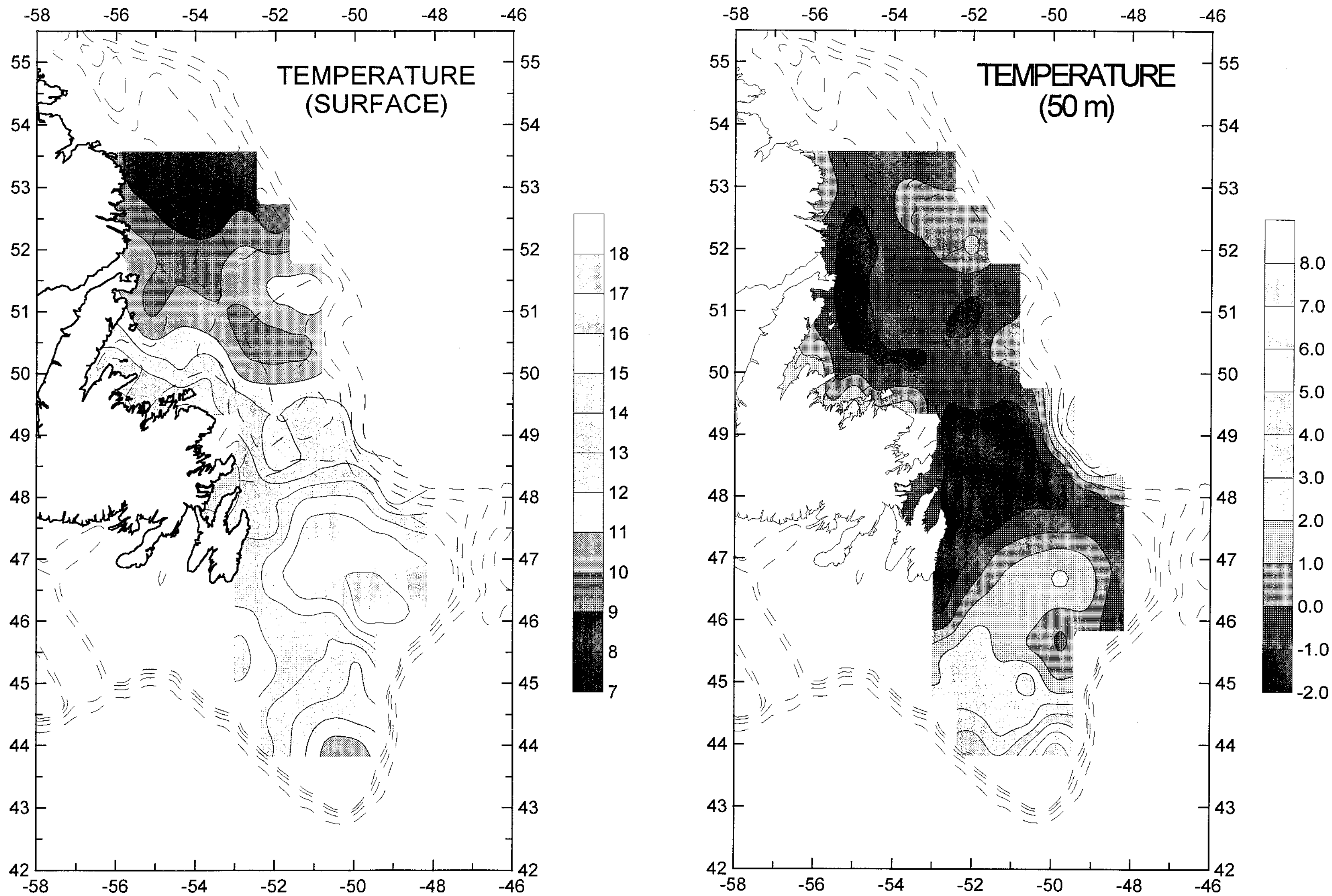

Figure 2. Distribution of surface tempertures (degrees C), left panel, and temperatures at 50m, during the 1998 pelagic 0-group survey in NAFO Divisions 2J3KLNO.

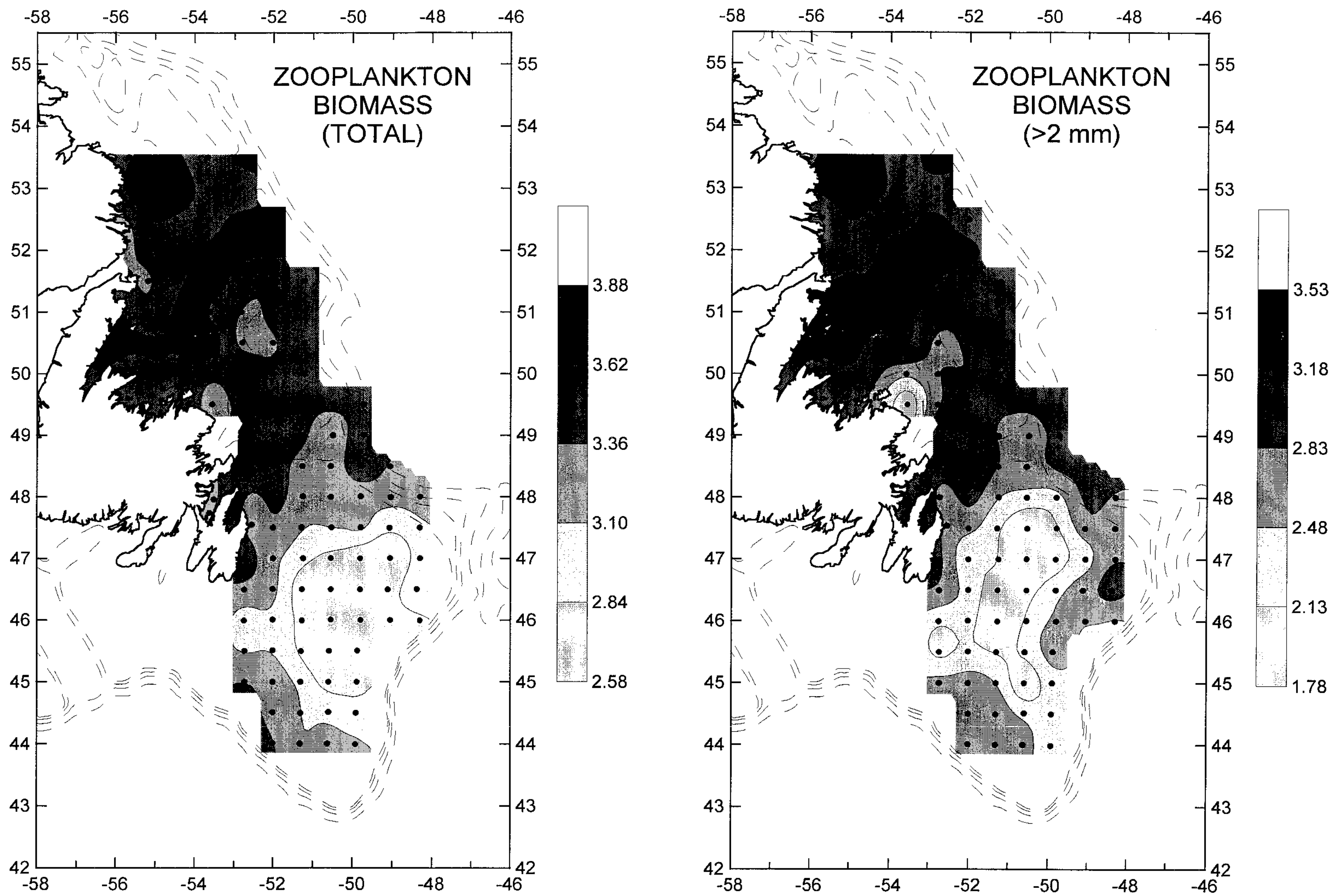

Figure 3. Distribution of total invertebrate zooplankton biomass (mgDW/m^2), left panel, and for the large size fraction (>2mm), caught in the bongos during the 1998 pelagic 0-group survey in NAFO Divisions 2J3KLNO.

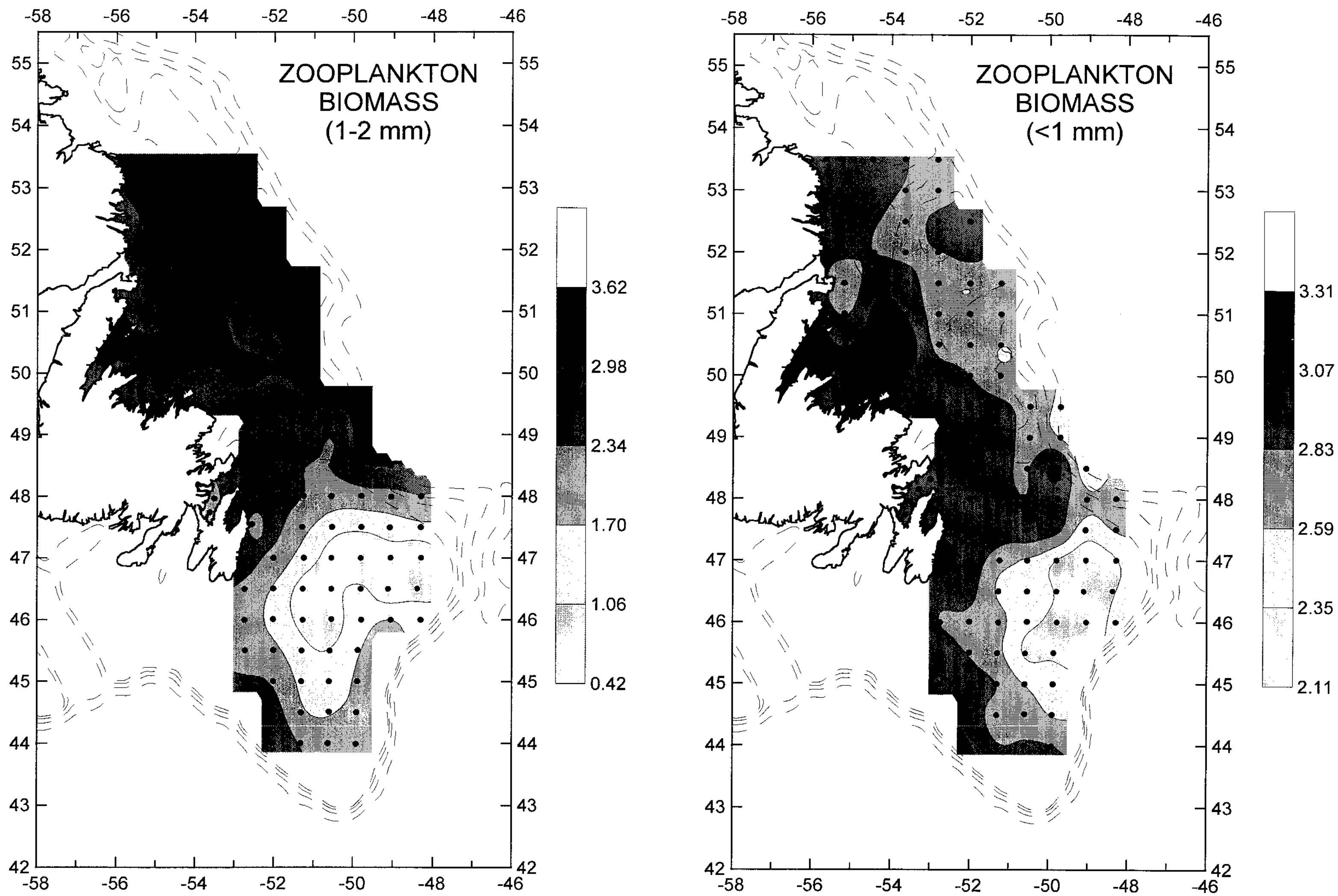

Figure 4. Distribution of the midsize fraction (1-2mm) of invertebrate zooplankton biomass (mgDW/m^2), left panel, and for the small size fraction (<1mm), caught in the bongos during the 1998 pelagic 0-group survey in NAFO Divisions 2J3KLNO.

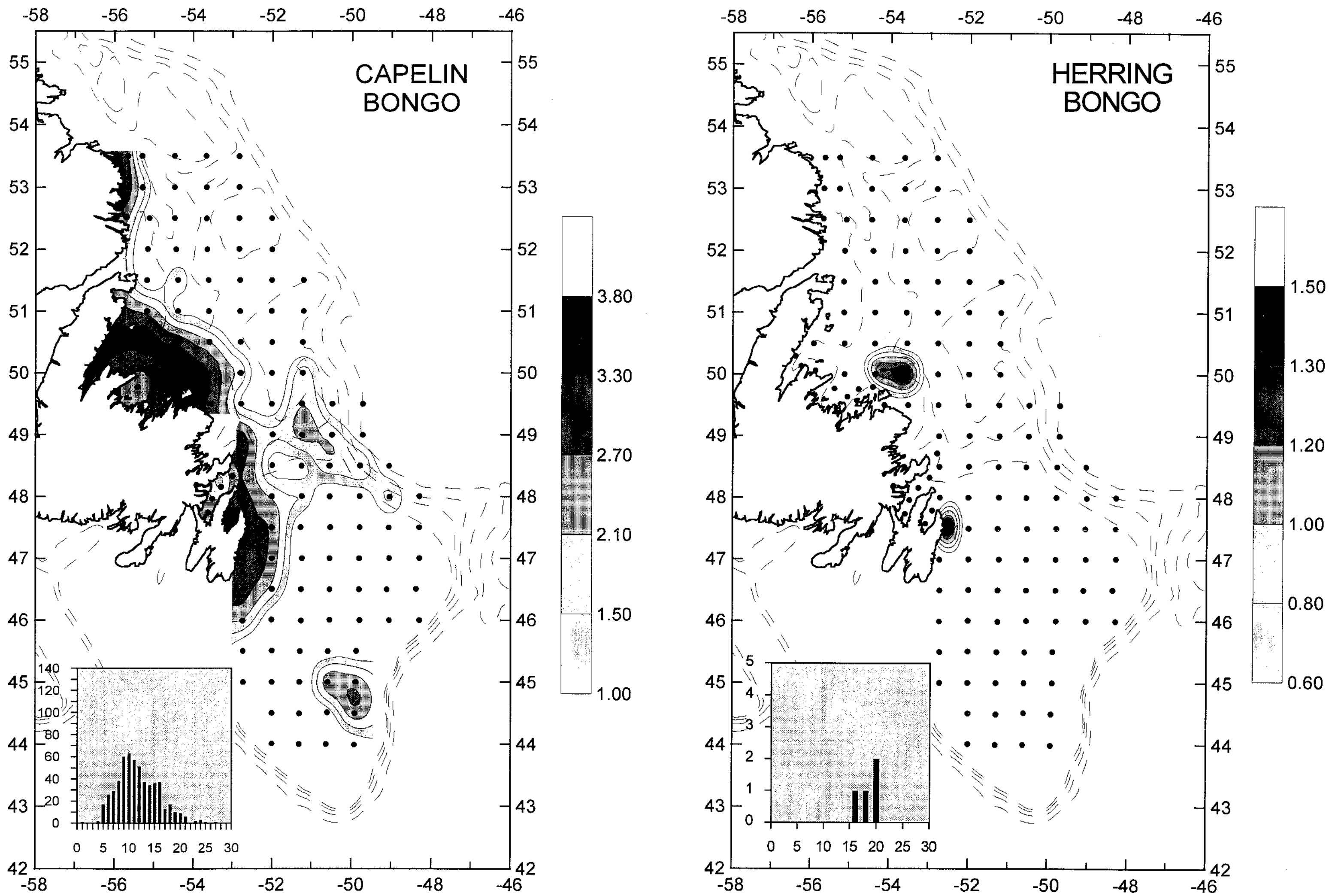

Figure 5. Distribution of capelin larvae (log_10 number 10^3 /m^3), left panel, and herring larvae, right panel, from the bongos during the 1998 pelagic 0-group survey in NAFO Divisions 2J3KLNO.

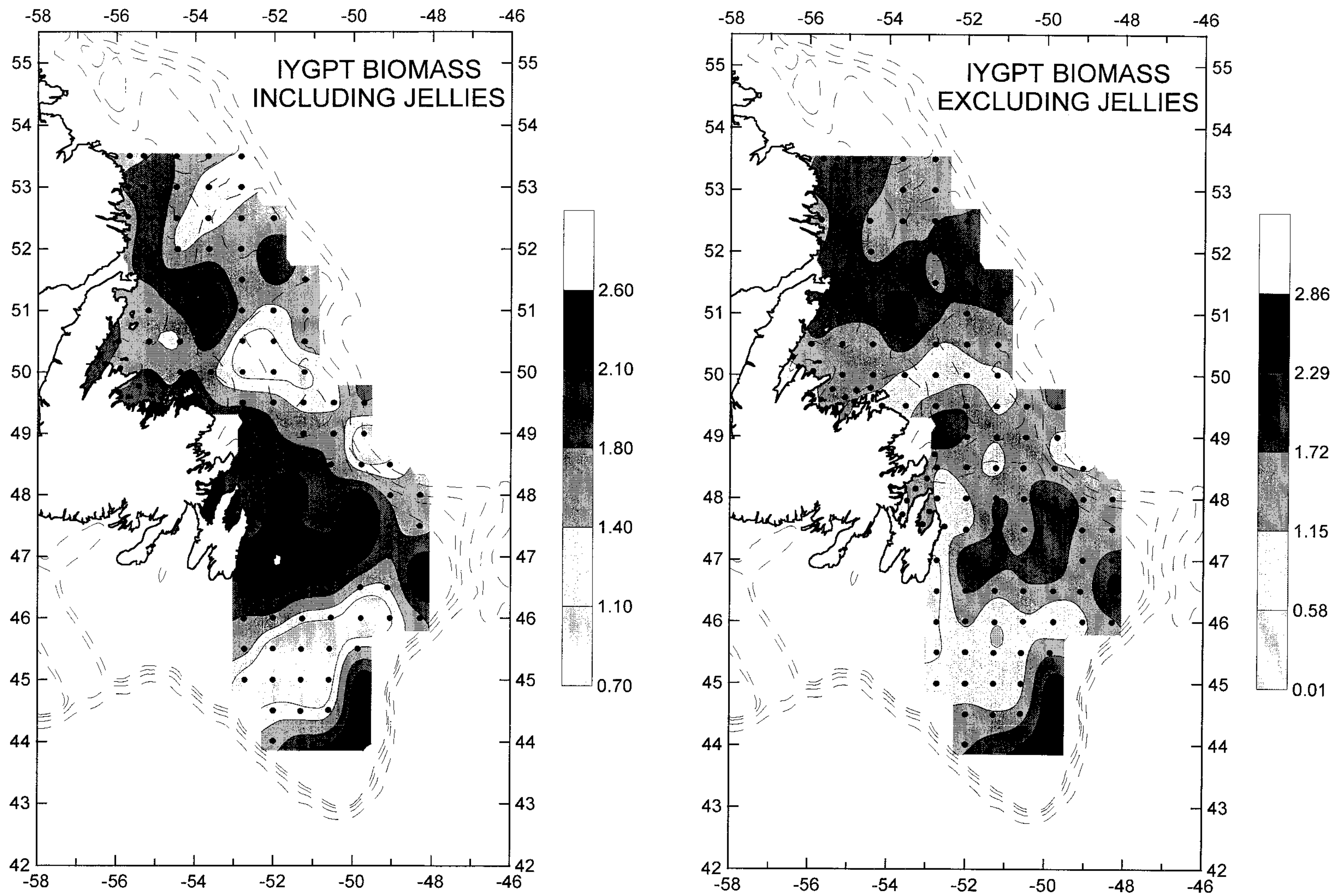

Figure 6. Distribution of total nekton biomass (kgWW/m^3) with jellyfish included, left panel, and without jellyfish, right panel, freom the IYGPT during the 1998 pelagic 0-group survey in NAFO Divisions 2J3KLNO.

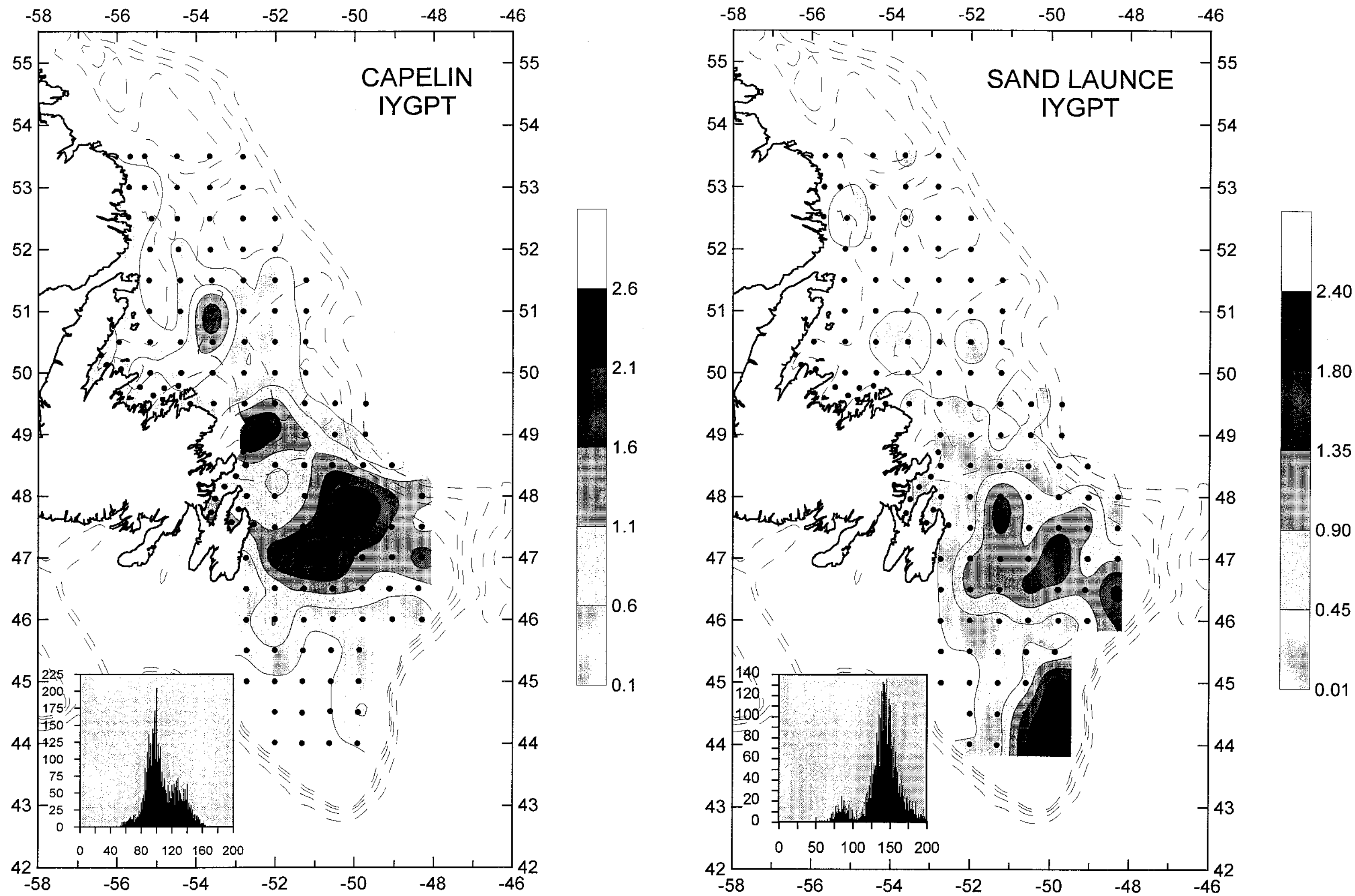

Figure 7. Distribution of capelin (log_10 number 10^4 /m^3), left panel, and sand lance, right panel, from the IYGPT during the 1998 pelagic 0-group survey in NAFO Divisions 2J3KLNO. Length frequency distribution (mm) of animals captured is shown in the bottom left hand corner of each panel.

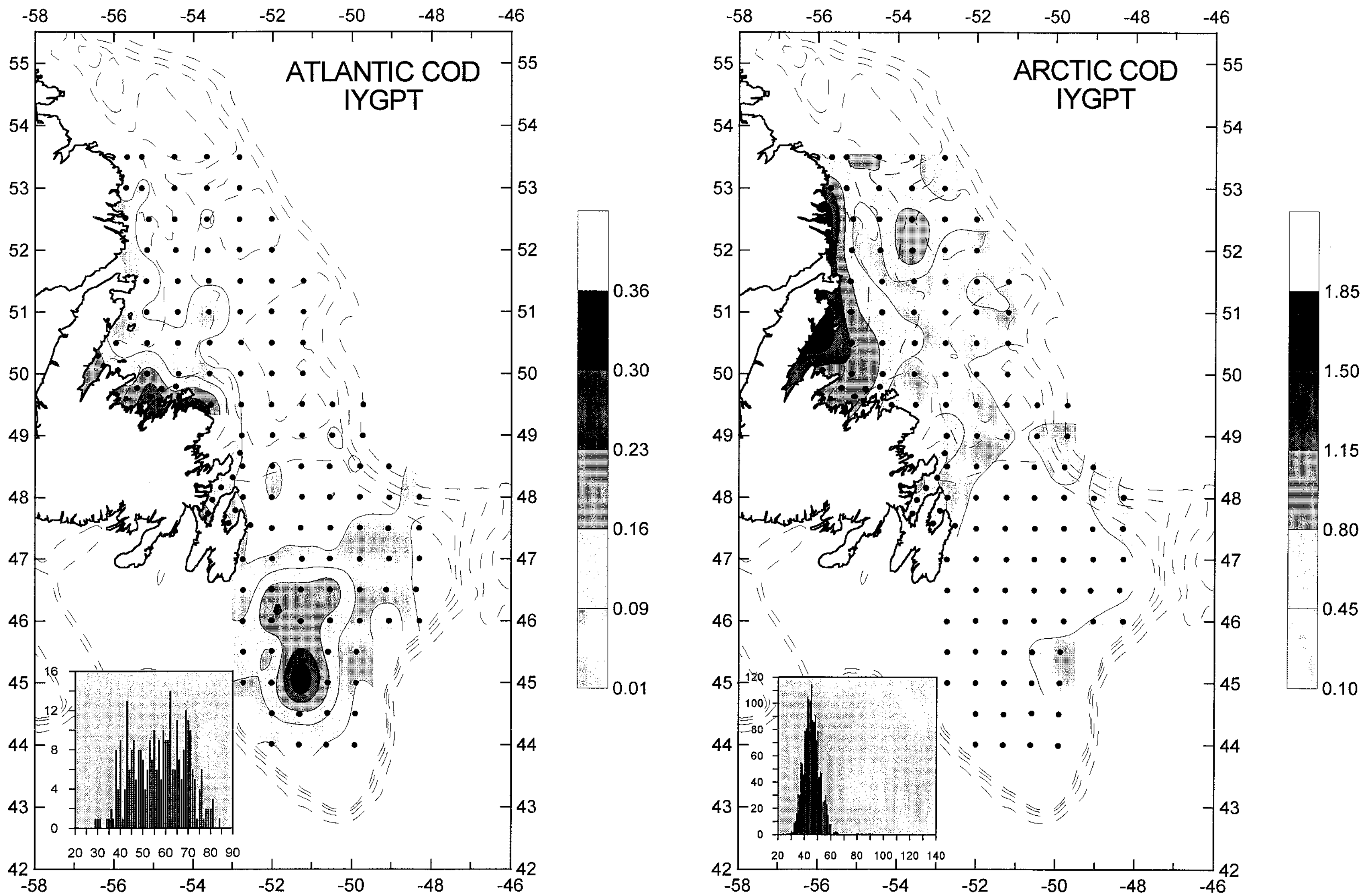

Figure 8. Distribution of pelagic 0-group cod (log_10 number 10^4/ m^3) left panel and Arctic cod, right panel, from the IYGPT during the 1998 pelagic 0-group survey in NAFO Divisions 2J3KLNO. Length frequency distribution (mm) of animals captured is shown in the bottom left hand corner of each panel.

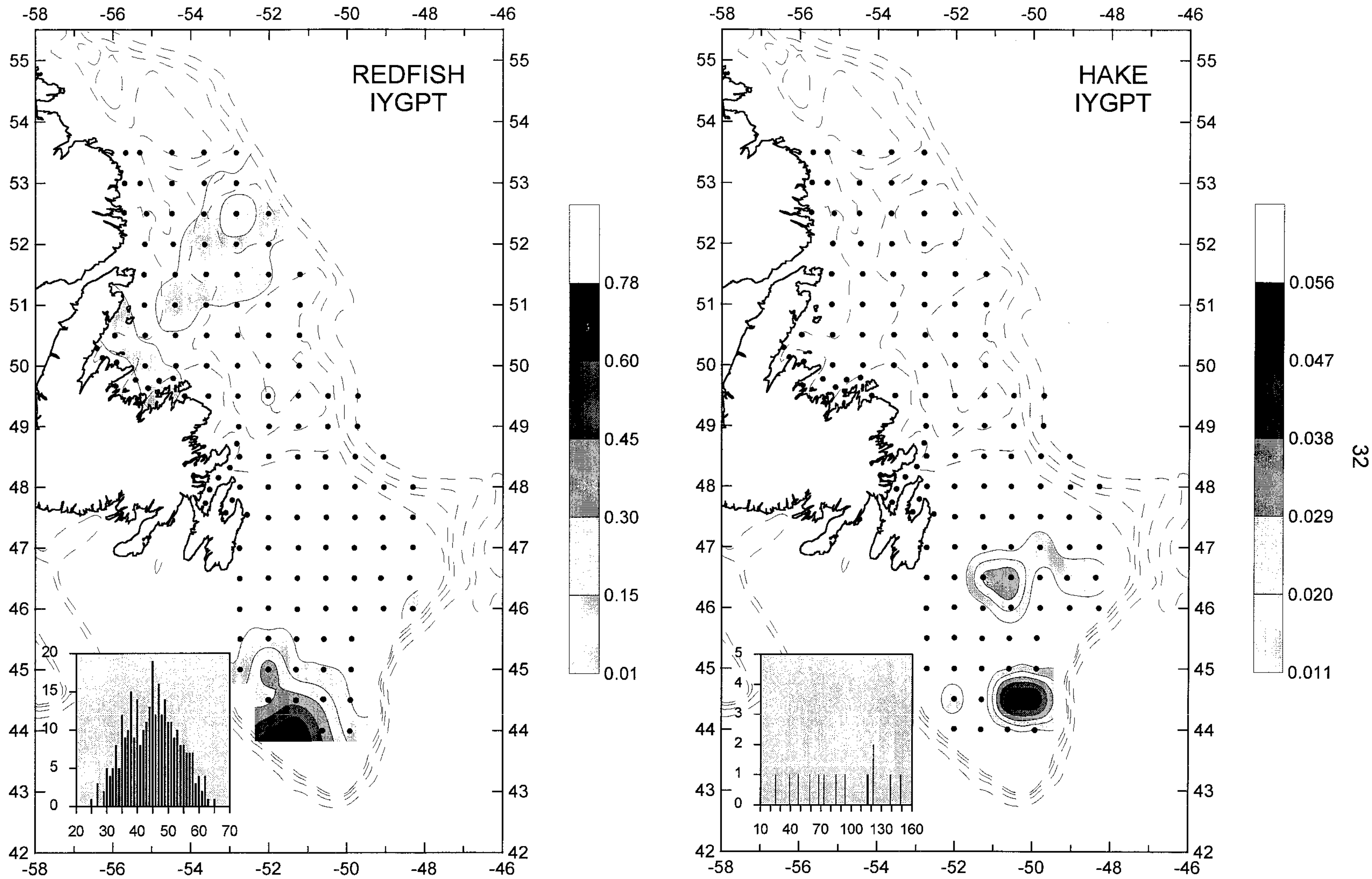

Figure 9. Distribution of redfish (log_10 number 10^4 /m^3), left panel, and white or common hake, right panel, from the IYGPT during the1998 pelagic 0-group survey in NAFO Divisions 2J3KLNO. Length frequency distribution (mm) of animals captured is shown in the bottom left hand corner of each panel.

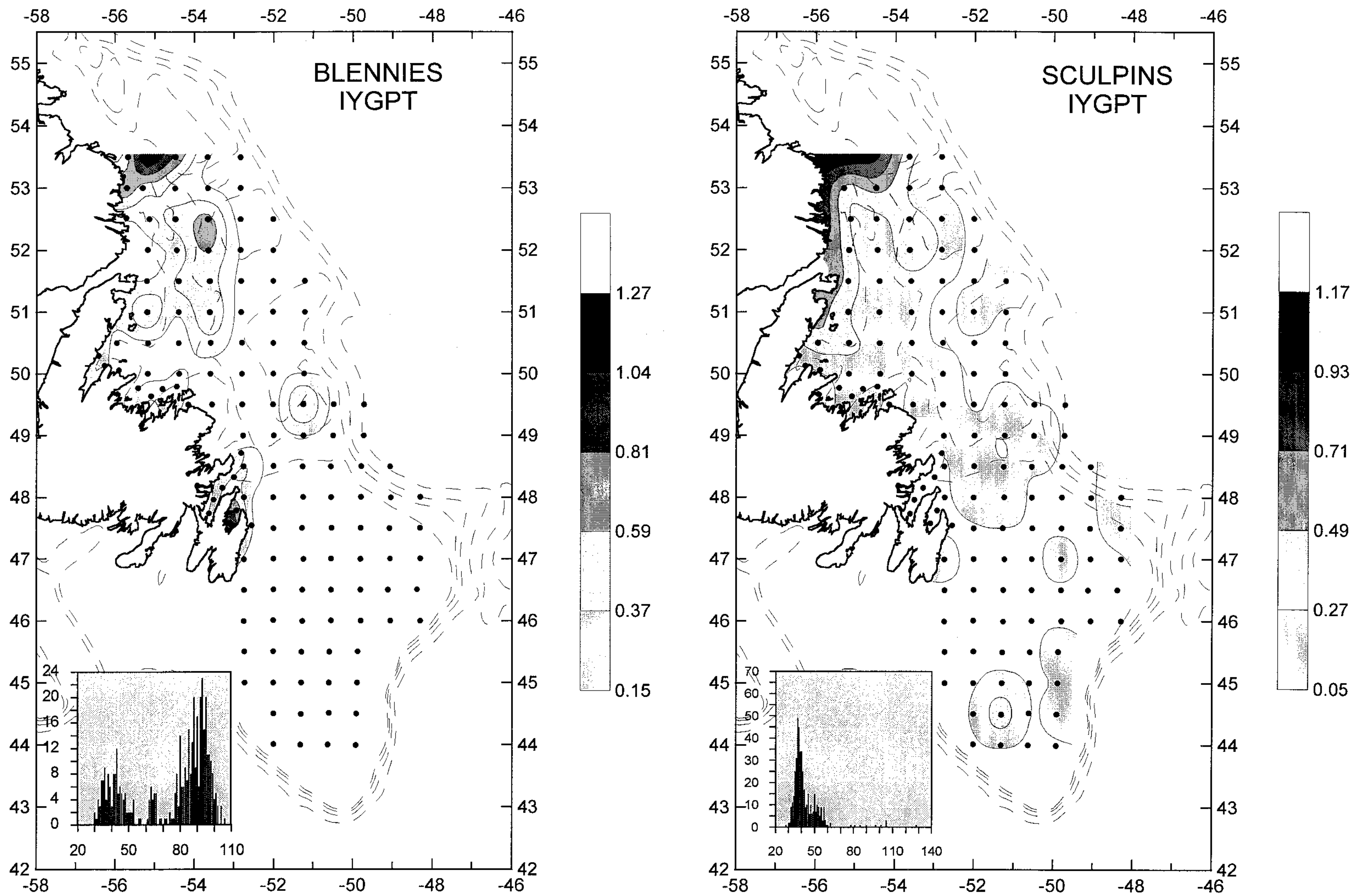

Figure 10. Distribution of blennies (log_10 number 10^4 /m^3), left panel, and sculpins, right panel, from the IYGPT during the 1998 pelagic 0-group survey in NAFO Divisions 2J3KLNO. Length frequency distribution (mm) of animals captured is shown in the bottom left hand corner of each panel.

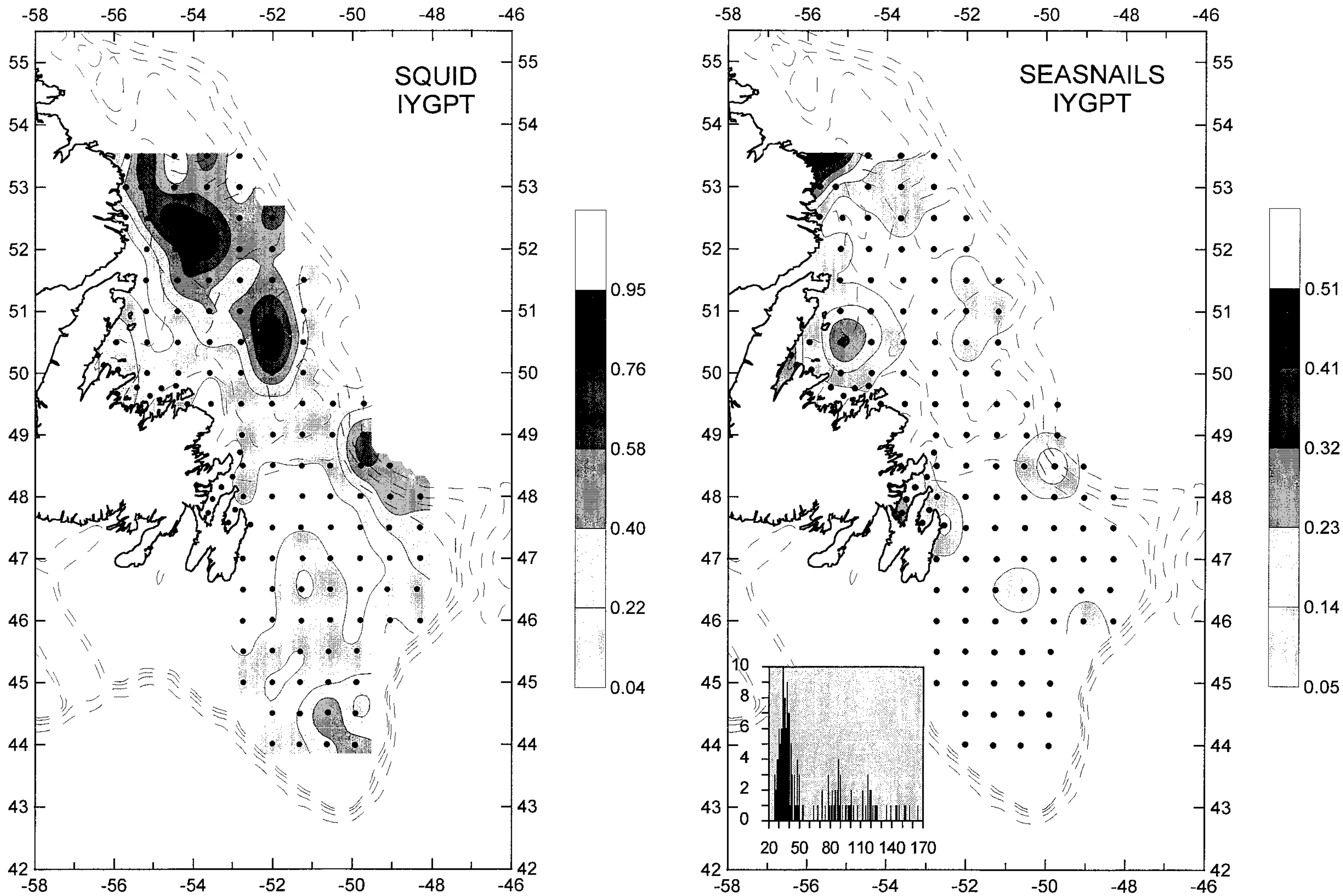

Figure 11. Distribution of squid (log_10 number 10^4 /m^3), left panel, and seasnails, right panel, from the IYGPT during the 1998 pelagic 0-group survey in NAFO Divisions 2J3KLNO. Length frequency distribution (mm) of animals captured is shown in the bottom left hand corner of each panel.

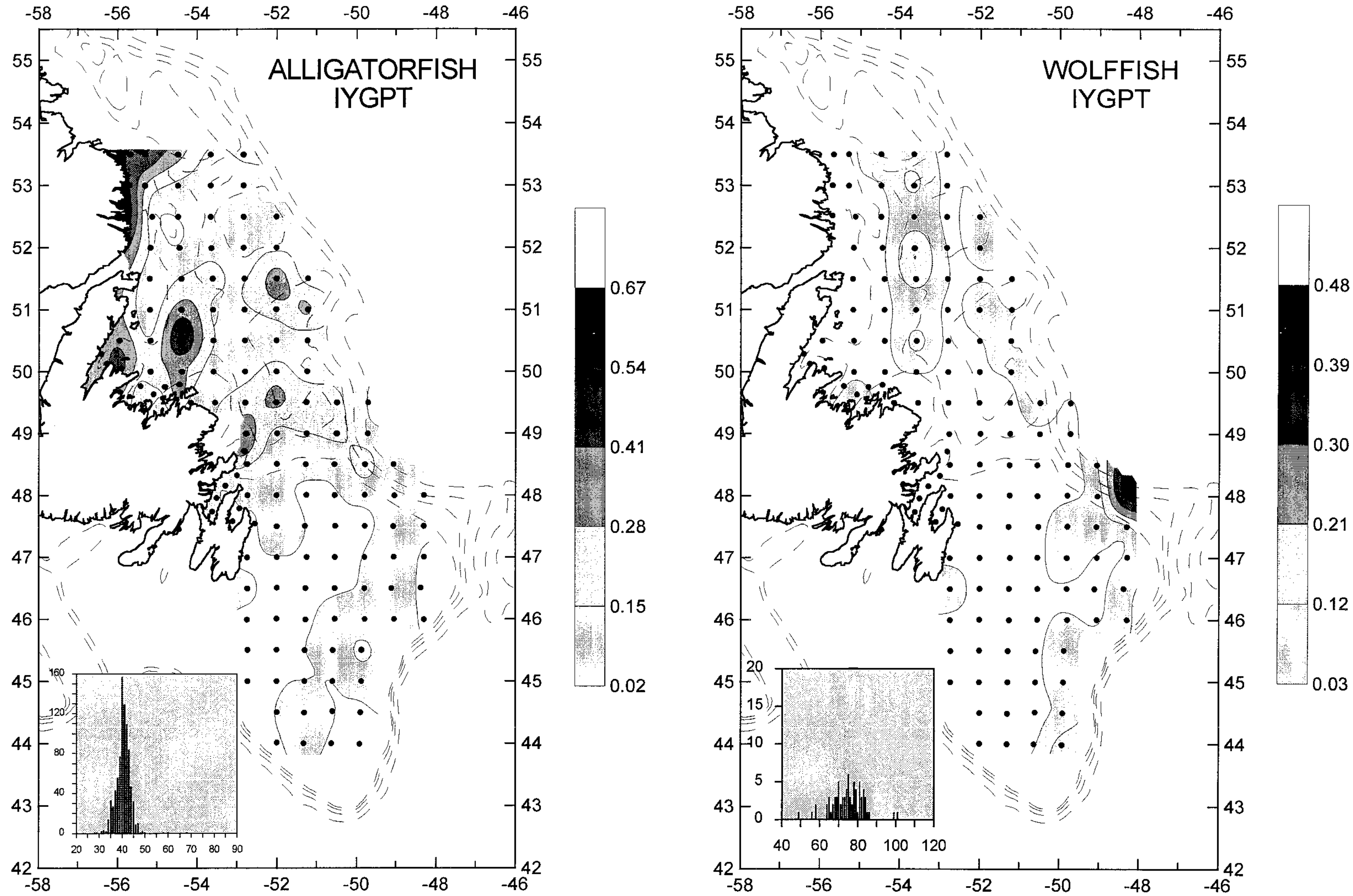

Figure 12. Distribution of alligatorfish (log_10 number 10^4 /m^3), left panel, and wolffish, right panel, from the IYGPT during the 1998 pelagic 0-group survey in NAFO Divisions 2J3KLNO. Length frequency distribution (mm) of animals captured is shown in the bottom left hand corner of each panel.

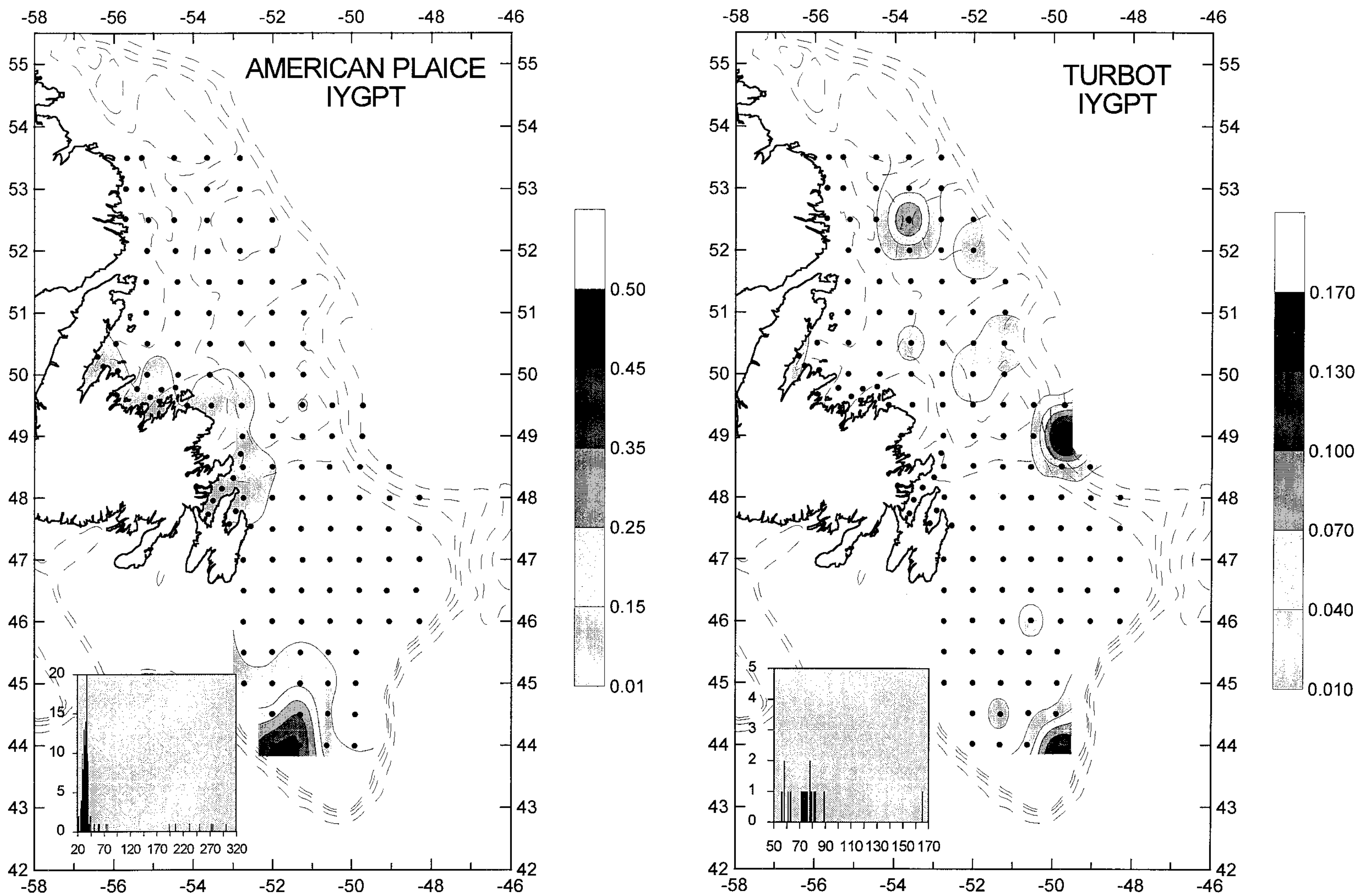

Figure 13. Distribution of American plaice (log_10 number 10^4 /m^3), left panel and turbot, right panel, from the IYGPT during the 1998 pelagic 0-group survey in NAFO Divisions 2J3KLNO. Length frequency distribution (mm) of animals captured is shown in the bottom left hand corner of each panel.

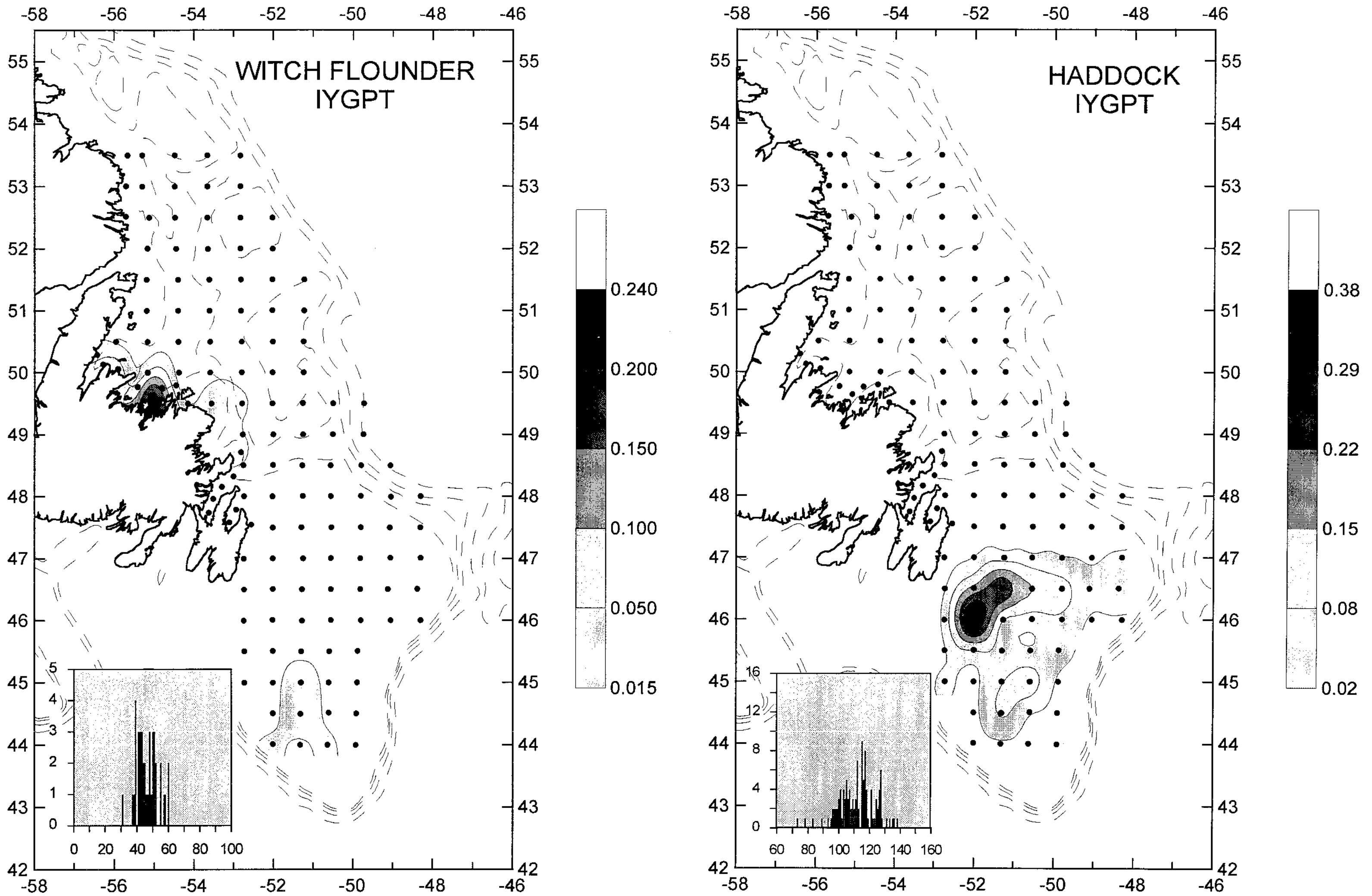

Figure 14. Distribution of witch flounder (log_10 number 10^4 /m^3), left panel, and haddock, right panel, from the IYGPT during the 1998 pelagic 0-group survey in NAFO Divisions 2J3KLNO. Length frequency distribution (mm) of animals captured is shown in the bottom left hand corner of each panel.