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**Spatial migration pattern of deep-sea redfish (*Sebastes mentella* Travin) of the Norwegian-Barents population from survey data**

by

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**Abstract**

Study of redfish migration by traditional tagging-methods faces great difficulties. The redfish taken onboard a vessel usually prove to be nonviable. A sharp hydrostatic pressure differential is lethal for the redfish having a closed swim bladder.

The main purpose of the present paper is to determine migration pattern of the deep-sea redfish juveniles. To study the deep-sea redfish migration, data from annual Russian and Norwegian scientific trawl surveys conducted during autumn and winter of 1982-1995 were used.

The Petersen method was applied to analyse size composition of the deep-sea redfish catches taken during the above trawl surveys. The conclusion made from prior researches that the deep-sea redfish year classes of 1982 and 1988 were strong compared to their neighboring ones was confirmed.

On the assumption that "peaks" in the length distributions of survey catches displayed strong yearclasses, the annual corresponding lengths were defined for the 1982 and 1988 year classes of deep-sea redfish at different age (from 0 to 7 years). Subsequently, using the database from trawl surveys and knowing the length of the deep-sea redfish from strong yearclasses at different age, the distribution of these yearclasses by year was mapped. Based on the analysis of these maps, migration patterns of the deep-sea redfish juveniles in the Barents and Norwegian Seas were plotted.

Keywords: deep-sea redfish, *Sebastes mentella*, migration, Barents Sea, survey

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## Introduction

Fishery for the deep-sea redfish (*Sebastes mentella* Travin) in the Barents and Norwegian seas dates back to 1952 (Zakharov *et al.*, 1977) and by the present has more than half a century history. Scientists have studied many issues of the deep-sea redfish biology. Nevertheless, one of the issues crucial for both understanding of the life history and fishery management, namely, migration of the deep-sea redfish has not been adequately explored.

Study of redfish migration by traditional tagging methods faces great difficulties. The redfish taken onboard a vessel usually prove to be nonviable. A sharp hydrostatic pressure differential is lethal for the redfish having a closed swim bladder.

At present Icelandic scientists and engineers have developed underwater tagging equipment (UTE) (Schrope, 2000). Information presented at the website of the Star-Oddi company ([www.star-oddi.com](http://www.star-oddi.com)) showed that in October 2003 Icelandic scientists tagged more than 200 redfish of 32-45 cm long at a depth greater than 500 m in the area northwest of Iceland, and in June 2004, another 552 redfish were tagged with the same equipment. As of 29 July 2004, seven tagged redfish were recaptured. Development of the underwater tagging equipment is a significant stride in the studies of the redfish biology. However, at present, this equipment cannot solve the problem with the study of juvenile redfish migration when length of individuals ranges from 3 to 22 cm, i.e. of immature redfish.

Nowadays, only one scientific paper on the redfish migration in the Barents and Norwegian seas is known. In 1961, Sorokin analysed data on the redfish distribution and fishery, which had been collected by PINRO researchers since 1946. Based on these data he patterned the migration of **mature deep-sea redfish** (Sorokin, 1961).

Thus, authors of the present paper attempted to create a principal migration pattern of **immature deep-sea redfish** of the Norwegian-Barents Sea population by the example of two strong yearclasses of 1982 and 1988 using data from the trawl surveys.

## Material and Methods

Materials used to study the deep-sea redfish migration were from Russian and Norwegian trawl surveys conducted in autumn from 1982 to 1995.

The Russian bottom trawl surveys in the Barents Sea have been conducted since 1982, along with the trawl-acoustic surveys in October-December since 1986. All the fishing grounds (around 150 000 nm<sup>2</sup>) on the shelf of the Barents, Norwegian and Greenland Seas were covered by the survey (Fig. 1). Depths were surveyed from 50 to 900 m. The survey data were used to estimate the abundance of juvenile yearclasses of the main commercial species as well as flatfish and catfish, and the abundance and biomass of cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and redfish (*Sebastes mentella* and *Sebastes marinus*) were estimated. Operations were performed on a 24 hr basis by 2 or 3 vessels simultaneously. Sampling gear was a bottom trawl with the distance between wings about 30 m and 7.8-8.0 m opening height. 16-mm inner mesh-size netting was installed into a trawl codend. The vessel speed was 3.2 knots and duration of haul was 1 hr (Lepesevich & Shevelev, 1997; Shevelev *et al.*, 1998).

In the annual Norwegian Svalbard survey in autumn, which has been conducted since 1981, all vessels have been equipped with the standard research bottom trawl Campelen 1800 shrimp trawl with 80 mm (stretched) mesh size in the front and a vertical trawl opening of about 4.5-5.0

meters (Randa & Smedstad 1982, Jakobsen *et al.* 1997). Until and including 1993 a cod-end with 40 mm (stretched) mesh size and a cover net with 70 mm mesh size were used. Since this mesh size may lead to considerable escapement of juveniles, the cod ends were in 1994 replaced by cod-ends with 22 mm mesh size. At present a cover net with 116 mm meshes is mostly used. The ground gear has also been changed during the time series. Since 1989, the trawl has been equipped with a rockhopper ground gear. Up to and including 1988 a bobbins gear was used. The sweep wire length is 40 meters (up to and including 1988 the sweep wire length was 80 meters) plus 10 m wire for connection to the doors. Waco doors (6m<sup>2</sup>, 1500kg) have been used as standard trawldoors on board the research vessels. On hired vessels V-type doors (6.4 m<sup>2</sup>, 1750kg) have been used. Standard tow duration is 30 minutes (up to and including 1988 the tow duration was 60 minutes), and the trawling speed has been 3 knots. Depths were surveyed from 50 to 500 m. Operations were performed on a 24 hr basis by 2 vessels simultaneously. On all trawl stations the trawl performance is constantly monitored by Scanmar trawl sensors, i.e., distance between the doors, vertical opening of the trawl and bottom contact control.

The catch per unit effort from these surveys is assumed to be an index of fish abundance. As was said above, the Russian survey covers mostly the Barents Sea area, while the Norwegian survey enclose the Svalbard area but together the surveys embrace almost the whole habitat of the deep-sea redfish of the Norwegian-Barents Sea population. If combined, the results from these surveys will give us almost complete coverage of the redfish habitat for each year for the period of 1981 to the present. Since 1996 (results not included in this paper), the autumn surveys have been extended to also cover the area north and east of Spitsbergen.

Figure 2 gives a map of currents and areas of the Barents Sea to which we will refer further in the text.

As was noted above, when studying migration of immature redfish particular emphasis was placed on 1982 and 1988 yearclasses. These yearclasses were the most abundant in the 1980-1990ies (Nedreaas, 1990; Anon, 2004), and thus, were adequately represented in catches during surveys.

Using the length frequency method (the Petersen method; Anon, 1981), the size composition of redfish catches taken during trawl surveys was analyzed (Figure 3 and 4). By recognizing that “peaks” on the plots of size composition of catches are referring to strong yearclasses, average length of individuals corresponding to the 1982 and 1988 yearclasses was determined at different age (from 0 to 7 years) (Table 1).

Based on knowledge about the length of deep-sea redfish from the 1982 and 1988 yearclasses at different age, and the database on the trawl surveys, catches (numbers per 1-hour tow) of juveniles from the above yearclasses were estimated for each age from 0 to 7 years for each tow, separately, for both the Russian and Norwegian surveys. As an example, from the database on Russian and Norwegian trawl surveys in 1982, the numbers per 1-hour tow of juvenile redfish being 3-7 cm long, is believed to correspond to age 0, and are seen from Table 1.

To map the distribution of deep-sea redfish from the strong yearclasses and to reach as full area coverage as possible, it was necessary to combine catches by tow for both surveys (Russian and Norwegian). However, in the Russian and Norwegian surveys different fishing gears with different catchabilities were used, and thus, initial data on catches in numbers per 1-hour tow could not be combined directly. To solve this problem we decided to present the catch from each haul as frequencies for each length group rather than in absolute numbers. Afterwards, the distribution maps were made by years. Based on the analysis of these maps, the principal

migration pattern of immature deep-sea redfish from the Norwegian-Barents Sea population was plotted.

## **Results**

### **Age 0**

Distribution of redfish from the 1982 yearclass at age 0 is shown in Figure 5, and correspondingly, from the 1988 yearclass in Figure 13.

Fingerlings of the redfish were distributed over a wide area due to the effect of the warm Atlantic currents. The densest concentrations occurred in the Skolpen Bank area and at the western Spitsbergen coast. The main difference in the distribution of the 1982 yearclass compared with the 1988 yearclass was the concentrations of juveniles at age 0 in 1988 in the Svalbard area which were distributed more northerly than in 1982.

### **Age 1**

Distribution of the deep-sea redfish from the 1982 yearclass at age 1 is shown in Figure 6, and from the 1988 yearclass in Figure 14.

At this age, differences in distribution of deep-sea redfish from the 1982- and 1988 yearclasses were observed to be great. The main concentrations of juveniles from the 1982 yearclass at age 1 were registered on the Skolpen Bank and south of the Central Bank, as well as along the western Spitsbergen coast from 77°N and further north to 79°N. Individuals from the 1988 yearclass at age 1 were mostly distributed in the Bear Island Channel and to the west of the Bear Island, as well as west of the Svalbard Bank and along the western Svalbard coast from 76°N and further north to 80°N.

### **Age 2, 3, 4 and 5**

Distributions of the deep-sea redfish from the 1982 yearclass at age of 2 to 5 are shown in Figures 7-10, respectively. Distributions of the 1988 yearclass at the same ages are given in Figures 15-18.

Distribution of juvenile deep-sea redfish from the 1982- and 1988 yearclasses at age of 2 to 5 years showed to be similar and stable. Individuals were mostly distributed in the Bear Island Channel and west and southwest of the Central Bank, as well as along the continental slope from the Bear Island and north to 80°N. Concentrations of the deep-sea redfish at age 2 and 5 were also found on the Skolpen Bank.

### **Age 6**

Distribution of the deep-sea redfish from the 1982 yearclass at age 6 is shown in Figure 11, and from the 1988 yearclass in Figure 19.

Distribution of the deep-sea redfish at age 6 is generally similar to that at age 5 with the main habitat areas being the Bear Island Channel and the continental slope along the western coast of Spitsbergen. However, the core concentrations at age 6 in the Bear Island Channel were shifted towards the west in relation to the distribution of redfish at age 5. No concentrations of deep-sea redfish at age 6 were found on the Skolpen Bank, but were observed northwest of it.

### **Age 7**

Distribution of the deep-sea redfish from the 1982 yearclass at age 7 is shown in Figure 12, and from the 1988 yearclass in Figure 20.

The deep-sea redfish from the 1982 yearclass at age 7 were almost entirely distributed along the continental slope from 72°N and further north to 78°N. Also the 1988 yearclass was distributed along the continental slope, but in addition, a concentration was observed northwest of the Skolpen Bank.

## Discussion

Based on the analysis of the distribution maps of deep-sea redfish from the 1982- and 1988 yearclasses, the principal migration pattern of immature deep-sea redfish from the Norwegian-Barents Sea population is suggested.

From spawning areas along the continental slope from 62°N to the Bear Island (Mukhina *et al.*, 1992; Nedreaas, 1995), juvenile redfish drift with the warm Atlantic currents (Figure 2) to the Barents Sea and Svalbard areas. The main nursery areas of the juvenile redfish are the Bear Island Channel and waters adjacent to the southwest of the Central Bank and continental slope along the western coast of Spitsbergen. During the first years of life (age 0 and 1) the redfish juveniles also drift to the Skolpen Bank (Figure 6), but later on, concentrations in this area are not observed. Concentrations of the deep-sea redfish may again be found on the Skolpen Bank at age 5 and older (see below). It seems plausible that individuals that drift to the Skolpen Bank may both continue to drift to the area south of the Central Bank and to the area occupied with warm waters east of the Skolpen Bank.

All this give reasons to assume that the drift of a deep-sea redfish yearclass may last for its two first years of life. First, the geographical spread of the spawning grounds result in the situation that larvae extruded concurrently in the northern and southern areas of the spawning ground have to cover different distance in the drift towards one and the same nursery area. Second, multiage structure of the mature stock leads to the lengthening of the spawning period from March to May (Mukhina *et al.*, 1992). Therefore, the extended drift period may be interpreted as survival adaptation of the population as it reduces the probability that the whole yearclass will get into unfavourable conditions.

The deep-sea redfish are distributed within the nursery areas until they are 4 years old. From then on, the redfish start active migration against the current towards the mature population distribution areas. Hence, having drifted to the continental slope area along the western coast of Spitsbergen, the redfish older than 4 years old migrate towards the Bear Island. From the Bear Island Channel they migrate to the west, to the continental slope area. As is indicated above, the deep-sea redfish concentrations may again be found on the Skolpen Bank at age 5, after not occurring in this area since age 2. This suggests that the deep-sea redfish partly migrate from the areas adjacent to the Central Bank to the continental slope via the Skolpen Bank. This means that the deep-sea redfish moving against the warm current, first migrate to the south and having reached the Skolpen Bank then migrate to the west towards the continental slope. Formation of the deep-sea redfish concentrations at age 5 on the Skolpen Bank may also be explained by their migration to the west, from areas east of the Skolpen Bank occupied with warm waters.

Our investigation covers the following life stages of the deep-sea redfish: larval, juvenile and young individuals. Migration of the redfish during the above indicated life stages could, according to Harden Jones (1968), be divided into three periods:

(a) From spawning area to nursery area

Our data, as noted above, show that the duration of this period for one yearclass of the deep-sea redfish from the Norwegian-Barents Sea population is not less than 2 years (age 0 - 1).

(b) Seasonal movements within the nursery areas

Results of the study being presented show that this period lasts 3-4 (5) years (the redfish age is 2-4 (5)). Since the present analyses were based on data from the annual autumn bottom surveys only, such periodicity of the observations did not allow us to investigate seasonal movements within the nursery areas.

Yet, from literature data it is known that the temperature range within which young redfish (less than 30 cm long) occur at the bottom, is fairly wide: from 0.5 to 5°C. Nevertheless, dense concentrations of the redfish were observed at temperatures above 2.5°C. Besides, young redfish at different age dwell at different depths: individuals at age 1 prefer depths not greater than 200 m, at age 2 and 3 they occur in the range of 200 to 300 m and at older age occupy the depth of 100-500 m (Berger & Cheremisina, 1968).

The diet of young redfish is dominated by plankton crustaceans such as *Copepoda*, *Hyperiidæ* and *Euphausiidæ*, as well as *Decapoda* (including young shrimp *Pandalus borealis*) and *Gammaridea*. With growth the importance of small plankton (*Copepoda*) in the diet is decreased and larger and more movable plankton (*Hyperiidæ*, *Euphausiidæ*) become predominant. *Decapoda* and fish also appear in the redfish diet (Dolgov & Drevetnyak, 1995).

Thus, it is safe to say that young redfish during their stay in the nursery areas make local migration to areas with optimum temperature, depth and food supply.

(c) Leaving the nursery areas

The deep-sea redfish of the Norwegian-Barents sea population start leaving the nursery areas at age 5-6.

Thus, the distribution of young deep-sea redfish in the Barents Sea and Svalbard areas is mostly affected by the system of warm currents.

## Acknowledgements

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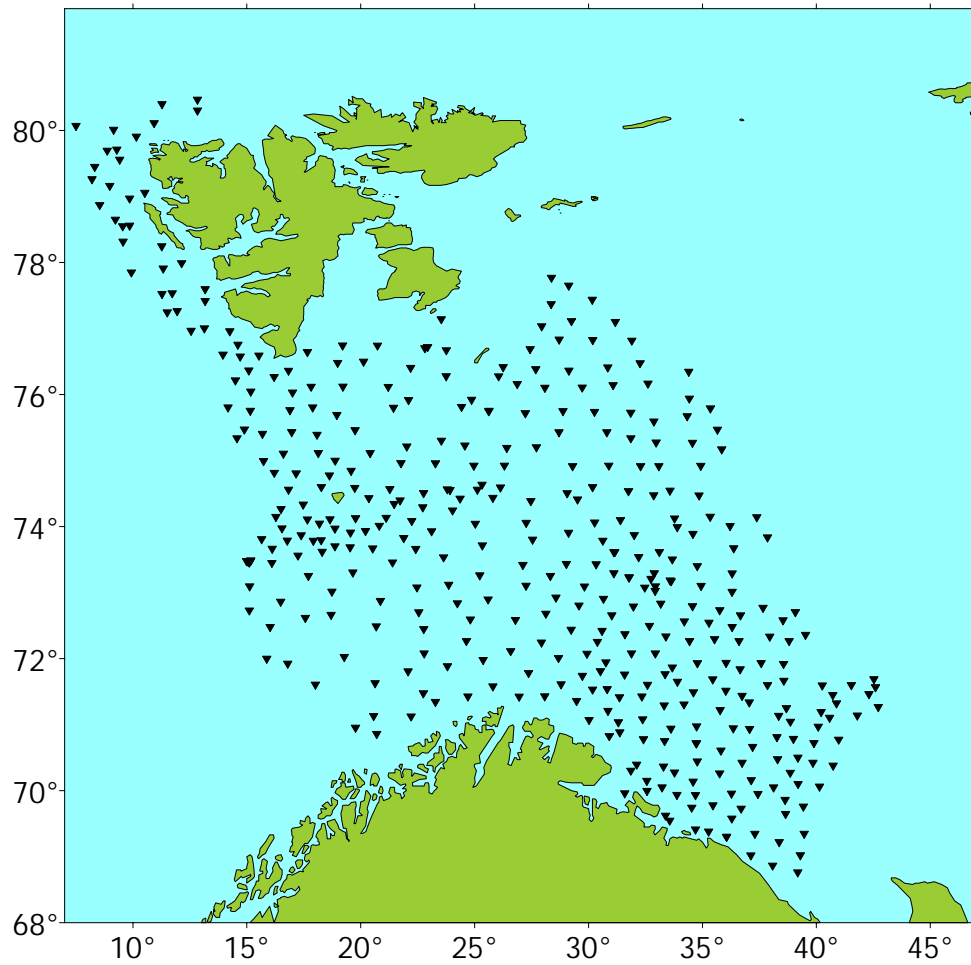
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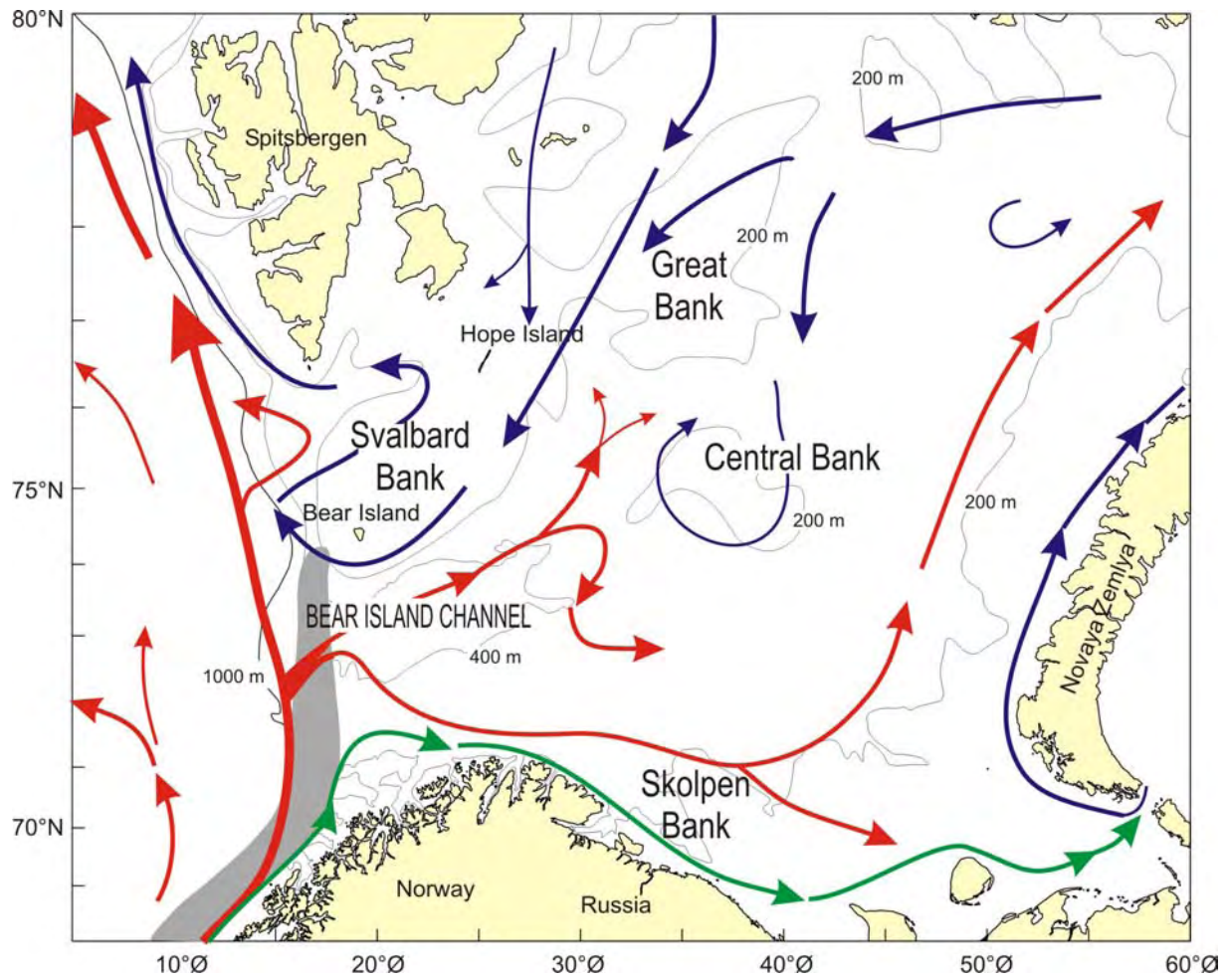
Table 1. Size range of the 1982 and 1988 yearclasses by age (see Figures 2 and 3).

Age	Length, cm	
	Yearclass 1982	Yearclass 1988
0	4-8	5-8
1	8-12	7-13
2	10-16	11-15
3	13-17	12-18
4	14-20	15-20
5	17-25	18-23
6	19-26	20-26
7	21-28	21-28

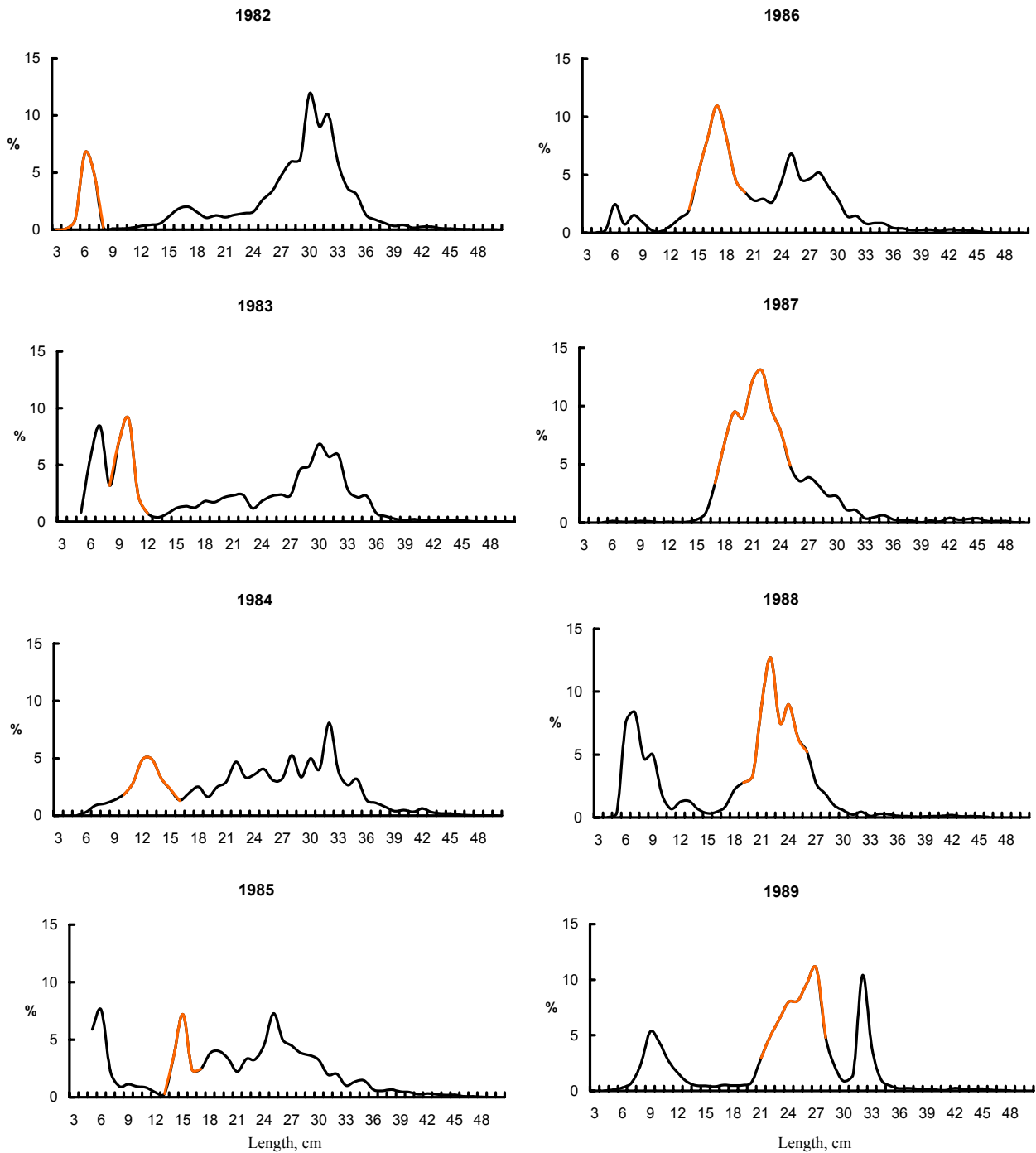




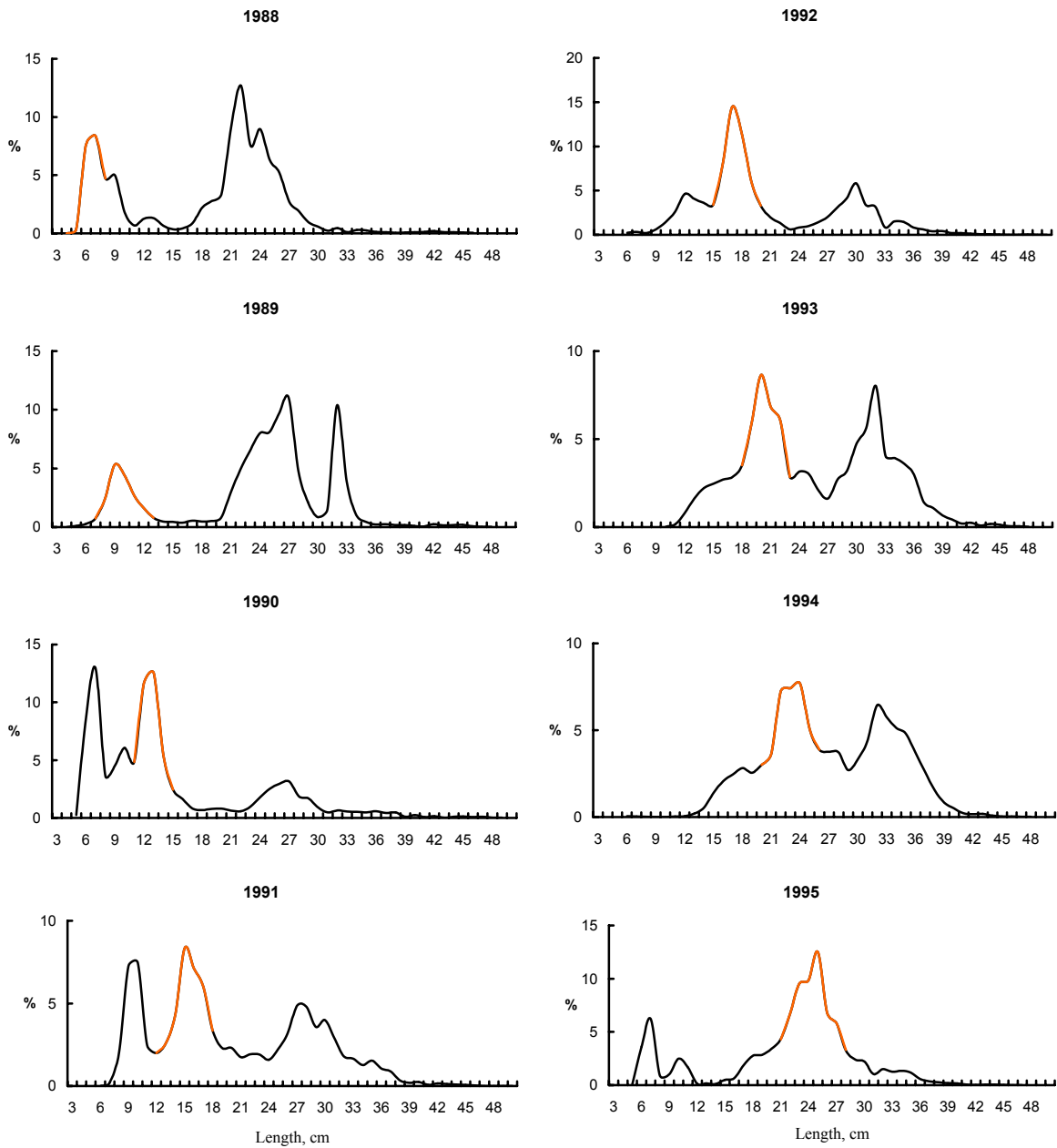
**Fig. 1.** Positions of trawl stations during the annual Norwegian and Russian trawl surveys in autumn.



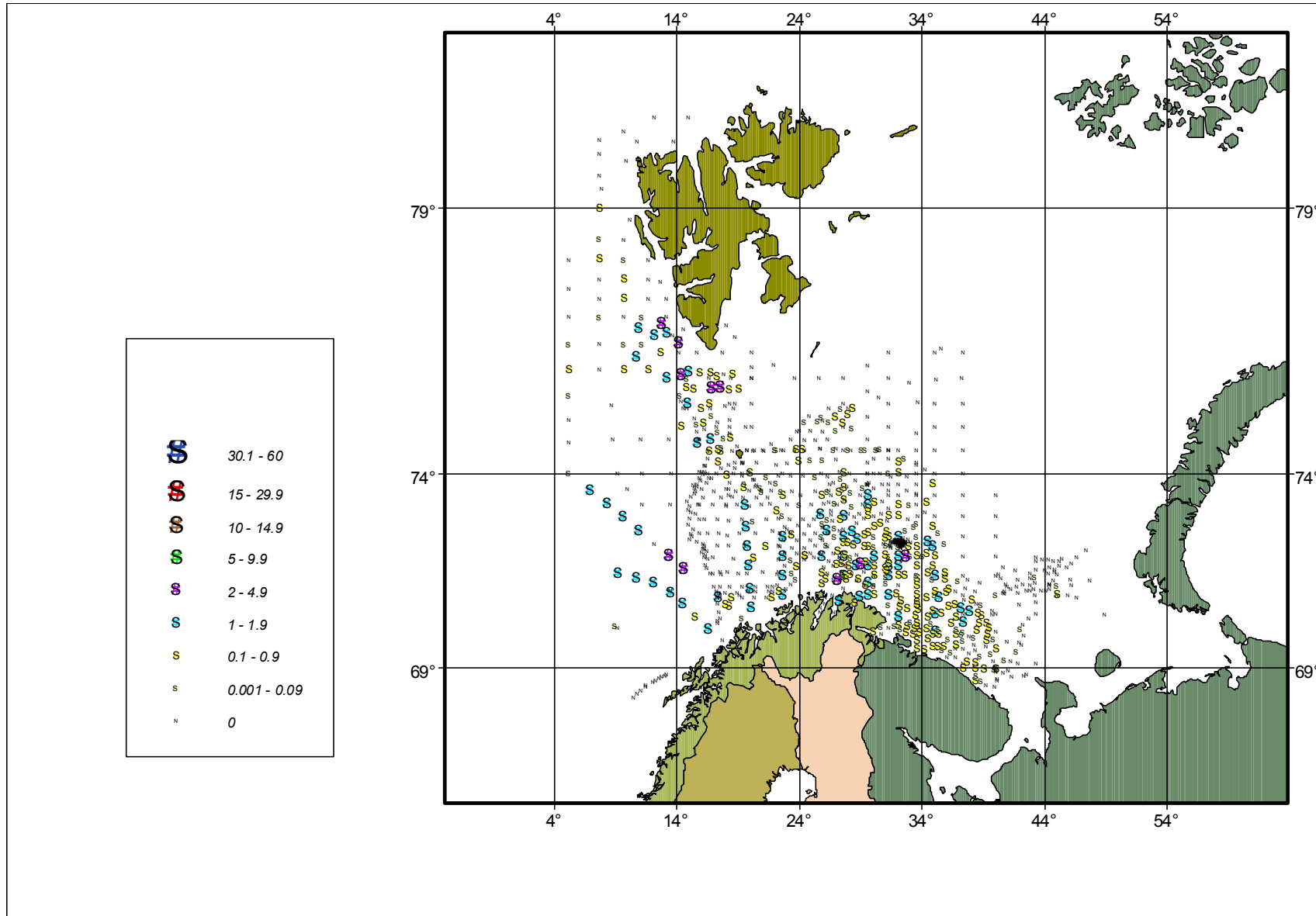
**Fig. 2.** Dominating prevalent current systems in Norwegian Sea/ Barents Sea. Red (Atlantic water) and green arrows (coastal water) – warm, dark blue - cold currents. Spawning area of *Sebastes mentella* has been emphasized (grey area).



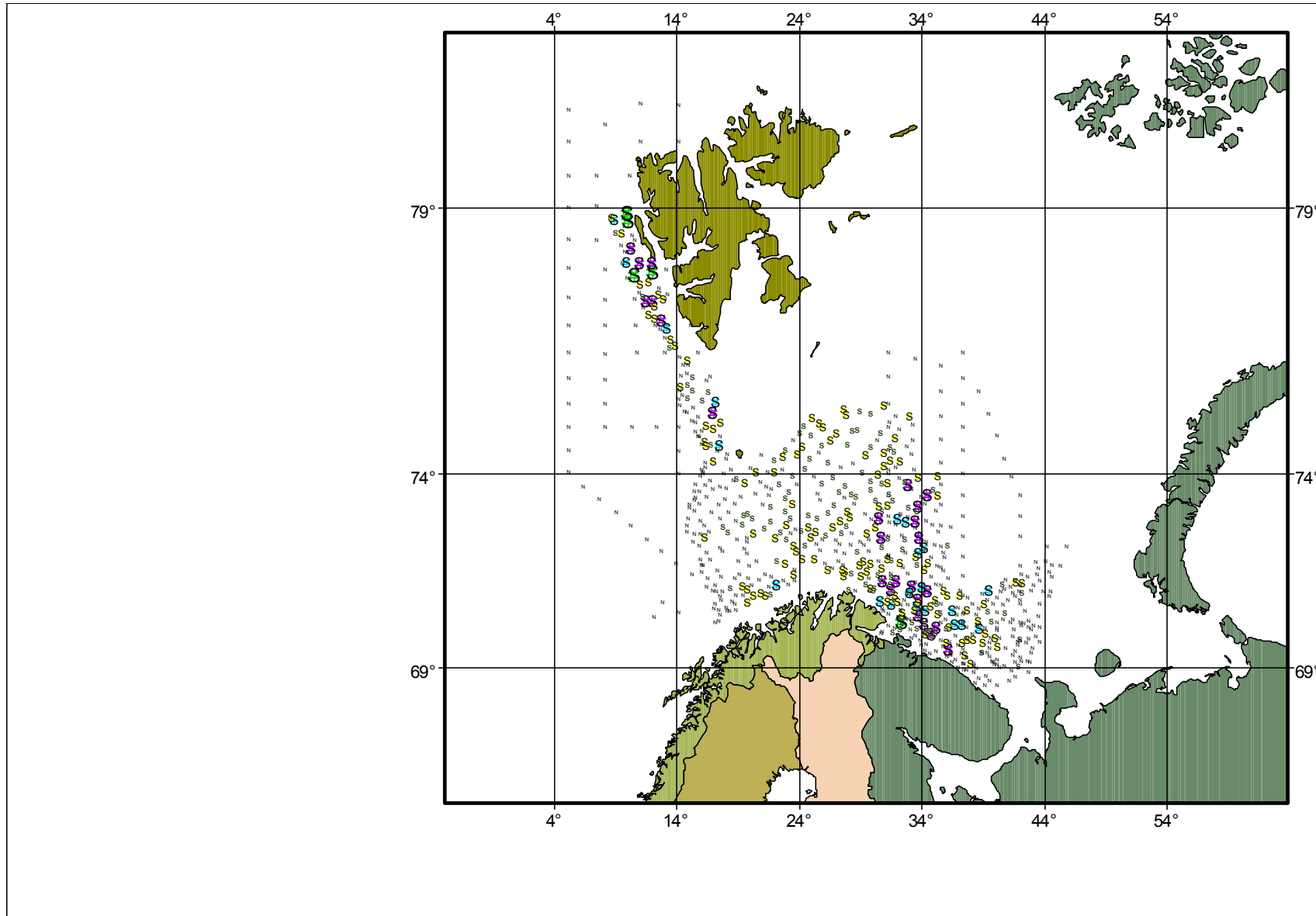
**Fig. 3.** Length composition of *Sebastes mentella* in October-December (Russian trawl survey) 1982-1989, the 1982 yearclass is shown in red



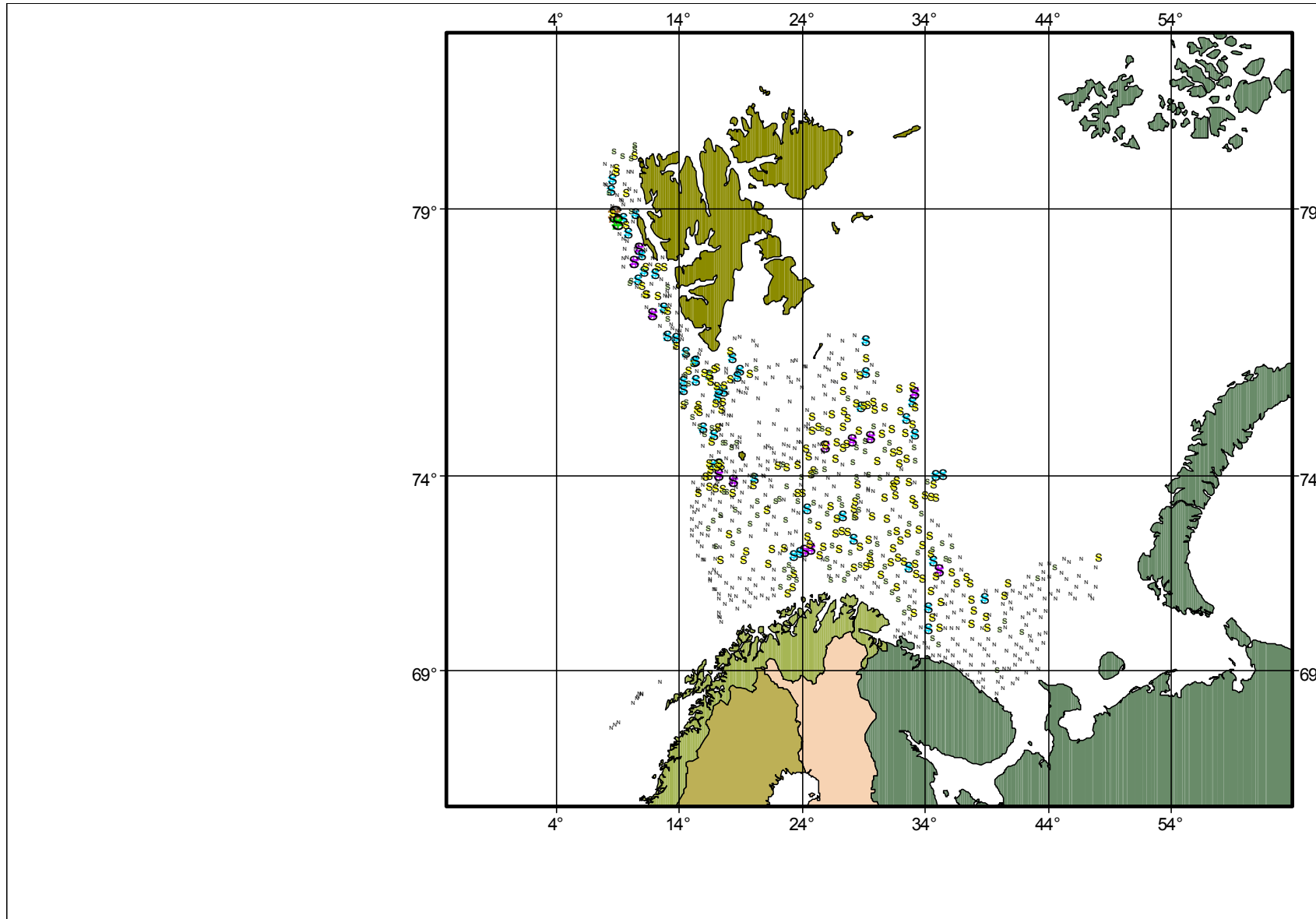
**Fig. 4.** Length composition of *Sebastes mentella* in October-December (Russian trawl survey) 1988-1995, the 1988 yearclass is shown in red



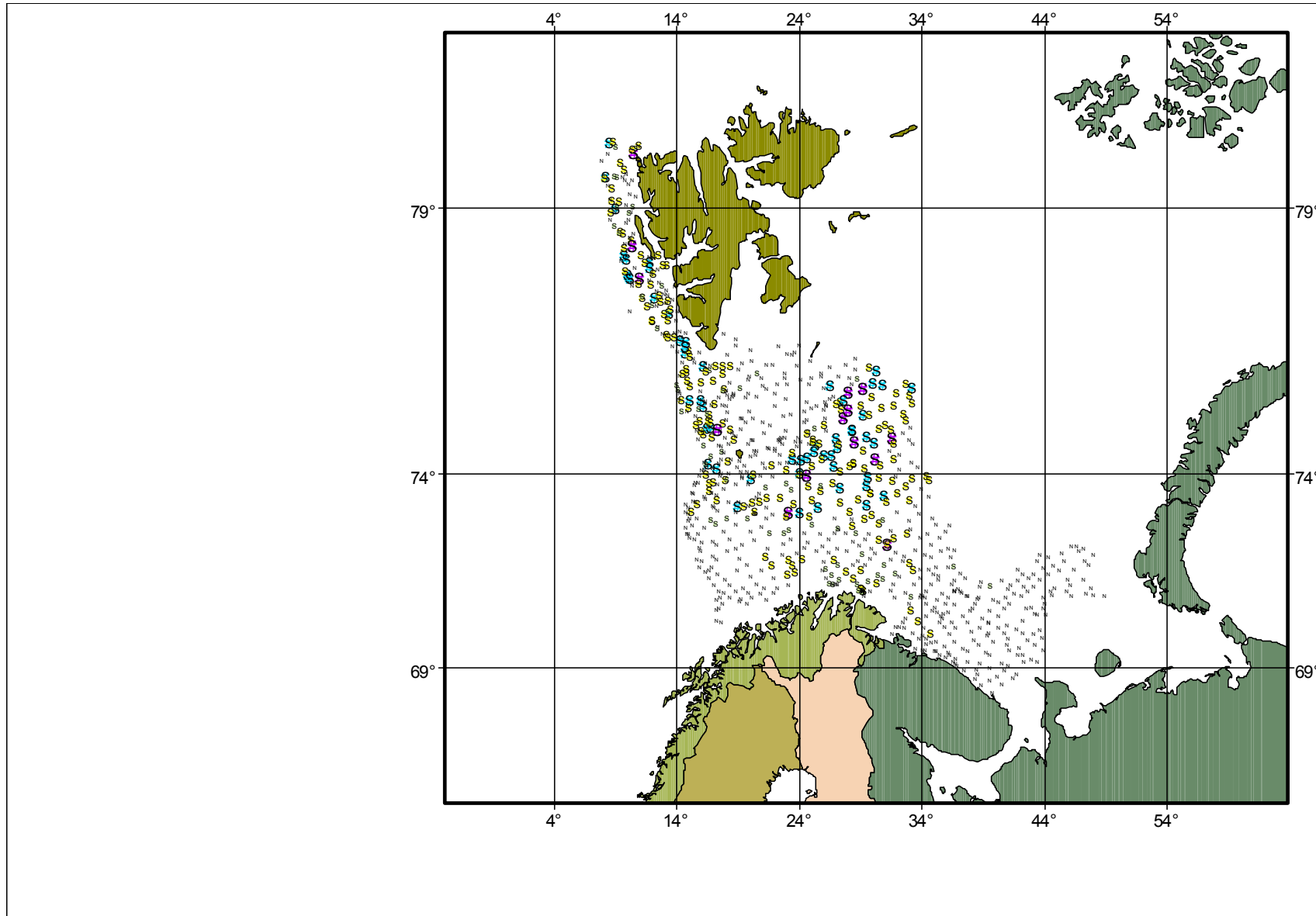
**Fig. 5.** Distribution of *S.mentella* at age 0 (yearclass 1982) in 1982. (Circles represent position of tows; their diameter corresponds to percentage of yearclass caught in a given position of its total catch during the survey)



**Fig. 6.** Distribution of *S.mentella* at age 1 (yearclass 1982) in 1983. See legend and outline in **Fig. 5**.

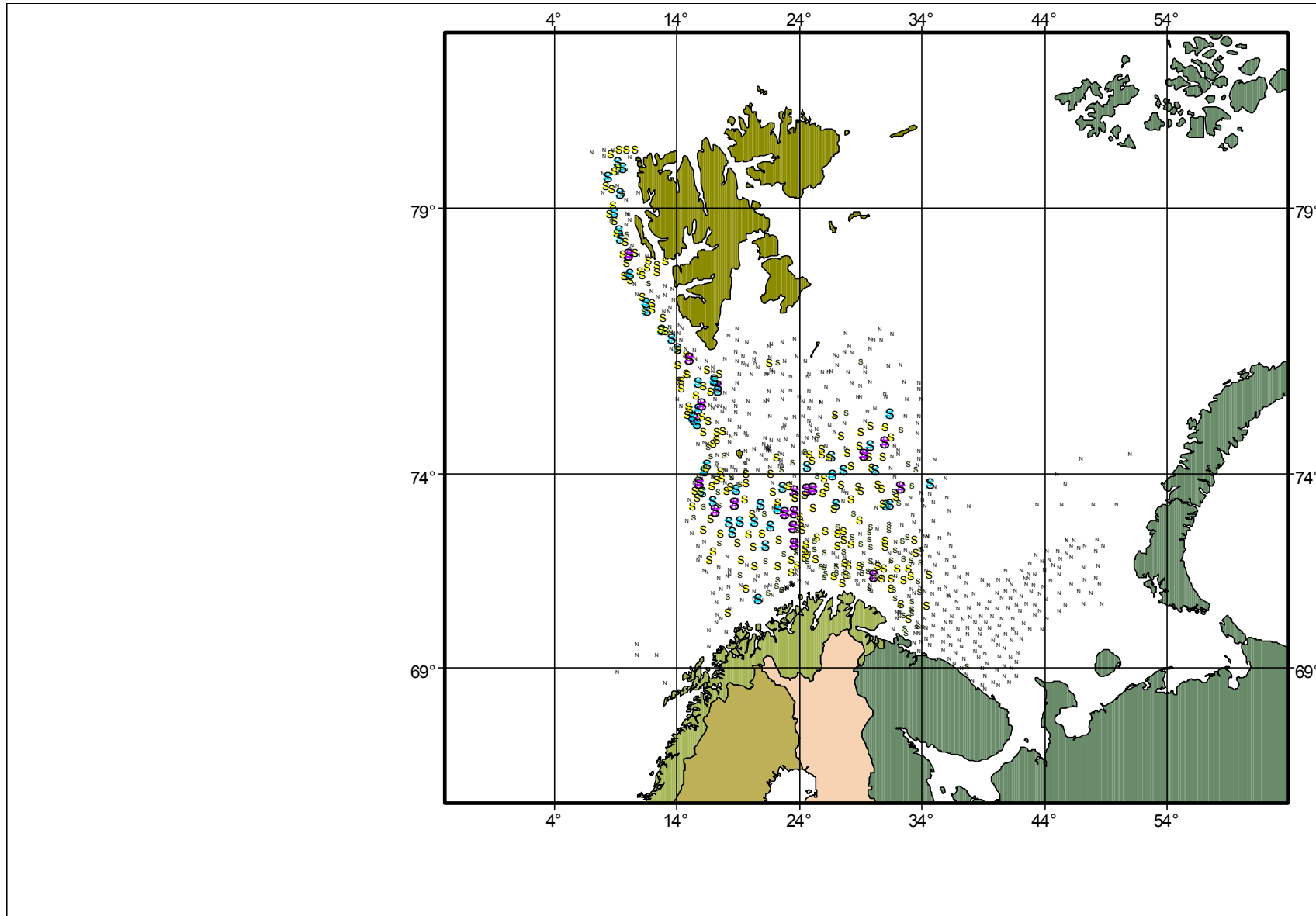


**Fig. 7.** Distribution of *S.mentella* at age 2 (yearclass 1982) in 1984. See legend and outline in **Fig. 5.**

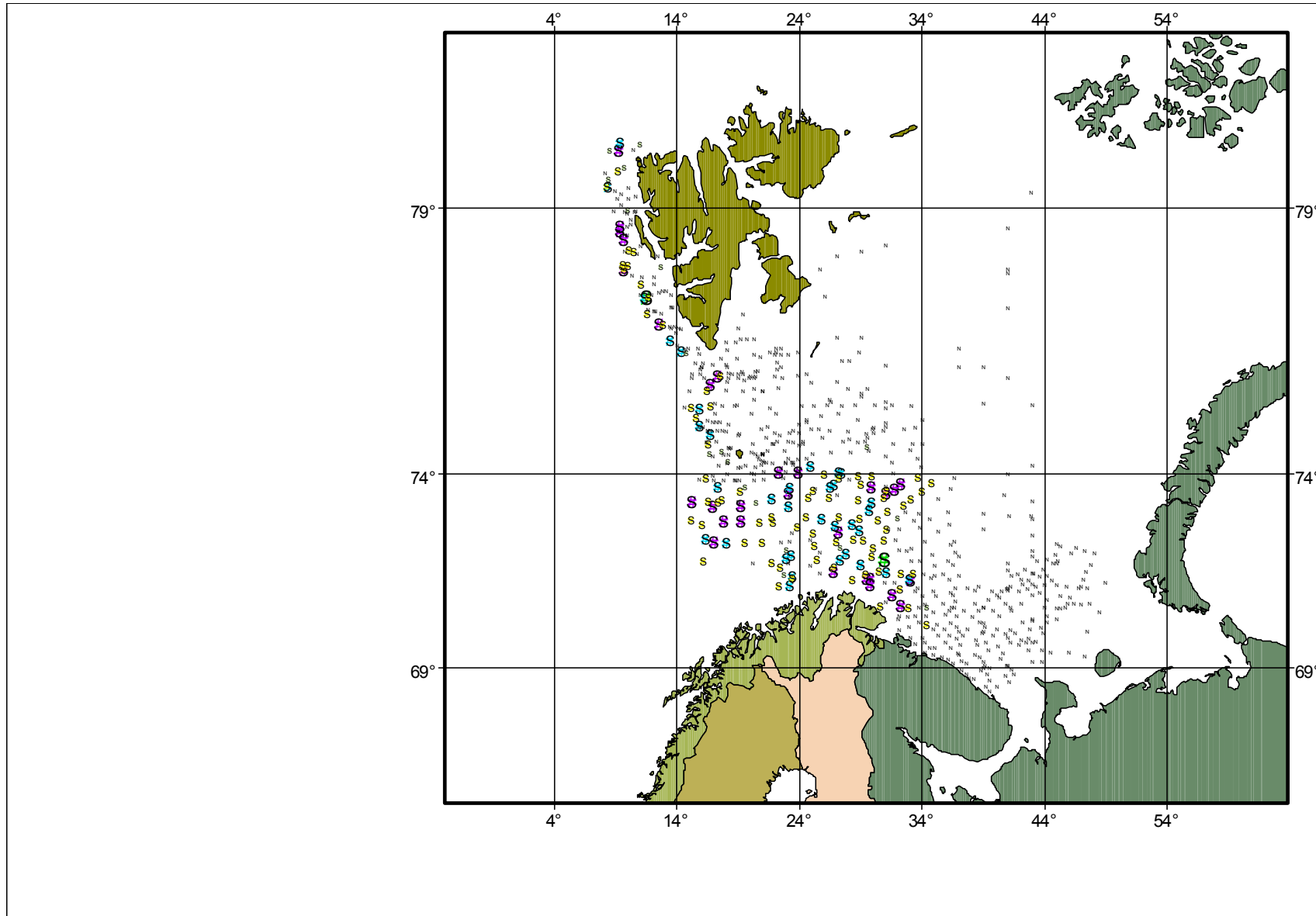


**Fig. 8.** Distribution of *S.mentella* at age 3 (yearclass 1982) in 1985. See legend and outline in **Fig. 5**.

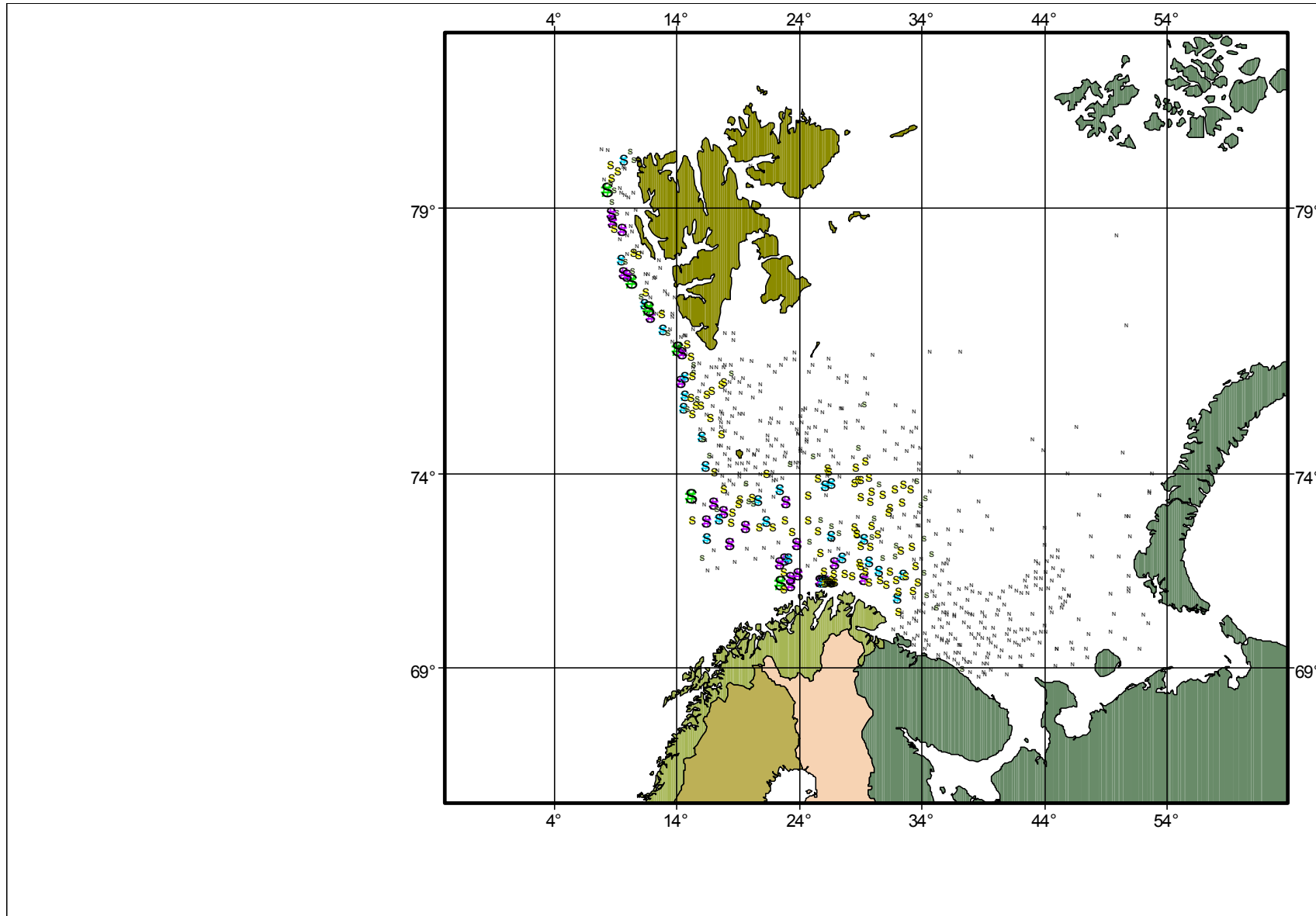




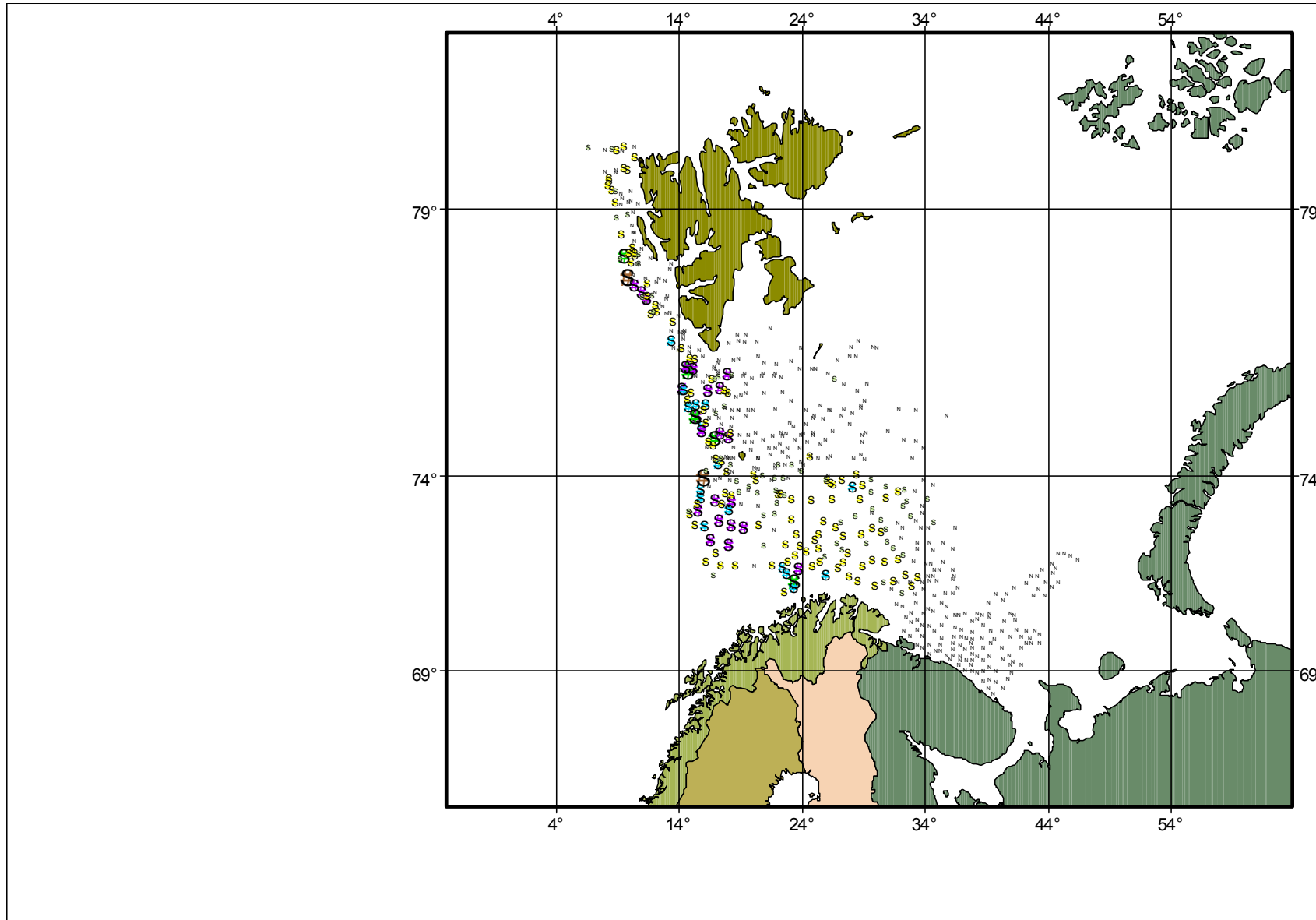
**Fig. 9.** Distribution of *S.mentella* at age 4 (yearclass 1982) in 1986. See legend and outline in **Fig. 5**.



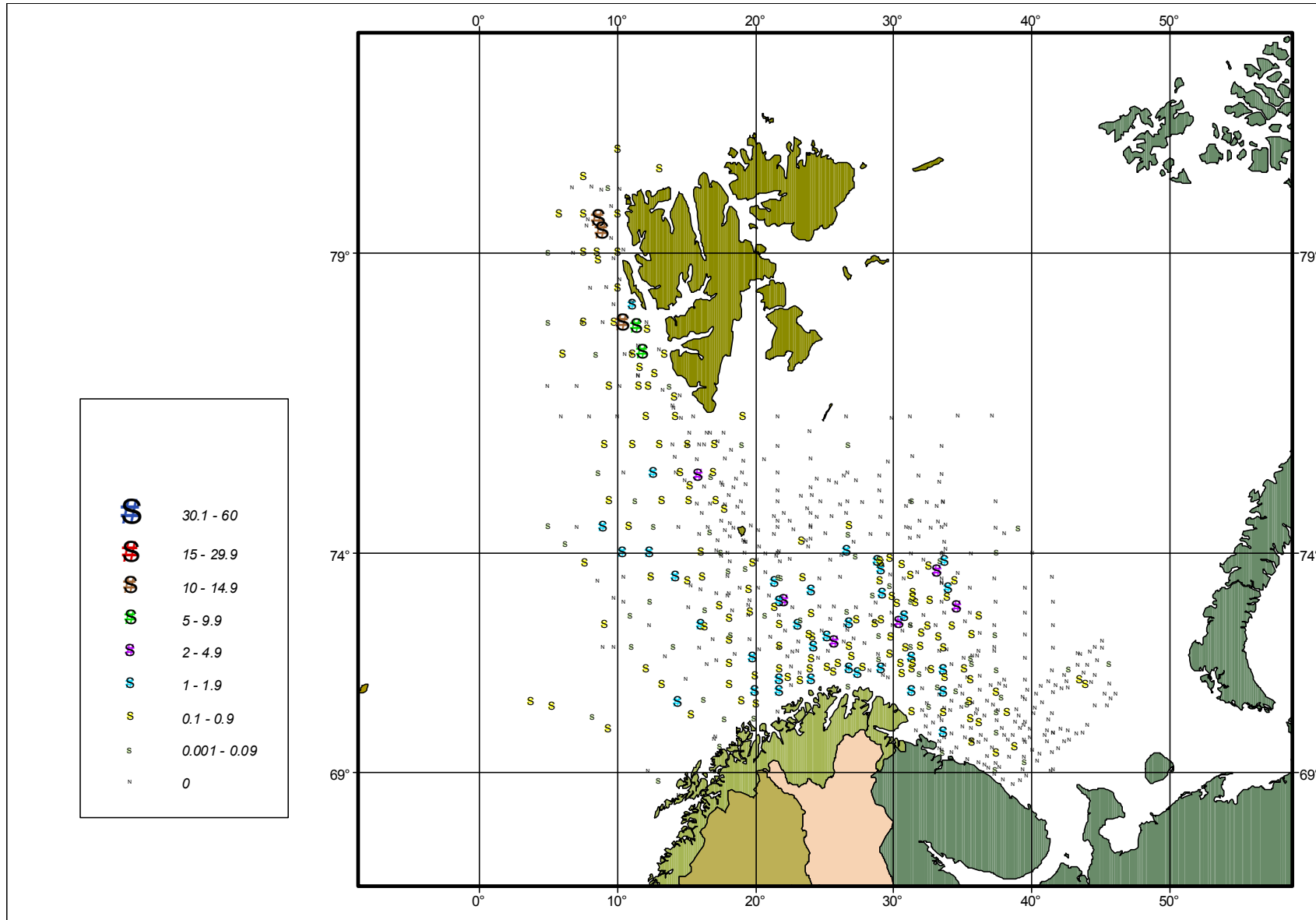
**Fig. 10.** Distribution of *S.mentella* at age 5 (yearclass 1982) in 1987. See legend and outline in **Fig. 5**.



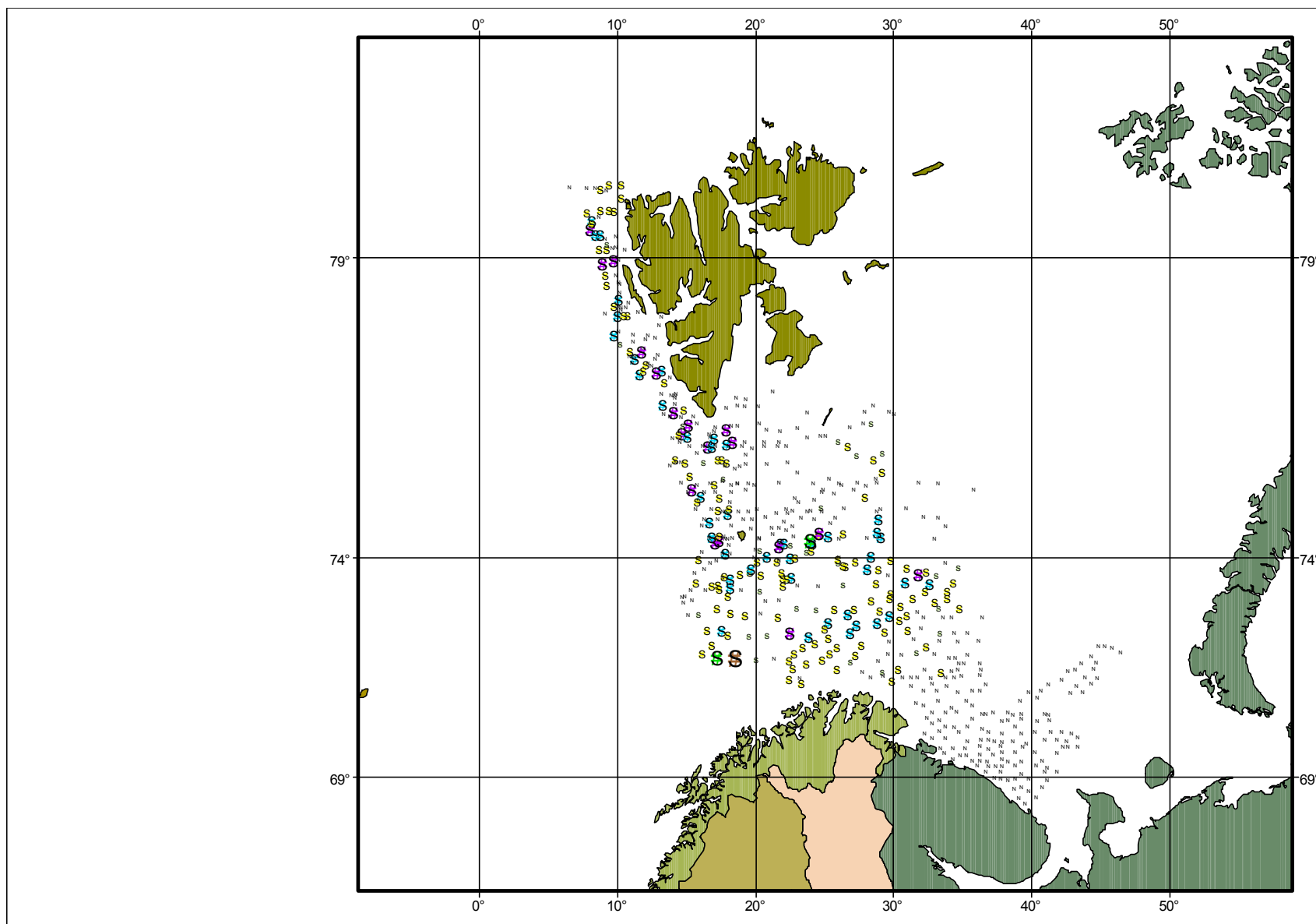
**Fig. 11.** Distribution of *S.mentella* at age 6 (yearclass 1982) in 1988. See legend and outline in **Fig. 5**.



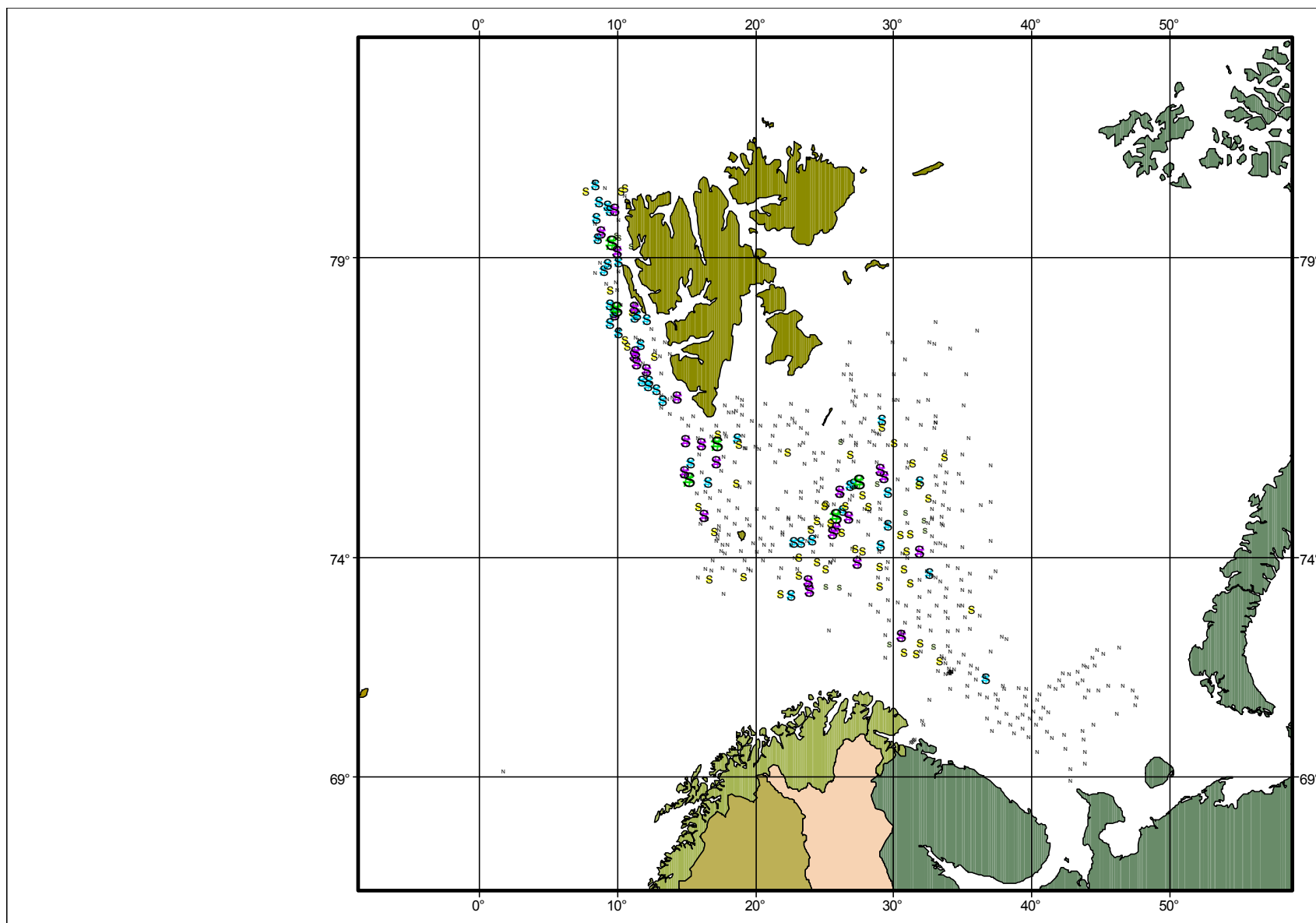
**Fig. 12.** Distribution of *S.mentella* at age 7 (yearclass 1982) in 1989. See legend and outline in **Fig. 5**.



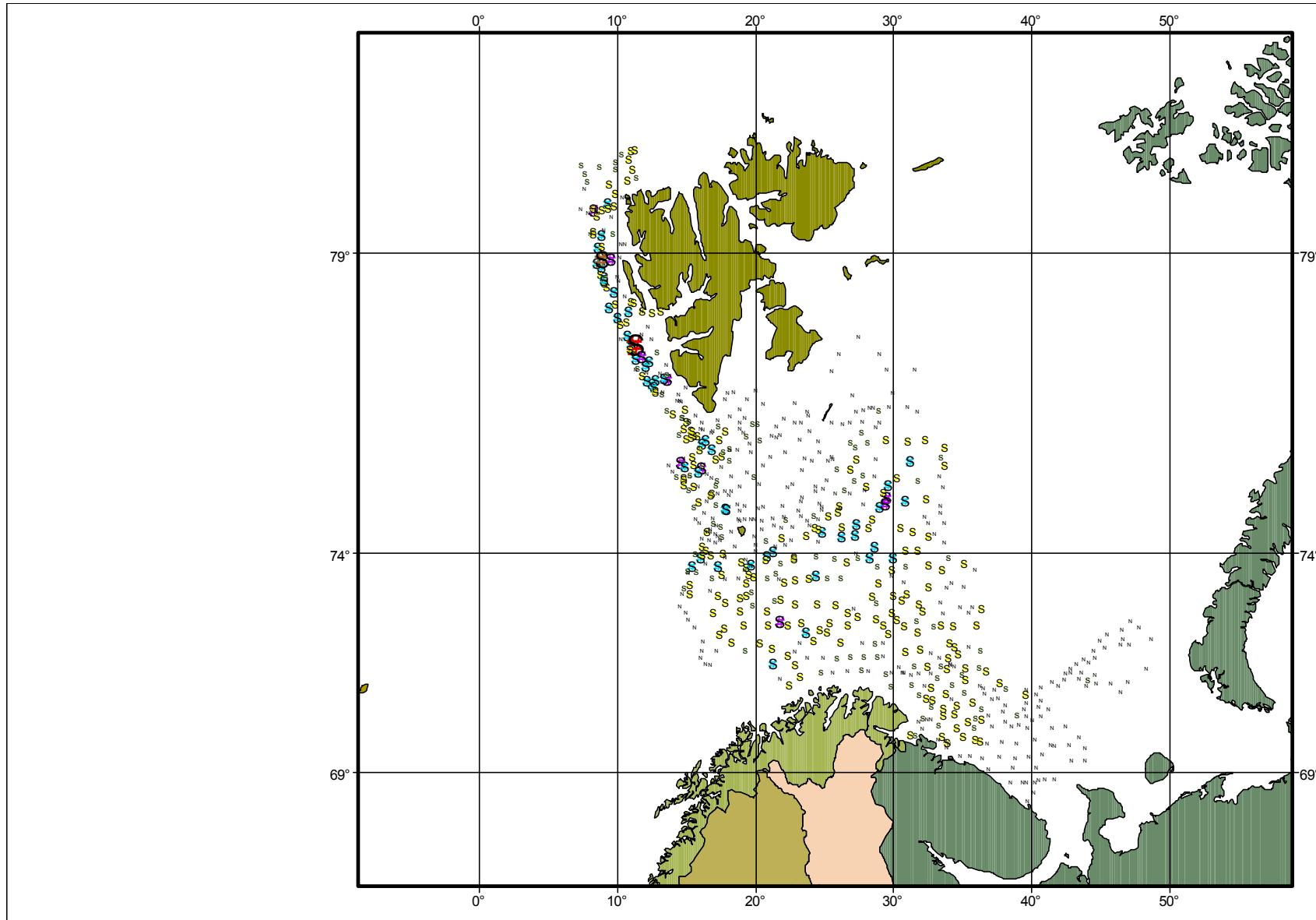
**Fig. 13.** Distribution of *S.mentella* at age 0 (yearclass 1988) in 1988. (Circles represent position of tows; their diameter corresponds to percentage of yearclass caught in a given position of its total catch during the survey)



**Fig. 14.** Distribution of *S. mentella* at age 1 (yearclass 1988) in 1989. See legend and outline in **Fig. 13**.

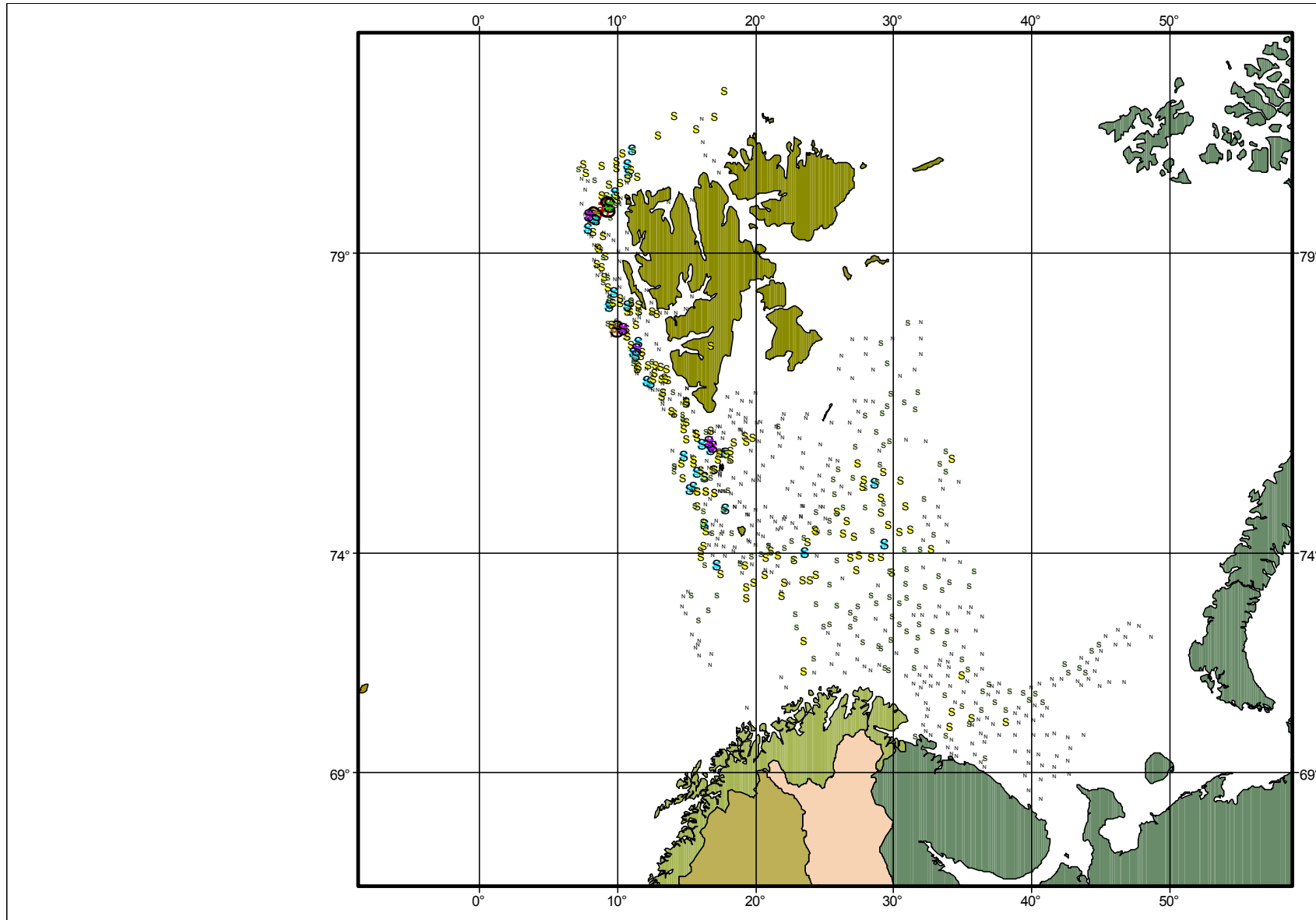


**Fig. 15.** Distribution of *S.mentella* at age 2 (yearclass 1988) in 1990. See legend and outline in **Fig. 13.**

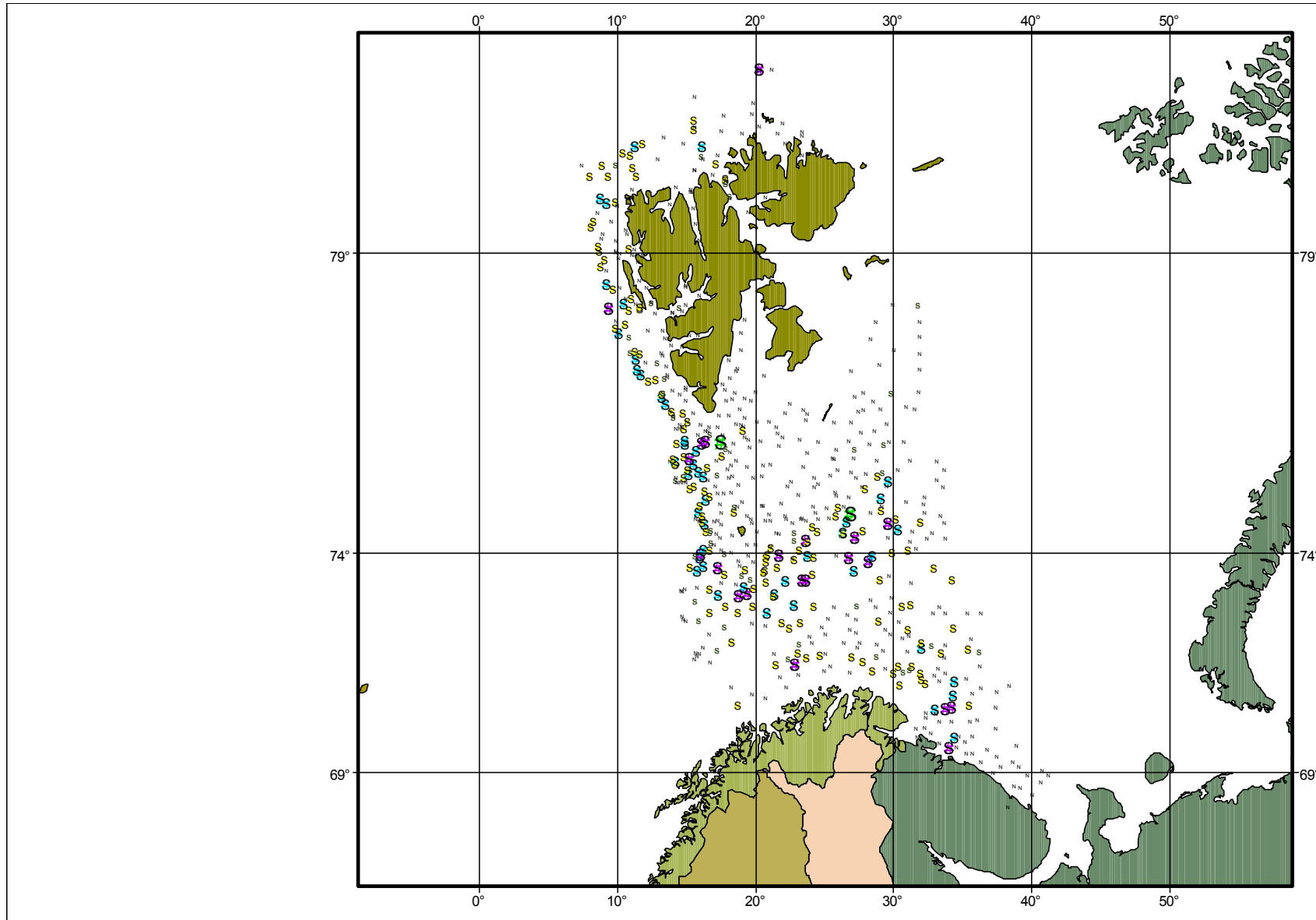


**Fig. 16.** Distribution of *S.mentella* at age 3 (yearclass 1988) in 1991. See legend and outline in **Fig. 13.**

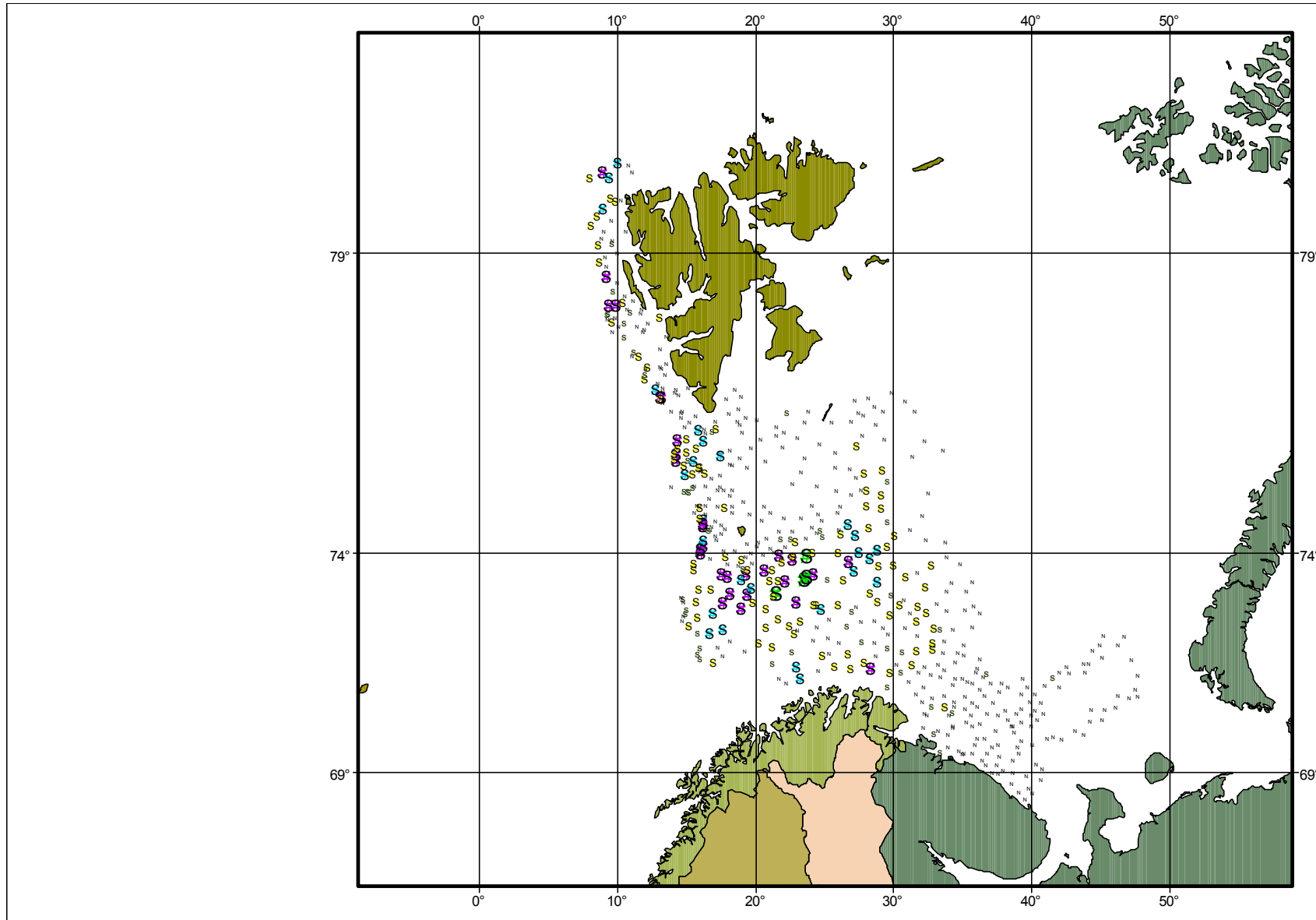




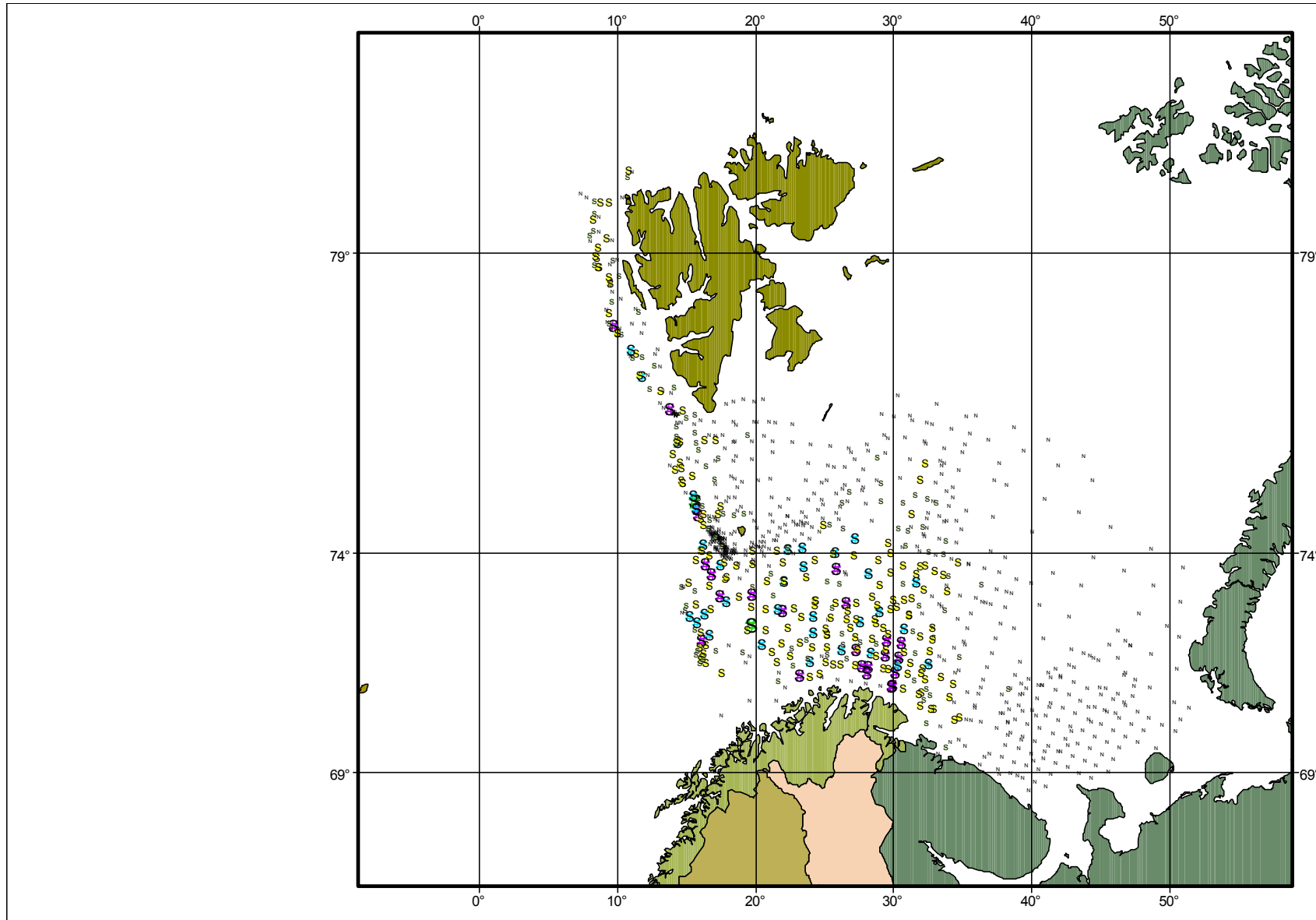
**Fig. 17.** Distribution of *S.mentella* at age 4 (yearclass 1988) in 1992. See legend and outline in **Fig. 13.**



**Fig. 18.** Distribution of *S.mentella* at age 5 (yearclass 1988) in 1993. See legend and outline in **Fig. 13.**



**Fig. 19.** Distribution of *S.mentella* at age 6 (yearclass 1988) in 1994. See legend and outline in **Fig. 13**.



**Fig. 20.** Distribution of *S.mentella* at age 7 (yearclass 1988) in 1995. See legend and outline in **Fig. 13**.