Northwest Atlantic Fisheries Organization

Serial No. N4775 **NAFO SCR Doc. 02/146**

SCIENTIFIC COUNCIL MEETING – NOVEMBER 2002

Abundance indices for juvenile (age 1 and 2) northern shrimp (*Pandalus borealis*) off West Greenland (NAFO Subareas 0+1), 1993 - 2002

by

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Abstract

Length frequency distributions of northern shrimp (*Pandalus borealis*) from the West Greenland Bottom Trawl Survey in the years 1993 to 2002 were analysed. The original data were pooled into five major regions defined by latitudinal differences in bottom temperature. Modal analysis was used to estimate mean length and abundance for age 1 and 2. For both ages, mean length was significantly correlated with bottom temperature and indicated a change to faster growth in the past years. The estimates of the 1-group abundance appear to be seriously effected by low catchability due to trawl selection while the abundance indices for the 2-group can be used to assess changes in recruitment.

Introduction

In the past years, recruitment of northern shrimp (*Pandalus borealis*) at West Greenland has been assessed based on visual inspection of length frequencies and an abundance index comprising all individuals with a carapax length of less than 17 mm (Kanneworff and Wieland 2001, 2002). A single size group with a modal length of between 13 and 15 mm CL has dominated this size range in the 1990's, but in 2000 smaller individuals (9 mm CL) were almost equally abundant. Additionally, the contribution of larger individuals with a modal length of about 19 to 20 mm CL increased in the past years as this peak in the length frequencies has become progressively closer to the limit of 17 mm CL used for the calculation of the recruitment index (Kanneworff and Wieland 2002). Hence, a change to faster growth as reported by Carlsson et al. (1999) and related to an increase in bottom temperature by Carlson and Kanneworff (1999) makes it difficult to assess changes in recruitment using abundance defined by a fixed size limit or by visual inspection of length frequencies. Therefore, the present study attempted to provide abundance indices for northern shrimp at age 1 and 2 by decomposing length frequencies from the West Greenland Bottom Trawl Survey on an area-disaggregated basis for the years 1993 to 2002.

Material and Methods

The West Greenland Bottom Trawl Survey for northern shrimp (and fish) has been conducted by the Greenland Institute of Natural Resources since 1988. The design of the survey has been subject to various changes. Major modifications include several extensions of the survey area and a reduction of the mesh size of the cod-end liner from 44 to 20 mm in 1993 (Carlsson et al. 2000). Due to the latter the present analysis is limited to the years 1993 and thereafter. A detailed description of the current survey design, fishing practice and sample analysis is given in Kanneworff and Wieland (2002).

Swept area estimates of catches of northern shrimp by 0.5 mm carapax length (CL) interval from the original sampling strata were pooled into 5 regions (Fig. 1). The regions were defined mainly based on latitudinal gradients

of bottom temperature for which pronounced differences in the survey area have been observed in particular in the past years (Wieland in prep., Tab. 1). Bottom temperatures were measured along the trawl tracks in intervals of 30 to 60 s with a SEAMON © recorder mounted on one of the trawl doors. Average bottom temperatures at the sampling sites were then used to calculate mean bottom temperatures weighted by stratum area for the five regions.

Modal analysis of the regional length frequencies for juveniles and males were conducted using the MIX 3.1A software (MacDonald and Pitcher 1979). No smoothing was applied prior to analysis, and initial estimates of the modes were obtained by visual inspection of the length frequencies. A constant coefficient of variation were used in the MIX analysis during a first run and, whenever possible, also in the final parameter estimation (Tab. 2). However, because the first age group was not well represented in many of the samples, a part of the larger males had already changed sex and differences in growth between cohorts were likely, varying coefficients of variation gave more realistic results in many cases, in particular for the second age group.

Results

Length frequencies of northern shrimp (juveniles and males) by region and year with fitted Gaussian components are shown in Figs. 2a-j and further results of the modal analysis, i.e. mean length, standard deviation and coefficient of variation, are listed in Tabs. 3 and 4 for the 1- and the 2-group, respectively. For regions 1 to 4, the Gaussian components fitted the observed distribution in the size range of the 2-group fairly well in almost all years. Problems occurred in the modal analysis for both, the 1- and the 2-group in region 5 (Southwest Greenland) in several years due to low abundance of individuals in the corresponding size range. Annual differences in the mean length at age between the regions were as large as 3.8 mm CL for the 1-group and 5.1 mm CL for the 2-group.

Mean length increased generally from north to south and was significantly correlated with bottom temperature in the current year for both ages and in the case of the 2-group correlation coefficients increased if bottom temperatures recorded in one or two preceded years were additionally included (Fig. 3).

Considerable numbers of age 1 northern shrimp were regularly found in region 4 (offshore between 61°45' and 65°45'N) and since 1997 also in regions 2 (Disko Bay) and 3 (offshore between 65°45' and 69°30' N) while the contributions from regions 1 (offshore north from 69°30'N) and 5 (offshore south from 61°45'N) to the overall abundance indices were negligible in almost all years (Fig. 4). The indices of total abundance for the 1-group increased since 1996 with an exceptional high peak in 2000.

Age 2 northern shrimp were found in regions 3 and 4 in all years and since 1996 with considerable numbers also in region 2 (Fig. 4). The 2-group was additionally abundant in regions 1 in the years 1999 to 2001 while it was nearly absent in region 5 throughout the entire time series. Total abundance in the survey area increased since 1997 to the highest value on record in 2001 and decreased in 2002 to a level, which is just above the long-term average.

Discussion

Length frequency distributions of northern shrimp from original sampling strata were pooled into five topographic regions, which were defined by differences in mean bottom temperature. The pooled length frequencies allowed the extraction of mean size and abundance for ages 1 and 2 by modal analysis. In general, reasonable fits of Gaussian components were obtained. Some uncertainties concerning the interpretation of the length frequencies occurred, but these were limited to regions and years with low numbers of individuals in the respective size range and thus its effect on the estimates of total abundance in the survey area can be regarded as small. Mean length at age 1 and 2 was significantly related with bottom temperature, which is a biologically plausible supporting the results of the modal analysis. In future studies, however, a finer spatial resolution might be considered for regions 3 and 4 where the juveniles occurred regularly in high numbers and a heterogeneous distribution of bottom temperature related to bathymetry has been observed (Wieland in prep., Fig 5).

The abundance indices for age 1 were very much below those for age 2 for all year-classes covered by the time series. Several processes may be involved in a low catchability of the 1-group in the survey. These include mesh size selection of the trawl, which appears to be most pronounced for individuals with a carapax length less than 11 mm (Wieland 2002), escapement of juveniles beneath the footrope (Nilssen 1986) and immigration from settling areas located at depths shallower than intensively covered by the survey (Wieland and Carlson 2001). These processes are likely size-dependent and are thus subject to the observed change in growth. Hence, the abundance indices for the 1- group as presented in this study should be treated with much caution.

Comparative sampling of juvenile shrimp with fine-meshed bags was recently conducted (Wieland 2002) and these data should be used to correct of the original length frequencies for mesh size selection of the trawl in the future. This could improve the abundance estimates for the 2-group and would make it more likely that the assumption of constant catchability is met even if changes in growth have occurred. Furthermore, the application of a certain degree of smoothing prior to modal analysis could be appropriate in order to reduce effect of details in length frequencies, which may be caused by differences between the numerous persons involved in measurements (Carlsson and Kanneworff 2000, Wieland 2001).

The abundance indices presented for age 2 should be regarded as preliminary estimates due to the methodological uncertainties discussed above. Nonetheless, they appear to be preferable to the recruitment indices defined the fixed size limit of less than 17 mm CL as used previously considering the observed change to faster growth in the past years.

Acknowledgements

The cooperation with Per Kanneworff, Greenland Institute of Natural Resources, who provided the temperature data for the trawl stations, is gratefully acknowledged.

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Table 1. Area weighted mean bottom temperatures (°C) at depths between 150 and 600 m in five regions off West Greenland 1991– 2002 (see Fig. 1 for the location of the regions).

Region	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
1	1.29	1.52	1.29	1.24	1.43	1.17	2.30	2.73	2.89	2.53	2.50	2.68
2	1.22	1.56	1.14	1.39	1.53	1.24	2.57	2.86	2.94	2.37	2.86	2.81
3	1.70	1.91	1.78	1.97	1.61	1.95	2.78	3.32	3.31	2.93	3.30	3.33
4	2.71	2.35	2.64	2.42	2.16	3.56	3.21	3.99	4.00	3.41	3.99	3.66
5	-	-	4.40	4.43	3.18	4.55	4.75	4.74	5.36	4.59	5.12	4.45

Table 2. Options used in the final run of MIX for the analysis of length frequencies of northern shrimp juveniles and males off West Greenland 1993 – 2002 (0: no constraints; 1: mean or standard deviation fixed for age 1; 2: mean or standard deviation fixed for age 2; 3: constant coefficient of variation for all age groups; 4: constant coefficient of variation except for the last age group).

	Region				
Year	1	2	3	4	5
1993	4	4	4	4	1, 2
1994	4	4	4	4	3
1995	4	4	3	3	1, 2
1996	0	0	0	4	3
1997	3	0	4	4	3
1998	0	0	4	0	1, 2
1999	4	0	4	0	2
2000	0	0	0	4	4
2001	4	0	0	0	2
2002	1	0	0	4	2

Table 3. Mean carapax length (mm), standard deviation and coefficient of variation for northern shrimp at age 1 off West Greenland 1993 - 2002.

a) mean:

	Region				
Year	1	2	3	4	5
1993	-	-	8.2	9.9	11.5
1994	-	8.1	7.8	8.9	11.5
1995	-	8.5	8.4	9.0	10.5
1996	-	9.8	8.0	9.1	-
1997	-	8.5	8.9	8.7	-
1998	7.7	9.5	9.5	10.9	11.5
1999	9.3	10.1	9.3	10.6	11.5
2000	7.9	8.8	9.0	9.2	11.0
2001	8.7	8.8	7.6	8.7	11.4
2002	9.5	8.6	8.8	9.1	10.4

b) standard deviation:

	Region				
Year	1	2	3	4	5
1993	-	-	0.78	0.86	0.50
1994	-	0.59	0.70	0.81	0.55
1995	-	0.61	0.89	0.82	0.40
1996	-	0.71	0.72	1.00	-
1997	-	0.72	0.82	0.86	-
1998	0.49	0.81	1.05	1.12	0.72
1999	0.88	1.04	0.83	1.40	0.80
2000	0.60	0.86	0.79	0.87	0.85
2001	0.88	0.97	0.87	1.11	0.55
2002	0.66	0.74	0.75	0.85	0.82

c): coefficient of variation:

	Region				
Year	1	2	3	4	5
1993	-	-	0.09	0.09	0.04
1994	-	0.07	0.09	0.09	0.05
1995	-	0.07	0.11	0.09	0.04
1996	-	0.07	0.09	0.11	-
1997	-	0.08	0.09	0.10	-
1998	0.06	0.09	0.11	0.10	0.06
1999	0.09	0.10	0.09	0.13	0.07
2000	0.08	0.10	0.09	0.09	-
2001	0.10	0.11	0.11	0.13	0.05
2002	0.07	0.09	0.09	0.09	0.08

Table 4. Mean carapax length (mm), standard deviation and coefficient of variation for northern shrimp at age 2 off West Greenland 1993 - 2002.

a) mean:

	Region				
Year	1	2	3	4	5
1993	11.2	12.0	13.0	15.0	14.1
1994	12.7	11.5	12.8	14.4	-
1995	11.2	12.4	13.8	12.6	-
1996	12.3	12.9	13.9	13.5	16.2
1997	12.9	12.9	12.4	14.0	13.0
1998	10.9	13.9	15.7	16.0	16.0
1999	14.6	15.2	14.8	15.2	15.5
2000	14.2	14.9	15.0	14.4	-
2001	13.9	13.1	13.2	13.8	13.5
2002	12.9	12.6	12.7	14.4	13.5

b) standard deviation:

	Region				
Year	1	2	3	4	5
1993	0.89	0.93	1.23	1.30	0.65
1994	0.95	0.84	1.15	1.32	-
1995	0.72	0.90	1.38	1.15	-
1996	0.93	1.02	1.18	1.48	0.79
1997	1.12	1.10	1.13	1.37	0.54
1998	1.22	1.36	1.73	1.21	1.04
1999	1.38	1.34	1.33	1.46	1.07
2000	1.72	1.34	1.37	1.36	-
2001	1.41	1.26	1.32	1.12	0.65
2002	1.23	1.45	1.28	1.34	1.06

c) coefficent of variation:

	Region				
Year	1	2	3	4	5
1993	0.08	0.08	0.09	0.09	0.05
1994	0.07	0.07	0.09	0.09	-
1995	0.06	0.07	0.10	0.09	-
1996	0.08	0.08	0.08	0.11	0.05
1997	0.09	0.08	0.09	0.10	0.04
1998	0.11	0.10	0.11	0.08	0.07
1999	0.09	0.09	0.09	0.10	0.07
2000	0.12	0.09	0.09	0.09	-
2001	0.10	0.10	0.10	0.08	0.05
2002	0.10	0.11	0.10	0.09	0.08

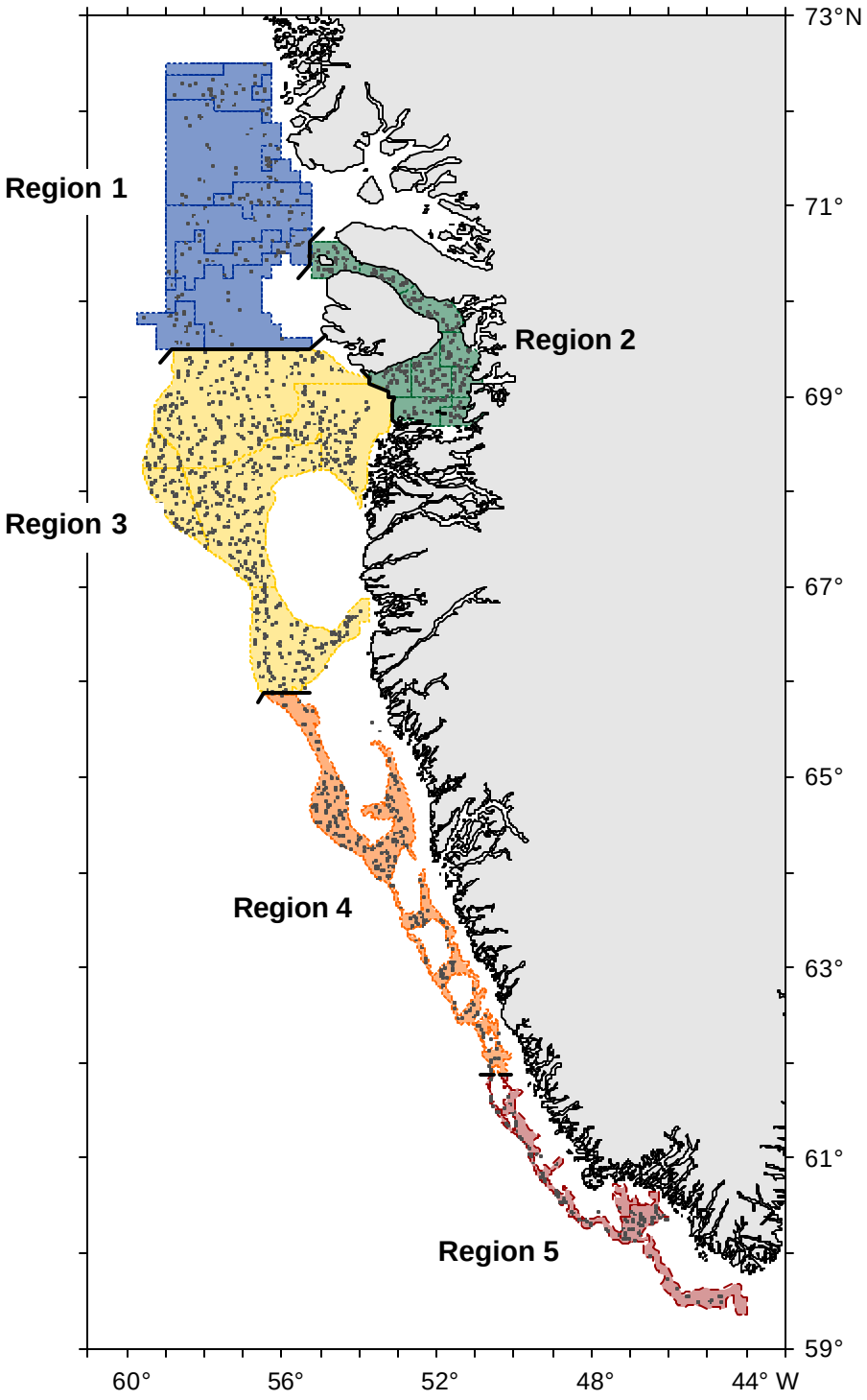

Fig. 1. Survey stratification and sampling locations in the West Greenland Bottom Trawl Survey for northern shrimp.

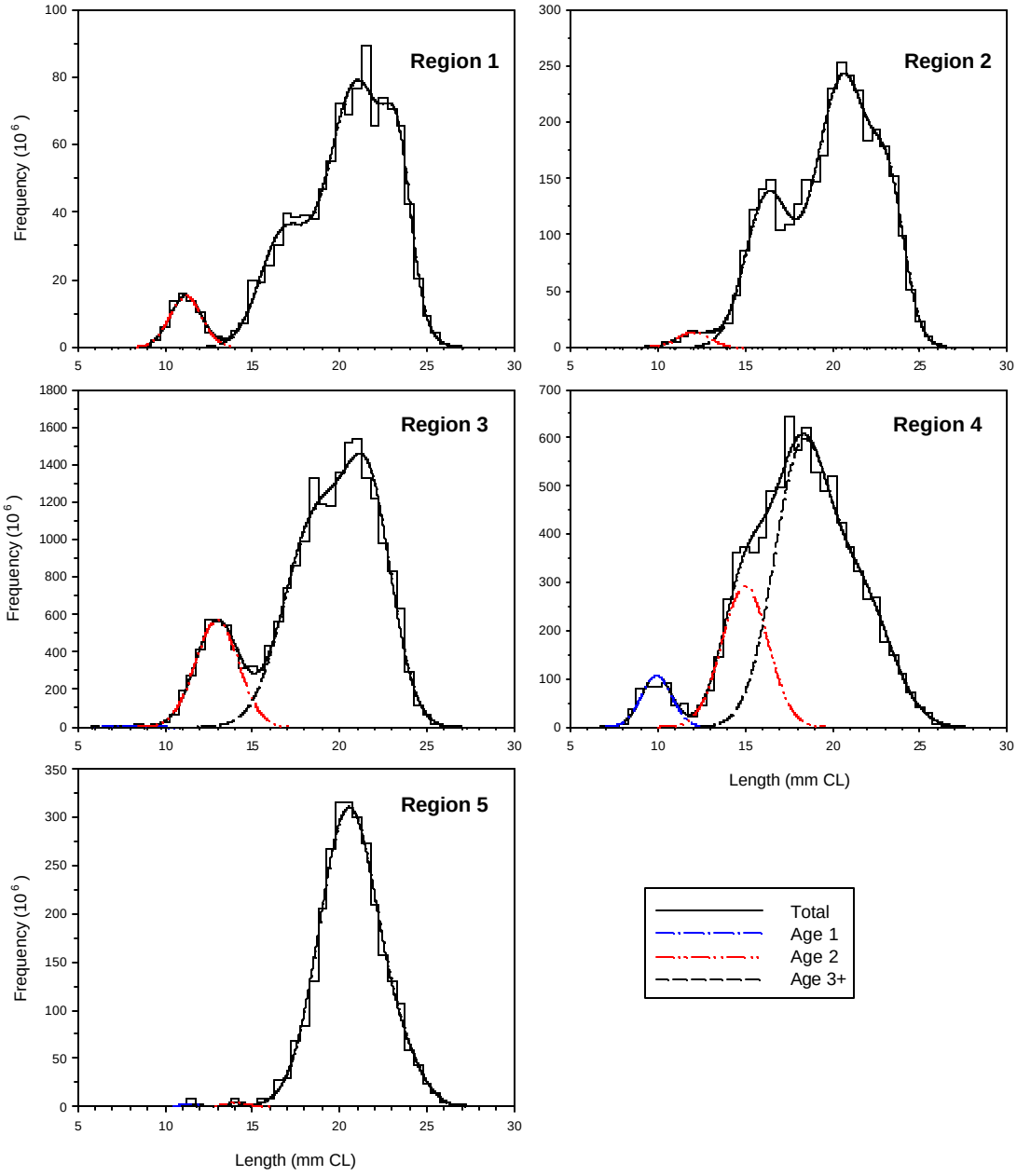

Fig. 2a. Regional length frequencies of northern shrimp (juveniles and males) off West Greenland in 1993.

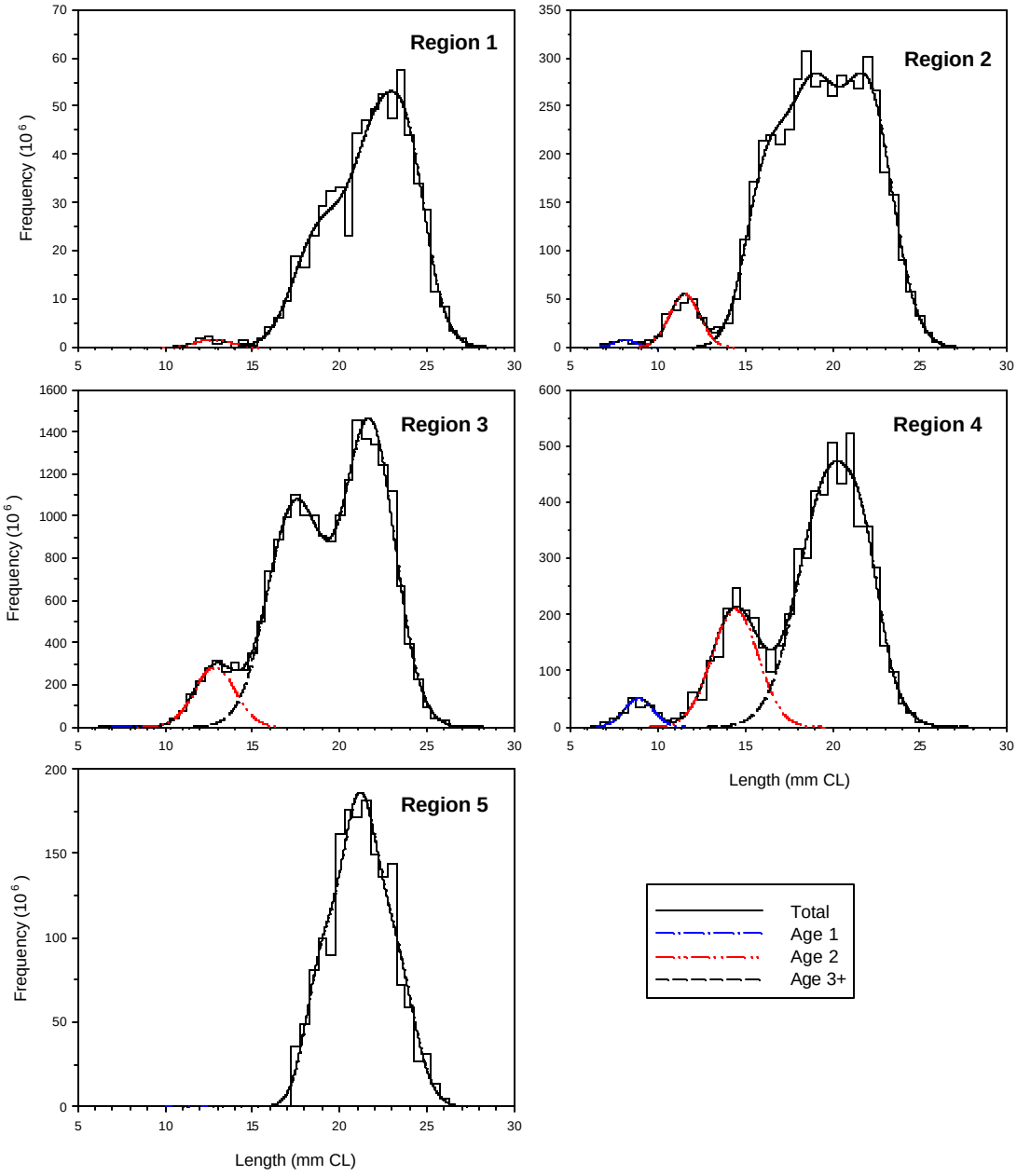

Fig. 2b. Regional length frequencies of northern shrimp (juveniles and males) off West Greenland in 1994.

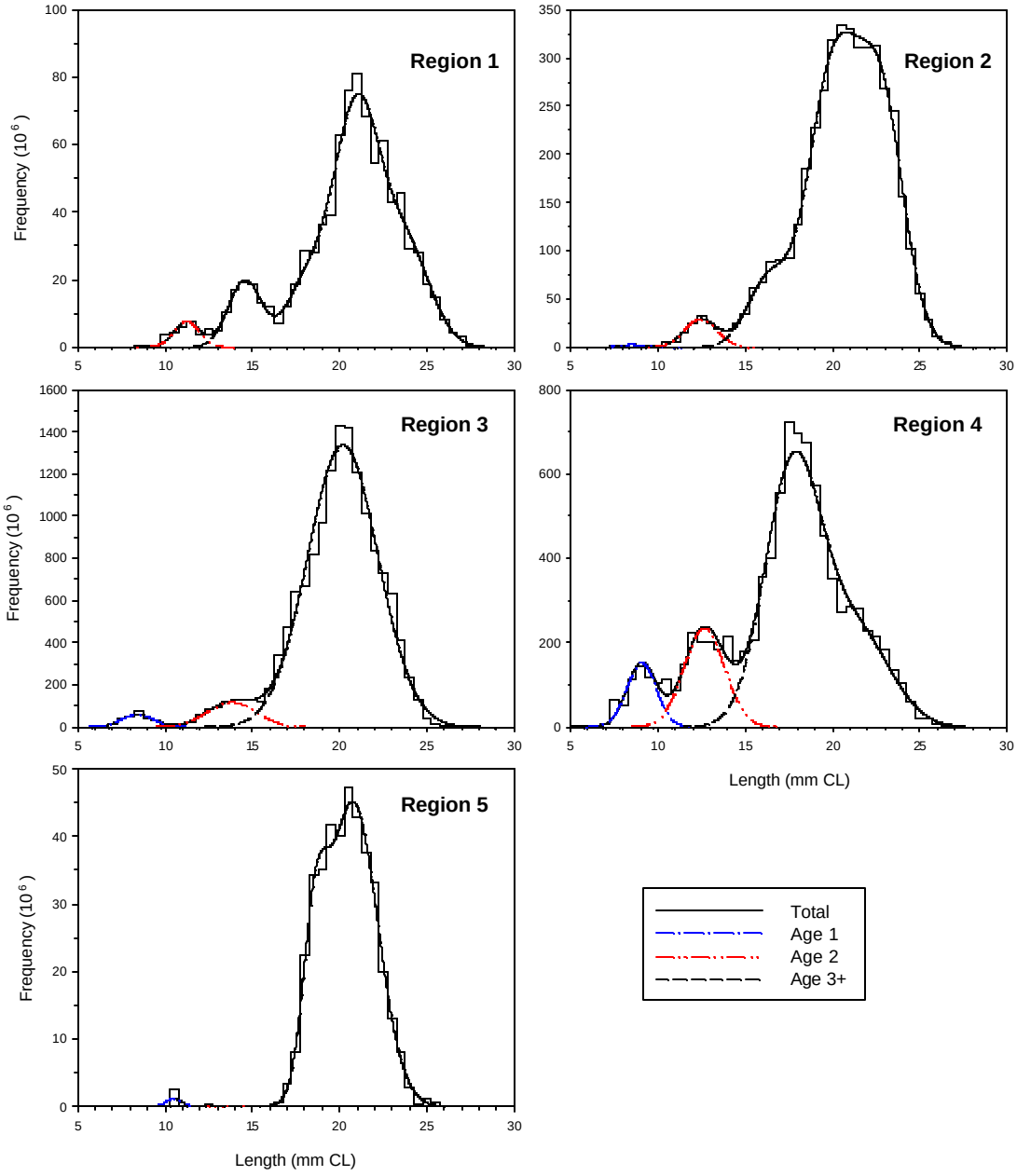

Fig. 2c. Regional length frequencies of northern shrimp (juveniles and males) off West Greenland in 1995.

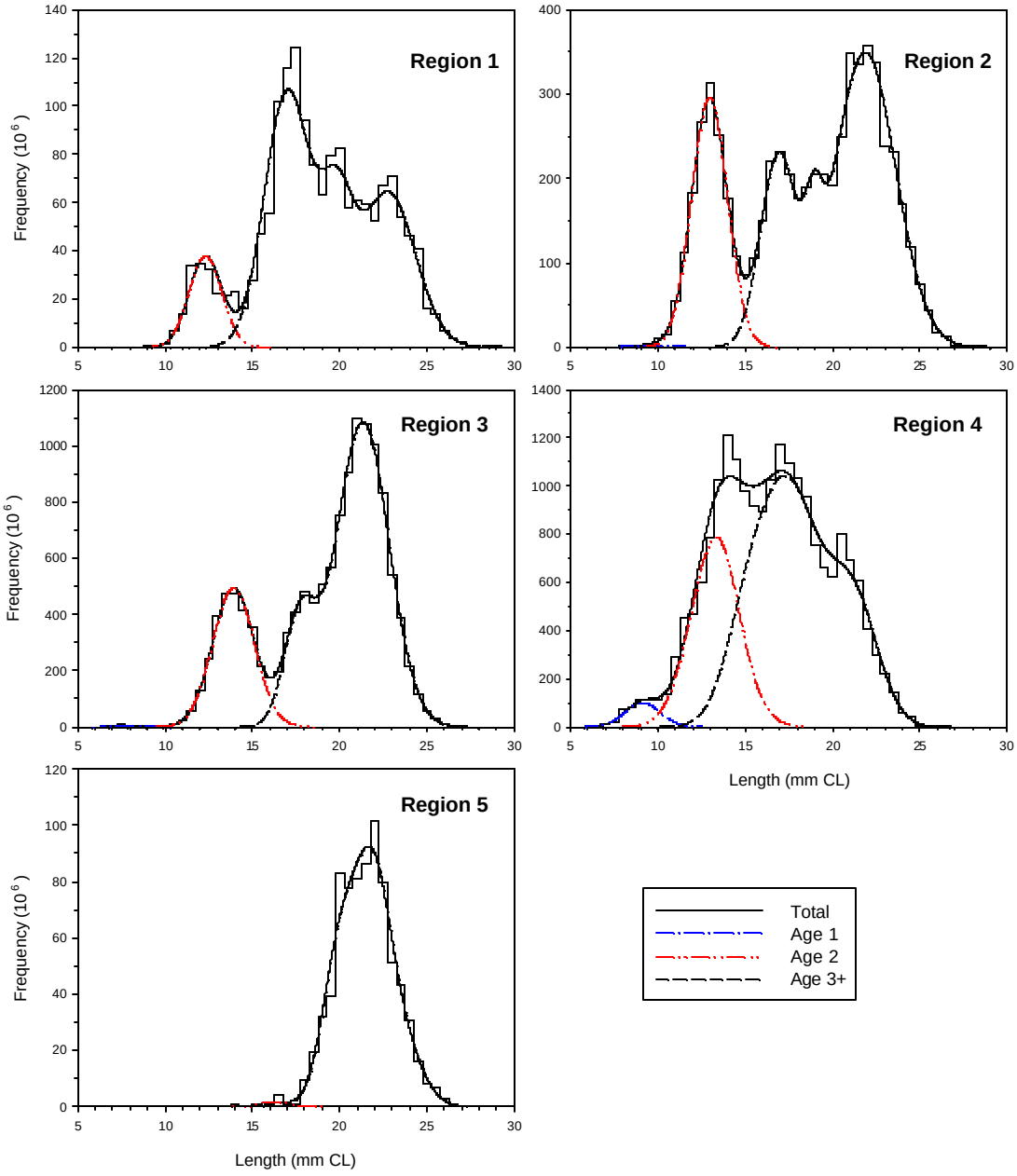

Fig. 2d. Regional length frequencies of northern shrimp (juveniles and males) off West Greenland in 1996.

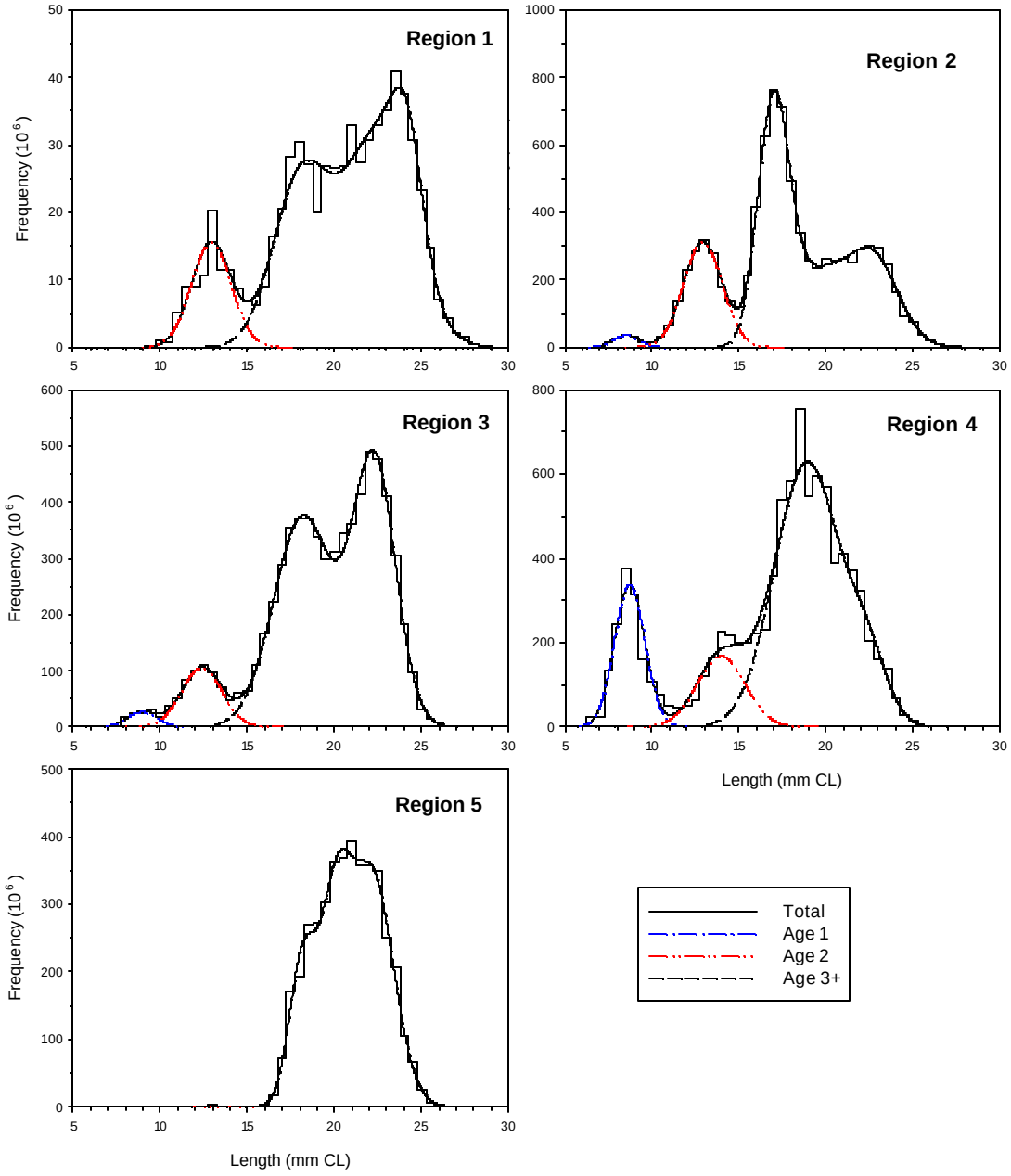

Fig. 2e. Regional length frequencies of northern shrimp (juveniles and males) off West Greenland in 1997.

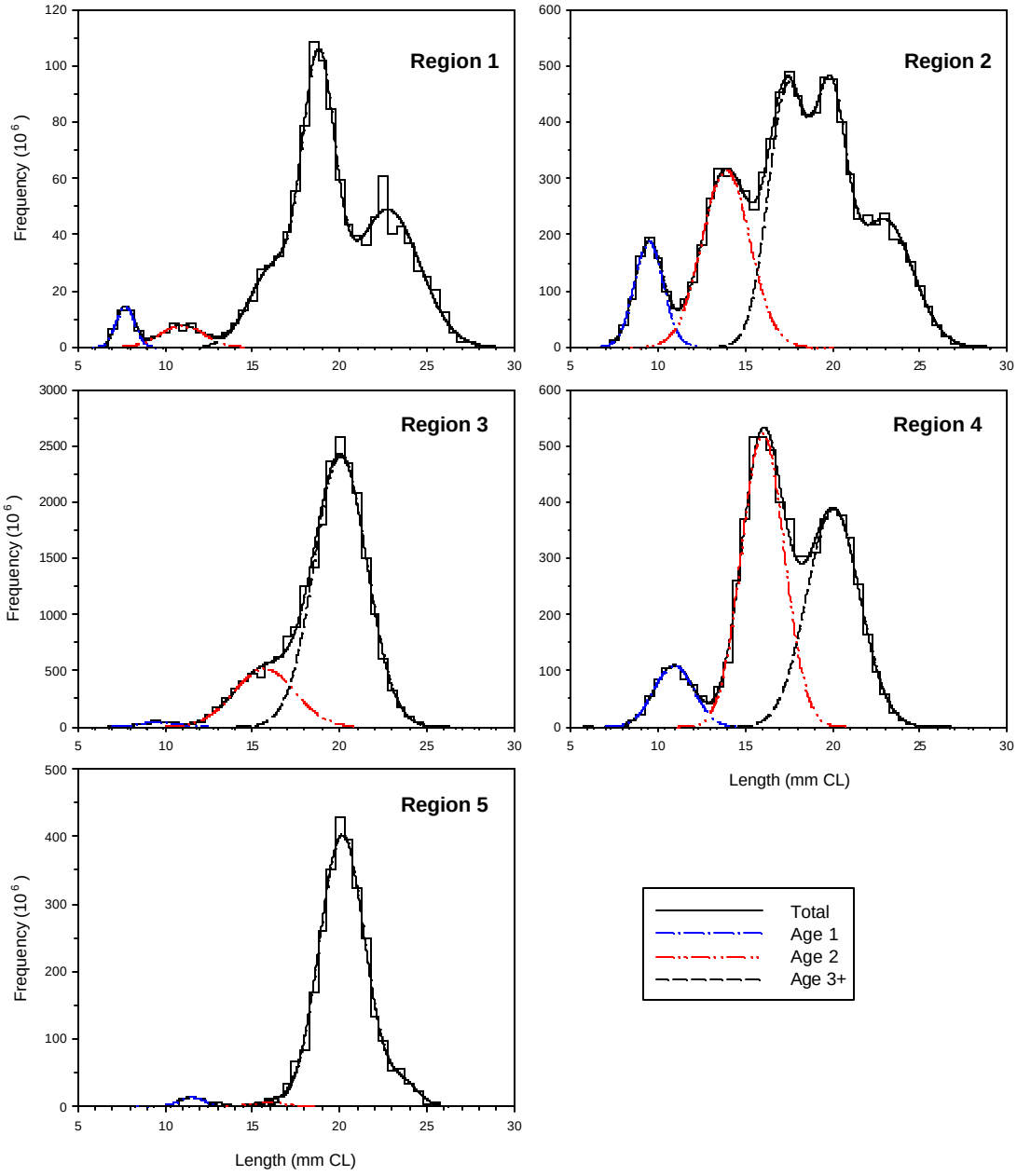

Fig. 2f. Regional length frequencies of northern shrimp (juveniles and males) off West Greenland in 1998.

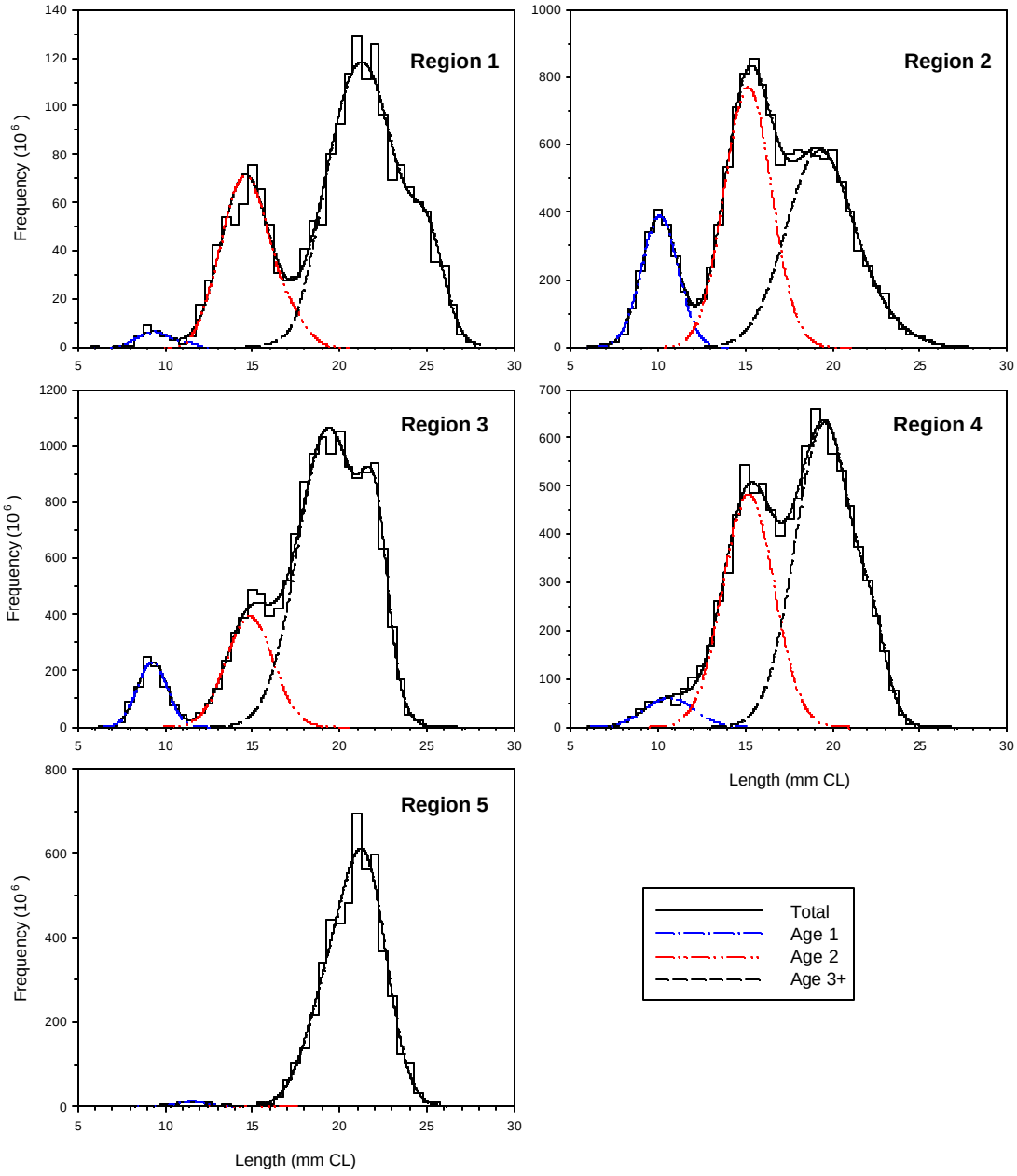

Fig. 2g. Regional length frequencies of northern shrimp (juveniles and males) off West Greenland in 1999.

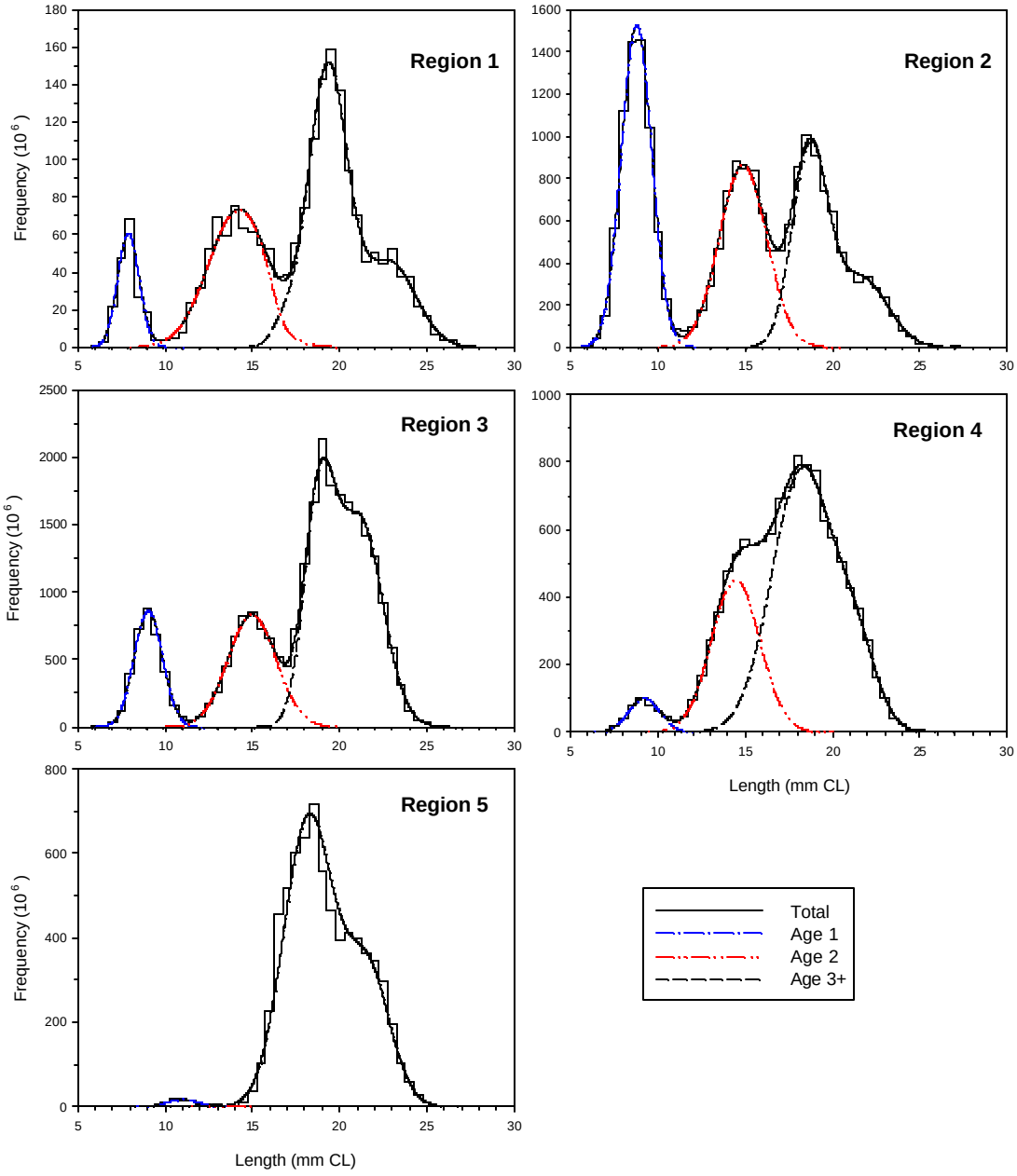

Fig. 2h. Regional length frequencies of northern shrimp (juveniles and males) off West Greenland in 2000.

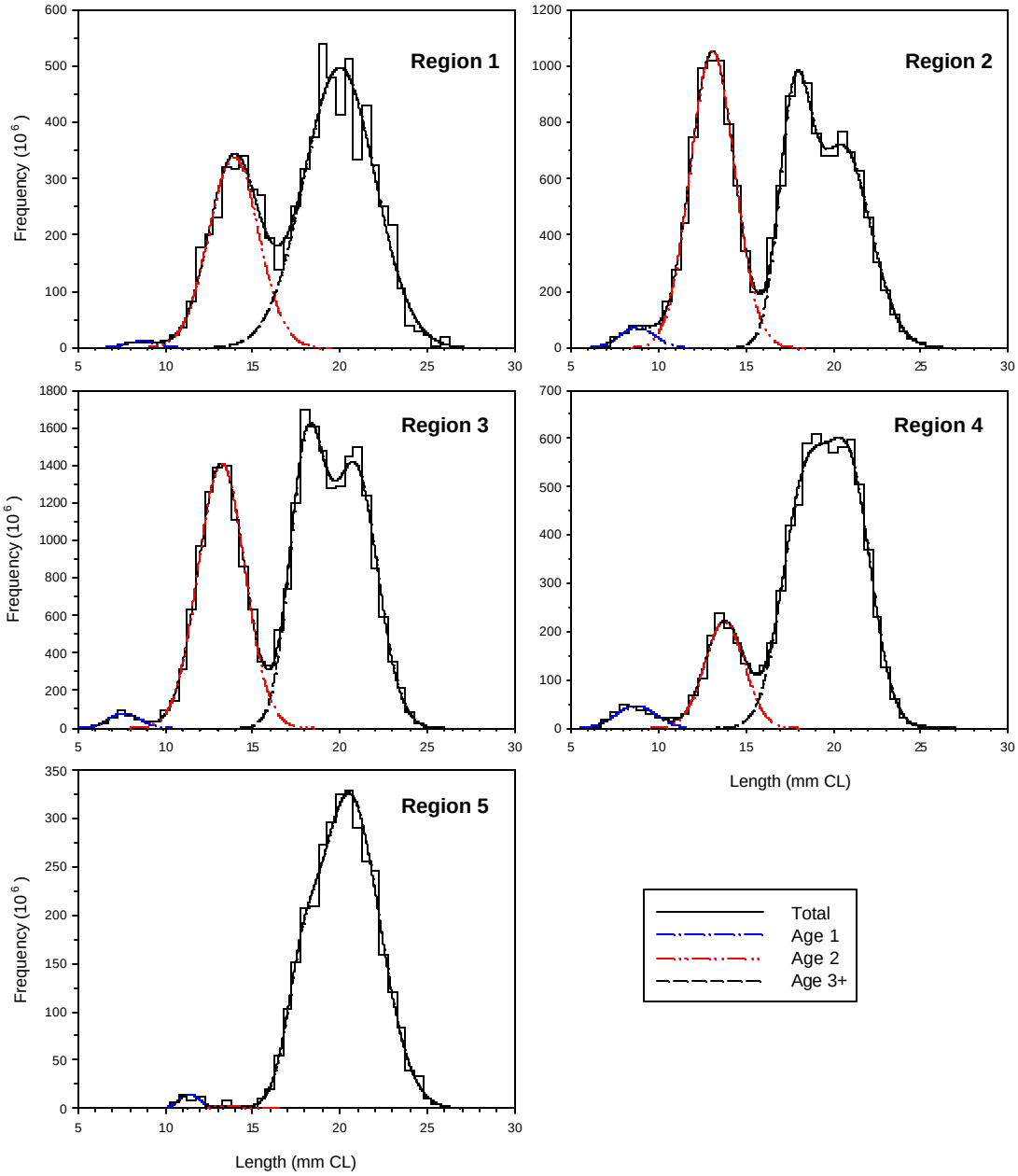

Fig. 2i. Regional length frequencies of northern shrimp (juveniles and males) off West Greenland in 2001.

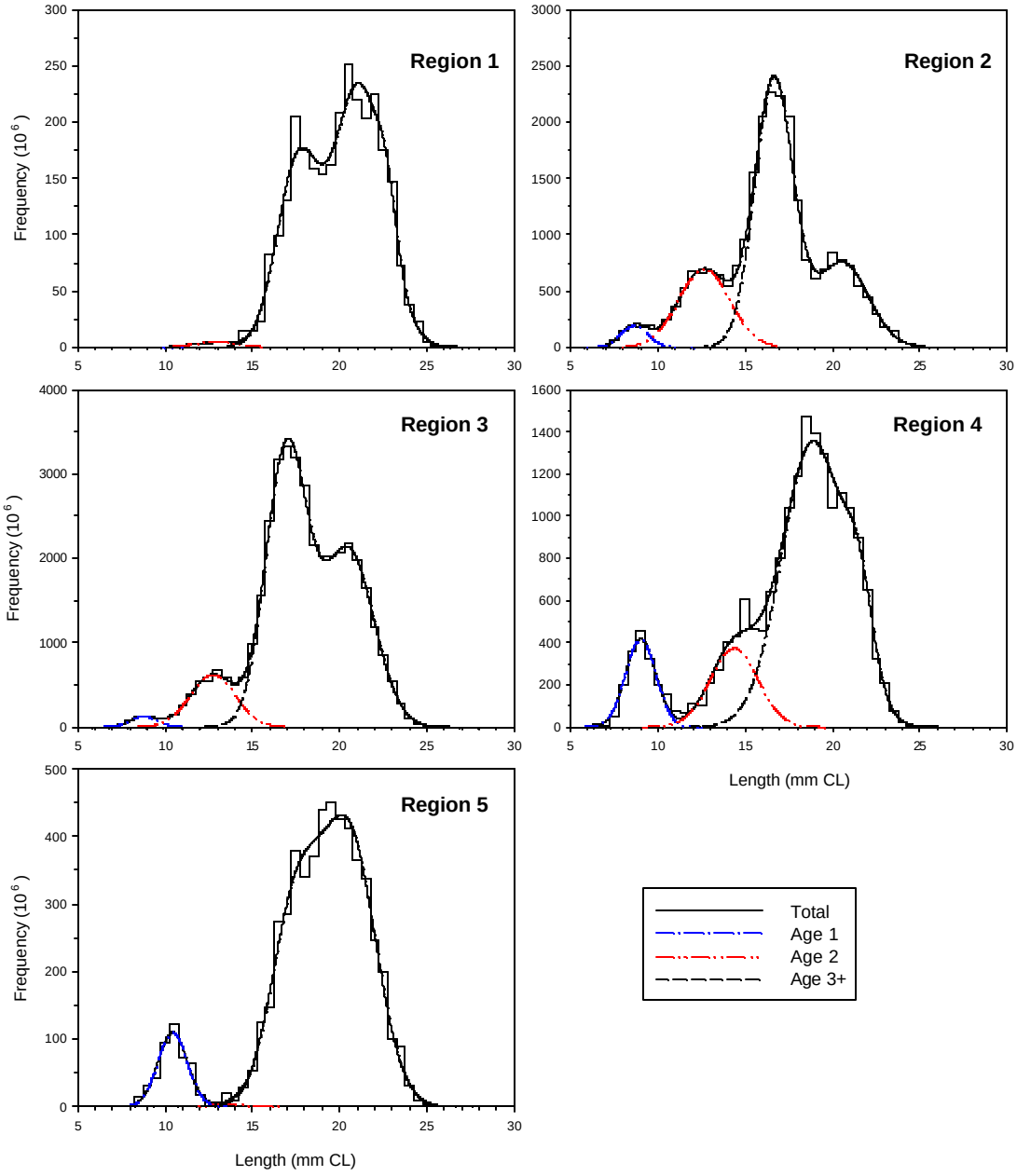

Fig. 2j. Regional length frequencies of northern shrimp (juveniles and males) off West Greenland in 2002.

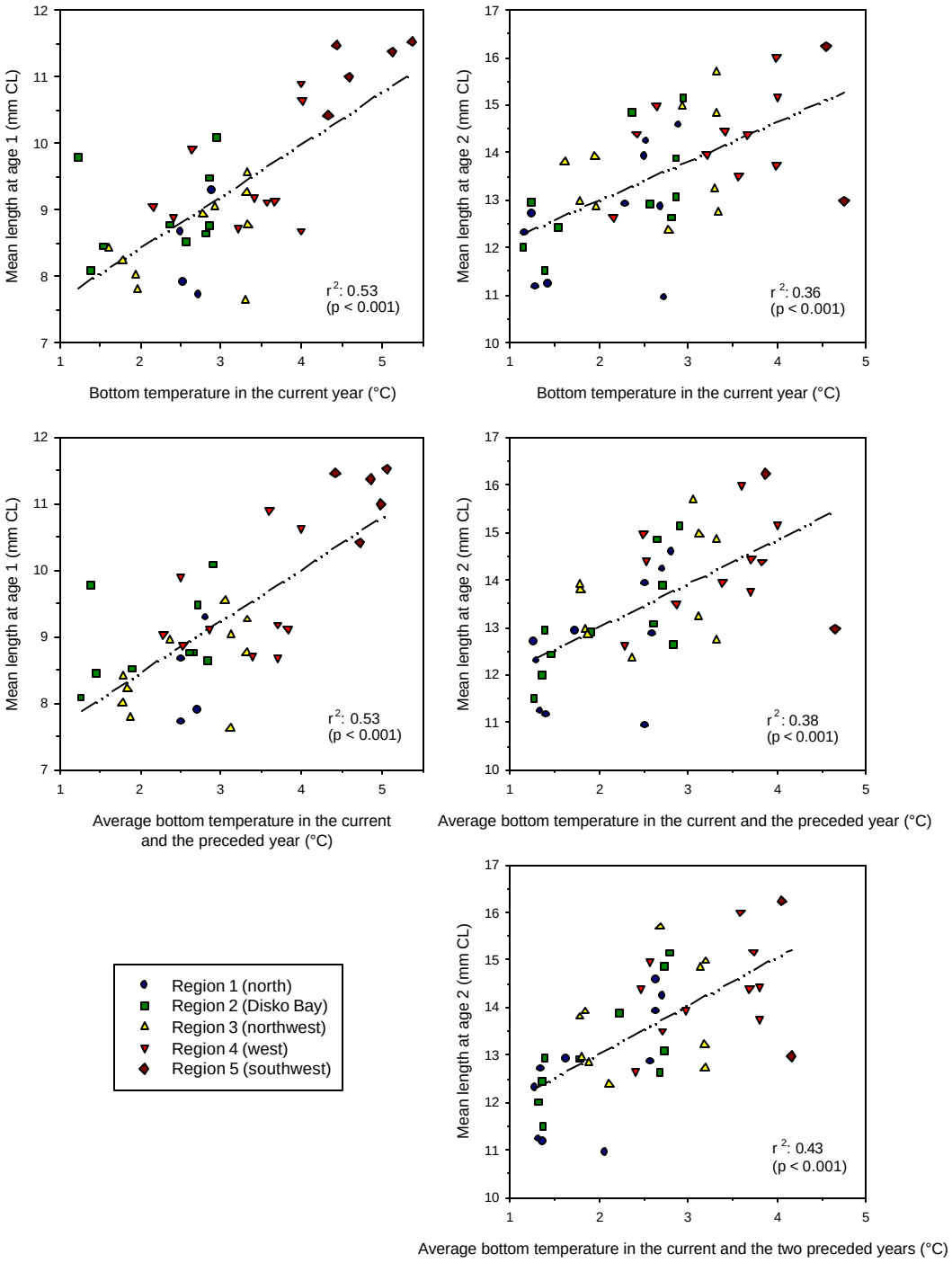

Fig. 3. Effect of bottom temperature on mean length of northern shrimp at age 1 and 2 off West Greenland, 1993 – 2002 (only mean lengths included which were not fixed in the final run of the modal analysis with MIX, see Tab. 2).

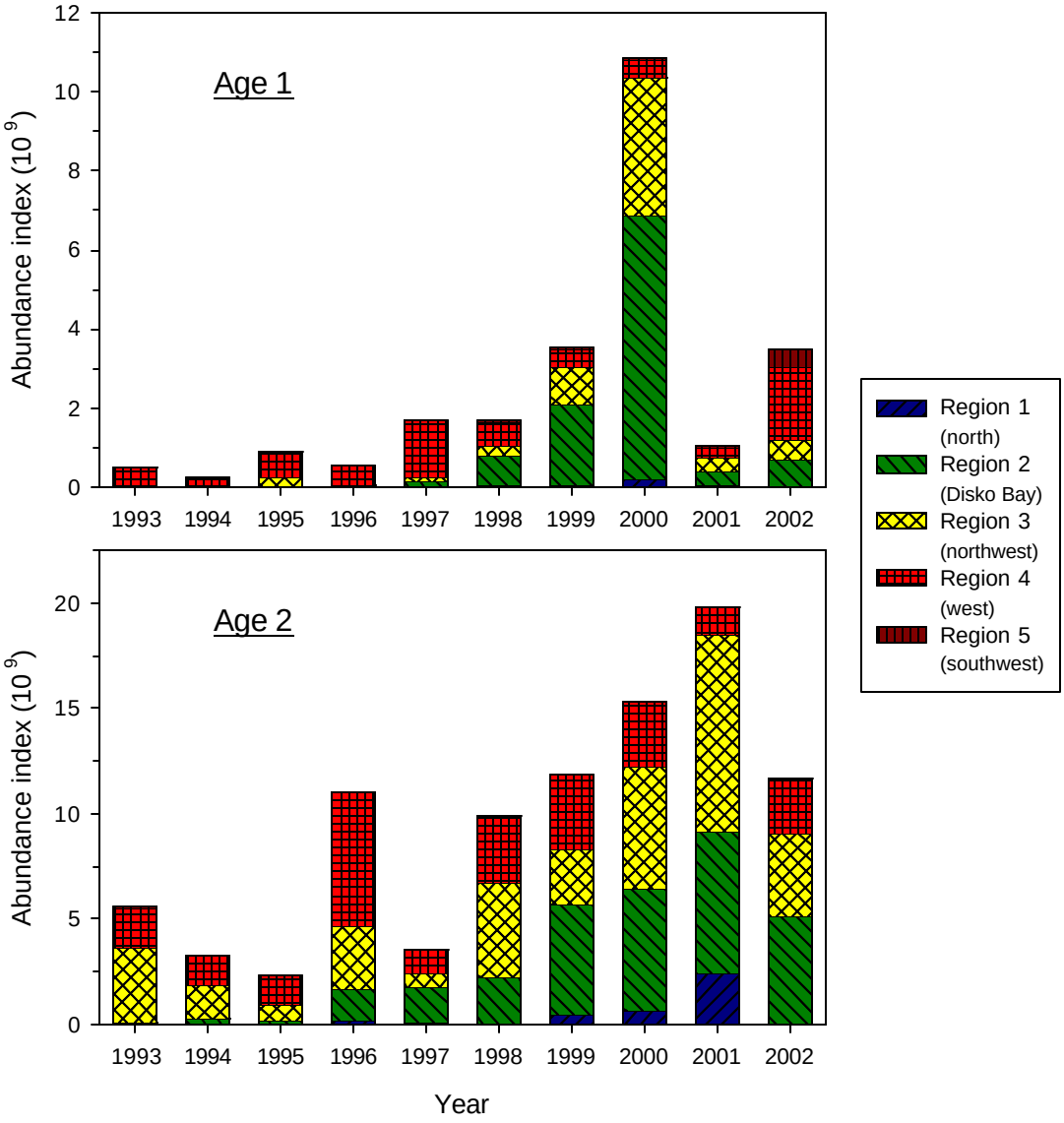

Fig. 4. Abundance indices for northern shrimp at age 1 and 2 off West Greenland, 1993 - 2002.

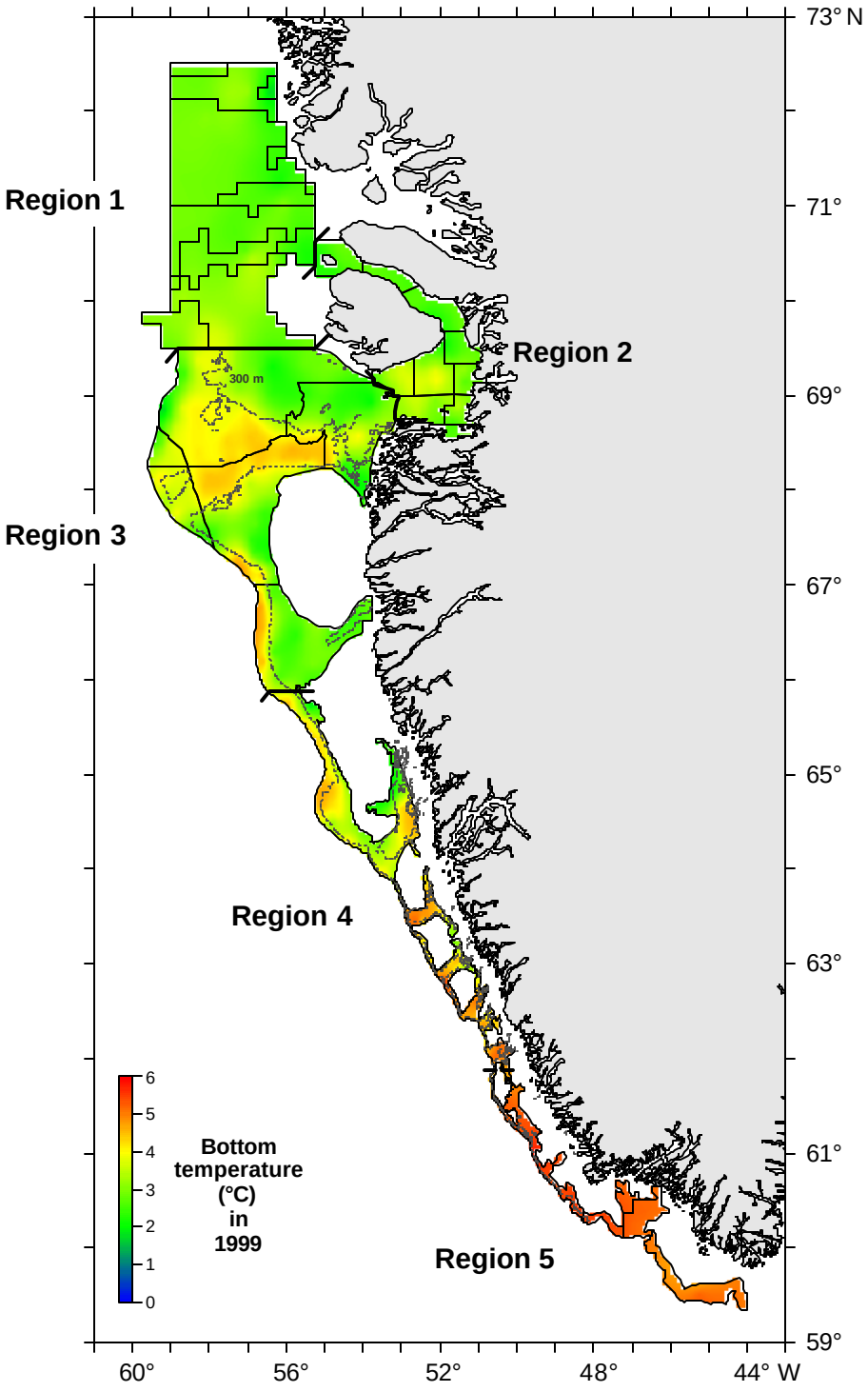

Fig. 5. Distribution of bottom temperature off West Greenland in 150 – 600 m depth in 1999.