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Recent Trends in the Dominant Pelagic Fish Species and Environment in the Northwest Atlantic, NAFO 2J3KLNO

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Abstract

We have characterized the pelagic ecosystem of the shelf waters off Newfoundland and Labrador as Arctic, Boreal and Temperate where the dominant fish species are Arctic cod (*Boreogadus saida*), capelin (*Mallotus villosus*) and sandlance (*Ammodytes* sp.), respectively. Arctic cod are exclusively young-of-the-year (0-group) while capelin and sandlance are predominantly one year old, and older, juveniles. The ocean environment has been warming since 1991 where surface layer water temperatures have been near, and above, normal beginning in 1994. On the Grand Bank, there was a large increase in bottom warm water habitat in the spring of 1998. Decreasing abundance and contraction in range of Arctic cod contrasted with an increasing abundance and expansion in range of capelin. These changes are consistent with expected biological changes in a warming ocean environment. The order of magnitude increase in the production of young (0-group) fish on the Southern Grand Bank in 1998 occurred across several species groups, including capelin, Atlantic cod (*Gadus morhua*), American plaice (*Hippoglossoides platessoides*) and haddock (*Melanogrammus aegelfinus*). The large increase in fish production appeared to result from the migration of adults into the Southern Grand Bank during the spring of 1998, in response to warm bottom water temperatures.

Résumé

Une caractérisation de l'écosystème pélagique du plateau de Terre-Neuve et du Labrador a permis d'identifier trois milieux : arctique, boréal et tempéré, dominés respectivement par la morue polaire (*Boreogadus saida*), le capelan (*Mallotus villosus*) et le lançon (*Ammodytes* sp.). La population de morue polaire est uniquement composée de jeunes de l'année (groupe d'âge 0), tandis que celles du capelan et du lançon comportent une majorité de juvéniles d'un an et plus. Depuis 1991, il se produit un réchauffement du milieu marin et, à partir de 1994, les températures de la couche superficielle se sont maintenues près de la normale ou au-dessus. Au printemps 1998, il y a eu sur le Grand Banc, une forte expansion de la zone du fond aux températures plus chaudes. La morue polaire a connu une baisse d'abondance et une contraction de son aire de répartition, contrastant avec le capelan, dont l'abondance et l'aire de répartition se sont accrues. Ces changements sont conformes aux modification biologiques prévues en cas de réchauffement du milieu marin. Au sud du Grand Banc, 1998 a été pour plusieurs espèces une année de prolifération des jeunes poissons (groupe-0); c'est le cas notamment du capelan, de la morue franche (*Gadus morhua*), de la plie canadienne (*Hippoglossoides platessoides*) et de l'aiglefin (*Melanogrammus aegelfinus*). Cette forte croissance de la production marine aurait été le résultat d'une migration des adultes vers la partie sud du Grand Banc au printemps 1998, en réaction aux températures plus élevées du fond.

Introduction

During the 1990's we have observed a warming trend in the annual water temperatures of the upper ocean in the Northwest Atlantic (Colbourne 1998, Figure 1). This warming followed a cooling trend that occurred throughout the 1980's, reaching a historical minimum in 1991. Previously, we have described the pelagic ecosystem of the shelf waters off Newfoundland and Labrador based on a multi-species pelagic trawl survey (Anderson and Dalley 1996, 1997, Dalley and Anderson 1997, 1998, 1999). This survey has been carried out in late summer each year, beginning in 1994, sampling from southern Labrador to the Southern Grand Bank (NAFO Divisions 2J3KLNO).

In this document, we focus on describing trends in distribution and abundance of the dominant pelagic fish species during the period 1994-1998. These species are all planktivores, feeding in the upper mixed layer, dependent on the summer production of zooplankton. With the exception of planktonic larval capelin, all other species are considered to be nekton.

Results

Capelin larvae (*Mallotus villosus*) have dominated the ichthyoplankton, where their relative abundance among all ichthyoplankton has been 50-90% (Anderson and Dalley 1997). No other species has occurred in significant abundance as either eggs or larvae. In the nekton, the dominant fish species have been juvenile capelin, primarily one and two years old, pelagic juvenile (0-group) Arctic cod (*Boreogadus saida*), and sandlance (*Ammodytes* sp.), which have ranged in age from 0-group to possibly five years old. Juvenile squid have also been an important component of the nekton, where the dominant species in the north is the Arctic squid (*Gonatus* sp.) (E. Dawe, Department of Fisheries and Oceans, St. John's, NF, per. Comm.). However, it has not been possible to carry out a comprehensive speciation of the juvenile squid community sampled by the survey and they are not considered further in this document.

The mean distributions of the dominant fish species in the nekton have formed a fairly distinct north to south cline during the five years in which the surveys have been done, 1994-1998. Arctic cod have dominated on the north and west of the Northeast Newfoundland Shelf. Capelin have dominated throughout the middle of the survey area, where abundance has typically been highest off Bonavista Bay and on the north slope of the Grand Banks. Sandlance have dominated to the south, including the eastern half of the Northern Grand Banks and over the entire extent of the Southern Grand Bank. We have characterized these patterns in distribution schematically as a composite of the distributions observed over five years (Figure 2).

Arctic cod have contracted their distribution from the south to the north and west during the first four years, 1994-1997 (Figure 3). Concomitantly, abundance has decreased by an order of magnitude (Figure 4). In 1998, the distribution of pelagic juvenile Arctic cod was similar to 1997.

Capelin have undergone an expansion of their range during this same period of time. The most dramatic increase in distribution was observed in capelin larvae in 1998. During the first three years of the survey, capelin larvae were only observed along the

northeast coast of Newfoundland and within the Avalon Channel. In 1997, a small number of capelin larvae were observed at one station off southern Labrador. In 1998, capelin larvae were observed at several stations along the coast of southern Labrador. In addition, a small but discrete distribution of capelin larvae were observed on the southern Grand Bank in 1998 (Figure 5). These larval distributions are indicative of spawning location, where spawning in 1997 and 1998 returned to Labrador and in 1998 to the Southeast Shoal of the Grand Bank. Larvae sampled in the surveys are typically 10-20 mm in length, which would approximate 20-40 days of age.

One year old juvenile capelin have been observed sporadically off the coast of southern Labrador during the period 1994-1998. One year old capelin were only observed in small numbers on the southern Grand Bank in 1994 and 1995. Capelin two years of age, and older, were first observed in small numbers off southern Labrador beginning in 1997 and again in 1998, and were observed for the first time on the southern Grand Bank in 1998. The distributions of 2^+ capelin in our survey mirror the distribution of larval capelin among years.

Year-class abundance of capelin has increased since 1991, where 1993 was the first relatively large year-class (Figure 6). Abundance in 1994 was lower but has been relatively high 1995-1997. The relative strength of each year-class has been the same at both the larval stage and as one year old juveniles, indicating that year-class strength in capelin was established by the early larval stage.

Sandlance abundance was relatively low and possibly decreasing during the first four years of our survey, 1994-1997, but underwent an order of magnitude increase in abundance in 1998 (Figure 7). Here we have estimated abundance over all lengths sampled during the survey which would include young of the year (0-group) as well as sandlance several years old. Since 1995, we have measured the length distributions of sandlance. Assuming that 0-group sandlance are less than approximately 110-120 mm in length, we estimate that the strongest year-class occurred in 1995 on the Grand Banks (Figure 8). Year-class abundance in 1996 and 1997 was very low but increased again in 1998, although it was much lower than in 1995. Therefore, based on the length frequency distributions, it appears that the large increase in abundance in 1998 occurred over all lengths in 1998 and was not a year-class effect.

On the Grand Banks in 1998 we also measured an order of magnitude increase in abundance of Atlantic cod (*Gadus morhua*) and American plaice (*Hippoglossoides platessoides*) (Figure 7). In addition, haddock (*Melanogrammus aeglefinus*) occurred on the Grand Banks in 1998 at similar abundance as cod and plaice (Figure 7). This was the first year haddock occurred in significant abundance. In 1994, we caught two specimens while no haddock were caught during the 1995-1997 surveys. All three species were distributed abundantly throughout the southern Grand Bank, and extended onto the northern Grand Bank.

The average spring (April-May) bottom temperature on the Grand Bank ranges from sub-zero °C on the northern and western Grand Bank and in the Avalon Channel to 3°C at the shelf edge (Figure 9). Over the central and southern areas, average bottom temperatures range from 0°C to above 2°C on the Southeast Shoal and to above 3°C along the edge of the bank. In general, bottom temperatures were nearly uniform at constant depth exhibiting onshore-offshore

gradients over most areas. The annual cycle in bottom temperatures over most areas was low in magnitude, however, they under go significant interannual variations. For example, the areal extent of sub-zero °C water is restricted to the to a small area in the Avalon Channel and northern Grand Bank during warm years (eg. 1998) but during cold years (eg. 1991) sub-zero water covers most of the Grand Bank. We examined the interannual variations in the bottom temperatures on the Grand Banks by computing the areal extent of the bottom covered with water in various temperature bins. This gives an indication of potential changes in temperature dependent habitat for various fish species

The gridded temperature data from the annual spring ground fish assessment surveys in NAFO Divs. 3LNO, 1971-1990, were used to compute a time series of bottom area covered by water in the selected temperature ranges. The data were gridded at a spatial resolution of approximately 390 km^2. A total of 640 grid points or 250,000 km^2 were used within the boundaries of the region. The mean bottom temperature for each grid was calculated and combined with the grid area to produce a time series of bottom area covered by water in selected temperature ranges. The areas are expressed as a percentage of the total surveyed area. The selected temperature ranges were ≤ 0 °C, 0 to 1°C and ≥ 1°C. Potential sources of error in this analysis include temporal aliasing, arising from the wide time interval during which a typical survey is conducted. This source of error is probably small, given the low magnitude of the annual cycle over most of the water depths considered in this analysis.

Since 1994 there has been a general decrease in the percentage area of the bottom covered by subzero °C water on the Grand Bank with values decreasing from more than 70% in 1991 to about 15% in 1998. The area covered by water in the 0° to 1°C temperature range varied from a low of less than 20% during 1991 and 1993 and up to a high of near 40% in 1996 and 1998. During 1990-1992, the area of bottom water ≥ 1°C occupied about 10% of the Grand Bank (Figure 10). This increased to as high as 30% during the period of 1993-1997. During the spring of 1998, water with temperatures ≥ 1°C covered more than 50% of the bottom area (Figure 9). The 1998 spring value represents the largest area of relatively warm water on the Grand Banks since 1983 and is only the fourth time in 28 years that this has occurred. The mean gridded temperature on the Grand Bank in water depths less than 100-m increased during the spring of 1998 reaching 1.2°C compared to the historical mean of 0.6°C.

Discussion

The pelagic ecosystem in the shelf waters off Newfoundland and Labrador embraces three distinct oceanic regimes, which we characterize as "Arctic", "Boreal", and "Temperate". In the north, Arctic cod dominated the Arctic regime. Here we also found Arctic squid (*Gonatus fabricii*) and other species associated with cold Arctic waters such as Arctic alligatorfish (*Aspidophoroides olriki*). In the southern part of the survey area, sandlance dominated the Temperate regime, along with other warm water species such as haddock (*Melanogrammus aegelfinus*) and Yellowtail flounder (*Limanda ferruginea*). In

the Boreal regime, lying between the Arctic and Temperate regimes, juvenile capelin (*Mallotus villosus*) was the dominant fish species found in the pelagic ecosystem.

During the first five years of our pelagic juvenile fish survey, 1994-1998, we have observed changes in the dominant pelagic fish species that are consistent with a warming ocean environment. These changes have included an expansion in geographical range and an increase in the production of young fish for Boreal and Temperate regime species, compared with a contraction of range to the north and decrease in abundance of the cold water species, Arctic cod. For capelin, we first observed an increase in year-class abundance in 1993, one year before we measured an increase in water temperatures.

Annual values of temperature and salinity change slowly over many years, when high frequency variations are filtered out. However, annual changes in the physical environment can occur abruptly, such as the extremely cold year in 1991. Similarly, we have observed patterns of increasing and decreasing trends in distribution and abundance in capelin and Arctic cod, respectively, over a period of 4-5 years. In contrast, however, was the abrupt increase in fish abundance on the southern Grand Bank in 1998. The increase in the abundance of young-of-the-year fish (0-group) occurred across several species groups that included capelin, Atlantic cod, haddock and American plaice. It appears that the increase in bottom water temperatures during spring in 1998 surpassed a threshold from a cold water, inhospitable environment, to a warm water, hospitable environment. The presence of large numbers of adult Atlantic cod and haddock during the 1998 spring 3LNO bottom trawl survey (Northwest Atlantic Fisheries Centre, unpubl. data) indicates that adults moved into the southern Grand Bank from areas to the west. Similarly, we caught adult, mostly spent, capelin on the southern Grand Bank for the first time in the 1998 survey. The increase in the abundance of large sandlance, in the absence of any evidence of high year-class production within the Southern Grand Bank, is consistent with the migration of older sandlance into this area in 1998. The degree of maturity in these sandlance is not known. Therefore, we tentatively conclude that the large increase in abundance of fish in the Southern Grand Bank in 1998 was a result of favourable environmental conditions in spring that facilitated the migration of adult fish into the area to spawn, followed by a relatively high survival during the egg and larval stages.

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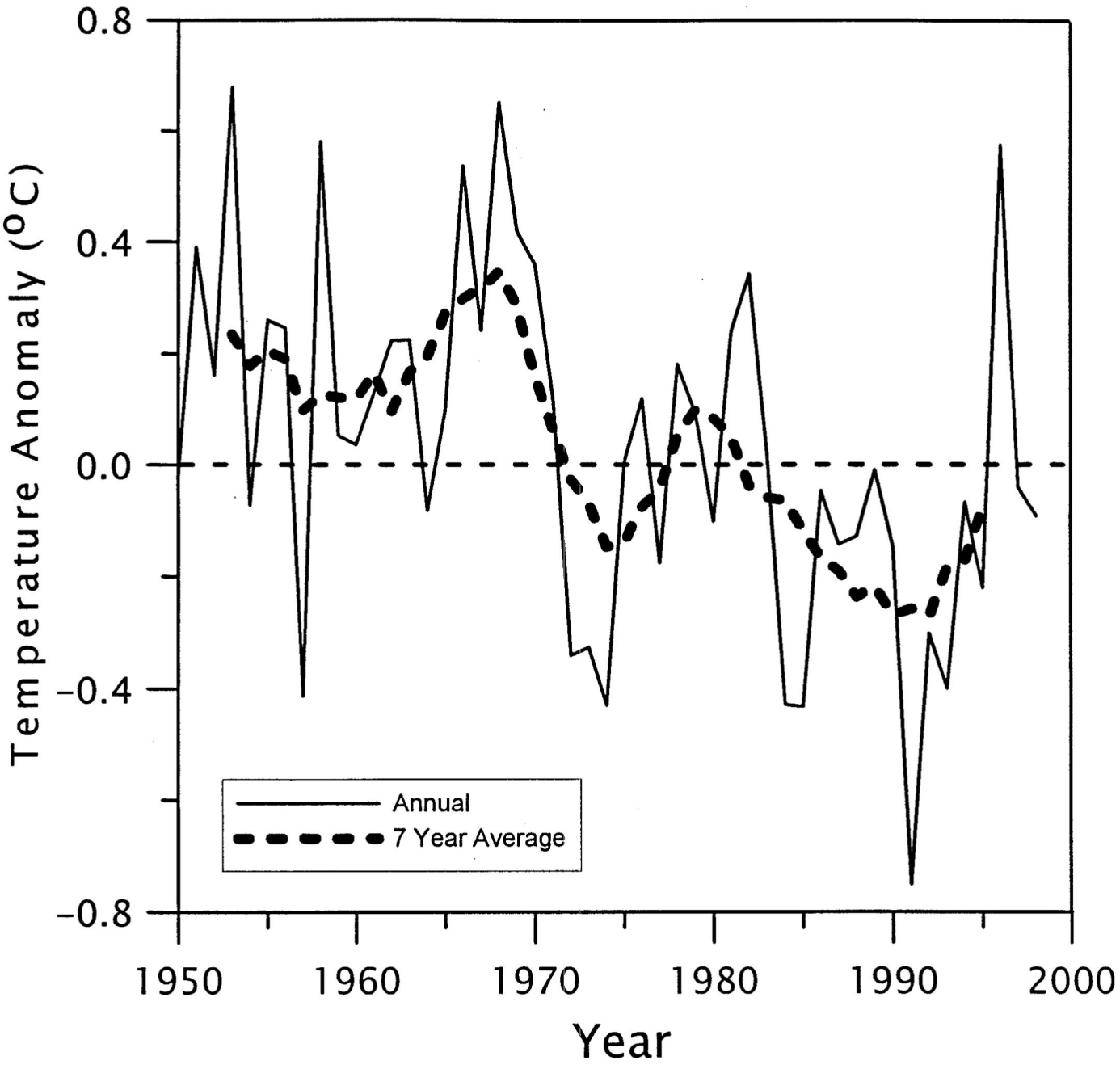

Figure 1. Time series of annual temperature anomalies (°C) at Station 27, Newfoundland. The fitted line is a seven year running mean.

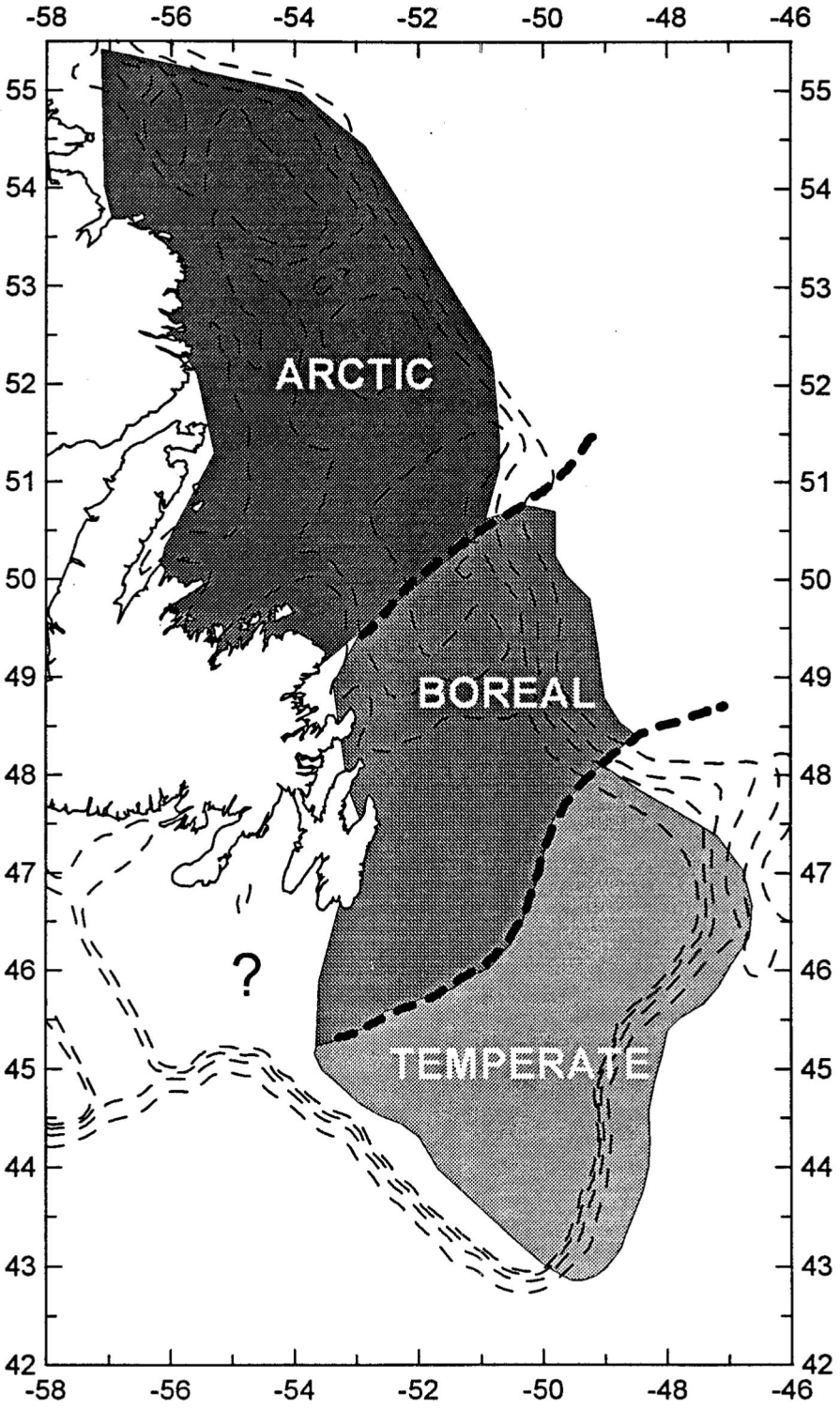

Figure 2. Schematic representation of the dominant nekton regimes in the Northwest Atlantic pelagic ecosystem.

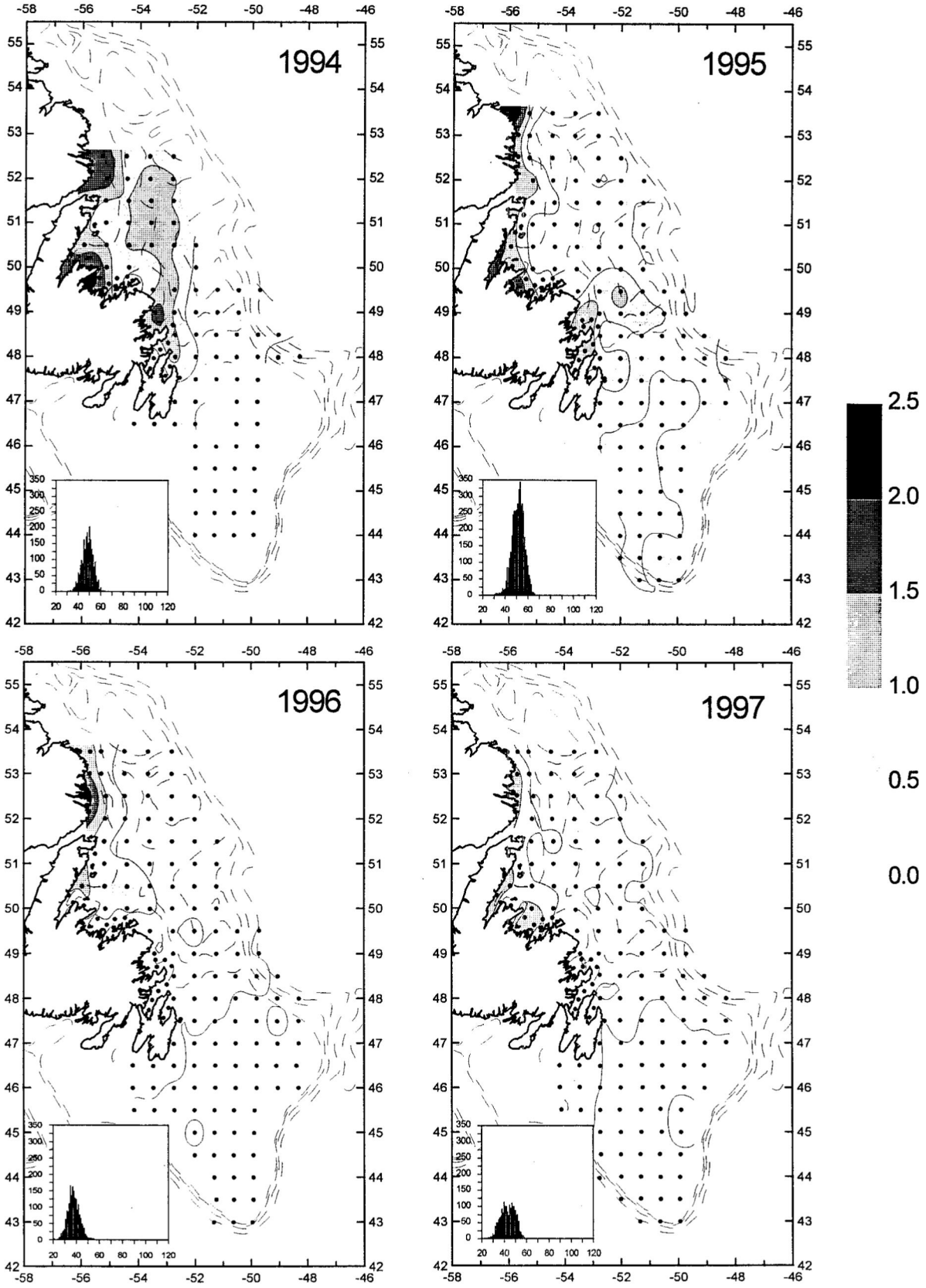

Figure 3. Distribution of pelagic juvenile (0-group) Arctic cod,1 1994-1997. The contoured data are log10 number per 10,000 cubic meters.

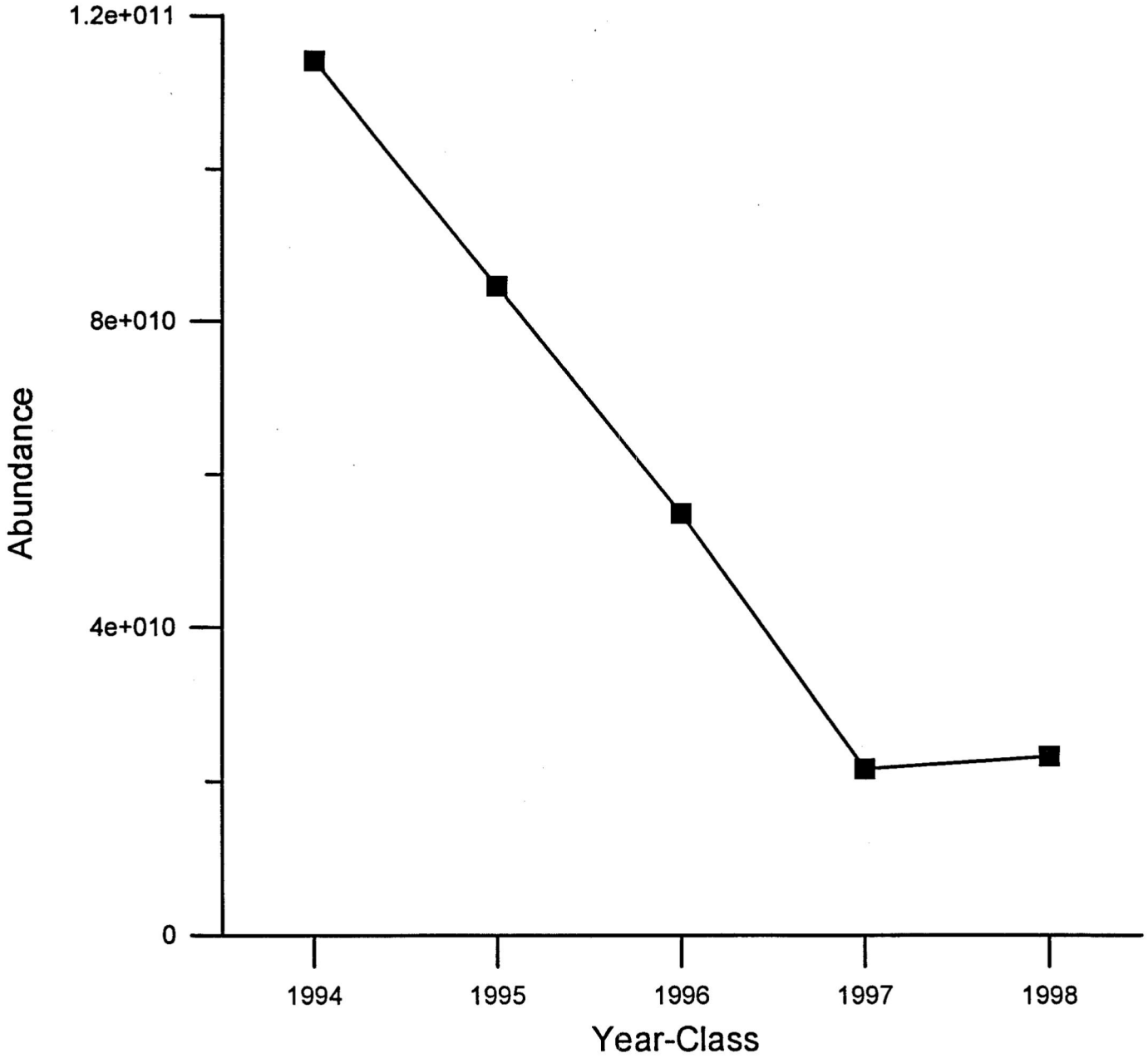

Figure 4. Abundance of pelagic juvenile (0-group) Arctic cod (*Boreogadus saida*) estimated for the Northwest Atlantic, 1994-1998.

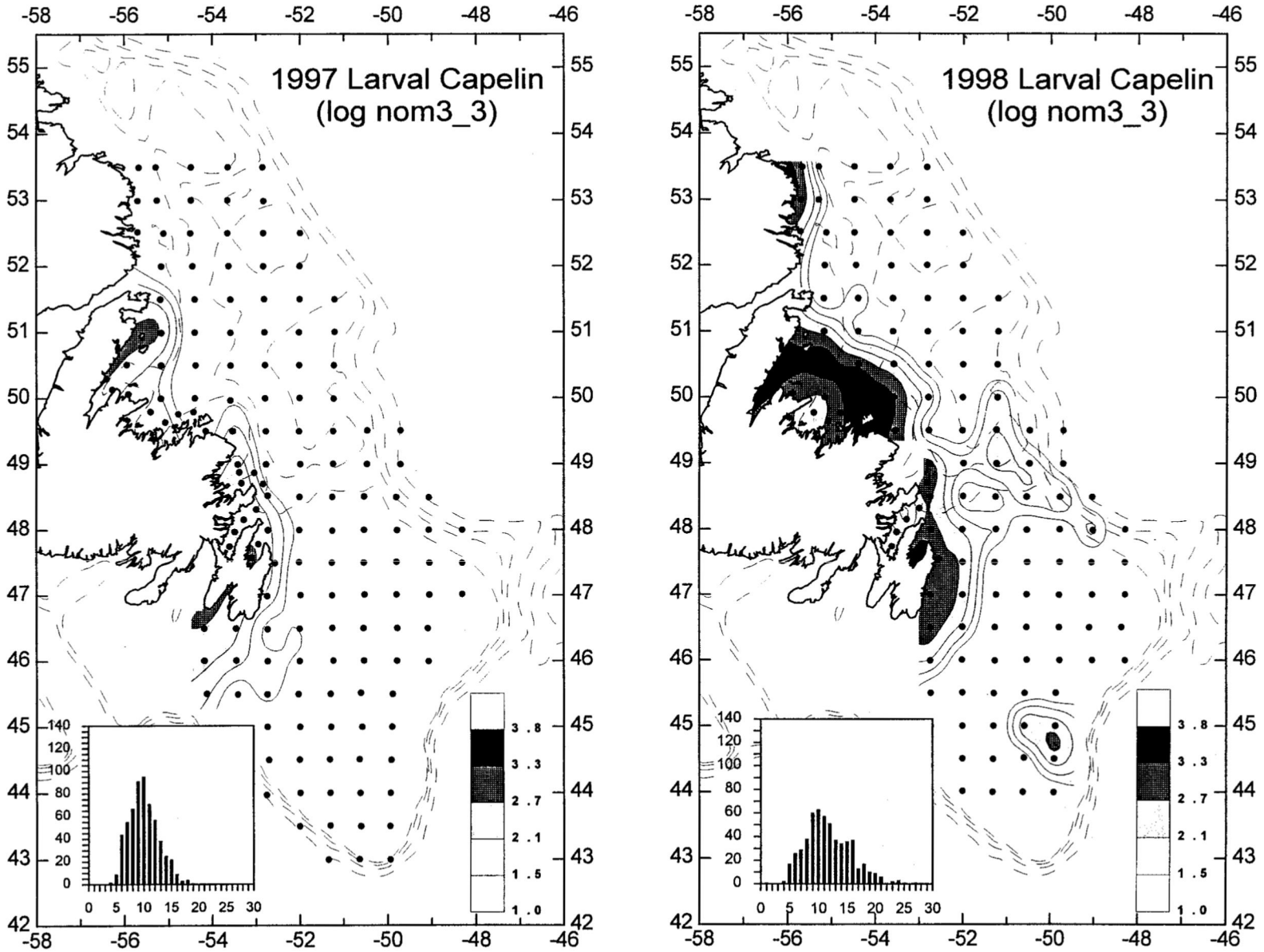

Figure 5. Distribution of larval capelin in 1997 and 1998. Contour levels are log10 intervals of capelin per 10,000 m^3.

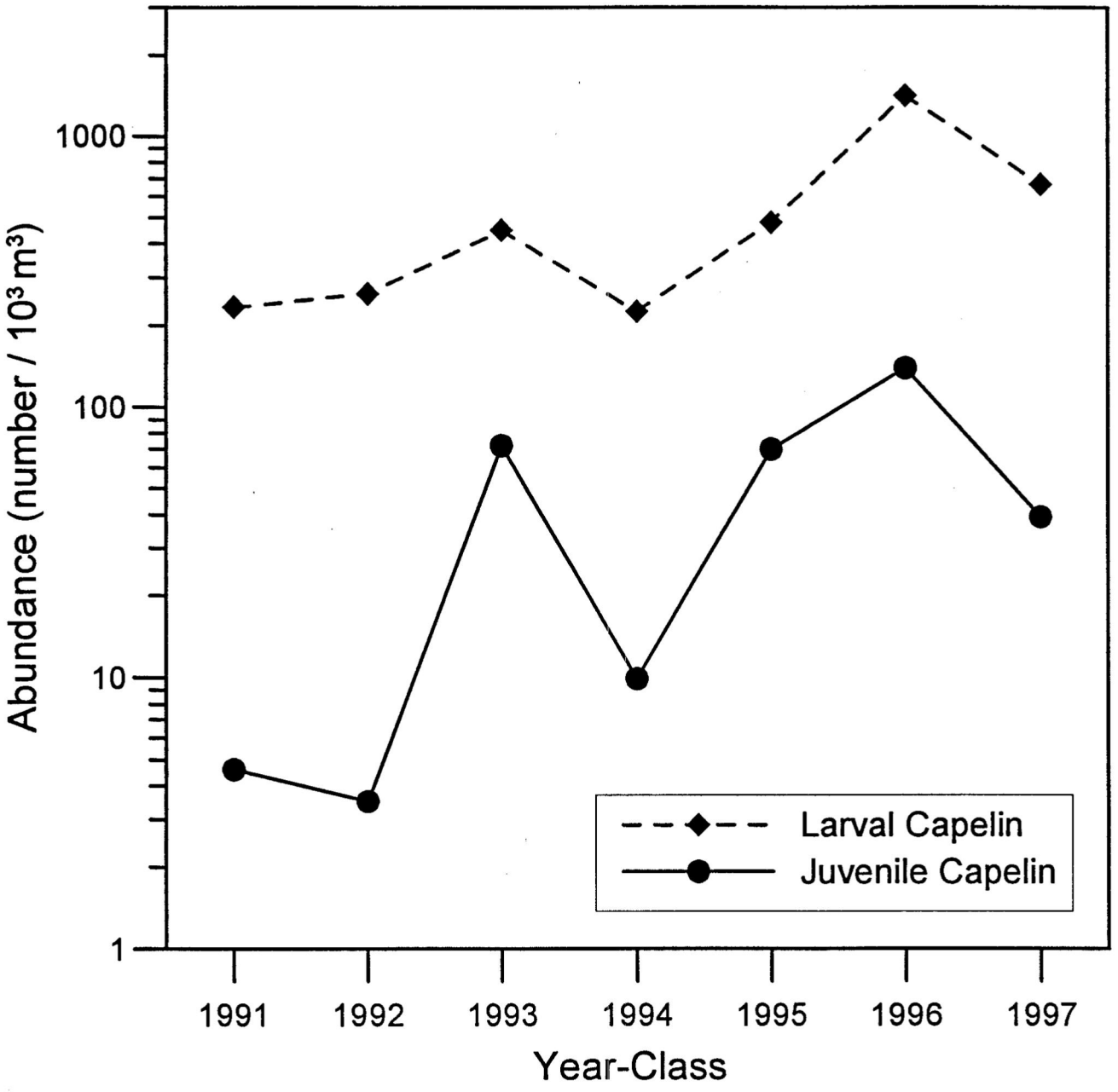

Figure 6. Abundance estimates of year-class strength in capelin at the larval (0-group) and one year old stages, 1991-1997.

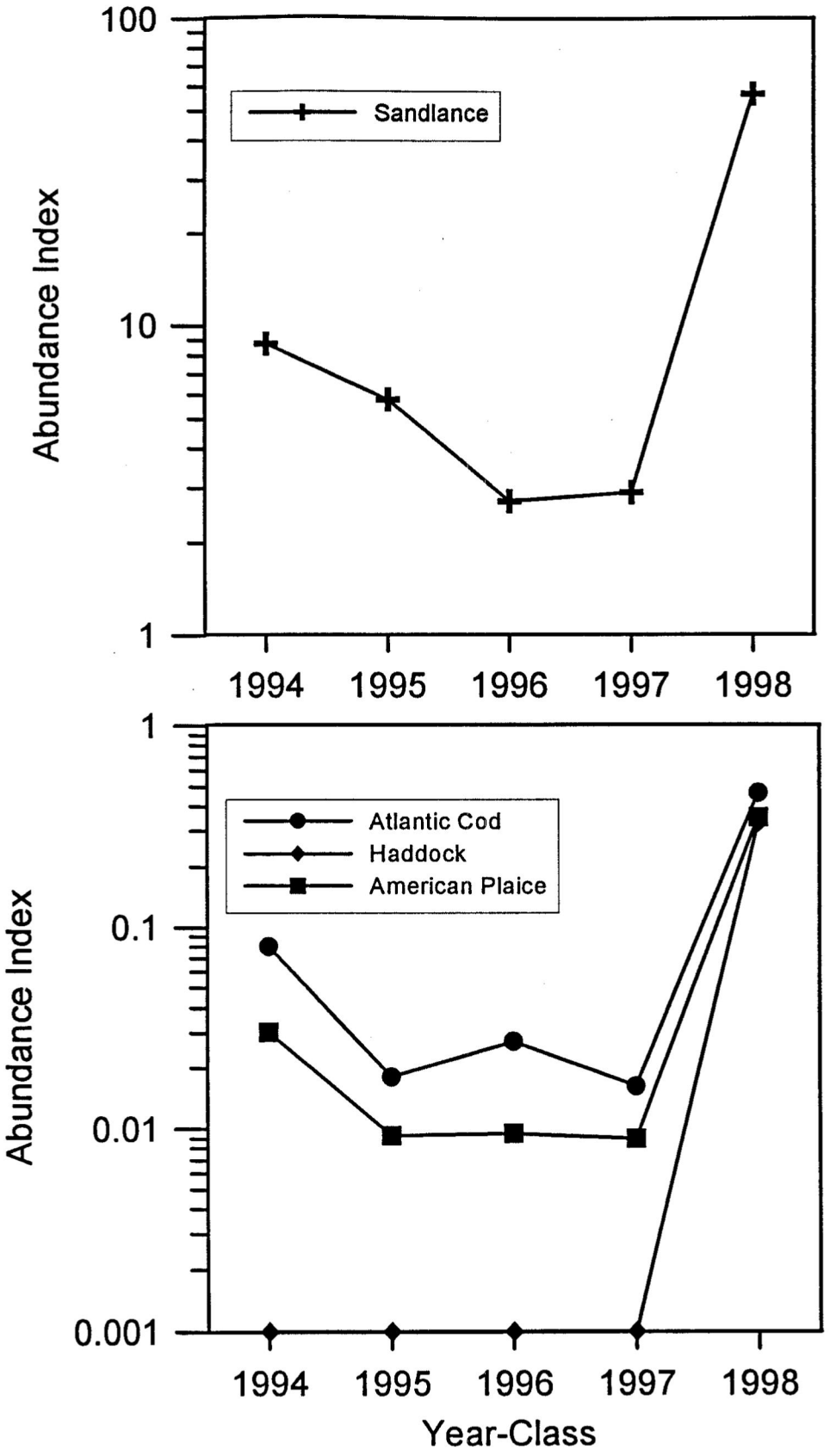

Figure 7. Relative abundance of a) Sandlance (*Ammodytes* sp.) and b) Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglef inus*) and American plaice *(Hippoglossoides platessoides*) on the Grand Banks, 1994-1998.

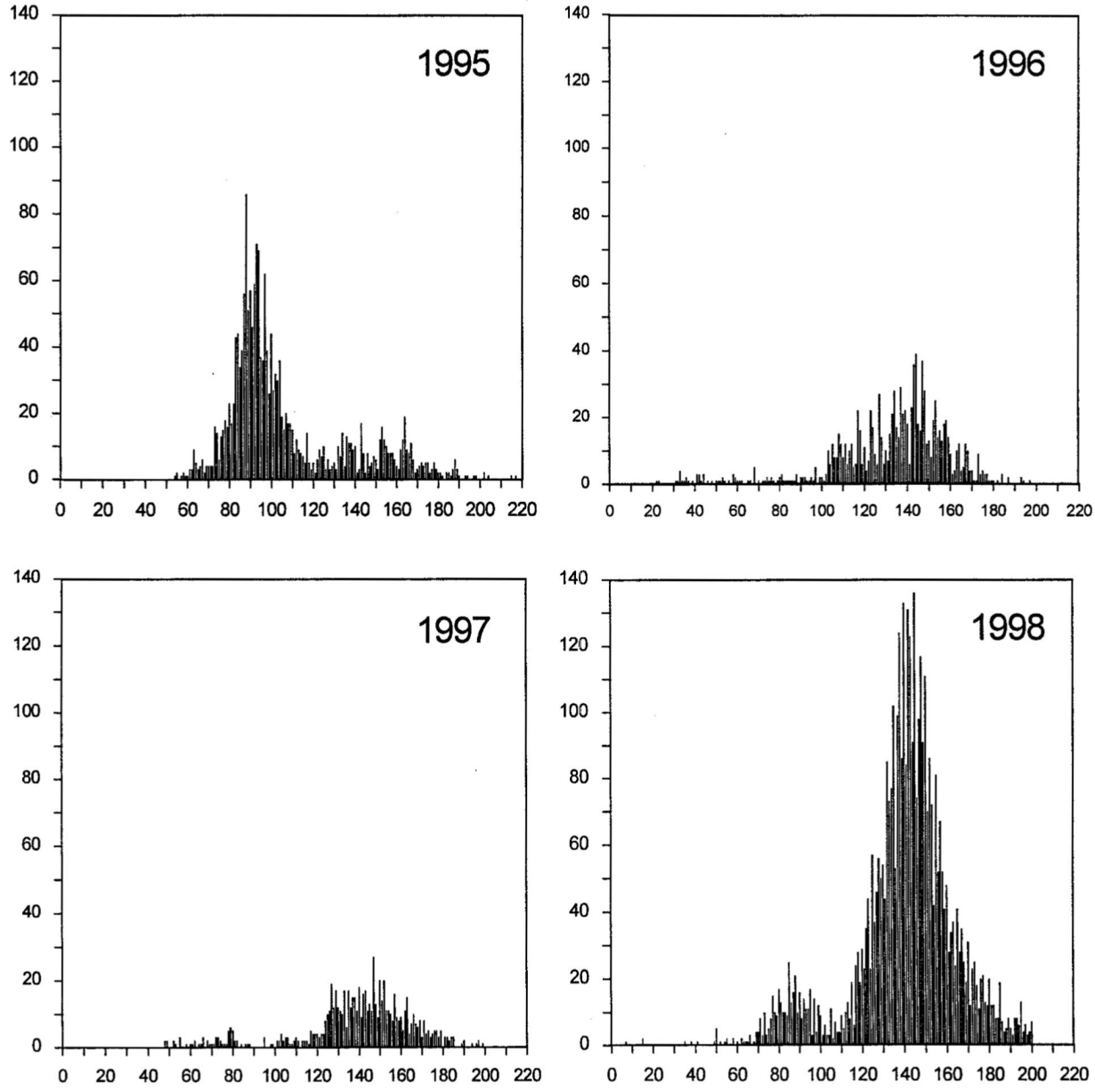

Figure 8. Length (mm) frequency distributions of sandlance (Ammodytes sp.) captured each year, 1995-1998, on the Grand Banks (3LNO).

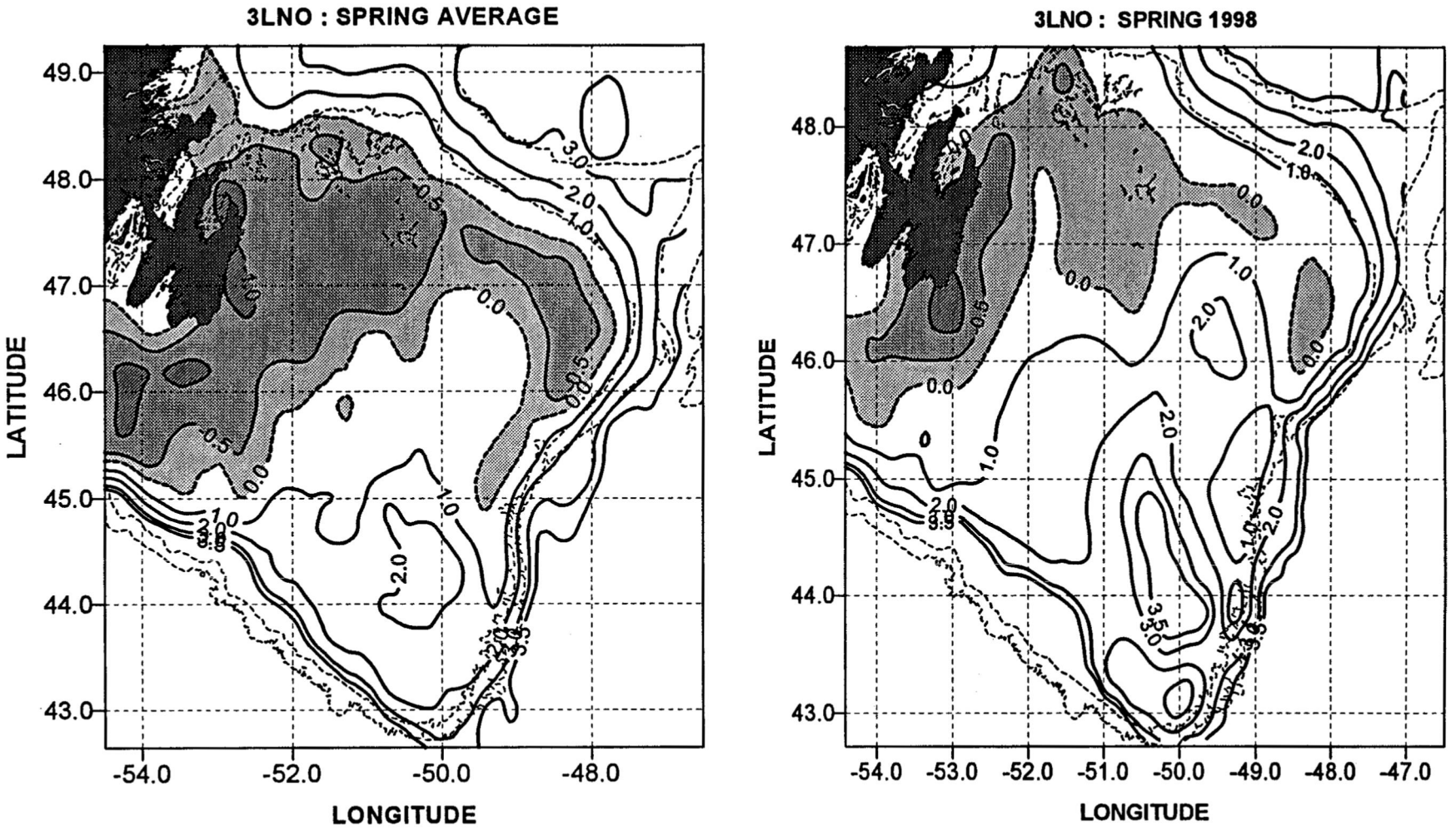

Figure 9. Distribution of spring bottom water temperatures on the Grand Banks, averaged for the period 1971-1990, and in the spring of 1998. The shaded areas represent water < 0 deg-C.

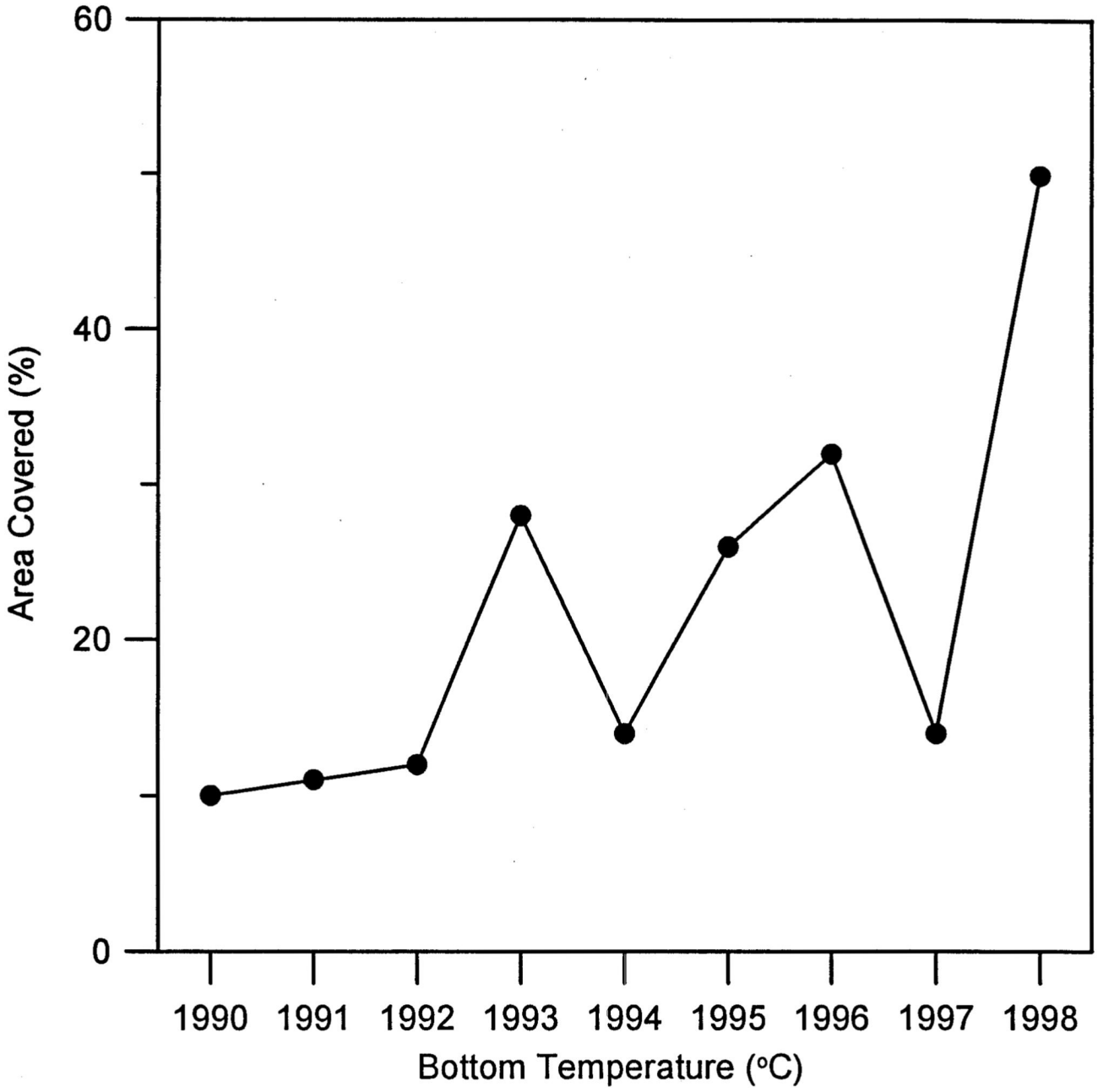

Figure 10. Area of the Grand Banks < 100 m deep covered by warm bottom water > 1 °C in the spring, 1990-1998.