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Stratified-random Trawl Survey for Northern Shrimp (*Pandalus borealis*) in NAFO Subareas 0+1 in 2003

by

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Abstract

Stratified-random surveys have been carried out since 1988 in NAFO Subarea 1 and Division 0A as a part of the assessment of the stock of *Pandalus borealis* off West Greenland. Data from this survey series are updated with data from the survey in July-August 2003.

Total biomass was calculated, and changes in the temporal and spatial distribution were studied. Total biomass of this stock has been fairly stable over the first ten years of the series, but after a comparatively low estimate of less than 300 thousand tons in 1997 the biomass has increased to more than 600 thousand tons in 2003. During the period of increase the biomass has changed mainly offshore in depths between 200 and 300 m and inshore in the Disko Bay - Vaigat area. Indices of spawning stock and fishable biomass are well above average and the actual length distribution indicates that progression of males to the female group is secured for the coming year.

Introduction

Since 1988, Greenland Institute of Natural Resources has conducted annual stratified-random trawl surveys in the shrimp distribution area in Davis Strait between July and September to assess the *Pandalus borealis* stock biomass and to obtain information on the size composition of the stock. This document presents the results of the 2003 survey, and compares them with previous results in the survey series (Kanneworff and Wieland, 2002).

Material and Methods

Survey design

The offshore survey area covers the depth interval 150-600 meters in NAFO Subarea 1 and a small part of Div. 0A. Since 1991 the survey has also included the inshore area in part of Div. 1A, Disko Bay and Vaigat.

Major strata correspond to geographical areas, where possible sub-stratified by depth (Carlsson *et al*., 1995). Offshore, where reliable depth information exists, four depth zones are applied: 150-200 m, 200-300 m, 300-400 m, and 400-600 m. In Disko Bay region the stratification is based on the distribution of the commercial fishery according to logbook information. Based on data for depths obtained from data loggings by the survey vessel recorded in the years since 2000 new depth isolines were constructed for the offshore area North of 69°30'N and for Julianehåb Bay in the south. Revised stratification schemes were made for these two areas, the former region N, now U and the former region S, now areas W8 and W9 as part of region W (Fig. 1). The Disko Bay – Vaigat area (region D) remains stratified by geographical areas only because the depth information was still regarded as insufficient.

From 1988 through 1997 trawl stations were allocated to strata proportionally to stratum area, but since 1998 the allocation has been weighted towards strata with historically high densities of northern shrimp, where high variances are observed, in order to get a more precise biomass estimate. An exponential smoothing technique for the weighting was applied to give higher influence of the more recent observations to the weight factors (Kingsley, 2001a).

In 1999 a new method of choosing stations for the survey was introduced using a minimum distance between stations (a buffer zone), however still keeping the randomness in placing stations (Kingsley *et al.*, in prep.).

From 1988 through 1998 stations have been selected at random by re-placing sampling sites for each year. To study the stability of the stock distribution and assess the performance of a fixed-station design relative to that of resampling (Kingsley, 2001a) about 50% of the stations from the surveys in 1998-2003, randomly chosen, were repeated as fixed stations in the following year. The remainder of the stations were re-selected, using the above-mentioned buffer zone method, and using the fixed stations as already chosen stations.

As the observed densities of northern shrimp in the region north of 69°30'N, had consistently been low and because of severe difficulties in finding suitable bottom for trawling, it was in 1998 decided to use a fixed-station sampling design in this area. To cover all nine strata with a minimum of two stations in each, 20 possible trawl tracks were chosen from which between 10 and 18 were realized annually in the years 1999-2002. In 2003, having obtained better information on depth structure, we introduced the same procedure for stratification and selection of stations as in other offshore areas.

In addition to the survey strata designed primarily for the sampling of northern shrimp, trawling was conducted at 32 stations in NAFO Div. 1B-1F at depths <150 m. The results of fish catches from these stations as well as from the shrimp survey area will be reported elsewhere.

Fishing practices

The survey was conducted with the 722 GRT trawler, *Paamiut*, using a 3000/20-mesh *Skjervøy* bottom trawl with a twin cod-end. Mesh size in the cod-end was reduced from 44 mm to 20 mm (stretched) in 1993, and the fine mesh cod-end has been used thereafter. Trawl doors were of the type *Greenland Perfect*, measuring 370 × 250 cm and weighing 2420 kg. Trawl geometry was measured with *Scanmar* acoustic sensors mounted on the trawl doors, and a *Furuno* trawl-eye on the headrope.

In order to minimise the influence of daily vertical migrations of shrimp, trawling was carried out only between 0900 and 1900 UTC. The position (GPS) of the vessel at the beginning and end of each tow was used to measure the length of the track, calculated as straight lines.

Tow duration has been changed through the years from 60 minutes (1988-97) stepwise shortened to a mixture of 15 and 30 minutes (2001-2003). These reductions were made after thorough analysis (Carlsson *et al*., 1998) in order to optimise the sampling schedule, obtaining more stations per day without loosing sampling information. To study further the effect of the reduction tow durations of 30 and 15 minutes were applied in the proportion 2:1, randomly distributed in the strata.

Due to exceptional extension of the ice ('West-ice') in 2003 some of the sites in the Canadian part of the distribution area could not be visited. Only 6 of 10 planned stations were taken in this area.

As earlier, a number of planned trawling sites had to be skipped for various reasons. As about half of the trawling sites are chosen at random some stations may have been placed in areas in which the conditions were not sufficiently known to judge if the sites should have been removed from the list of trawlable areas. Of 199 planned stations 29 had to be skipped, mainly due to bottom or ice conditions, 2 extra stations were added, but time restriction due to bad weather in the end of the survey period did not allow to find more alternative trawl tracks. In total, samples and data from 172 trawl stations were used to describe the stock situation of northern shrimp in 2003.

Swept area

The distance between the trawl doors was recorded 3 or 5 times in each haul (for tow durations of 15 and 30 minutes, respectively), and the mean wingspread was calculated from that. The nominal swept area was calculated as the straight-line track length between start and end-positions (GPS) multiplied by the mean wingspread for the tow.

Unweighted estimates of biomass (tow duration and end error)

Two different target tow durations were used in 2003 (15 and 30 minutes). Analyses have so far found that shorter tows are no more variable than long tows (Kingsley, 2001b); therefore, no weighting was applied to tows of different durations. Analyses of the survey data from 1999 also showed that the effective swept area is somewhat larger than the estimated (Kingsley, l.c.), corresponding to about 8% of the swept area of a 30-minute haul (or approximately 2.8 minutes per trawling operation). No correction of this end-effect has yet been included, as further analyses of the survey data from recent years are expected to refine the results. For each tow, the catch was divided by the nominal swept area, i.e. that calculated from wingspread and track-length, to estimate the density, which was multiplied by the stratum area to estimate stratum biomass. Unweighted means and variances of these biomass estimates were added to those of other strata to get regional and overall estimates.

Fixed stations

The fixing of some stations from year-to-year since 1998 has been ignored in the analyses carried out for the present document, i.e. data from the fixed and the re-placed stations have been analysed together without distinction. Analyses are therefore the same as in the years in which all stations were randomly selected.

Biological samples

From each survey catch a sample of about 2-3 kg of shrimp was taken and sorted to species. Northern shrimp were grouped into males, primiparous and multiparous females based on their sexual characteristics defined by Allen (1959) and McCrary (1971), and oblique carapace length (CL) was measured by slide callipers to the nearest 0.1 mm.

The number of northern shrimp in the samples was weighted by total catch and stratum area to obtain estimates of total number by sex and length group (0.5 mm intervals) for each stratum, for different inshore and offshore areas and the total survey area. These data were used to construct area-specific length frequencies and to calculate abundance indices for males and females as well as for small (<17 mm) males, which are expected to enter the fishery in the coming year.

An index of spawning stock biomass (SSB) index was computed from the proportion of females in weight converted from the overall length distribution and the estimate of total survey biomass. Fishable biomass (FB) was derived from the total number of shrimp with a length equal to and greater than 17 mm CL converted to weight. Here, length-weight relationships provided by Carlsson and Kanneworff (2000) and Wieland (2002a) were used for the period prior to 2001 and the year 2001 and 2002, respectively. In 2003 new length-weight data were collected from all parts of the survey area and SSB and FB were calculated from the actual length-weight relationship.

Bottom temperature

As in earlier years (Wieland and Kanneworff, 2002), temperature was measured with using Seamon data storage sensors mounted on one of the trawl doors. The data were recorded in intervals of 30 seconds and average temperatures for the respective time period of the single trawl tracks were calculated after retrieval of the sensor. In total, observations form 198 trawl stations were available from which 166 measurements were taken at depths >150 m and were used to calculated a mean bottom temperature weighted for the area of the survey strata.

Results and Discussion

Biomass, total estimate

For all strata biomass estimates have been calculated (Tables 1a-1d) on the basis of the nominal swept area. The biomass estimates (in tons) for the four main regions in 2003 are:

REGION	BIOMASS ESTIMATE	NO. OF HAULS	COEFFICIENT OF VARIATION (%)
Disko	116,383	22	17.2
North	122,623[1]	16	27.2
Canada	6,295	6	32.0
West	407,958	128	15.5
OVERALL	653,258[1]	172	11.4

[1]) Figures might be overestimated (see text for explanation).

The estimated biomass for the period 1988-97 was fairly stable around a mean of 230 thousand tons. After 1997, the biomass has increased significantly to a record high estimate for 2003 of 653 thousand tons (Table 2, Fig. 2). After having optimised the sampling procedure, i.e. selection of sampling sites (Kingsley, 2001a), reducing the tow duration and operating with a mixture of fixed and reallocated stations, the error variation of the biomass estimates has improved (Table 3), and the coefficient of variation in 2003 was 11.4%, the second lowest since all areas were included in the sampling.

The distribution of the biomass in 2003 was rather traditional (Fig. 1) with high densities in the deeps south of the shallow banks along the coast, especially in Sukkertoppen and Holsteinsborg Deeps (around 64°30'N and 66°30'N, respectively) and in Disko Bay-Vaigat. Also, in the area north of Store Hellefiskebanke (about 68-69°N) and in the westernmost part of area W1 very good concentrations were found. The Disko Bay–Vaigat region, the southernmost region and the Canadian part of the survey area did not change much from 2002 to 2003, but increase was found in all other areas along the coast.

Ice coverage hampered a full coverage of the stations in region C, the Canadian zone. Due to the lower number of stations a higher variation than normal was expected. One of the strata could not be reached, and the biomass was thus estimated by applying the observed average change of the other strata in the region from 2002 to 2003.

In region U, the former region N north of 69°30'N offshore, biomass was in 2003 estimated by means of stratification based on the newly obtained depth contours. The planned coverage in this region was very low with only 16 stations in this large area, as the observed densities of northern shrimp and its variance in the preceding years have been low compared to other parts of the survey area. During the survey many of the planned sites in this region had to be moved to more suitable places for trawling and at one of the new locations a catch that was considerably above average density resulted in an unrealistic high overall biomass estimate. In this case a post-stratification seemed applicable. One of the former strata, representing an area with historically high shrimp density, was re-introduced (Stratum U3, see Fig. 1), and the total biomass for the region was recalculated. The new biomass figure seemed more realistic, however still with a possible overestimate. For comparison, biomass estimates for the earlier years were recalculated based on the 2003 stratification. In general, the recalculated estimates were higher than the original, adding on average 10 thousand tons (3-4%) to the total estimates (Fig. 3).

The former region S, Julianehåb Bay, now named W8 and W9 as the southernmost part of region W (Fig. 1) was in 2003 also stratified by means of new depth contours. In contrast to the northern region the new stratification did not differ drastically from the earlier used, and despite severe difficulties in finding suitable trawl bottoms in large parts of some strata the proportion of the biomass in Julianehåb Bay to the overall estimated biomass was in 2003 close to the average level of 6-7%.

The biomass estimates given in this paper are calculated – as earlier – from the nominal swept area with no corrections for a possible end-error (Kingsley *et al*., in press). It is assumed that an end-error, i.e. error in estimating the total trawling time, is mainly connected with the time of beginning of the haul. This point is defined by means of a trawl sonde ('trawl eye'), where the distance between the various parts of the trawl (headline and ground gear) and the bottom can be read. As the trawl gear takes some time to completely 'land' on the bottom the time of beginning of a haul has to be defined by e.g. an agreed distance from the headline to the bottom. The chosen point of beginning appears from the end-error analysis to have been set a little too late. Included in the end-effect is also fishing time on that part of the shrimp stock which is swimming freely above the bottom at the time of fishing, however, this effect is very difficult to assess and is assumed to be extremely variable with time of the day, composition of the stock etc. If an end-error correction of the estimated magnitude (2.78 minutes, calculated for the 1999-survey) is applied to the biomass calculation for 2003, the total estimate is reduced by 11.5 % to about 578 thousand tons.

Biomass, geographical and depth distribution

Large variations in the distribution of this stock are indicated, both from year to year and seasonally. During the time series the trawl surveys have been carried out at the same period of the year (July-September), and seasonal variations are therefore assumed to be minimized. Table 2 shows the variations in biomass distribution over various geographical areas. Most strata have exhibited large variations through the years, but in the most recent years the biomass is indicated to have a more even distribution over the distribution area than earlier. Relative distribution of the biomass in depth layers (Fig. 4) indicates that since 1994 the bulk of the biomass has gradually moved from the 300-400 m layer to 200-300 m, which in 2001 exhibited close to 70% of the overall observed biomass. Figure 5 shows, however, that the depth layer 300-400 m in the period 1996-2002 had a fairly stable biomass, whereas an increase in the biomass is seen in the depth layer 200-300 m since 1995, changing from 2000 to a constant, very high increase.

The Disko Bay-Vaigat area has the longest history of commercial fishery for shrimp in Greenland, as it developed in the early 1950s. When the trawl survey first included this area (1991) a biomass of around 50 thousand tons was estimated, corresponding to 29% of the biomass for the total survey area at that time. The estimates through the following years have developed steadily from a low in 1993 to the record high estimates of near 120 thousand tons in 2002 and 2003 (24% and 18%, respectively of the total). It should be pointed out that in contrast to the offshore increase in biomass of about 20% (excluding region U) between 2002 and 2003 the biomass in Disko Bay region seems to have stabilised. Estimated densities of northern shrimp in the Disko Bay-Vaigat area are very high compared to the offshore areas (Table 4), in the two recent years having more than 10 grams shrimp per square meter, about three times the average density offshore.

Bottom temperature

Bottom temperatures ranged from 1.1 °C in the northwestern part of area U1 to 5.9°C in areas W8 and W9 (Fig. 6). Values above 4°C were found in large parts of areas W5-W7 as well as at the offshore slope at depths >300 m in area W4 while temperature between 2 and 3°C prevailed in the remaining parts of the survey area. The overall mean area weighted bottom temperature amounted to 3.08°C, which is close to the average of the most recent years. This indicates that the recent relative warm period has continued, and it is further remarkable that the change from a cold to a warm period comprised all different depth strata in a similar manner (Fig. 7).

Stock composition

Size distribution by area in 2003

Length distributions for the offshore areas U (strata U1-U3), C (strata C1 + C3), and W1-W9 indicate a relative high abundance of males between 19 and 21 mm CL (Fig. 8). In some of the areas, i.e. U, W1, W2, and W4-W6 smaller (15-18 mm CL) males were also abundant while larger males and females (>21 mm CL) prevailed in particular in areas W7-W9. Males smaller than 15 mm CL were generally rare. Length frequencies for the inshore area (Disko Bay and Vaigat, strata D1-D9) showed similar patterns than the offshore distributions, but with a more pronounced presence of males smaller than 13 mm CL (Fig. 9).

Figure 10 shows the geographical distribution of mean size of all sexual groups pooled. Low mean size (<17 mm CL) of males was found in a two distinct areas, southwest of Disko Island (areas W1 and W2) and between the fishing banks and the coast at about 62 to 63°N (area W6). Mean sizes of about 19 mm CL were observed in particular in the Disko Bay – Vaigat area (strata D1-D9), but also in most of the offshore areas. The highest mean sizes (>24 mm CL) were observed in the deeper (>300 m) parts of areas W1, C1, W4 and W5. This pattern indicating a smaller extension of areas with values below 17 mm mean CL and a wider extension of areas with medium mean sizes in the Disko Bay and large parts of the offshore area differs from those reported for the past years by Wieland and Carlsson (2001) and Kanneworff and Wieland (2002) and can be explained by the dominance of the exceptionally strong '1999 year-class'.

Annual size distribution

Overall length distributions for the offshore and the inshore (Disko Bay and Vaigat) areas in 1988 to 2002 are compared in Fig. 11a-d. Visual inspection of the offshore length frequency for 2003 indicates modes of the males at approx. 16.5 and 19.5 mm CL, a mode of primiparous females at about 24 mm CL and one of multiparous females around 25.5 mm CL, and the abundance of small (<15 mm CL) males appeared to be low compared to previous years. Different modes were obvious in the inshore length frequency for 2003 in particular for the males (8, 12, 15.5 and 18.5 mm CL), and the modes for the primiparous and multiparous females were found at somewhat smaller sizes (23.5 and 25 mm CL, respectively) than in the offshore areas.

Figure 12 shows overall length frequencies combined for the offshore and the Disko Bay – Vaigat area for 2000 to 2003. A progression of the '1999 year-class' from 9 mm CL in 2000 to about 13.5 mm CL in 2001, to 17.5 mm CL in 2002 and to 20 mm CL in 2003 is clearly visible. Here, the considerable increase in the level of abundance at the progressing modes from 2.5×10^{9} at age 1 in 2000 to about 7×10^{9} at age 3 in 2002 is striking. A similar effect is visible for the '2000 year-class' with its modes at about 12.5 mm CL in 2002 and 16 mm CL in 2003 and corresponding abundance levels of about 1.5×10^{9} at age 2 and 6×10^{9} at age 3. Several processes, which include mesh selection of the trawl especially for shrimp smaller 11 mm CL (Wieland, 2002b), escapement of juveniles below the footrope (Nilssen, 1986) and immigration from nursery areas at depths shallower than intensively covered by the survey (Wieland and Carlsson, 2001) may be involved in this.

The actual strong presence of males between 14 and 22 mm CL is promising in terms of progression to the fishable biomass as well as to the female group in the coming year.

Length-weight relationship

Measurements of individual length and weight were pooled for all sexual groups and survey areas, and the resulting length-weight relationship for 2003 was quite similar to those used in previous years (Fig. 13). Lower weights at lengths above 27 mm CL may, however, indicate a decrease of condition and growth performance of northern shrimp in the most recent years.

Total abundance, spawning stock biomass, fishable biomass and recruitment to the fishery

Total numbers and proportions of male and female shrimp in the survey area (including both inshore and offshore areas) estimated from overall length distributions are given in Table 5. The total number of males and females together for 2003 is the highest on record exceeding considerably the long-term mean. Corresponding estimates of biomass derived from a conversion of the length frequencies to weight are listed in Table 6. Total biomasses calculated in this way were about 2 to 5% lower than the direct estimates of survey biomasses (Table 2), except for 1989 (- 6.2%), 1991 (- 15.0%), 1992 (- 5.7%) and 2002 (- 5.2%). The proportion of females is close to the long-term average, both in terms of abundance and in biomass.

Spawning stock biomass (SSB) indices estimated from the proportions of females in the stock based on weight, i.e. derived from the conversion of the overall length distributions to weight (Table 5), and the direct estimates of survey biomasses (Table 2) are given in Table 7. The total SSB for the 2003 survey exceeds that for 2002 by 37% and amounts to more than two times the long-term average.

Table 8 shows the fishable biomass (FB) calculated from the number of individuals equal to and above 17 mm CL. This size limit is assumed to correspond roughly to the L_{50} value of a commercial shrimp trawl with a mesh size of 44 mm in the cod-end. The total FB for the 2003 survey indicated a substantial increase and is by far the highest on record, which is mainly a result of the progression of the exceptional strong '1999 year-class' and a large proportion of the '2000 year-class' beyond 17 mm CL (Fig. 12).

The 2003 abundance index of small (<17 mm CL) males is the second highest in the time series (Table 9) indicating that recruitment to the fishery is secured for the coming year.

The contribution of the inshore (Disko Bay and Vaigat) component of the stock to SSB, FB and recruitment to the fishery varied substantially through the years (Tables 7-9) and is actually 18% in terms of spawning stock biomass, 17% in terms of fishable biomass, and 29 % in terms of recruitment to the fishery. These values are close to or below average, which indicates an increasing importance of the offshore area in the most recent years.

Conclusions

During the period of stratified random surveys in the offshore areas of northern shrimp (*Pandalus borealis*) distribution the biomass estimates have indicated a good stability until 1997 around a level of 200-250 thousand tons, apart from a somewhat lower value in 1991. From 1997 a significant increase is observed with record high biomass in 2003 of about 600 thousand tons. Large variations from year to year both geographically and over depth zones are observed and may suggest that the stock is highly migratory. Some areas account for a large proportion of the variances of the estimated biomasses. The survey design has been evaluated and adjusted in the later years in order to reduce the sampling variation and to study and optimise the performance of the sampling. Indices of spawning stock and fishable biomass are well above long term average and the actual length distribution indicates that progression of males to the female group is secured for the coming year.

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Table 1a. Estimated trawlable biomass (tons) and sampling statistics for strata in region W, 2003.

Area	Stratum	Km²	Biomass	Hauls	STD	CV
W1	150-200 M	3053	276	2	299	108.3
W1	200-300 M	5872	57912	5	71442	123.4
W1	300-400 M	7298	50682	9	65830	129.9
W1	400-600 M	950	175	2	151	86.0
W2[1]	150-200 M	1751	337	1	332	.
W2	200-300 M	2707	29672	4	14276	48.1
W2	300-400 M	1812	16737	7	13844	82.7
W2	400-600 M	873	1517	3	726	47.9
W3	150-200 M	2134	183	2	8	4.2
W3	200-300 M	4713	50297	19	64573	128.4
W3	300-400 M	2370	5399	3	5793	107.3
W3	400-600 M	2879	3610	2	624	17.3
W4	150-200 M	4252	19907	2	12657	63.6
W4	200-300 M	1791	9700	3	9147	94.3
W4	300-400 M	812	11021	6	26865	243.8
W4	400-600 M	1967	11	3	6	49.0
W5	150-200 M	1995	11697	6	21666	185.2
W5	200-300 M	3454	34002	12	67135	197.4
W5	300-400 M	1797	1385	3	285	20.6
W5	400-600 M	2806	5	2	0	3.2
W6	150-200 M	1095	7730	2	10063	130.2
W6	200-300 M	1491	10451	5	21792	208.5
W6[1]	300-400 M	1300	13919	1	13710	.
W6[1]	400-600 M	884	2484	1	2447	.
W7[1]	150-200 M	2419	0	1	0	.
W7	200-300 M	985	28401	6	69564	244.9
W7[1]	300-400 M	239	2	1	2	.
W7	400-600 M	273	0	2	1	141.4
W8	200-300 M	575	694	2	383	55.2
W8	300-400 M	424	25017	2	25823	103.2
W8	400-600 M	434	14722	3	16849	114.4
W9	150-200 M	1788	0	2	0	.
W9	200-300 M	959	1	2	1	141.4
W9	400-600 M	833	9	2	11	116.4
Overall		68985	407955	128		

[1]) STD calculated from Biomass * 0.985

Table 1b. Estimated trawlable biomass (tons) and sampling statistics for strata in region C, 2003.

Area	Stratum	Km²	Biomass	Hauls	STD	CV
C1	300-400 M	768	1894	2	161	8.5
C1	400-600 M	453	206	2	43	21.1
C3[1]	200-300 M	897	3703	1	3647	.
C3[1]	300-400 M	1344	493	1	486	.
C3[2]	400-600 M	793	33	.	.	.
Overall		4255	6329	6		

[1]) STD calculated from Biomass * 0.985

[2]) Estimated due to missing hauls

Table 1c. Estimated trawlable biomass (tons) and sampling statistics for strata in region D, 2003.

Area	Stratum	Km²	Biomass	Hauls	STD	CV
D1	D1	819	17483	3	3160	18.1
D2	D2	566	5401	2	1478	27.4
D3	D3	1124	15499	2	7036	45.4
D4	D4	1834	20879	2	14541	69.6
D5	D5	612	5908	2	548	9.3
D6	D6	1014	9001	2	5573	61.9
D7	D7	1447	17480	3	21812	124.8
D8	D8	652	4141	2	137	3.3
D9	D9	1305	20591	4	19067	92.6
Overall		9373	116383	22		

Table 1d. Estimated trawlable biomass (tons) and sampling statistics for strata in region U, 2003.

Area	Stratum	Km²	Biomass	Hauls	STD	CV
U1	150-200 M	3364	4645	2	6570	141.4
U1	200-300 M	4495	4392	2	4774	108.7
U1	300-400 M	4775	11524	2	7163	62.2
U1	400-600 M	7708	5973	2	7331	122.7
U2	150-200 M	2085	982	2	1012	103.1
U2[1]	200-300 M	9318	13657	1	13452	.
U2	300-400 M	9667	64941	2	41431	63.8
U2	400-600 M	7420	5931	2	2119	35.7
U3[1]		389	10577	1	10418	.
Overall		49221	122622	16		

[1]) STD calculated from Biomass * 0.985

Table 2. Biomass estimates 1988-2003 (thousand tons) in combined areas from north to south. Standard errors and error percentages are also given.

Year	N1-N9	U1-U3[1]	D1-D9[2]	W1-W2	W3-W4	C1+C3	W5-W7[3]	W8-W9	Total	SE[4]	%[4]
1988	21.7		46.5	58.6	74.4	9.6	19.0	-	229.8	24.7	13.5
1989	11.3		46.5	48.2	79.6	3.9	38.6	-	228.0	32.3	17.8
1990	11.1		46.5	82.1	54.2	11.1	23.3	-	228.3	32.6	17.9
1991	5.8		50.6	30.9	52.4	4.8	28.1	-	172.6	22.8	13.2
1992	20.6		47.4	52.0	35.0	24.1	46.1	-	225.1	29.2	13.0
1993	8.0		33.6	103.1	41.3	3.4	67.5	-	256.8	30.0	11.7
1994	8.0		40.0	107.7	49.7	6.8	37.7	20.7	270.6	53.0	19.6
1995	8.2		47.3	43.7	58.6	4.4	53.0	1.7	217.1	29.1	13.4
1996	10.0		54.3	53.8	34.9	1.7	90.5	3.7	248.9	39.9	16.0
1997	7.2		52.3	40.1	15.1	0.2	66.5	24.9	206.2	30.9	15.0
1998	8.3		61.9	42.2	107.1	0.4	50.9	22.3	293.3	55.6	18.9
1999	14.4		61.2	54.2	26.1	11.9	55.9	63.7	287.4	40.6	14.1
2000	9.6		83.5	68.0	72.7	11.7	79.6	24.5	349.5	37.8	10.8
2001	39.0		82.7	83.1	52.7	4.2	67.7	19.7	349.2	43.1	12.3
2002	21.8 [5]		119.4	128.4	70.5	6.0	109.1	37.6	492.7	65.9	13.4
2003		122.6	116.4	157.3	100.1	6.3	110.1	40.4	653.3	74.3	11.4

[1]) New stratification of the former region N introduced in 2003

[2]) D1-D9 1988-90 not sampled, but set to mean of 1991-97.

[3]) Areas W6 and W7 were sampled from 1990 and 1993, respectively

[4]) SE calculated excluding D1-D9 in 1988-90

[5]) Underestimated due to poor coverage of the northern part of area

Table 3. Error coefficients of variation for the biomass estimates in the five main regions 1988-2003.

Year	Region					
	C	D	N/U	S	W[1]	Overall
1988	37	-	30	-	16	13.5
1989	44	-	23	-	16	17.8
1990	44	-	42	-	20	17.9
1991	25	23	40	-	17	13.2
1992	77	16	17	-	17	13.0
1993	54	20	51	-	14	11.7
1994	19	26	48	99	24	19.6
1995	45	17	47	84	18	13.4
1996	91	10	52	95	22	16.0
1997	59	14	37	16	24	15.0
1998	41	18	41	59	26	18.9
1999	80	14	54	51	14	14.1
2000	7	13	37	56	15	10.8
2001	46	18	27	49	19	12.3
2002	46	29	101	45	16	13.4
2003	32	17	27	-	15	11.4

[1]) Region W includes former region S from 2003.

Table 4. Estimated mean shrimp densities in groups of strata in 1988-2003. Densities are given in t/km² (or g/m²).

Area	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
D1-D9	-	-	-	5.40	5.06	3.59	4.27	5.05	5.80	5.58	6.61	6.53	8.92	8.84	12.75	12.42
N1-N9/U1-U3	0.52	0.25	0.25	0.14	0.50	0.19	0.21	0.21	0.26	0.19	0.21	0.37	0.25	1.01	0.56	2.49
C1+C3	2.79	1.12	3.23	1.39	6.99	0.98	1.98	1.28	0.49	0.07	0.13	3.46	3.39	1.22	1.74	1.48
W1-W2	2.49	2.66	3.48	1.31	2.21	3.89	4.07	1.65	2.03	1.51	1.60	2.05	2.57	3.14	4.85	6.47
W3-W4	3.43	3.67	2.50	2.42	1.61	1.88	2.27	2.67	1.59	0.69	4.89	1.19	3.32	2.40	3.21	4.79
W5-W7	1.89	3.84	1.57	1.90	3.11	3.60	2.01	2.83	4.83	3.55	2.72	2.98	4.25	3.62	5.82	5.87
S1-S2/W8-W9	-	-	-	-	-	-	3.98	0.26	0.57	3.81	3.43	9.77	3.76	3.03	5.77	6.69
Average	1.83	1.85	1.68	1.51	1.97	2.12	2.19	1.74	1.99	1.65	2.35	2.30	2.80	2.79	3.94	4.92

Table 5. Numbers (billions) of males and females from overall length distributions for the total survey area (mean values for Disko Bay/Vaigat area 1991-1997 used in 1988-1990).

Year	Males	Females	Total	Males %	Females %
1988	24.3	9.9	34.2	71.1	28.9
1989	35.0	7.6	42.6	82.2	17.8
1990	28.5	10.0	38.5	74.0	26.0
1991	17.4	6.2	23.6	73.7	26.3
1992	29.7	7.3	37.0	80.3	19.7
1993	35.5	9.7	45.2	78.5	21.5
1994	33.9	10.9	44.8	75.7	24.3
1995	29.2	7.9	37.1	78.7	21.3
1996	41.4	8.1	49.5	83.6	16.4
1997	29.5	7.6	37.1	79.5	20.5
1998	42.9	11.5	54.4	78.9	21.1
1999	44.8	11.3	56.1	79.9	20.1
2000	66.7	12.7	79.4	84.0	16.0
2001	61.1	13.7	74.8	81.7	18.3
2002	90.6	16.7	107.2	84.5	15.5
2003	103.2	27.9	131.1	78.7	21.3
Average	44.6	11.2	55.8	79.1	20.9

Table 6. Biomass estimates of males and females (thousand tons) in the total survey area, based on length-weight relationships applied to overall length-frequency distributions (mean values for Disko Bay/Vaigat area 1991-1997 used in 1988-1990).

Year	Males	Females	Total	Males %	Females %
1988	120.5	102.9	223.4	53.9	46.1
1989	140.8	74.0	214.8	65.5	34.5
1990	124.3	97.9	222.2	55.9	44.1
1991	89.9	60.1	150.0	59.9	40.1
1992	141.3	71.7	213.0	66.3	33.7
1993	150.3	97.9	248.2	60.6	39.4
1994	153.5	109.6	263.1	58.3	41.7
1995	129.0	81.1	210.1	61.4	38.6
1996	155.5	83.6	239.1	65.0	35.0
1997	121.2	76.2	197.4	61.4	38.6
1998	174.9	107.2	282.1	62.0	38.0
1999	169.6	108.4	278.0	61.0	39.0
2000	221.2	116.8	338.0	65.4	34.6
2001	208.2	127.6	335.8	62.0	38.0
2002	305.3	144.6	449.9	67.9	32.1
2003	397.6	237.2	634.8	62.6	37.4
Average	175.2	106.0	281.2	61.8	38.2

Table 7. SSB index (female biomass, thousand tons) in offshore, Disko/Vaigat and total survey area (mean values for Disko Bay/Vaigat area 1991-1997 used in 1988-1990).

Year	Offshore	Disko	Total
1988	88.1	18.8	106.9
1989	59.7	18.8	78.5
1990	83.0	18.8	101.8
1991	48.2	20.9	69.1
1992	59.7	16.1	75.8
1993	85.6	15.7	101.3
1994	97.2	15.5	112.7
1995	62.5	21.3	83.8
1996	61.8	25.2	87.0
1997	62.9	16.8	79.7
1998	88.6	22.8	111.4
1999	93.2	18.8	112.0
2000	88.5	32.3	120.8
2001	101.1	31.6	132.7
2002	123.8	28.4	152.2
2003	199.8	44.0	244.1
Average	87.7	22.9	110.6

Table 8. Index of fishable biomass (≥ 17 mm CL, thousand tons) in offshore, Disko/Vaigat and total survey area (mean values for Disko Bay/Vaigat area 1991-1997 used in 1988-1990).

Year	Offshore	Disko	Total
1988	174.8	42.1	216.9
1989	157.5	42.1	199.6
1990	171.8	42.1	213.9
1991	100.3	46.0	146.3
1992	158.6	43.4	202.0
1993	201.3	31.4	232.7
1994	213.2	36.3	249.5
1995	156.8	44.4	201.2
1996	163.8	48.2	212.0
1997	140.7	44.7	185.4
1998	209.3	53.7	263.0
1999	204.6	47.0	251.6
2000	236.2	64.9	301.0
2001	234.6	69.7	304.3
2002	316.7	76.6	393.3
2003	483.3	98.7	582.0
Average	207.7	52.0	259.7

Table 9. Abundance index for males < 17 mm CL (billions) in offshore, Disko Bay/Vaigat and total survey area.

Year	Offshore	Disko	Total
1993	8.21	0.65	8.86
1994	6.15	1.07	7.22
1995	5.10	0.43	5.53
1996	14.06	2.06	16.12
1997	4.74	3.18	7.92
1998	7.00	3.59	10.59
1999	8.38	7.21	15.59
2000	15.13	12.19	27.32
2001	15.05	7.59	22.64
2002	19.93	12.85	32.78
2003	19.44	8.02	27.46
Average	11.20	5.35	16.55

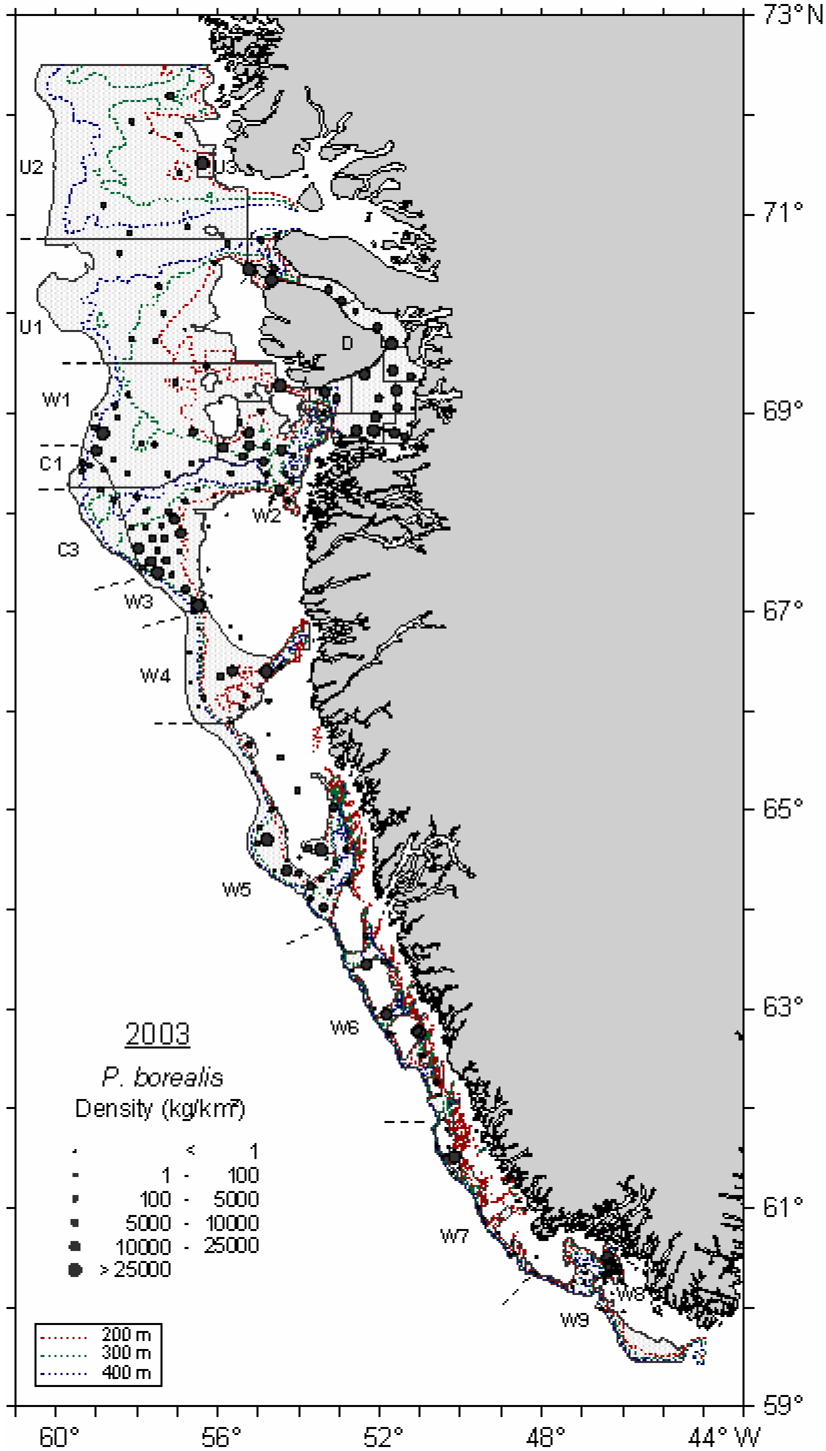

Fig. 1. Survey stratification, sampling locations and density of northern shrimp in 2003.

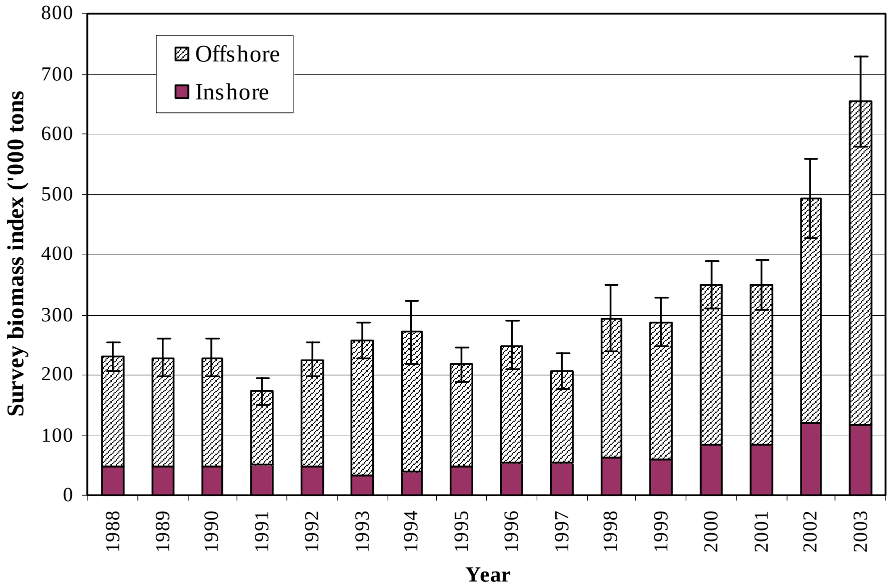

Fig. 2. Estimated total yearly biomass 1988-2003 with standard errors. Average biomass estimate for inshore areas 1991-1997 is inserted in 1988-1990 to facilitate between-year comparisons.

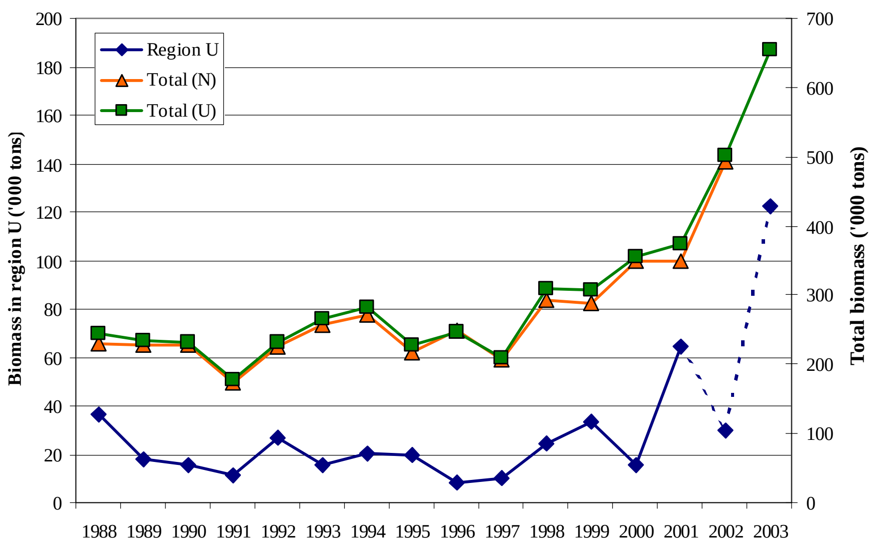

Fig. 3. Recalculated biomass estimates ('000 tons) for region U 1988-2003 based on the new stratification from 2003. Total biomass estimates by both methods are also shown. Note the different y-axis scales.

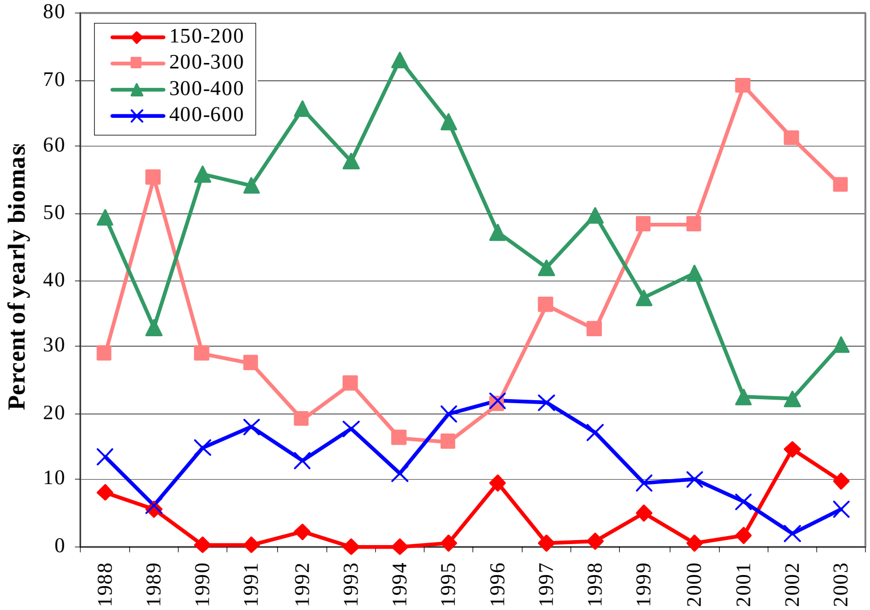

Fig. 4. Relative distribution (%) of the offshore biomass in depth strata, 1988-2003

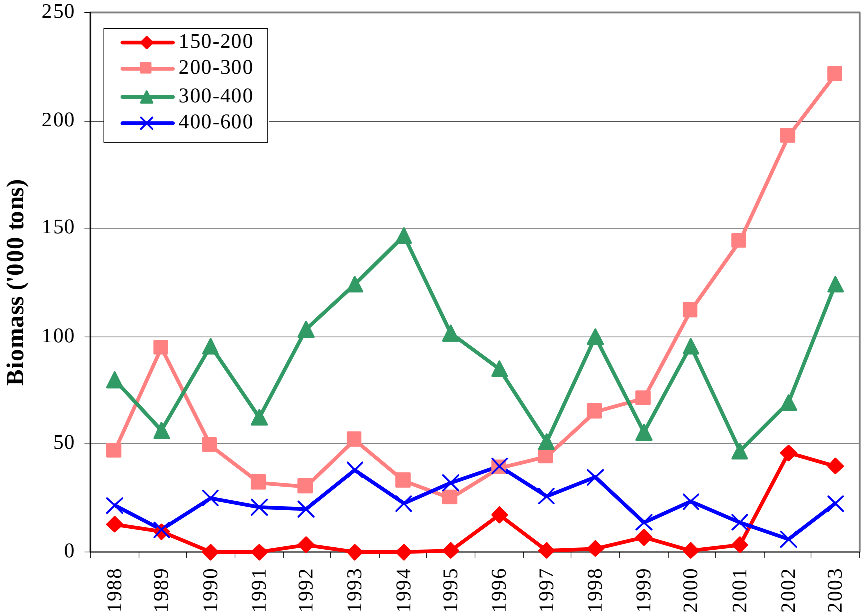

Fig. 5. Distribution of estimated biomass in depth strata for surveys in SA0+1 offshore, 1988-2003.

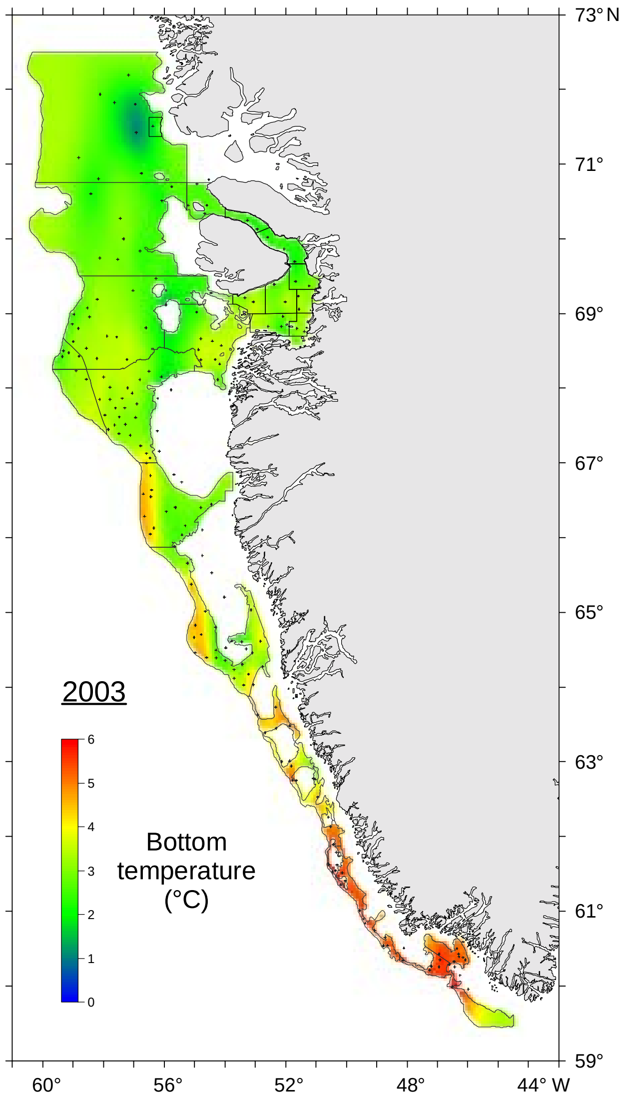

Fig. 6. Distribution of bottom temperature in the survey area between 150 and 600 m depth in 2003.

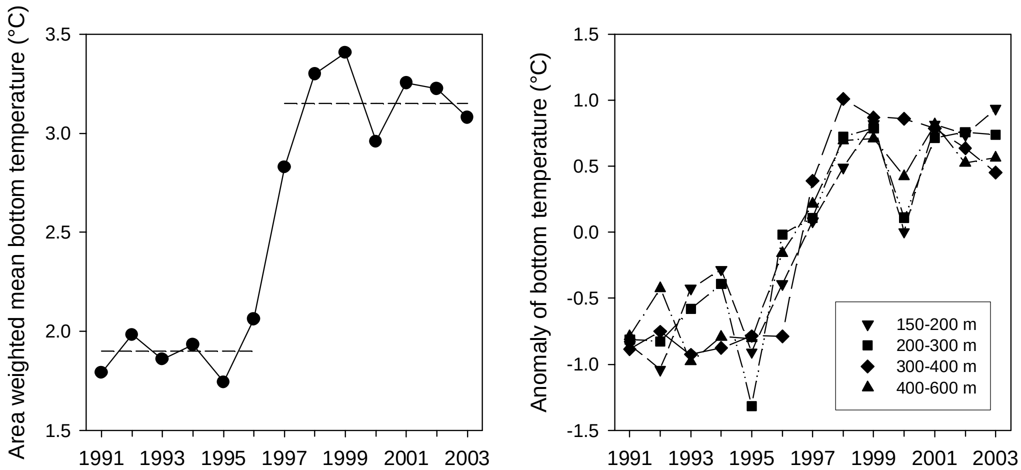

Fig. 7. Area weighted mean bottom temperature for the entire survey area and temperature anomalies in the different depth strata in offshore areas C and W1-W7 in 1991 - 2003.

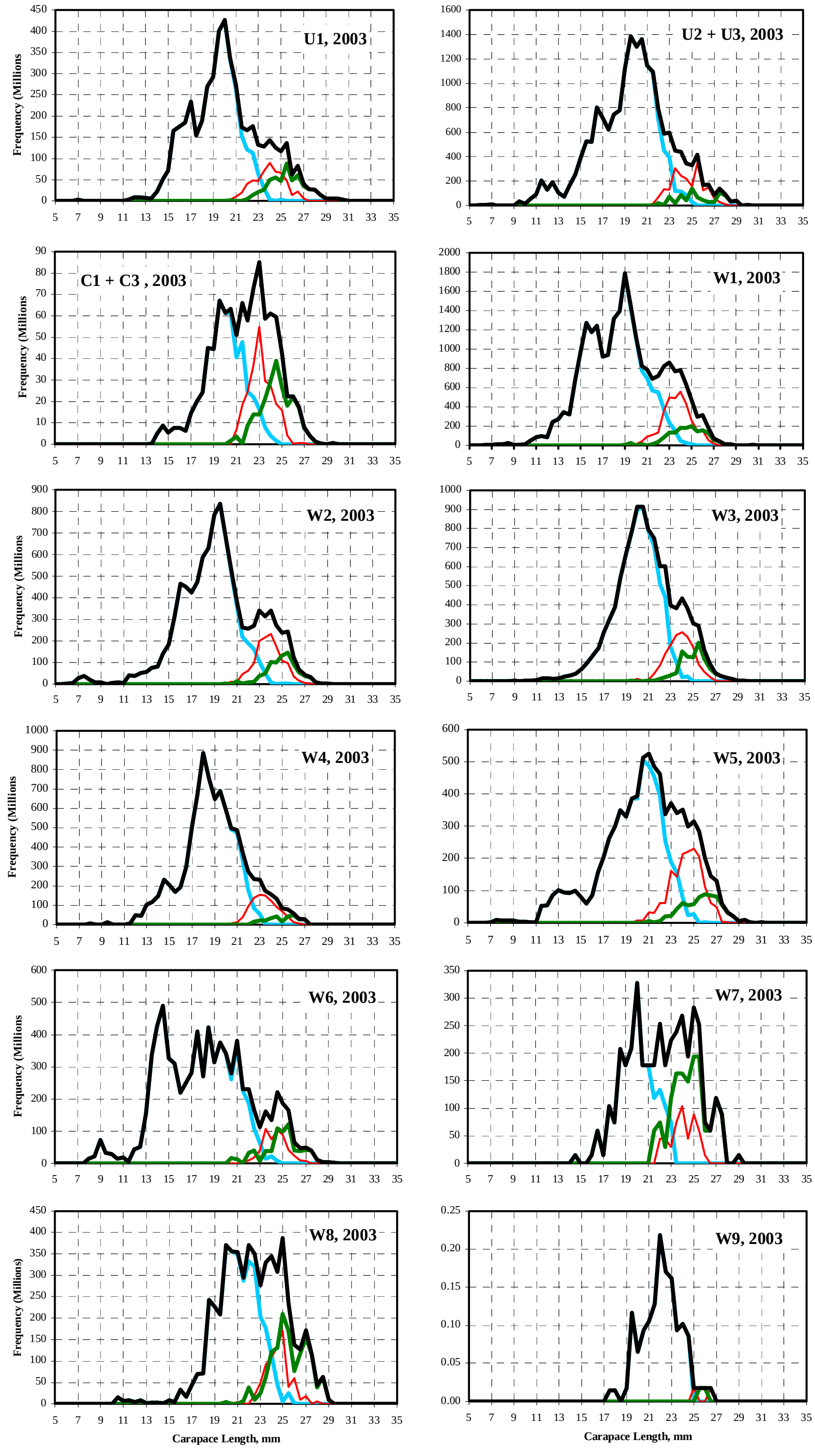

Fig. 8. Length frequencies of northern shrimp in offshore areas U1, U2+U3, C1+C3, and W1 – W9 in 2003 (see Fig. 9 for legend).

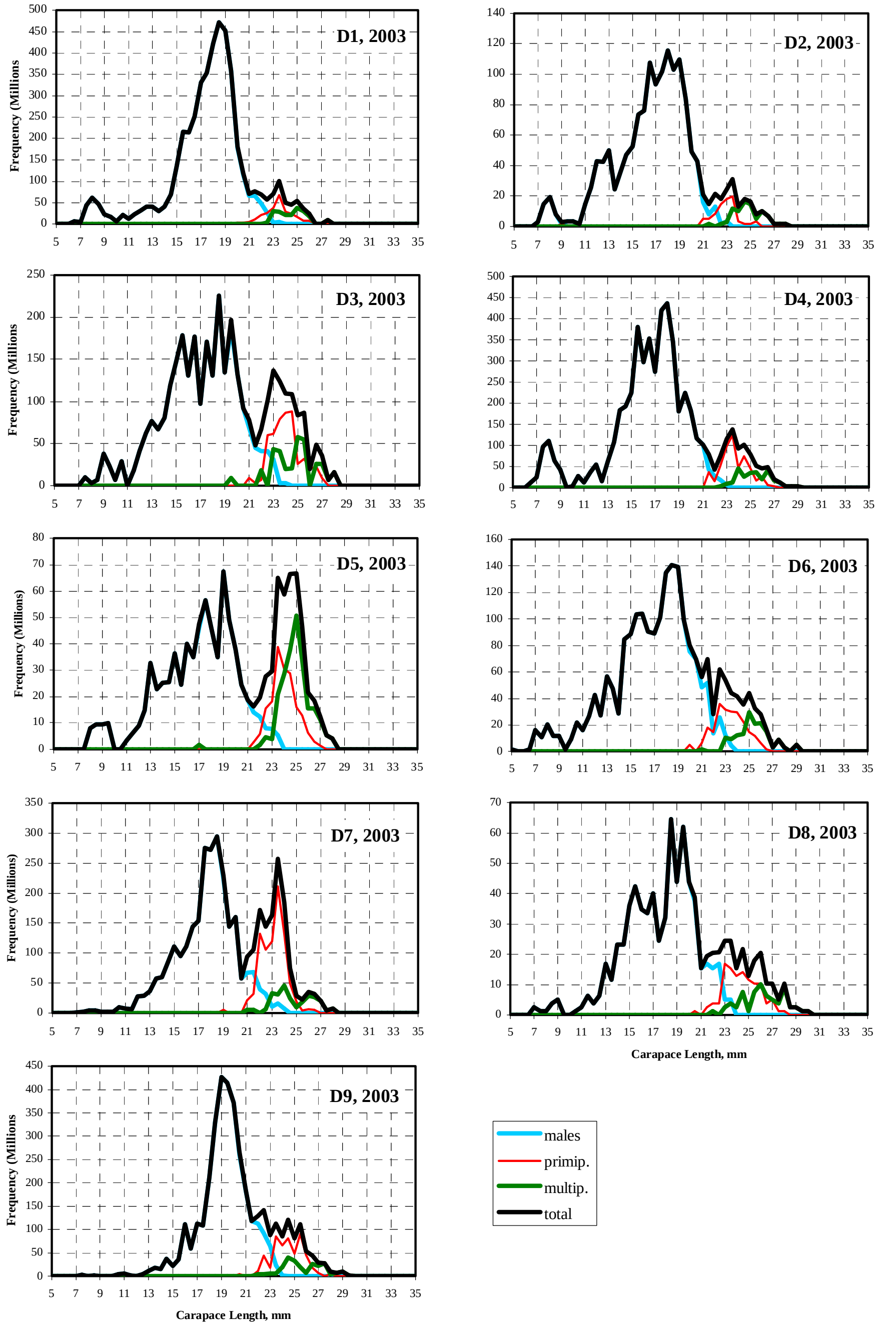

Fig. 9. Length frequencies of northern shrimp in inshore strata D1 – D9 in 2003.

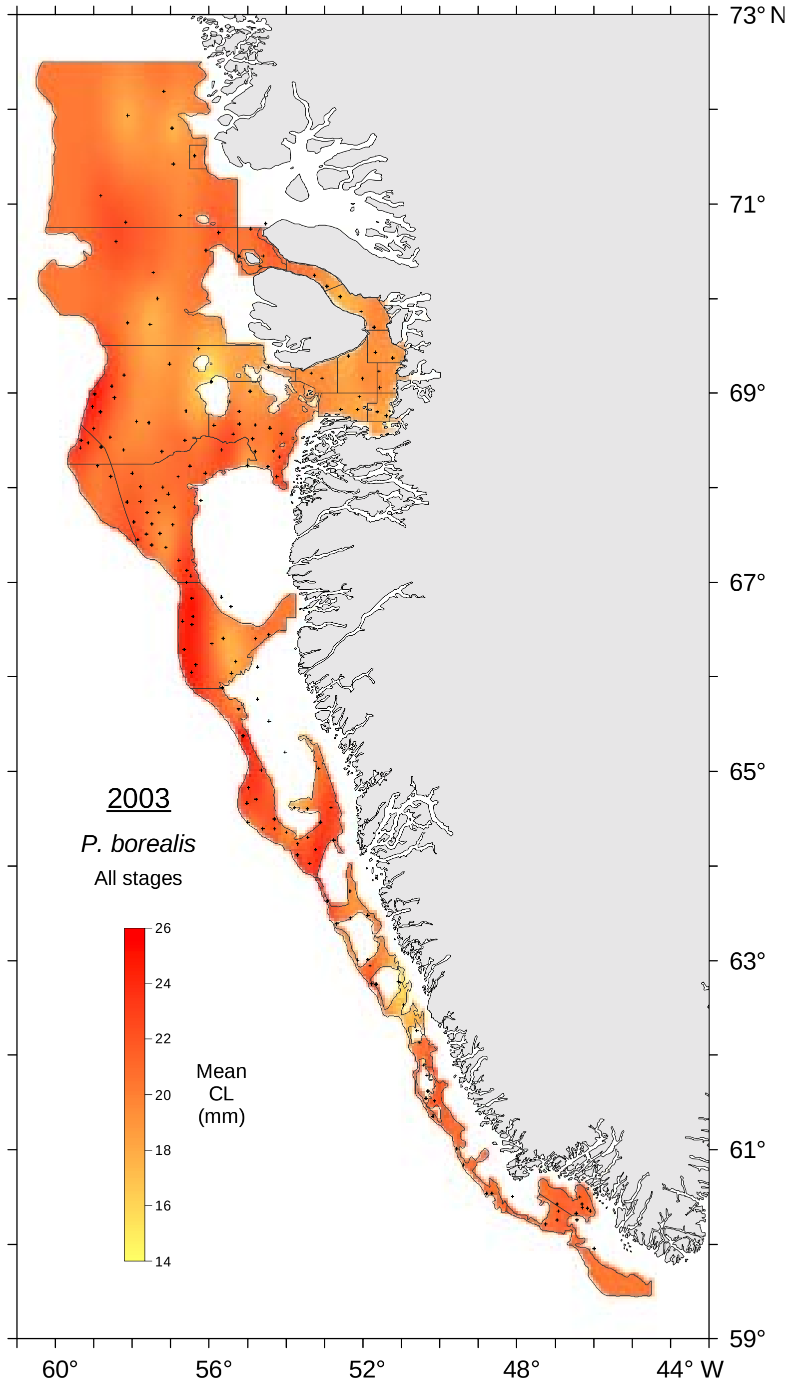

Fig. 10. Geographical distribution of mean size of northern shrimp in 2003.

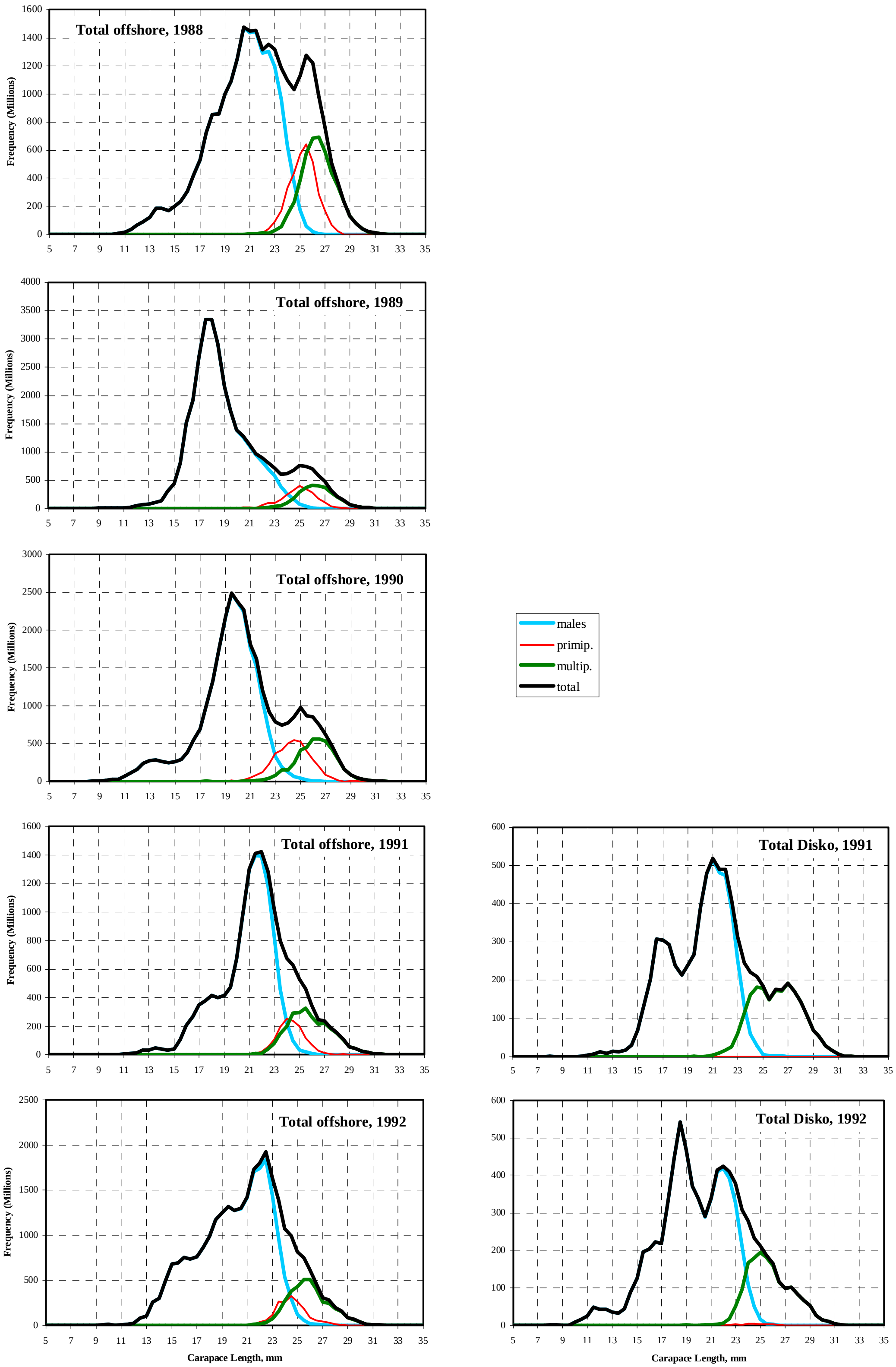

Fig. 11a. Length frequencies of northern shrimp in total offshore area 1988-1992 and Disko Bay/Vaigat area 1991-1992 (no surveys in Disko Bay/Vaigat area 1998-1990).

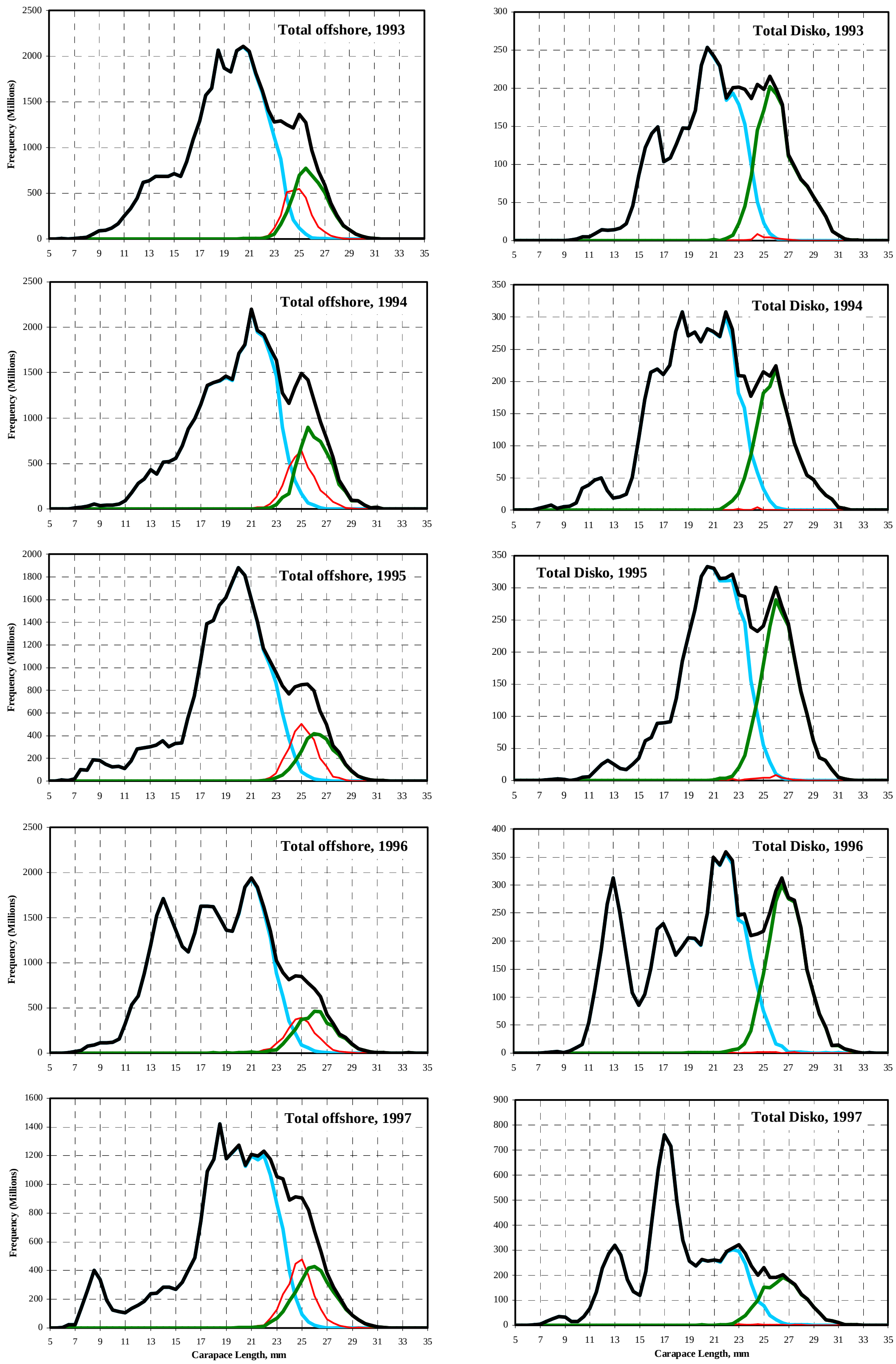

Fig. 11b. Length frequencies of northern shrimp in total offshore and Disko Bay/Vaigat area 1993-1997.

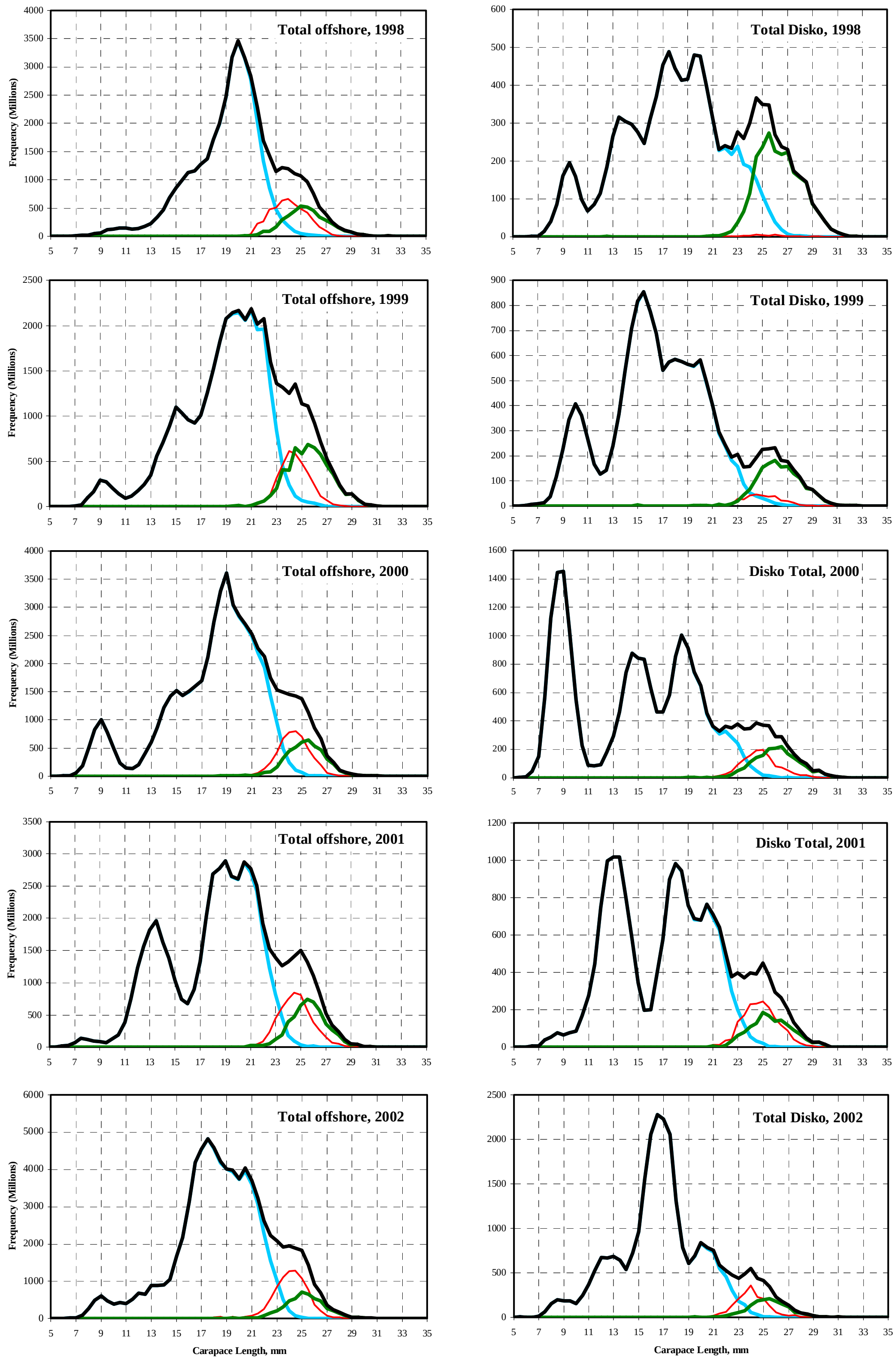

Fig. 11c. Length frequencies of northern shrimp in total offshore and Disko Bay/Vaigat area 1998-2002.

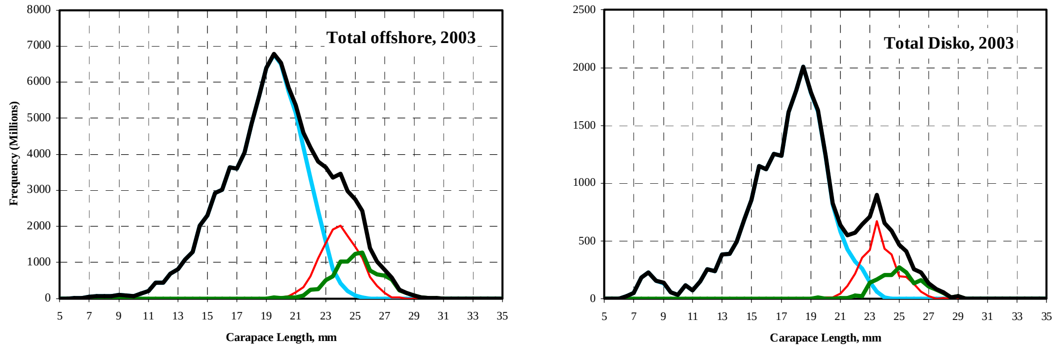

Fig. 11d. Length frequencies of northern shrimp in total offshore and Disko Bay/Vaigat area 2003.

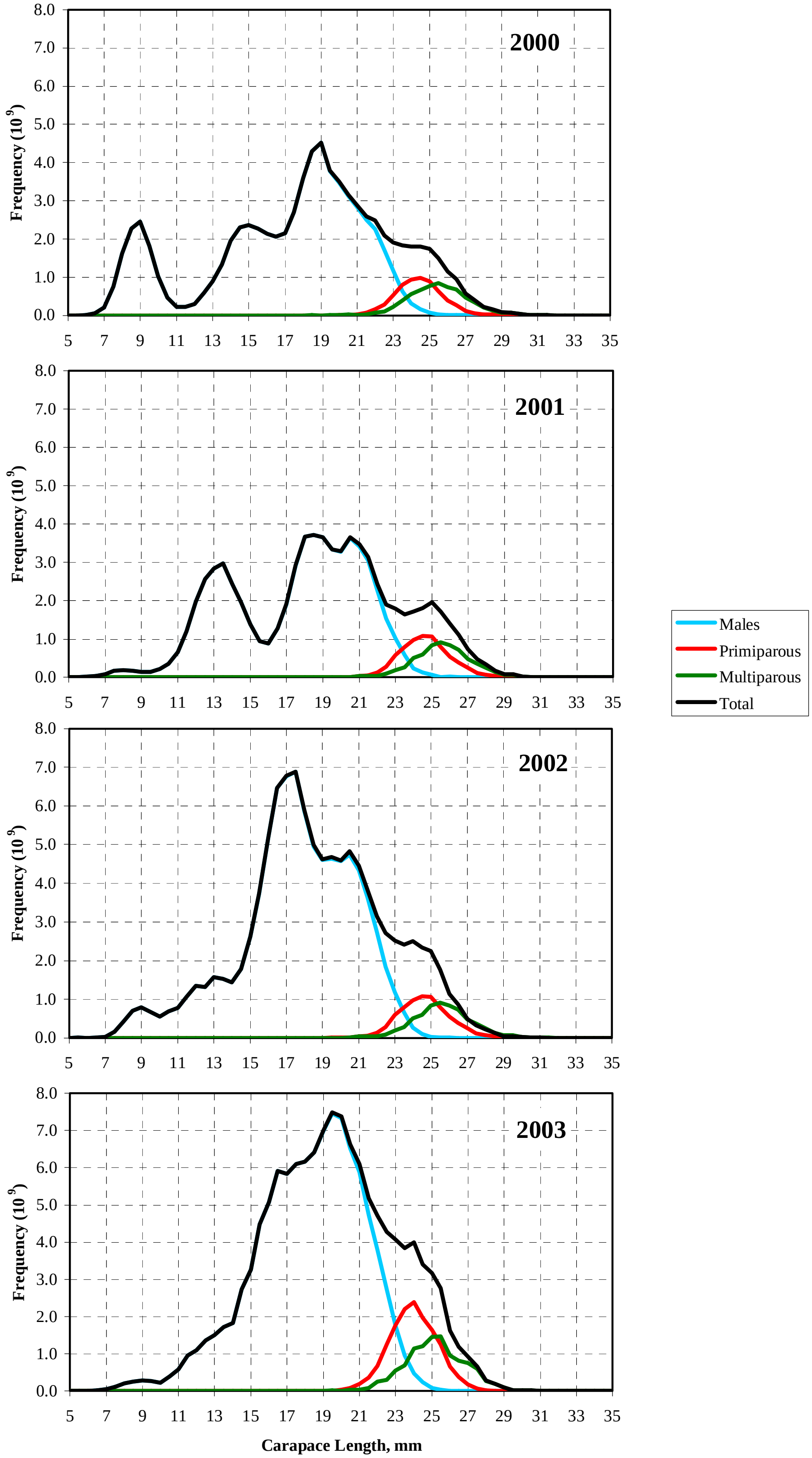

Fig. 12. Length frequencies of northern shrimp in the total survey area (offshore and Disko Bay/Vaigat combined) 2000-2003

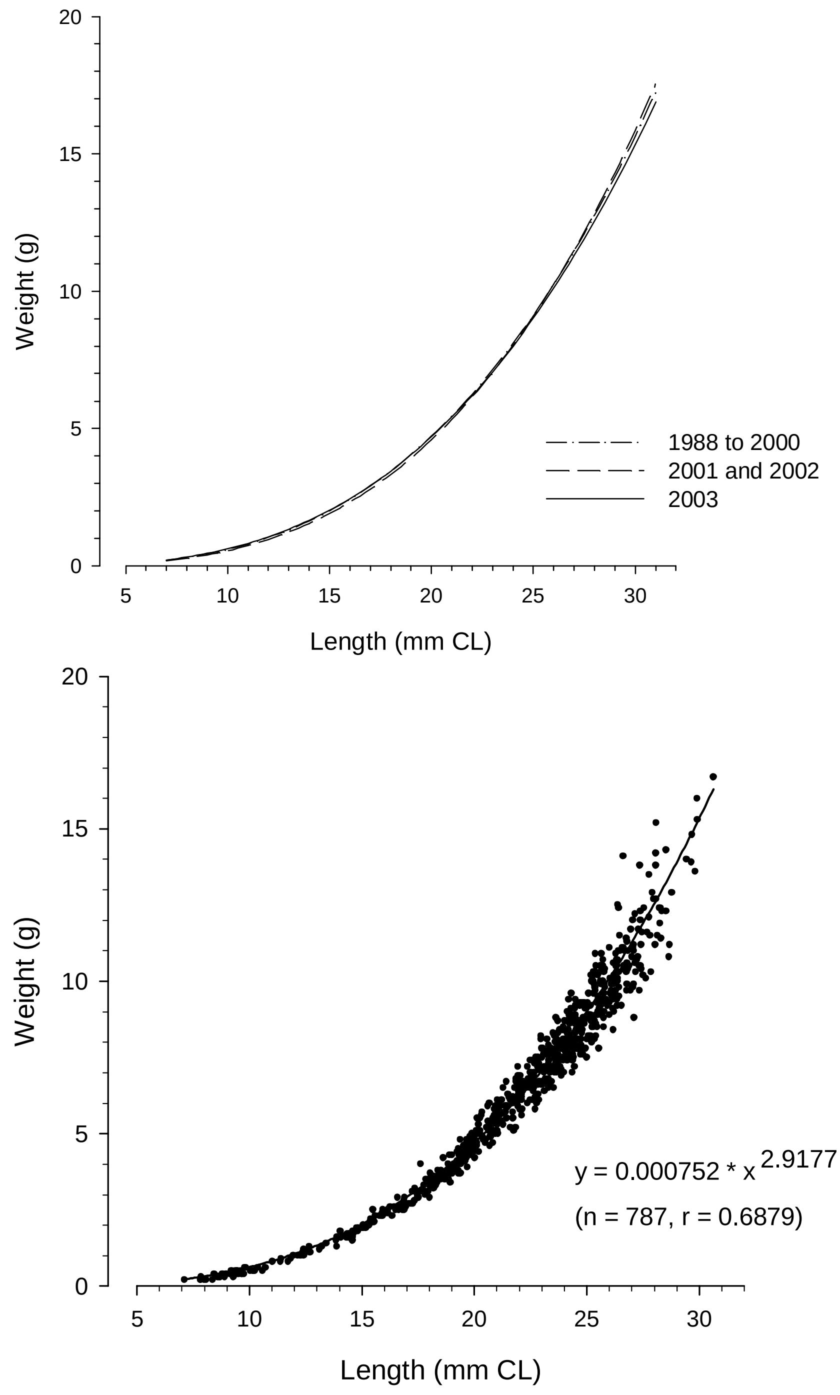

Fig. 13. Length-weight relationship of northern shrimp off West Greenland in 2003 and comparison with length-weight relationships used in previous years.