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Short Term Fluctuations in the Pelagic Ecosystem of the Northwest Atlantic

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Abstract

Spatial and/or annual effects accounted for significant variation in all variables examined during a broad-scale survey of the marine pelagic environment carried out for the sixth consecutive year, late summer 1999, in NAFO Divisions (2J3KLNO). Area differences were generally larger and associated with latitudinal or inshore/offshore clines. A north to south cline in temperature characterizes the area. In 1999, biomass of the smallest zooplankton size fraction remained relatively high, ranking second following initial increases in biomass from 1994 to 1997. The mid size increased each year, ranking highest in 1999 whereas mean biomass of the largest size remained relatively constant following an initial increase in 1995. In 1999 capelin larvae were relatively large, abundant and widespread but did not extend to southern Labrador coast as they did in 1998. Mean total nekton biomass (including jellyfish) in 1998 and 1999 was significantly higher than earlier years. Capelin (age 1+) and sand lance continued to dominate total nekton, but redfish increased to rank third in overall abundance, increasing by 2 orders of magnitude since 1998 and 3 orders since 1997. Arctic cod, which decreased in abundance in early years, maintained a relatively low, stable abundance over the past 3–4 years. Mean catch of pelagic capelin ranked highest in 1999, but was significantly higher than 1998 and 1995 only. The mean catch rate of pelagic 0-group Atlantic cod increased for the third year in succession. It was significantly higher in 1999 as a result of increases in the inshore particularly, but also the Northern Grand Bank. Catch rates of American plaice were highest in the time series in 1999 and hake were 2 orders of magnitude more abundant than in 1998. Six northern taxa that decreased sharply in 1998, all increased again in 1999 but remained relatively low in comparison to 1994 – 1997 levels. Of twenty measures of the nekton community examined in 1999 all but two ranked higher (6 significantly) than 1998 indicating a growing nekton community.

Résumé

Des facteurs spatiaux et/ou annuels ont expliqué la variation significative de toutes les variables examinées lors du relevé à grande échelle du milieu pélagique marin effectué pour la sixième année consécutive, à la fin de l'été 1999, dans les divisions 2J3KLNO de l'OPANO. Les différences dans la zone étudiée ont généralement été plus prononcées et associées à des gradients latitudinaux ou entre la côte et le large. Un gradient nord–sud de la température caractérise cette zone. En 1999, la biomasse de la fraction du zooplancton de plus petite taille est demeurée relativement abondante, se classant au deuxième niveau le plus élevé après les augmentations initiales observées de 1994 à 1997. La fraction de taille moyenne, a augmenté tous les ans, atteignant son plus haut niveau en 1999, tandis que la biomasse moyenne de la fraction de plus grosse taille est demeurée relativement inchangée après l'augmentation initiale notée en 1995. En 1999, les larves de capelan étaient relativement grosses, abondantes et répandues, mais elles n'ont pas été retrouvées jusque dans le sud de la côte du Labrador comme en 1998. La biomasse moyenne de l'ensemble du necton (incluant les méduses) a été significativement plus élevée, en 1998-99, par rapport aux années précédentes. Le capelan (âge 1+) et le lançon ont continué de dominer dans l'ensemble du necton, mais le sébaste a gagné en abondance, se classant au troisième rang. Ce dernier affiche une augmentation de la biomasse de 2 ordres de grandeur depuis 1998 et de 3 ordres de grandeur depuis 1997. La morue polaire, qui présentait une baisse d'abondance au cours des premières années, est demeurée à un niveau relativement bas et stable depuis 3–4 ans. Le taux moyen de capture du capelan pélagique a atteint son niveau le plus élevé en 1999, mais a été significativement supérieur aux taux de 1998 et de 1995. Le taux moyen de capture de la morue pélagique du groupe d'âge 0 a augmenté pour la troisième année consécutive. Il à été significativement plus élevé en 1999 en raison d'augmentations notamment dans la zone côtière, mais aussi dans la partie nord du Grand Bank. Des taux de capture élevés ont été enregistrés en 1999 pour la plie canadienne, soient les plus hauts de la série temporelle, de même que pour le merlu/merluche, qui a montré une hausse de 2 ordres de grandeur par rapport à 1998. Six taxons du Nord qui avaient diminué de façon marquée en 1998 ont tous augmenté en 1999, tout en demeurant à des niveaux relativement faibles en comparaison à ceux de la période de 1994 à 1997. Des 20 mesures du necton examinées en 1999, toutes, sauf 2, ont été classées supérieures (significativement dans 6 cas) aux mesures de 1998, indiquant la croissance de cette communauté.

Introduction

This contribution presents results of the 1999 pelagic 0-group survey, a comprehensive large-scale survey of the marine pelagic environment off Newfoundland and Labrador (NAFO Divisions 2J3KLNO). The survey has been carried out annually during late summer since 1994 (Anderson and Dalley 1997; Dalley and Anderson 1997, 1998, Dalley et al 1999). In addition to providing an independent pre-recruit measure of pelagic 0-group Atlantic cod, and Northwest Atlantic capelin at the larval stage (0-group), and as one-year-old capelin, (1+) this survey provides an across taxa multi-species measure of the state of the pelagic ecosystem. It is a response to various recommendations arising from Task forces to examine problems associated with understanding the marine environment, particularly recruitment to commercial fish species. We wanted to provide a basis to compare future surveys, in an effort to understand short and long-term variations in the pelagic environment. This environment harbours pre-recruit stages of numerous commercial and non-commercial fish species and invertebrates, in addition to older life history stages of pelagic species such as capelin and sand launce.

The survey was undertaken for a sixth consecutive year in August/September 1999. The purpose of this document is to present results of the 1999 survey including descriptions of annual and geographic variation in temperature, zooplankton, total nekton biomass and composition over the past 6 years. Following any adjustments for diel differences in catch rate, the variables are statistically examined for spatial patterns throughout the large zoogeographic area surveyed. In particular we examine annual (1994-1999) fluctuations to identify trends over the six-year period (1994-1999).

Materials and Methods

The 1999 survey was carried out from August 23 to September 19. The mid-day of the survey was day 248 of the year. This compares to survey mid days of 241, 257, 241 and 233, 244 for the 1994, 1995, 1996, 1997 and 1998 surveys respectively. Thus, 1999 was the latest mid-day of any survey except 1995, 15days later than 1997, approximately 4 days later than 1998, and 4 days later than the mean mid-day of all six surveys. The RV Teleost (103 stations) covered the northern part of the survey area, all the inshore, and most of the Northern Grand Bank, and the RV W. Templeman (26 stations) the southern portion. 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. In 1999 temperature at some stations was measured using an Applied Microsystems STD-12. 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 has been presented for capelin and herring and for the first time crab larvae in 1999. Catch rates were estimated by subsampling catch from the right side of the bongos at sea. In the 4 most recent years 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°C, and weighed to the nearest milligram.

Spatial distribution throughout the large geographic area was examined by dividing it into seven smaller areas (Figure 1). The smaller areas were based on predominant geographical features (e.g., banks), proximity to shore, and latitude. Seven core areas were consistently sampled all six years. Notation used in the document for the 7 core areas examined using ANOVA 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.

A 'daynight' variable was created to examine diel differences 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 performed on 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 (e.g., temperature, zooplankton biomass, total nekton biomass, species, or groups of species abundance) as the dependent variable. The main effects, area and year, were 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 variable. All biological variables were standardised to the volume of water filtered and logged_{10} prior to the analysis of variance.

Results

Geographic distribution of each variable examined during the 1999 survey is presented using contour plots covering the survey area. Total variability accounted for by the ANOVA was significant in all cases and annual and spatial variation of 42 means (7 areas x 6 years) for each variable was significant in 26 of 27 cases (Table 1). The interaction of the two main effects in the analysis of variance was significant for all variables except two, but as in previous analyses, the partial F-value attributable to interaction was small compared to the main effects (Table 1). Statements made in the following presentation regarding differences between areas and years are based on the results of the GT2 test (Appendix 1).

A latitudinal cline in surface temperature that was observed during earlier surveys (Dalley et al., 1999) persisted in 1999 (Figure 2, left panel). There was warmer water to the south and a tendency for slightly warmer surface water in the bays than adjacent latitudes on the shelf. The GLM model for surface temperature has the highest R^2 (0.82) of any variable (Table 1). Considering all years mean temperature on the southern Grand Bank was warmer than the Northern Grand Bank, which was higher than the inshore, all of which were higher than Northeast Newfoundland shelf. There was no difference in mean temperature of the 2 areas constituting the southern portion of the Northeast shelf (ISS and FIBI). Both were warmer than the northern portion of the inner Northeast shelf (ISN and BIBI). During the period of the surveys (1994-1999) there has been a constant trend towards warming of ocean conditions throughout the survey area (Colbourne 2000).

The weaker north/south cline in temperatures described in previous years at 50m also persisted in 1999 (Figure 2, right). Warmest water at 50m was located over the southern Grand Banks. As in previous years relatively warm water also occurred at some stations near the shelf break.

During the 1999 survey 15 biological variables had significant daynight differences (Table 2) compared to 8, 7, 10, 8, and 13 during the 1994 to 1998 surveys. There were four variables with relatively low probabilities; ($0.05 < P < 0.01$) including midsize zooplankton, American plaice, Arctic cod, and turbot. As in other surveys, daynight differences were highly variable depending on species or group. Consistent with all previous years, mean biomass of the large and mid-size zooplankton fractions was significantly greater during night sets than day sets in 1999. The difference in day and night catches of the small-size fraction was not significant, as it had been during 1994 and 1995 only. The total wet biomass of nekton, with jellyfish, had no difference in daynight catches during the first four years, but significantly more was caught at night during the 2 most recent surveys. Without jellyfish there was a significantly greater biomass caught at night during each of the past four surveys. Significantly more Atlantic cod (8.45x) and Arctic cod (2.33) were taken at night in 1999. Consistent with other recent years capelin catches varied the most dielly, 30.8x higher at night in 1999. Catch rate of blennies was 14.3x higher at night in 1999. In the two most recent years there were significantly more sculpins taken at night. This is in contrast to 1997 (when there were more taken during the day), and the three earliest years when no daynight differences were observed for sculpins. More seasnails were taken at night in 1999, which is consistent with 3 of the 5 previous years. In all surveys, except the 2 earliest, catch rate of squid was 2.2 –3.5 times greater at night. Consistent with all years, except 1994 there were more turbot taken at night in the 1999 survey. In 1994 7.6 times more turbot were caught during the day whereas during the 5 most recent years there from 1.7 to 7.8 times more were caught at night. Wolffish exhibited daynight differences in catch rate in 1999, 1998 and 1996, when 3.0 - 8.5x more were caught at night. For the first year American plaice catches were significantly higher (5.57x) at night in 1999. Alligatorfish, haddock, hake, redfish, witch flounder, and yellowtail had no daynight differences in catch rate in 1999 whereas sand launce catches were, for the first year, significantly higher at night.

Highest total zooplankton biomass in 1999 (Figure 3, right) occurred on the Northeast Newfoundland Shelf. It occurred at stations in a band running north/south on the inner shelf, and also near the shelf edge. Lowest weights occurred on the eastern portion of the Grand Banks. Total mean biomass (all years) ranged from 289.3 – 6452.7 mg/m2 (Table 1). The four areas on the NE Shelf ranked highest and were not significantly different from each other. Mean biomass in the more northern areas (BIBI and ISN) was higher than the inshore, whereas that from the southern shelf (ISS and FIBI) was not significantly higher than the inshore. All five areas had higher biomass than NGB, which was higher than SGB. Mean total zooplankton biomass in 1997 and 1998 was significantly higher than all other years except 1999 (3^{rd} highest).

Highest concentrations of the large zooplankton size fraction occurred on the inner central and northern offshore portions of the NE shelf (Figure 3, right). Mean weights ranged from 163.9-2296.2mg/m2 (Table 1), which is a new high mean, and occurred on the inner Northeast shelf. Again there was a general trend of decreasing weights from north to south. There was no significant difference in mean biomass in the 4 northern areas or the inshore except ISN, which ranked highest, was greater than the inshore. All 5 areas had significantly higher biomass than on the Grand Banks. Mean biomass of the large size fraction ranked highest in 1995. Mean biomass in 1999, which ranked 5 of 6, was significantly lower than 1995, but not lower than any of the 3 most recent years (1996-98).

Mean weights of the mid-size (1-2mm) fraction over the time series ranged from 37.1 to 3513.6 mg/m2, in 1999 in ISN. Lowest biomass occurred on the Grand Banks (Figure 4, left) and highest levels in Northeast Newfoundland Shelf. R^2 for the model was 0.62 (Table 1). Highest mean biomass in 1999 occurred in ISN whereas over the whole period the highest mean biomass occurred on BIBI. Mean weights in all the northern areas were higher than weights on the Grand Banks. Weights inshore were higher than on the Grand Banks and lower than 3 of 4 areas of the Northeast shelf, Funk Isle Bank being the exception. Mean biomass of the midsize fraction increased each year of the survey such that 1999 ranked highest, and was significantly higher than 1994.

Biomass of the small-size fraction also indicated an inshore/offshore cline (Figure 4, right) with highest biomass occurring inshore around White Bay and Fogo Island. Biomass was relatively high on the central southern portion of the NE Shelf and in the extreme northern areas. The model explained 60% of the variation, but in contrast with other plankton size fractions, and all other variables, annual variation was greater than geographic variation (Table 2). Over the 6 years there was a cline from north to south with the 2 most northern areas ranking highest and the inshore similar to FIBI and ISS; all 5 more northern areas having higher biomass than the Grand Banks. Overall mean weights of the smallest zooplankton size fraction were significantly higher in 1997 than all other years except 1999, which was not significantly greater than 1998. The three most recent years are significantly higher than the earlier three. Lower mean weight of this size fraction in the 2 earliest years is expected as a result of the coarser mesh used on the bongo codends during these years. However, since similar mesh was used in each of the 4 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 in 1999. However during the first two years, when a courser mesh was used there was 1.3 to 1.45x more biomass taken at night. When 333um mesh was used higher catches of the small size fraction were at night, but all four years that the 232um mesh was used there was no difference in daynight catches. This observation indicates animal size to be a factor determining differences in day and night catches. In terms of zooplankton gear avoidance, for whatever reason, the size range from 232 –333 microns appears to be important. The two larger size fractions (> 1mm) have higher mean catches at night during all surveys.

Total zooplankton biomass over the period of the surveys was lowest during the early years, peaked in 1997 and remained relatively high in both recent years (Figure 5). There was an initial (1994 – 1995) increase in the large size fraction. The mid-size fraction has increased steadily over the time period whereas the largest increase in the small size fraction occurred in 1997 and has remained relatively high since. The temporal trends in zooplankton biomass of the small size fraction are similar in both northern (NE shelf and inshore) and southern (Grand Banks) areas, except for 1999 (Figure 6). Higher biomass levels exist to the north, as opposed to the Grand Banks, where levels of small zooplankton actually decreased from 1998.

Distribution of larval capelin during the survey represents dispersal that has occurred since larval emergence from near shore spawning habitats. Overall distribution of capelin larvae during the 1999 survey (Figure 7, left) was similar to other recent years. As in 1998, dispersal was fairly extensive offshore, especially in the area of the Northern Grand Bank. Highest densities occurred in the southern bays as opposed to Notre Dame Bay and White Bay, where highest catches occurred in 1998. In contrast to the 1998 distribution, capelin larvae did not extend as far north as the coast of Labrador. A distinct distribution of spawning products from the Southeast Shoal capelin stock was also less extensive than in 1998. Mean night catches were higher than day catches ($P < 0.05$) in 1995 and 1997 and were adjusted accordingly. Mean catch rate in 1999 ranked third highest but was not significantly different from 1995 which ranked highest, or 1997 which was lowest. All years combined, mean catch rate inshore was significantly higher than that of the southern inner NE shelf (ISS) and the NGB, which were not different. Catch rates in these 3 areas were higher than the other 4 of which FIBI ranked highest. No capelin larvae were ever taken on BIBI. Later survey time is reflected in the larger size of capelin in 1998 and again in 1999, which ranged from 5 - 30mm (Figure 7, left) with the mean length of 13.2mm, which is the largest mean length, any year. This compares with mean lengths of 11.7, 10.0, 9.9, 10.7, and 8.9 in the 1998, 1997, 1996, 1995 and 1994 surveys respectively (Anderson and Dalley 1999).

Although low numbers of herring larvae were taken near the inshore in all previous surveys, none were taken in 1999. This again may reflect the later survey time in that any larvae from spring spawning may have metamorphosed.

For the first year distribution of crab larvae was determined from the bongos (Figure 7, right), although species identification is pending. Most of these crab larvae were later stage megalops as opposed to zoae. They were widely distributed, occurring in approximately 70% of all bongo sets and occurring in all core areas. Highest catch rates occurred at several stations on the outer portion of the Northeast Shelf and the southern Avalon Peninsula.

In 1999 highest concentration of total IYGPT nekton biomass (including jellyfish, Figure 8, left) occurred on the central portion of the northern Grand Bank, and the inshore areas south of White Bay. There is an inshore/offshore cline in nekton biomass. Across all years, mean biomass inshore was significantly higher than all other areas except the inner NE shelf (ISS and ISN). The southern Grand Banks ranked lowest and was significantly lower than all other areas except the northern Grand Bank. Biomass on the NGB increased in ranking ahead of BIBI in 1999, whereas in 1998 all the NE shelf areas ranked higher than the northern Grand Bank. Across all years mean biomass ranked highest in 1999 and was significantly greater than all other years, except 1998, which was significantly greater than all earlier years. Lowest mean biomass occurred in 1996. Mean nekton biomass was approximately 3x greater in night sets compared to day sets.

Highest nekton biomass (with jellyfish removed, Figure 8, right) occurred at stations on the NE shelf, some inshore stations and at 2 stations on the southern Grand Bank. Distribution of biomass over the whole area is quite variable. Considering all years (5 only), mean biomass in the 4 northern areas, was greater than that of the inshore, which in turn was greater than that of the Grand Banks. The difference in the two nekton measures indicates that most jellyfish occur inshore and on the northern Grand Bank. Jellyfish were most abundant in 1998 and 1999. There has been a consistent increase in mean nekton biomass each year of the survey such that 1999 and 1998 were greater than the 3 earliest years. Nekton biomass was higher (~5.5x) in night than day catches, the daynight differences being greater than with jellyfish included.

Both zooplankton and nekton biomass have increased over the period of the surveys (Figure 9). Zooplankton biomass peaked in 1997, ahead of nekton, which, in 1999 had the largest increases since 1997 and continues to increase. There have been large increases in the biomass of jellyfish each of the past two years.

Approximately 135,223 fish were caught in 1999 (Table 3) compared to 106,400 in the 1998 survey and ~120,000 in 1997. Consistent with the 2 most recent years, juvenile capelin was the most abundant fish. Actual numbers of capelin caught increased but relative abundance was lower than recent years (54.1% in 1999 compared to 58% in 1998 and 85.7% in 1997. In 1999 capelin occurred as frequently as 1998 (~60%) compared to 39.3% in 1997. For the second year in succession there was an increase in numbers of sandlance (ranking second in overall numbers of fish caught and occurring in nearly 1/2 of all sets). Redfish had the greatest increase in catch in 1999 comprising 14% of all catch numbers compared to 0.3% in 1998 and occurring in 58.1% of sets, compared to 17% in 1998. Mean catch rate of Arctic cod was comparable to the past 2 years, at a level lower than the 1994-95 surveys. Lanternfish occurred in the same number of sets as 1998 but few were caught compared to 1998. Squid ranked fifth in terms of overall abundance but had the widest distribution of all groups (74.4%). Atlantic cod distribution increased from 46 to 54% and relative abundance from 0.3 to 1.6% compared to the 1998. Alligatorfish were widely distributed occurring in 65% of all sets. Sculpins occurred in ~1/2 the sets whereas American plaice, blennies and seasnails occurred in ~40%. Lumpfish occurred in ~30%; hake, wolfish, witch flounder and Greenland halibut occurred in ~ 20%.

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 10, left). Capelin were mostly absent from Belle Isle Bank but relatively high catch occurred on Funk

Island Bank and the northern Grand Bank in 1999. Low numbers were taken on the southern Grand Bank. The GLM model accounted for a relatively low proportion of overall variability (R^2=0.25) in capelin catch rates (Table 1). Over the 6 years, highest abundance occurred inshore, which was significantly greater than all other areas except the Northern Grand Bank. Both these areas had significantly greater abundance than the other 5 areas, which were not different. Mean catch rate using transformed (log_{10}) ranked highest in 1999 but was significantly greater than 1995 and 1998 only. The 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 et al. 2000a, 2000b)

In 1999 sand lance abundance increased over 1998, which was 13x that of 1997. The center of distribution (Figure 10, right), shifted further north on the Grand Banks compared to other recent years. Low catch rates occurred on the NE shelf and towards the coast of southern Labrador. Abundance of sand lance increased in the inshore in 1999 relative to 1998 and distribution extended from the Grand Banks to the Avalon Peninsula and into the Northeast coast Bays to southern Labrador. Highest catch rates occurred on the northern Grand Banks. R^2 for the model was 0.34, mostly attributable to area (Table 1). Mean catches in NGB and SGB were higher than that of all the other areas, which were not significantly different. The inshore increased in abundance relative to the inner Northeast shelf and Funk Isle Bank in 1999. Overall abundance of sand lance in 1999 ranked highest and was significantly greater than all other years except 1998. The length frequency distribution indicates smaller fish and a relatively unimodal distribution compared to that of 1998.

Distribution of pelagic 0-group cod in 1999 (Figure 11, left) was more extensive than in any other year, particularly 1996, when cod were practically absent. As in other years, highest catch rates in 1999 occurred inshore, being relatively abundant in all Northeast coast bays; the highest catch rates occurred in Conception Bay. Catches on the inner NE shelf and Grand Banks were also relatively high whereas those on the offshore Northeast Newfoundland Shelf were negligible. The model explained 53% of variation in catch rate of pelagic 0-group cod (Table 1). Over the 6 years, mean abundance inshore was significantly higher than all other areas, ISS ranked highest of the others, FIBI the lowest. Since 1998 ranking of NGB increased from last to fourth. Mean catch rate in 1999 was significantly greater than any other year. Catch rate was significantly higher in 1994 than the 3 subsequent years. Lengths of cod ranged from ~28-95mm; mean length was 47.9mm, 9.45mm smaller than 1998, the largest mean length of pelagic cod sampled, any year. 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, Dalley et al. 2000).

Total catch and distribution of Arctic cod in 1999 was similar to that taken in 1997 and 1998 (Figure 11, right), being mostly restricted to the northern half of the survey area. Highest catch rates occurred inshore and in the more northern inshore portion of the survey area (ISS and ISN), decreasing toward the shelf edge and with decreasing latitude. In the model both main effects contributed significantly in explaining ~50% of variation in catch rate (Table 1). Considering all years highest mean catch rate occurred inshore, a change in ranking since 1998 when ISN ranked highest. Catch rate was significantly higher on BIBI and FIBI than on the Grand Bank. 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 1999, 1998 or 1996. Lengths in 1998 ranged from ~25-60mm which is similar to other years.

Redfish occurred in 58% of all sets compared to only 17% in 1998 and relative abundance increased from 0.3% to 14%. Redfish continued to be centered in two distinct areas, one offshore on the NE shelf (FIBI and BIBI), and one on the southern Grand Bank (Figure 12, left). Mean catch rate on SGB was 10x the previous high. Redfish occurred in the northern bays as in other recent years (1997-8), but not earlier years (1994-6). The overall GLM model, explained more variability in catch rate (R^2=0.26) than in previous years, and for the first year the annual effect was significant (Table 1). Considering all years catch rate on SGB was significantly higher than all other areas of which FIBI ranked highest and the inner northeast shelf rank lowest. Mean catch rate in 1999 was statistically higher than all other years, of which 1994 ranked highest and 1997 lowest. Lengths of redfish were similar to 1998 with a range of ~ 25-65mm, and there was at least two modes evident in the distribution.

Hake (common and/or white; Figure 12, right) also extended its distribution in 1999 (24% of all sets compared to 7% in 1998). Distribution of hake has been centered on the southern Grand Bank but extended onto NGB in 1999. Mean catch rate in 1999 was significantly greater than any other year of which 1996 was highest and 1995 lowest. Lengths ranged from ~25 to 150mm.

Pelagic 0-group haddock were observed in 1998 for the first time since the 2-ship survey started. Abundance was lower and distribution more restricted in 1999 than in 1998 (Figure 13, left panel). Lengths ranged from ~100-147mm.

Mean catch rate of lumpfish (Figure 13, right panel) ranked higher in 1999 than any other year but was significantly higher than 1994 and 1995 only, not the more recent years. Overall mean catch rate of lumpfish on the inner portions of the NE shelf (ISN and ISS) was significantly higher than all other areas except the southern portion (ISS) was not higher than the inshore.

Abundance of American plaice, the most abundant of four species of flatfish sampled with the survey, was significantly higher in 1999 than any other year. In 1997, American plaice catch rates increased but distribution was mostly restricted to the inshore, whereas in 1998 distribution extended onto the southern Grand Bank. In 1999 distribution (Figure 14, left) increased again to ~40% compared to 21% in 1998. Over all years mean catch rate inshore was significantly higher than all other areas. Abundance was lowest on the northern portions of the NE Shelf. Lowest catch rate occurred in 1996. Lengths ranged from ~17 - 60mm in a uni-modal length distribution.

Total catch of turbot in 1999 was 46 compared to only 18 in 1998. Catch rate in 1995 was significantly higher than the other years of which 1999 ranked 2nd in abundance. Highest catch rates in 1999 occurred at several locations on the NE shelf and, consistent with previous years, were sporadic inshore, and on the southern Grand Banks (Figure 14, right). Over the 6 years, mean catch rate on BIBI was significantly higher than all other areas. As in 1998 lengths were distributed mostly in a single mode (~52 - 88mm), as opposed to 1997 when 2 modes were observed.

With a total catch of only 76 fish in 1999 abundance of witch flounder was higher than any previous year, except 1998. They occurred around Notre Dame Bay as well as on the southern Grand Bank but were most numerous around the southern Avalon Peninsula (Figure 15, left panel). The model explained only 18% of variability in catch rate (Table 1). The model indicated that the area effect was significant (P=0.0053), but the GT2 test indicated no area difference in catch rate. The southern Grand Bank ranked highest followed by the inshore, with BIBI ranking last. Sizes of witch flounder ranged from ~23 - 71mm and there was no difference in day and night catches.

Over the six years of the survey extremely low numbers of yellowtail flounder have been taken. In 1999 only 18 were taken compared to four juveniles taken at 2 stations on the southern Grand Bank in 1998. The model explained only 6% of variability (Table 1) 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 1999 ranked second behind 1996.

Considering all areas, there was a decline in abundance of 5 components of the pelagic ecosystem (Figure 16) from 1994 to 1996 in the case of American plaice and cod. The decline continued to 1997 in the case of Arctic cod, sand lance and redfish. Since these minima all except Arctic cod have increased in abundance by approximately 2 orders of magnitude, representing a system response across species lines and is consistent with Arctic species being replaced by more temperate species. Annual variation in catch rates of capelin, the dominant species in recent years, indicates a peak in 1997 (Figure 17). This ranking differs somewhat from that resulting from the analysis of variance, which is based on the mean of the individual $\log_{10}$ (catch rates) and ranks 1999 as highest but not significantly higher than 1997. Using either set of values catch rate in 1999 and 1997 were relatively high compared to 1998, which is not consistent with the trends in abundance of the other species.

The trend towards increasing abundance in recent years is particularly noteworthy when considering the Grand Banks only (Figure 18). Since minima in 1997 all species have shown one to two orders of magnitude increases. The largest increases in abundance since 1997 have been in redfish. Haddock, which was not observed in any year until 1998, is the only species except Arctic cod, which ranked lower in abundance in 1999 than in 1998.

Not only did these species increase in mean catch rate in recent years, there was a corresponding increase in geographic range as measured by percent occurrence (Figure 19). Both sand lance and redfish increased in range in 1995 but decreased in 1996. Since 1996 all species (except capelin) has increased from ~ 10 –20 % to ~40 –60% of stations sampled. Capelin also increased its distribution in recent years but its minimum was ~ 40% in 1996.

Six taxa represent major nekton components on the Northeast Newfoundland Shelf. Spatial patterns of these groups on the shelf have been identified from previous surveys (Dalley et. al 1999). Blennies, sculpins and seasnails were more confined to the inner shelf waters whereas wolffish were predominant over the offshore banks. Squid were more abundant in the northern portions, whereas alligatorfish tended to be more abundant over the southern portions of the NE shelf.

As in previous years shannies and blennies were mostly restricted to the northern portion of the survey area with highest catch near the Labrador coast and occurring in the northern bays (Figure 20, left). Overall catch rate ranked second in 1999 and was not significantly different from the two most recent years, which were generally higher than in earlier years. Occurrence increased from 26 to 48% from last year. Abundance over the 6 years was significantly higher in the inner NE shelf (ISS and ISN) than the other 5 areas. Catch rates on offshore NE Shelf (FIBI and BIBI) were not significantly higher than the inshore. The group is made up of several species and, as in previous years, displays a multi-modal length distribution (ranging from ~ 25 - 120mm).

In 1999 catch rate of sculpins increased significantly over 1998 and was not significantly different from 1997 or 1996. Distribution (Figure 20, right) was similar to other recent years being mostly restricted to the area north of the Grand Bank, but with sporadic low catches occurring on the bank. Over 6 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. Lengths ranged mainly from approximately ~28 - 60mm with some specimens ranging over 100mm. The length distribution was mainly uni-modal despite the number of species occurring in the group.

Pelagic squid (numerous unidentified species) are the most widely distributed group in 1999, occurring in 74.4% of all sets (Figure 21, left). Catch rate increased slightly in 1999 following a sharp decrease in 1998. They were distributed from north to south throughout the survey area with highest catch occurring on the north and outer portion of the NE shelf. There was a distinct distribution with low catch rates on the southern Grand Bank. Over the 6 years mean catch rate of squid was significantly higher on ISN and BIBI. The inshore and the Grand Banks had significantly lower catch rates than the other 4 areas. Overall mean catch rate in 1999 ranked third, not significantly different from any other year except 1995, which ranked highest but was not significantly higher than 1997.

Several species of seasnails of the family Liparidae were also mainly distributed in the northern half of the survey area (Figure 21, right). In 1999 seasnails were more abundant than 1998 when only 1/5 the number were taken as in 1997. Distribution on the NE shelf continues to be less continuous than in 1997. Highest catch rates occurred near the coast of southern Labrador and in White Bay. Sporadic low catches were taken on the Grand Banks. Considering all years, catch rates on the northern inner NE shelf (ISN) were significantly higher than all other areas. 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, as observed in previous years.

Alligatorfish ranked second behind the squid group, in terms of extent of distribution, occurring in ~65% of all sets in 1999. Alligatorfish (3 species of Family Agonidae), (Figure 22, left panel) was most abundant on the southern portion of the NE shelf. This was similar to the 1997 distribution when highest catch rates occurred further offshore than near the coast. There was a distinct distribution of lower catches on the southern Grand Bank. Mean catch rate in 1999 ranked 5th ahead of than 1998, but there was no overall difference in years. 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 inner northern portion (ISN), which was similar to the inshore. Catch rate on the Grand Banks was sporadic. Length of alligatorfish in 1999 ranged, in a unimodal distribution, from ~35 - 50mm.

Highest catch rates of wolffish, constituting 2-3 species of Anarhichus, occurred on the Funk Isle Bank area again in 1999, with negligible catches on the Grand Bank (Figure 22, right). Over all years Funk Isle Bank ranked highest, and was significantly higher than all others except BIBI. The inner southern portion of the NE Shelf ranked third and was not lower than BIBI. Over the 6 years wolffish abundance ranked highest in 1999 but was significantly greater than 1995 only. Lengths of wolffish ranged from ~55 -100mm with at least 2 modes in the length frequency distribution.

Of the six northern taxa annual variation in abundance of squid, sculpins and seasnails is greater than that of alligatorfish, blennies and wolffish, which have not had a strong annual effect (Figure 23). Combined, the overall abundance of these groups remained relatively high for the first four years but decreased sharply in 1998 and remained relatively low in 1999. This is in contrast to trends in abundance for other species, particularly more southern ones, which have increased in abundance, particularly the 2 most recent years.

Summary

The overall ANOVA model indicated significant ($P<0.0001$) spatial and annual effects in all variables examined during in 1999 (Table 1). The partial F-value attributable to area was significant ($P<0.05$) for all variables, except haddock ($P<0.1137$), which occurred in the two most recent years only. Annual variation, generally lower, was also significant ($P<0.05$) in all but 1 variable, yellowtail flounder, which has been low in abundance all years.

Temperature, which has been increasing throughout the period of the surveys, showed similar patterns to other years with a cline of warmer water to the south of the survey area, and slightly warmer temperatures inshore. Oceanographic conditions have undergone a period of warming during the period of the surveys (Colbourne 2000).

The mean total zooplankton biomass remained relatively high following a trend of increasing biomass during the first 4 surveys. Mean biomass of the largest size fraction ranked second lowest in 1999, but was not significantly less than any higher-ranking year, except 1995. Mean biomass of the mid-size zooplankton ranked highest, and has shown a steady increase in mean biomass over the time period. Biomass of the smallest size fraction in 1999 ranked second overall but after undergoing significant increases in biomass in 1997 has maintained a level, that is higher than the first 3 years.

Mean catch rate of capelin larvae ranked third highest in 1999. For the second year in succession capelin larvae occurred on the Southeast Shoal of the Grand Bank but catch rates were lower than in 1998.

For the second year in succession total nekton biomass, with jellyfish, was significantly greater than any previous year. As in 1998 highest biomass of jellyfish occurred inshore and on the northern Grand Bank. Without jellyfish, which were particularly abundant the two most recent years, nekton biomass in 1999 was significantly greater than all other years, except

1998. Nekton biomass in 1999, as it was in 1998, the highest in the time series, with or without jellyfish.

Nekton was dominated by capelin and sand lance, both of which were relatively abundant in 1999. Highest catch rates of capelin occurred inshore, with ISS ranking second. Highest catch rates of sand launce occurred on the northern as opposed to the southern Grand Bank.

Mean catch rate of pelagic 0-group Arctic cod decreased after the first year of the survey. In 1999, with diel adjustments, mean catch rate ranked significantly lower than 1994 but was not significantly different from any other year, indicating a fairly stable abundance in recent years. (Without diel adjustments, catch rate of Arctic cod ranked fourth below the first three years and slightly above the 2 most recent).

Mean catch rate of pelagic 0-group Atlantic cod increased for the third year in succession. Catches increased slightly in 1997 over 1996. Increase in 1998 over 1997 was due to higher catches on the Grand Bank, particularly the southern portion. In 1999 significantly higher catch rates were mostly attributable to increased catch rate inshore, and as a result of increased catch rate on the northern Grand banks. Highest increases in catch rate of cod in 1999 occurred in the inshore, and abundance of cod decreased compared to 1998 on the southern Grand Bank. Mean catch rate of cod on the Northern Grand Bank increased in 1999 compared to 1998.

In 1998 overall abundance of 6 northern taxa decreased sharply compared to 1997. In 1999 abundance of all six again was slightly higher than their 1998 levels but well below a level that was maintained during the first four years.

Catch rates of all nekton measures, except Arctic cod and haddock, ranked higher (5 were statistically higher) in 1999 than 1998.

Relatively low abundances of several Grand Bank species (e.g. sand lance, haddock and hake) occurred in 1997, but increased again in 1998 (Dalley et al. 1999). In 1998 a significant increase (13x) in catch rate of sand lance was a result of high abundances on the Grand Bank. Catch rates increased again in 1999, largely as a result of higher abundances on the northern Grand Bank as opposed to the southern portion. Hake, which are mainly restricted to the southern Grand Bank, were significantly more abundant in 1999 than any previous year. Redfish, which increased in distribution and abundance in 1999, had highest catch rates on the southern Grand Bank. Pelagic 0-group haddock, which were observed for the first time in the survey in 1998, were present, but are the only southern group which was less abundant in 1999, than in 1998.

Pelagic 0-group American plaice, which have been observed on the Grand Bank in previous years, but restricted to the inshore in 1997 were more abundant in 1999 than any previous year due to increased catches inshore and an expanded range, particularly the northern Grand Bank.

Three flatfish species remained relatively low in abundance, but increased compared to 1998. Pelagic 0-group yellowtail ranked second in 1999, and witch ranked highest being significantly greater than all other years except 1998. Turbot ranked third and was not different than any other year except 1995, which was higher than all others.

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 A. Murphy, E. McDonald, G. Redmond, D. Fiander and P. Eustace are thanked for their assistance in carrying out the sampling program.

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Table 1. Results of analysis of variance carried out on variables measured during the 1994-1999 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
^{o}C 0m	7.2	18.0	0.82	66.96 (.0001)	337.25 (.0001)	33.69 (.0001)	11.26 (.0001)
^{o}C 50m	-1.3	3.1	0.49	13.82 (.0001)	63.64 (.0001)	16.49 (.0001)	3.01 (.0001)
Zootot	289.3	6452.7	0.51	15.31 (.0001)	80.23 (.0001)	8.09 (.0001)	1.84 (.0044)
Zoo >2	163.9	2296.2	0.41	9.91 (.0001)	50.37 (.0001)	3.40 (.0049)	2.04 (.0010)
Zoo 1-2	37.1	3513.6	0.62	23.23 (.0001)	143.32 (.0001)	2.26 (.0472)	1.84 (.0045)
Zoo <1	78.5	3129.5	0.62	23.41 (.0001)	48.61 (.0001)	77.52 (.0001)	2.77 (.0001)
Nekton1 with	10.3	380.8	0.42	10.45 (.0001)	23.45 (.0001)	19.23 (.0001)	3.76 (.0001)
Nekton2 w/0	9.2	210.7	0.27	5.48 (.0001)	17.75 (.0001)	7.09 (.0001)	1.63 (.0313)
Capelin	0	1940.7	0.25	5.00 (.0001)	18.40 (.0001)	2.27 (.0463)	2.29 (.0001)
Sand lance	0	169.9	0.34	7.45 (.0001)	22.35 (.0001)	5.88 (.0027)	3.38 (.0001)
Atlantic cod	0	9.2	0.53	16.48 (.0001)	32.38 (.0001)	19.69 (.0001)	8.52 (.0027)
Arctic cod	0	65.9	0.50	14.72 (.0001)	74.85 (.0001)	15.43 (.0001)	3.68 (.0001)
Redfish	0	49.8	0.26	5.14 (.0001)	13.03 (.0001)	6.26 (.0001)	2.87 (.0001)

Table 1. (con't)

Dependent variable	Min. mean	Max. mean	r^2	Overall F-value /(Prob.)	Partial F area / (Prob.)	Partial F year / (Prob.)	Interaction factor
Hake	0	2.6	0.26	5.10 (.0001)	8.91 (.0001)	2.96 (.0119)	4.19 (.0001)
Haddock	0	0.2	0.16	2.75 (.0001)	2.58 (.1137)	3.28 (.0063)	2.00 (.0014)
Blennies	0	7.8	0.36	8.06 (.0001)	25.87 (.0001)	12.84 (.0001)	3.57 (.0001)
Sculpins	0	18.9	0.46	12.25 (.0001)	44.07 (.0001)	18.48 (.0001)	4.68 (.0001)
Squid	0.02	22.2	0.49	13.82 (.0001)	59.80 (.0001)	9.90 (.0001)	4.40 (.0001)
Seasnail	0	7.3	0.41	10.10 (.0001)	31.81 (.0001)	28.43 (.0001)	4.40 (.0001)
A.plaice	0	2.4	0.41	10.22 (.0001)	14.08 (.0001)	9.68 (.0001)	6.39 (.0001)
Turbot	0	0.7	0.37	8.45 (.0001)	28.02 (.0001)	21.41 (.0001)	4.26 (.0001)
Alligatorfish	.01	2.0	0.37	8.61 (.0001)	44.22 (.0001)	2.92 (.0130)	2.85 (.0001)
Wolffish	0	0.5	0.27	5.45 (.0001)	21.83 (.0001)	3.64 (.0030)	2.40 (.0001)
Witch	0	0.1	0.18	3.10 (.0001)	2.16 (.0448)	3.36 (.0053)	2.60 (.0001)
Yellowtail	0	0.1	0.06	3.92 (.0001)	6.47 (.0001)	0.87 (.4994)	NS
Lumpfish	0	0.4	0.19	3.44 (.0001)	9.71 (.0001)	6.55 (.4994)	1.76 (.0078)
Capelin larvae*	0	770.3	0.56	73.55 (.0001)	133.01 (.0001)	5.39 (.0001)	NS

Table 2. Results of analysis of variance of mean day and night catch rates of biological variables examined during the 1999 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 day catches where differences are statistically significant (P<0.05).

Dependent Variable	Day mean	Night Mean	Partial F-value	Probability	Night/Day Ratio
Zoo(all)	2288.98	3223.87	1.78	0.1855	
Zoo(Large)	408.72	910.18	12.39	0.0006	2.23
Zoo(mid)	615.59	1172.45	5.53	0.0205	1.91
Zoo(small)	1264.67	1141.24	0.46	0.5012	
Nekton1	58.99	184.52	16.72	0.0001	3.13
Nekton2	18.58	102.79	27.98	0.0001	5.53
Alligatorfish	0.379	0.45	2.3	0.1327	
American plaice	0.126	0.702	4.24	0.0422	5.57
Arctic cod	1.528	3.563	5.21	0.0246	2.33
Atlantic cod	0.293	2.476	11.03	0.0012	8.45
Blennies	0.08	1.144	24.94	0.0001	14.30
Capelin	3.07	94.55	14.16	0.0001	30.80
Haddock	0.002	0.008	2.72	0.1019	
Hake	0.814	0.056	1.59	0.2105	
Redfish	14.136	3.379	1.04	0.3091	
Sand launce	4.681	39.889	7	0.0094	8.52
Sculpins	0.173	0.527	16.55	0.0001	3.05
Seasnails	0.087	0.278	10.39	0.0017	3.20
Squid	0.708	1.652	13.36	0.0004	2.33
Turbot	0.007	0.034	6.06	0.0156	4.86
Witch Flounder	0.044	0.029	1.3	0.2571	
Wolffish	0.014	0.119	35.37	0.0001	8.50
Yellowtail	0	0.21	1.94	0.1667	

Table 3. Relative occurrence and abundance of dominant fish species caught in the IYGPT during the pelagic 0-group survey in 1999.

Species	**Scientific Name**	**No. Caught**	**Relative Abundance(%)**	**Incidence(%)**
Capelin	Mallotus villosus	73205	54.1	61.2
Sand lance	Ammodytes sp.	28619	21.2	47.3
Redfish	Sebastes sp.	18967	14.0	58.1
Arctic cod	Boreogadus saida	3918	2.9	56.6
Squid	Cephalopoda	2816	2.1	74.4
Atlantic cod	Gadus morhua	2164	1.6	54.3
Sculpins	Cottidae	1029	0.8	51.9
Hake	Urophysis	1001	0.7	19.4
Shannies Blennies	Stichaeidae	940	0.7	41.4
Alligatorfish	Agonidae	688	0.5	65.2
American plaice	H. platessoides	668	0.5	39.5
Lanternfish	Myctophidae	397	0.3	2.3
Seasnails	Liparus sp.	317	0.2	36.4
Lumpfish	Cyclopterus lumpus	125	0.1	29.5
Wolffish	Anarhichus sp.	120	<0.1	21.7
Witch flounder	G. cynoglossus	76	<0.1	18.6
Greenland halibut	R. hippoglossoides	46	<0.1	17.1
Herring	Clupea harengus	37	<0.1	3.1
Yellowtail	Limanda ferruginea	18	<0.1	2.3
Haddock	M. aeglefinus	10	<0.01	5.4

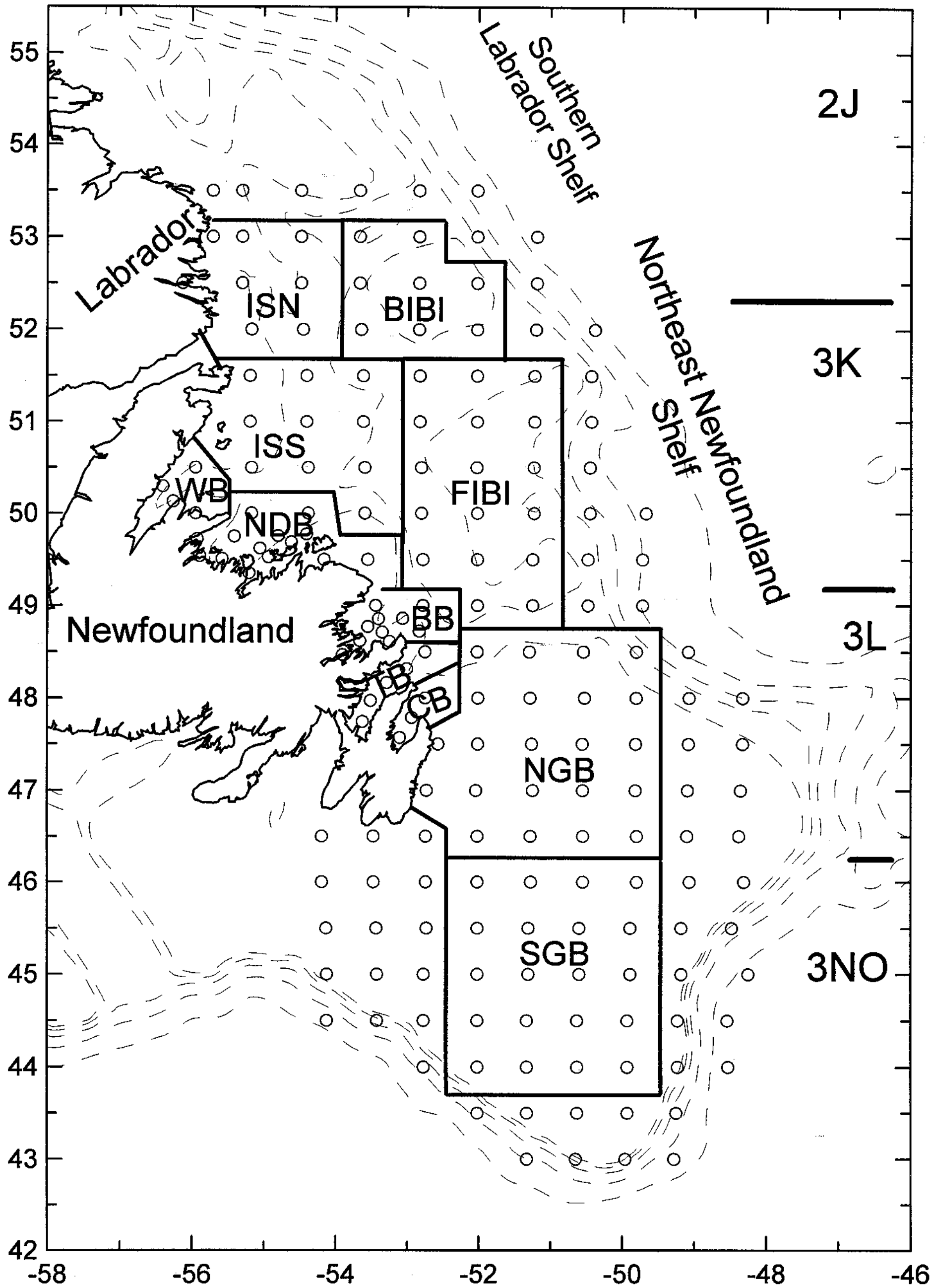

Figure 1. Survey area showing stations sampled during the 1999 pelagic 0-group survey on the southern Labrador Shelf, Northeast Newfoundland Shelf, and Grand Banks. Each of the seven subareas is indicated. (ISN = inner shelf, northern; BIBI = Belle Isle Bank; ISS = inner shelf, southern; FIBI = Funk Isle Bank; INSH = inshore; NGB = Northern Grand Bank; SGB = Southern Grand Bank)

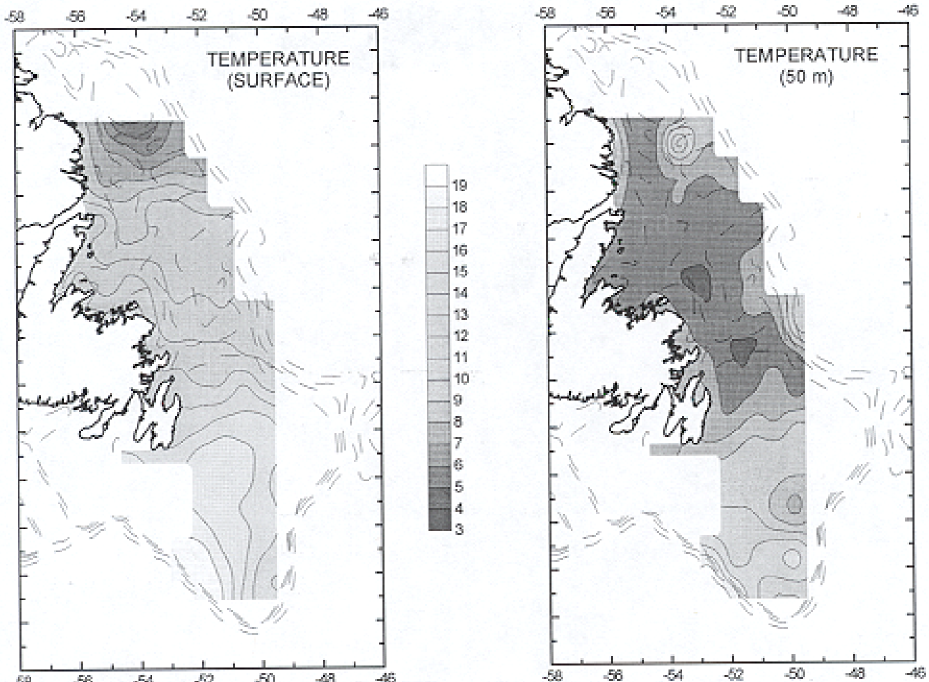

Figure 2. Distribution of surface temperature (^{O}C), left panel, and temperature at 50m, during 1999 the pelagic 0-group survey in NAFO Divisions 2J3KLNO.

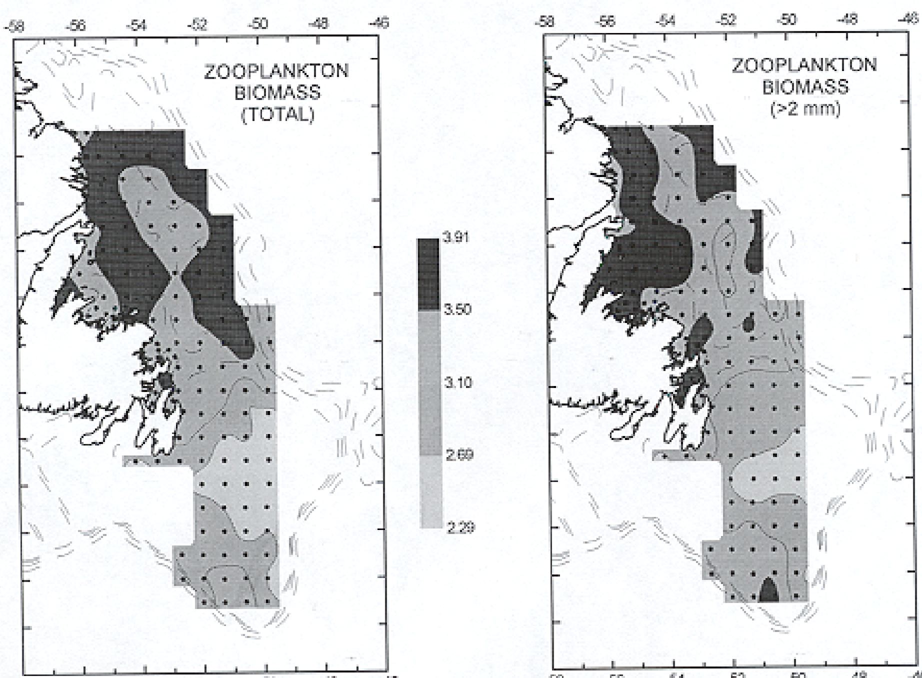

Figure 3. Distribution of total invertebrate zooplankton biomass (mgDW/m^2), left panel, and the >2mm size fraction, caught in the bongos during the 1999 pelagic 0-group survey in NAFO Divisions 2J3KLNO.

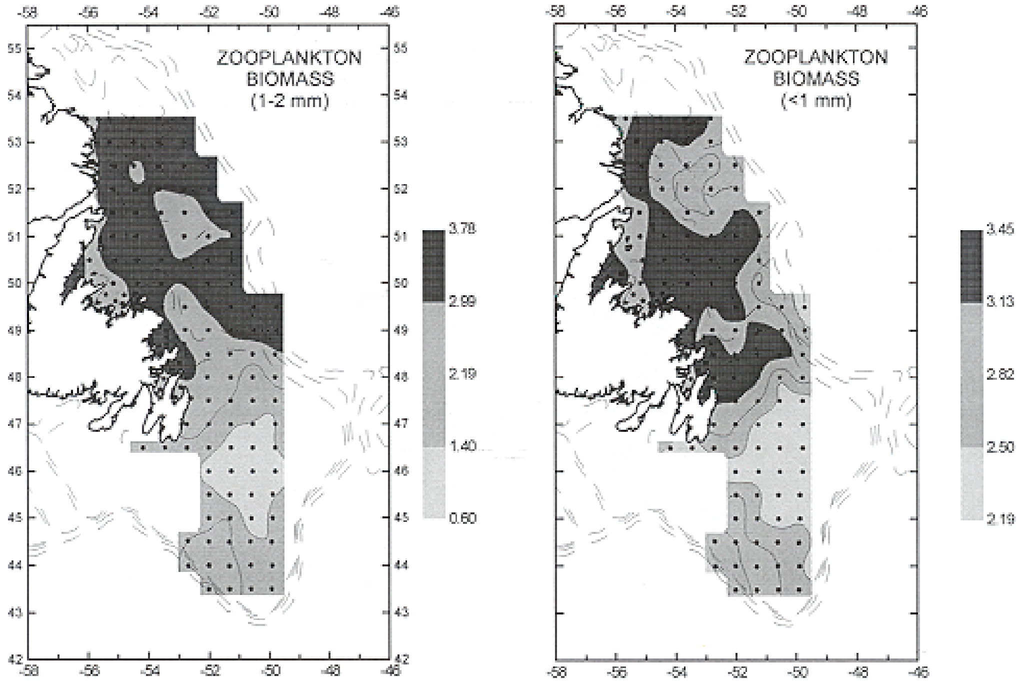

Figure 4. Distribution of the 1-2mm size fraction of invertebrate zooplankton biomass (mgDW/m^2), left panel, and the <1mm size fraction, right panel, caught in the bongos during the 1999 pelagic 0-group survey in NAFO Divisions 2J3KLNO.

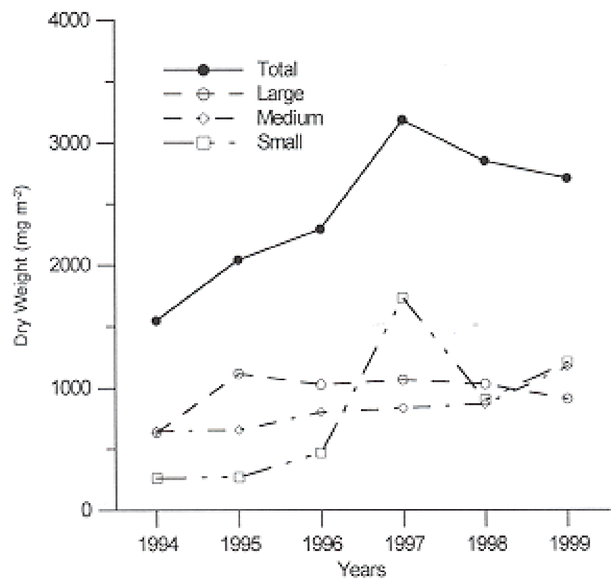

Figure 5. Annual variation in mean zooplankton biomass (total and three size fractions) measured during pelagic 0-group surveys in NAFO Divisions 2J3KLNO, 1994 – 1999.

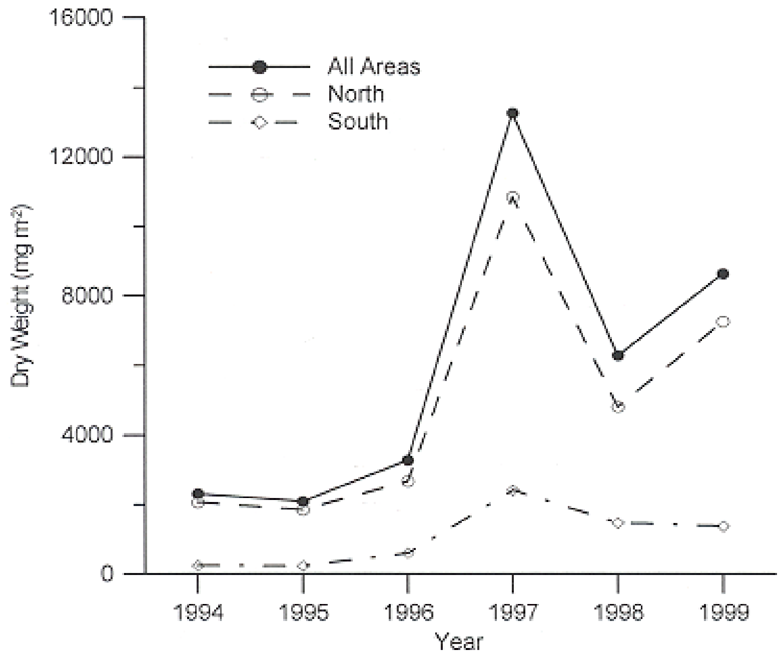

Figure 6. Comparison of small zooplankton biomass in north and south portions of the area surveyed during annual pelagic 0-group surveys carried out in NAFO Divisions 2J3KLNO, 1994 – 1999.

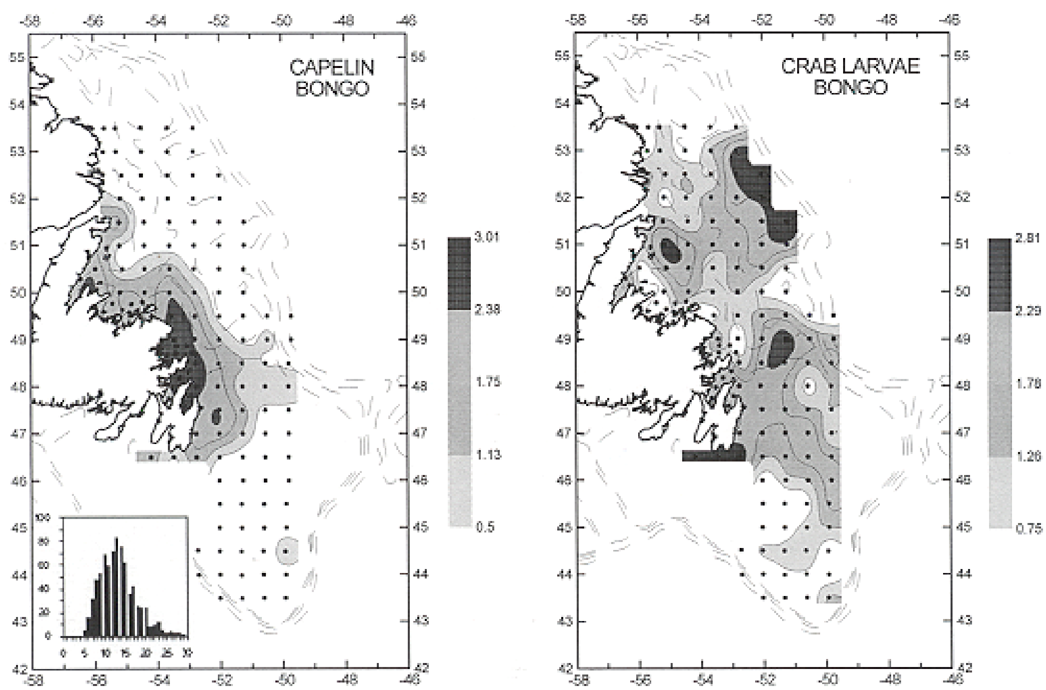

Figure 7. Distribution of capelin larvae ($\log_{10}$ number $10^3/m^3$), left panel, and crab larvae, right panel, from the bongos during the 1999 pelagic 0-group survey in NAFO Divisions 2J3KLNO.

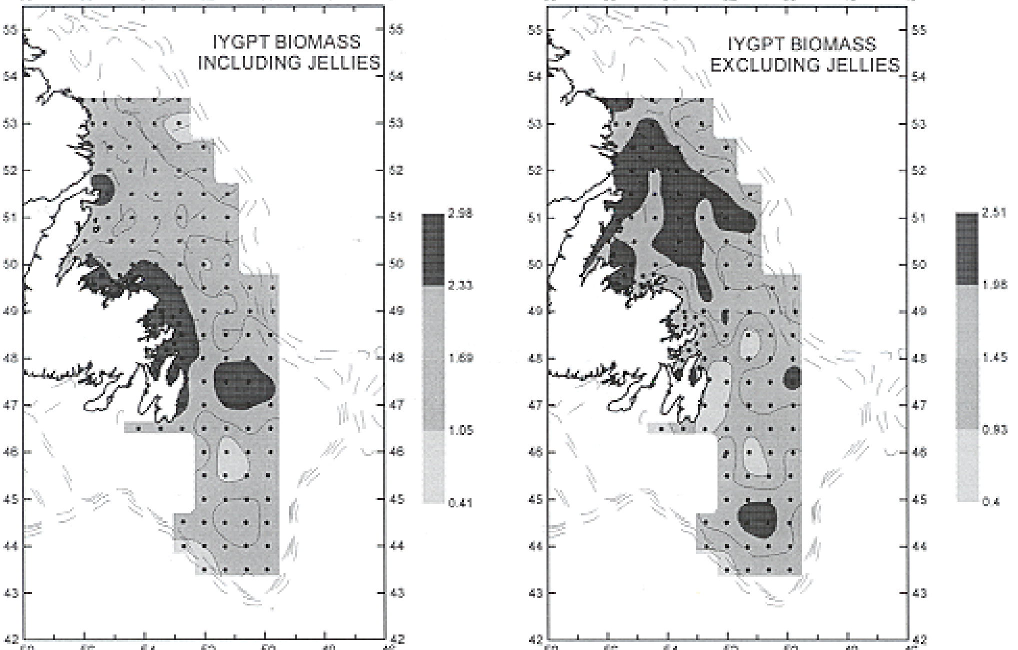

Figure 8. Distribution of total nekton biomass (kgWW/m^3) with jellyfish, left panel, and without jellyfish, right panel, from the IYGPT during the 1999 pelagic 0-group survey in NAFO Divisions 2J3KLNO.

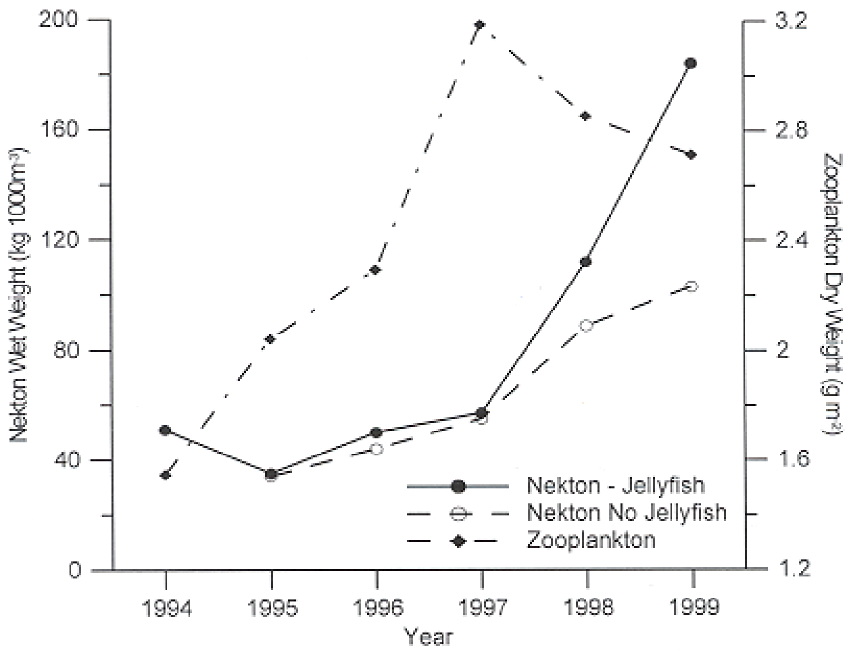

Figure 9. Comparison of annual variation in total zooplankton and total nekton biomass measured during pelagic 0-group surveys carried out in NAFO Divisions 2J3KLNO, 1994 – 1999.

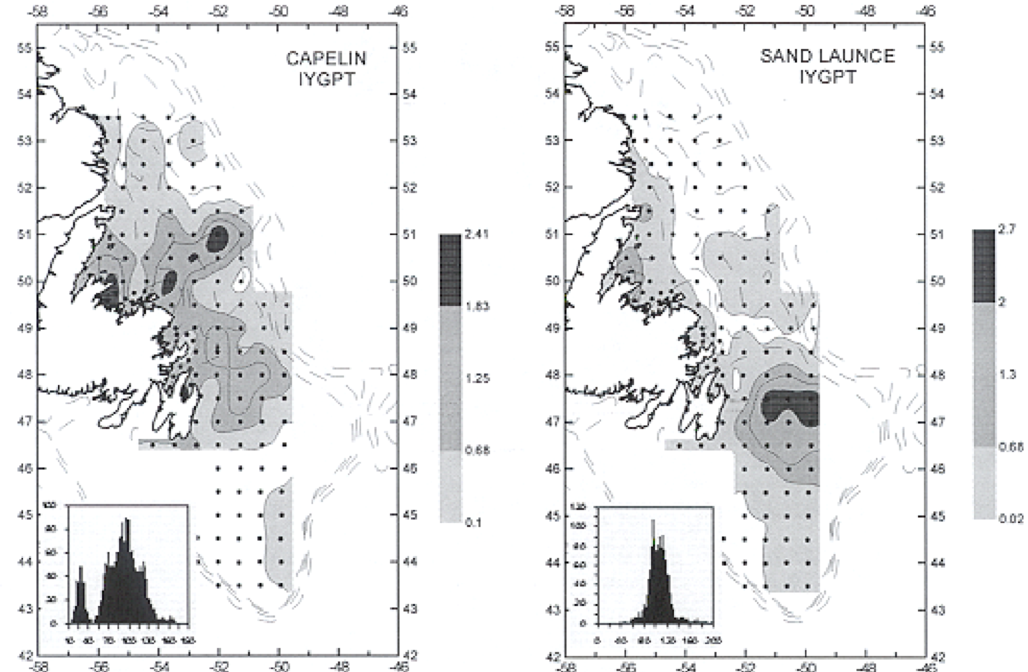

Figure 10. Distribution of capelin ($\log_{10}$ number $10^4/m^3$), left panel, and sand lance, right panel, from the IYGPT during the 1999 pelagic 0-group survey in NAFO Divisions 2J3KLNO. Length frequency distribution (mm) is shown on bottom left of each panel.

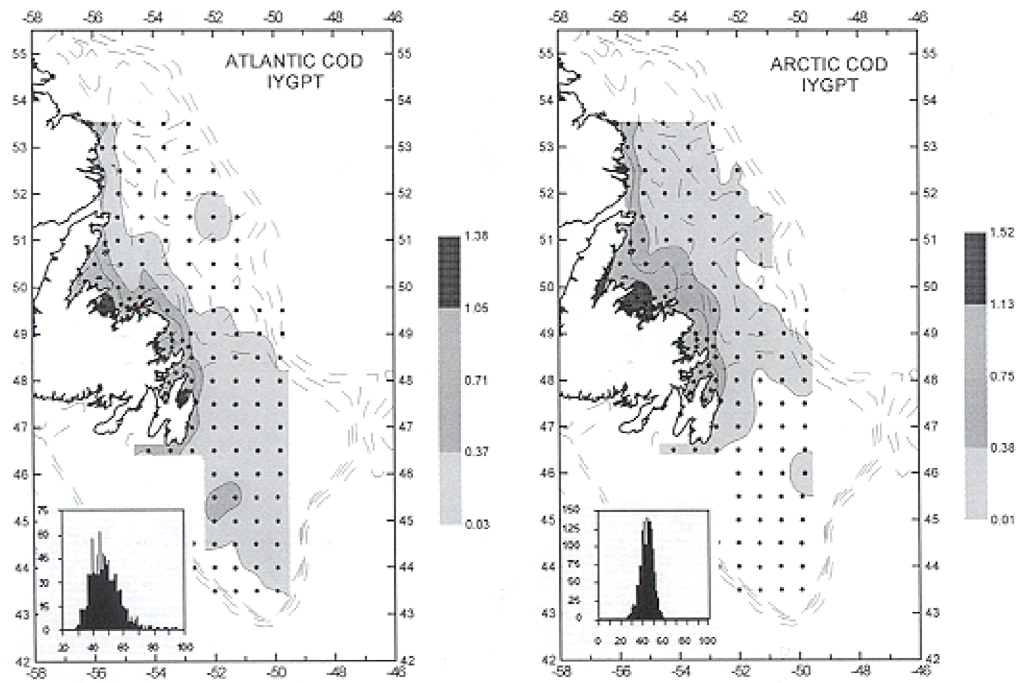

Figure 11. Distribution of pelagic 0-group cod ($\log_{10}$ number $10^4/m^3$), left panel, and Arctic cod, right panel, from the IYGPT during the 1999 pelagic 0-group survey in NAFO Divisions 2J3KLNO. Length frequency distribution (mm) is shown on bottom left of each panel.

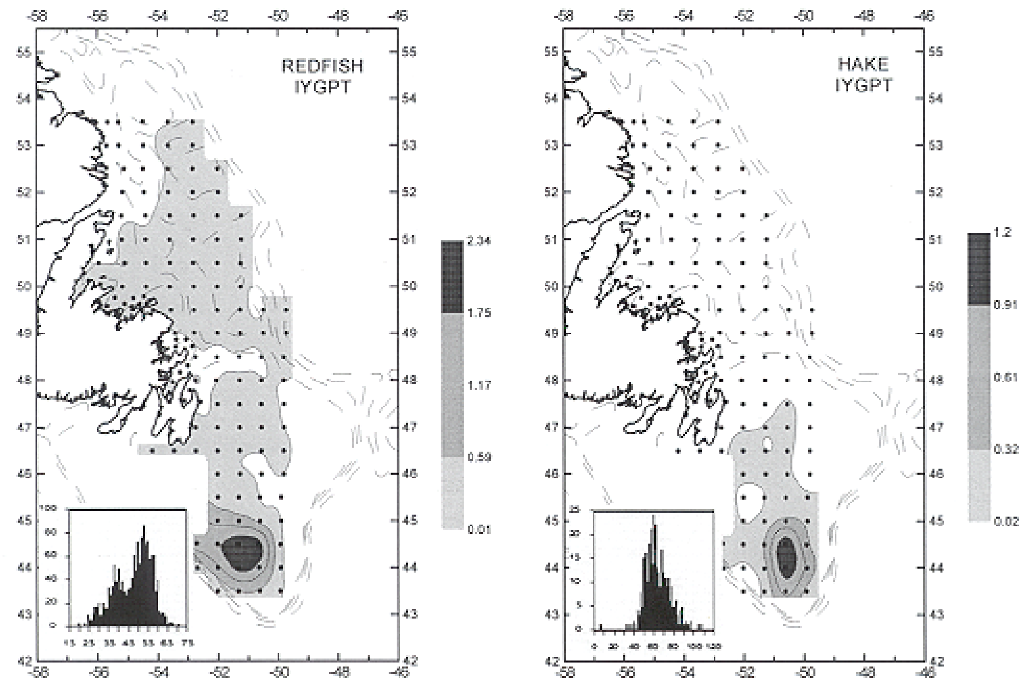

Figure 12. Distribution of redfish ($\log_{10}$ number $10^4/m^3$), left panel, and hake, right panel, from the IYGPT during the 1999 pelagic 0-group survey in NAFO Divisions 2J3KLNO. Length frequency distribution (mm) is shown on bottom left of each panel.

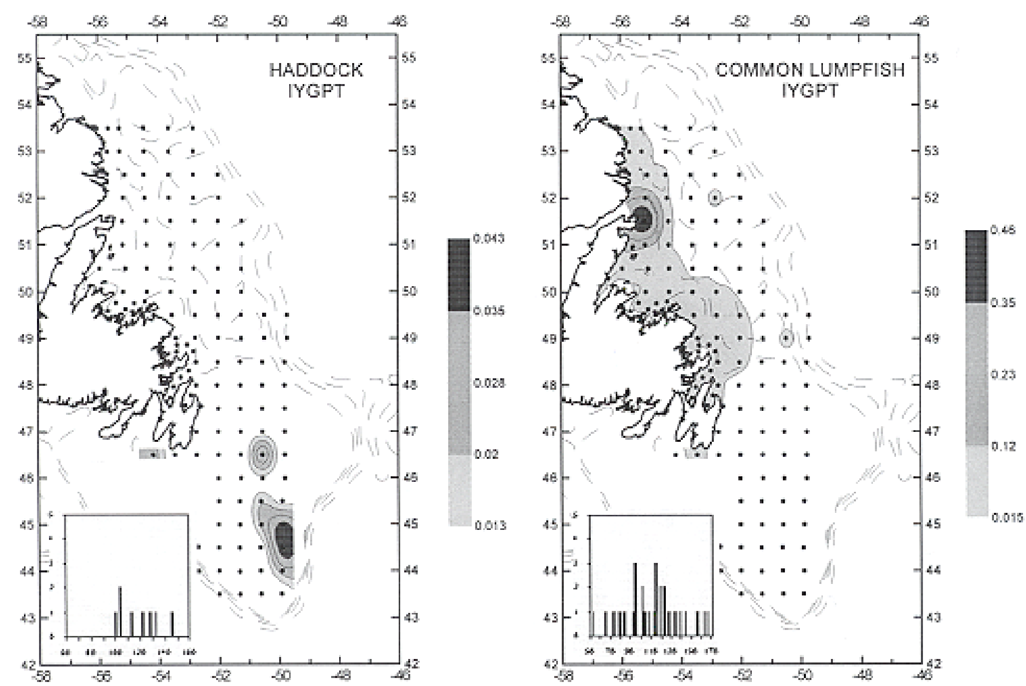

Figure 13. Distribution of haddock ($\log_{10}$ number $10^4/m^3$), left panel, and lumpfish, right panel, from the IYGPT during the 1999 pelagic 0-group survey in NAFO Divisions 2J3KLNO. Length frequency distribution (mm) is shown on bottom left of each panel.

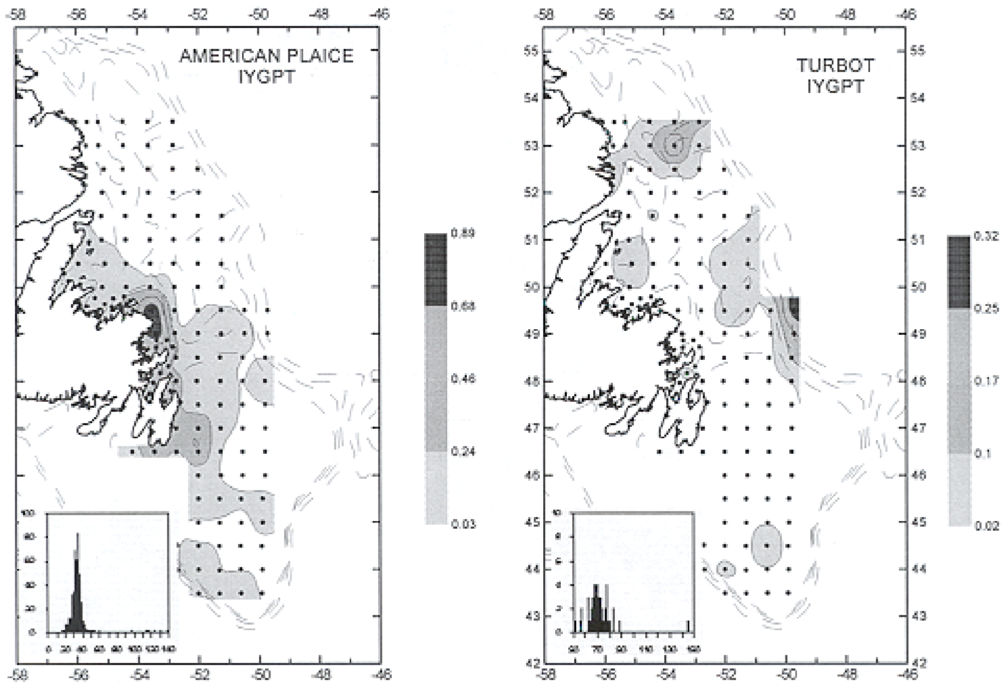

Figure 14. Distribution of American plaice ($\log_{10}$ number $10^4/m^3$), left panel, and turbot, right panel, from the IYGPT during the 1999 pelagic 0-group survey in NAFO Divisions 2J3KLNO. Length frequency distribution (mm) is shown on bottom left of each panel.

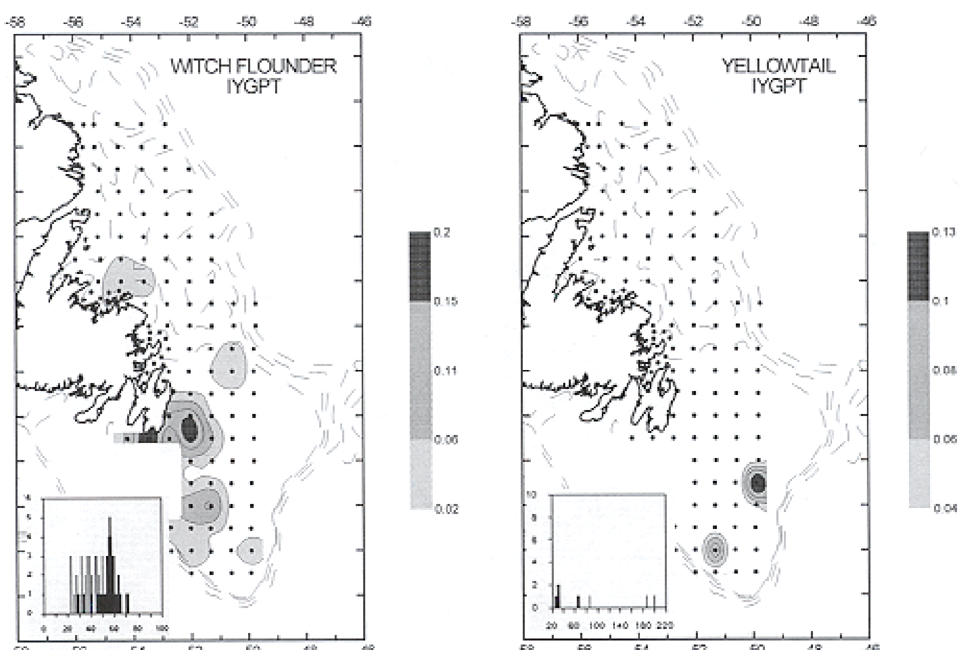

Figure 15. Distribution of witch flounder ($\log_{10}$ number $10^4/m^3$), left panel, and yellowtail, right panel, from the IYGPT during the 1999 pelagic 0-group survey in NAFO Divisions 2J3KLNO. Length frequency distribution (mm) is shown on bottom left of each panel.

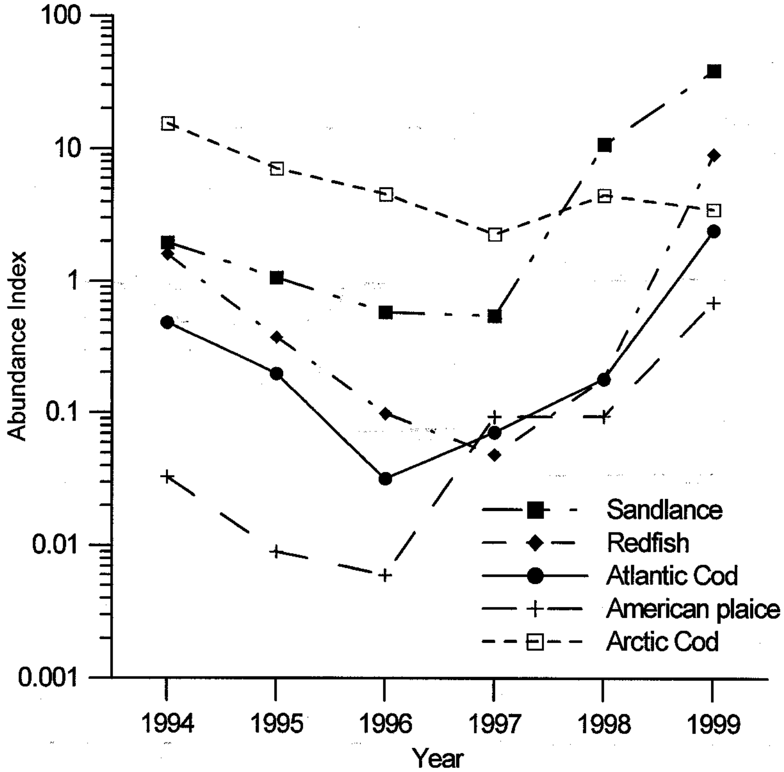

Figure 16. Comparison of abundance indices of 5 species of relatively abundant nekton sampled each year, 1994 – 1999, during pelagic 0-group surveys carried out in NAFO Divisions 2J3KLNO.

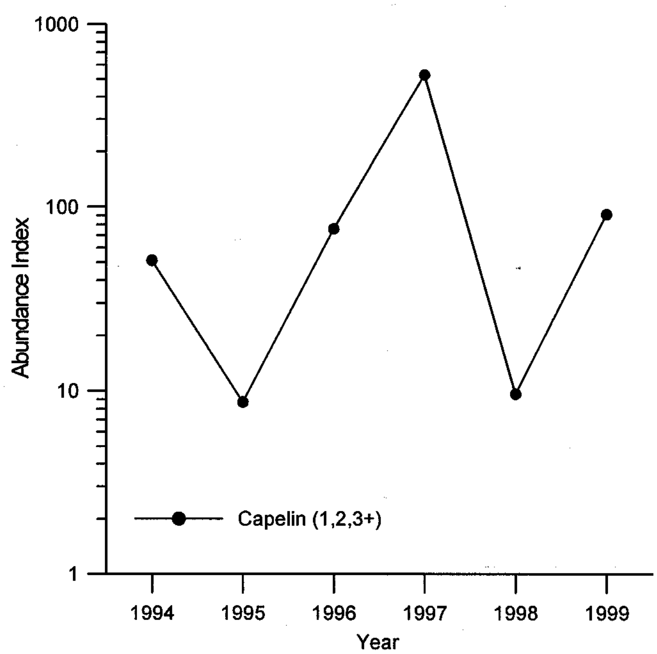

Figure 17. Annual variation in the abundance index of age 1-3 capelin obtained during pelagic 0-group surveys, in NAFO Divisions 2J3KLNO, 1994 – 1999.

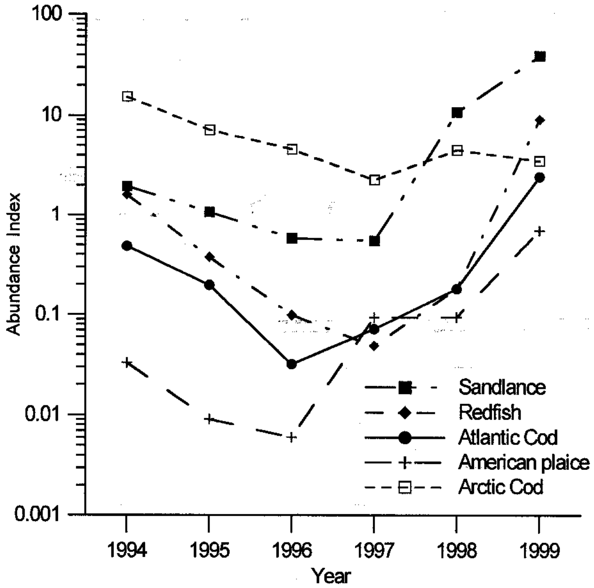

Figure 18. Comparison of annual abundance indices of several common species sampled each year on the Grand Banks during pelagic 0-group surveys carried out 1994 – 1999.

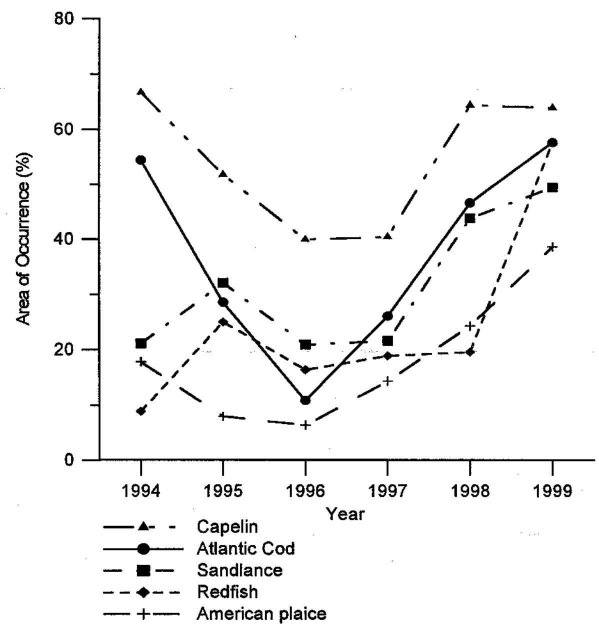

Figure 19. Annual variation in extent of distribution, represented by the percent occurrence, of several species, sampled during pelagic 0-group surveys carried out 1994 – 1999.

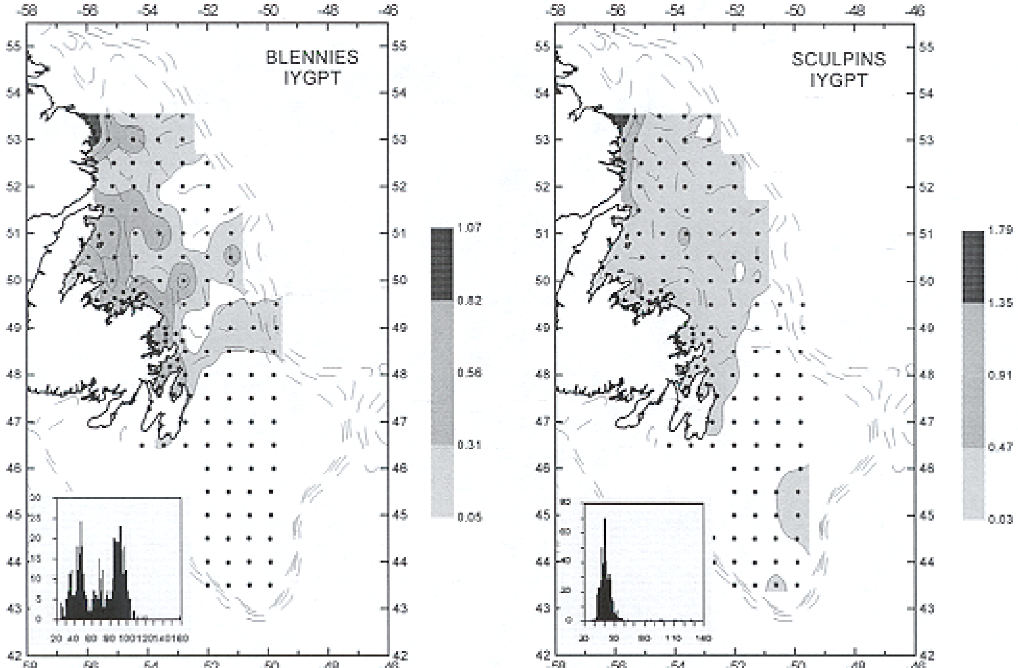

Figure 20. Distribution of blennies ($\log_{10}$ number $10^4/m^3$), left panel, and sculpins, right panel, from the IYGPT during the 1999 pelagic 0-group survey in NAFO Divisions 2J3KLNO. Length frequency distribution (mm) is shown on bottom left of each panel.

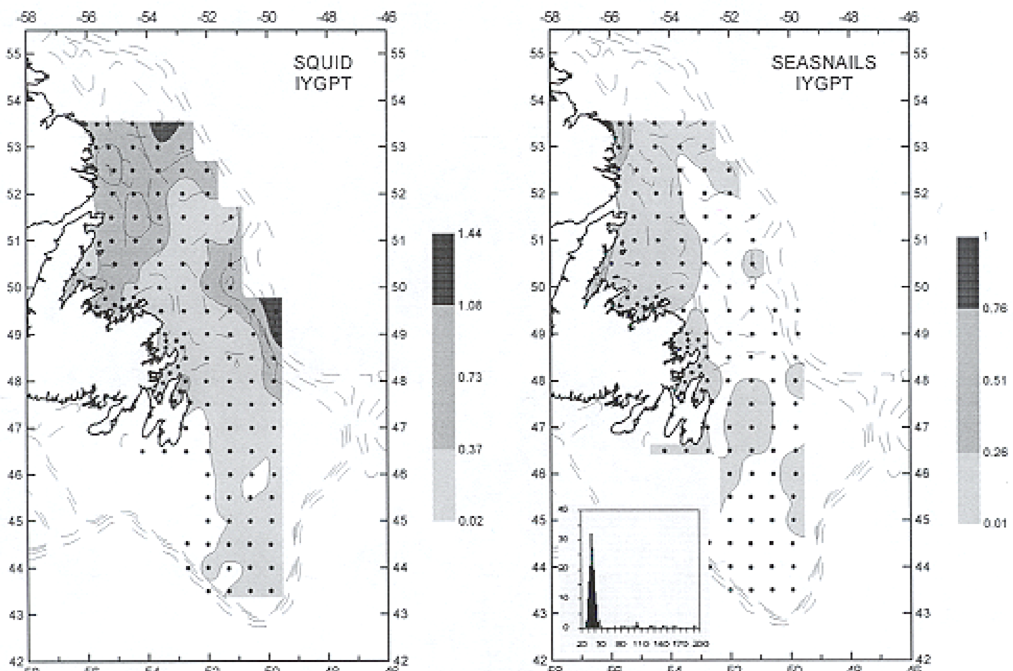

Figure 21. Distribution of squid ($\log_{10}$ number $10^4/m^3$), left panel, and seasnails, right panel, from the IYGPT during the 1999 pelagic 0-group survey in NAFO Divisions 2J3KLNO. Length frequency distribution (mm) is shown on bottom left of each panel.

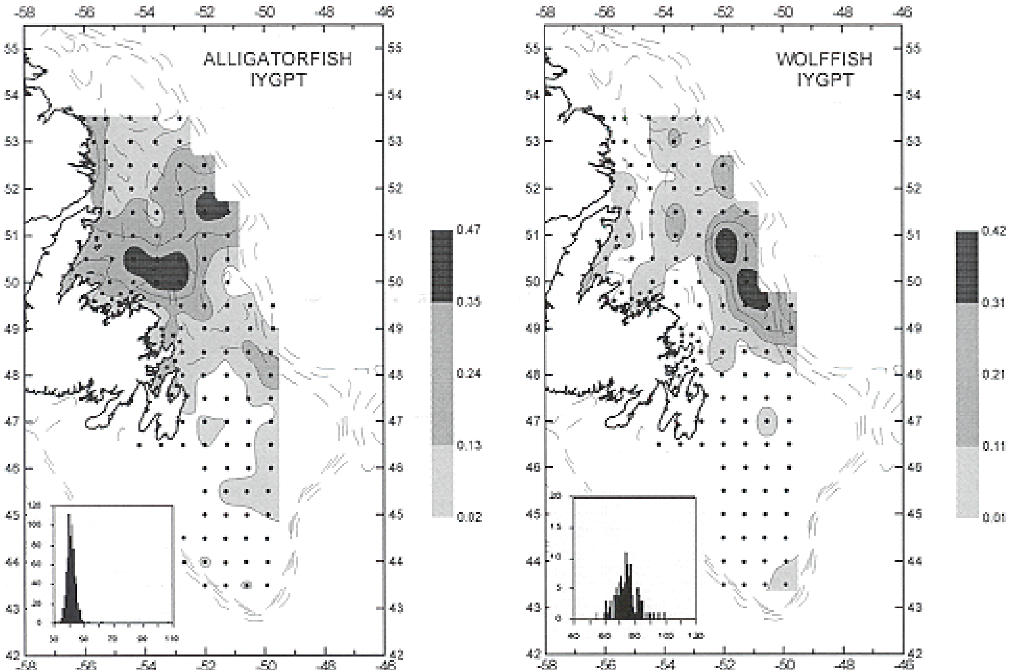

Figure 22. Distribution of alligatorfish ($\log_{10}$ number $10^4/m^3$), left panel, and wolffish, right panel, from the IYGPT during the 1999 pelagic 0-group survey in NAFO Divisions 2J3KLNO. Length frequency distribution (mm) is shown on bottom left of each panel.

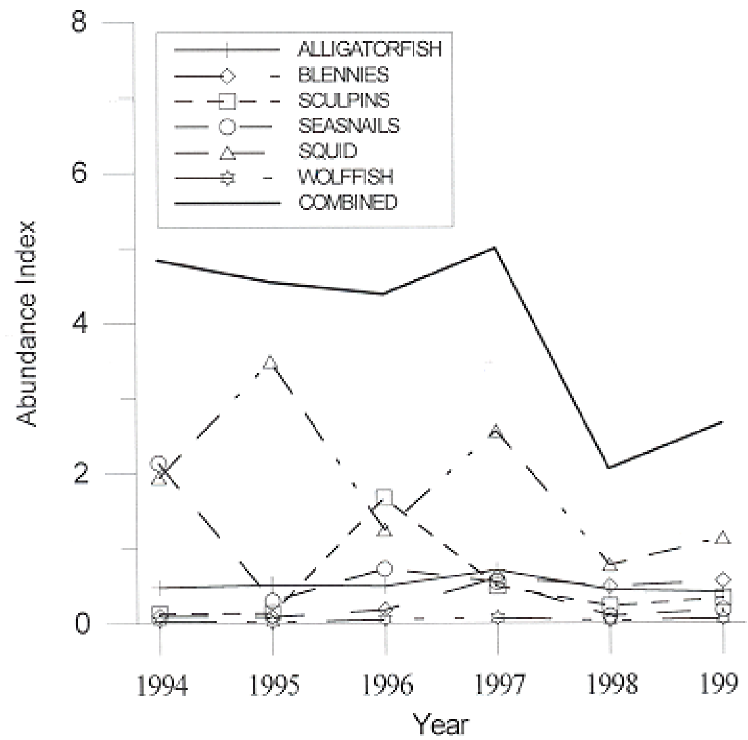

Figure 23. Annual variability in mean catch rate of 6 predominantly northern nekton taxa sampled during pelagic 0-group surveys carried out in NAFO Divisions 2J3KLNO, 1994-1999.

Appendix 1. Results of the Studentized Maximum Modulus test to identify spatial and annual differences in variables examined during 6 annual pelagic 0-group surveys. Ranking is from highest to lowest. Areas and years joined by the same line are not significantly different. Indices of abundance for biological variables have been adjusted for day/night differences, when applicable.

TEMPERATURE (0m)
SGB>NGB>INSH>FIBI>ISS>ISN>BIBI

94>96>98>99>97>95

TEMPERATURE (50m)
SGB>INSH>BIBI>NGB>ISN>FIBI>ISS

95>96>99>98>97>94

TOTAL ZOOPLANKTON
BIBI>ISN>ISS>FIBI>INSH>NGB>SGB

97>98>99>95>96>94

ZOOPLANKTON >2MM
ISN>ISS>BIBI >FIBI>INSH>NGB>SGB

95>97>96>98>99>94

ZOOPLANKTON 1-2MM
BIBI>ISN>ISS>FIBI>INSH>NGB>SGB

99>98>97>96>95>94

ZOOPLANKTON < 1MM
ISS>BIBI>ISN>INSH>FIBI>NGB>SGB

97>99>98>96>95>94

TOTAL NEKTON BIOMASS (Jellies Included)
INSH>ISN>ISS>FIBI>NGB>BIBI>SGB

99>98>97>94>95>96

TOTAL NEKTON BIOMASS (NO JELLYFISH, 95, 96,97 and 98 ONLY)
ISN>ISS>FIBI>BIBI>INSH>SGB>NGB

99>98>97>96>95

CAPELIN
INSH>NGB>ISS>FIBI>ISN>SGB>BIBI

99>96>94>97>95>98

SAND LANCE
NGB>SGB>INSH>ISS>FIBI>ISN>BIBI

99>98>95>94>96>97

HERRING
INSH>ISS>FIBI>ISN>BIBI>NGB>SGB

95>99>96>94>97>98

ATLANTIC COD
INSH>ISS>SGB>NGB>BIBI>ISN>FIBI

99>94>98>95>97>96

ARCTIC COD
INSH>ISN>ISS >BIBI>FIBI>NGB>SGB

94>95>98>99>96>97

REDFISH (SEBASTES)
SGB>FIBI>BIBI>ISS>INSH>NGB>ISN

99>94>95>98>96>97

HAKE
SGB>NGB>ISS>FIBI>INSH>ISN>BIBI

99>96>94>98>97>95

LUMPFISH
ISN>ISS>INSH>FIBI>BIBI>NGB>SGB

99>96>98>97>94>95

BLENNIES (4 SPECIES)
ISN>ISS>INSH>FIBI>BIBI >NGB>SGB

97>99>98>96>94>95

SCULPINS (13 SPECIES)
ISN>ISS>BIBI>INSH>FIBI>SGB>NGB

97>96>99>98>94>95

SQUID (VARIOUS SPP)*
ISN>BIBI>ISS>FIBI>INSH>SGB>NGB

95>97>99>94>98>96

SEASNAILS (4+ SPECIES)
ISN>ISS>INSH>BIBI>FIBI>NGB>SGB

96>97>95>94>99>98

AMERICAN PLAICE
INSH>NGB>SGB>FIBI>ISS>BIBI>ISN

99>98>97>94>95>96

TURBOT
BIBI>ISS>ISN>FIBI>SGB>INSH>NGB

95>94>99>96>97>98

WITCH FLOUNDER
SGB>INSH>NGB>ISS>FIBI>ISN>BIBI

99>98>96>95>94>97

YELLOWTAIL
SGB>INSH>FIBI>ISN>BIBI>NGB>ISS

96>99>94>95>98>97

ALLIGATORFISH
ISS>FIBI>ISN>INSH>BIBI>NGB>SGB

94>97>95>96>99>98

WOLFFISH
FIBI>BIBI>ISS>ISN>SGB>INSH>NGB

99>96>97>98>94>95

CAPELIN LARVAE (BONGOS)
INSH>ISS>NGB>FIBI>ISN>SGB>BIBI

95>96>99>98>94>97