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Stratified-random trawl survey for northern shrimp (*Pandalus borealis*) in NAFO Subareas 0+1 in 2002

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. This paper updates the survey series with data from the survey in July-August 2002.

The survey design has been changed in the later years: *1*. The allocation of hauls to strata was changed from pure area-proportional allocation to include a weighing factor based on historical density variance; *2*. Trawl sites were chosen using a minimum distance between stations (buffer zone); *3*. About half of the stations were fixed from year to year, while the rest were selected at random as earlier; *4*. Tow duration was reduced from the earlier used 60 minutes in the offshore areas to 30 and 15 minutes.

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 in 1997 the biomass has increased to a record high amount of about 470 thousand tons in 2002. During the period of increase a concentration of the biomass in depths between 200 and 300 meters is indicated.

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 (Kanneworff and Wieland, 2001).

This document presents the results of the 2002 survey, and compares them with previous results in the survey series.

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). Where reliable depth information exists four depth zones are applied: 150-200 m, 200-300 m, 300-400 m, and

400-600 m. In regions without reliable depth information the stratification is based on the distribution of the commercial fishery according to logbook information.

From 1988 through 1997 the trawl stations were allocated to strata proportionally to stratum area, but since 1998 the allocation has been weighted towards strata with historically high shrimp densities, 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.

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*., 1999).

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 1998-2001, 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 in region N (offshore, North of 69°30'N, Fig. 1) had consistently been low and because of severe difficulties in finding suitable bottom for trawling, it was in 1988 decided to use a fixed-station sampling design in this area. 20 sites were chosen covering all nine strata with a minimum of two stations in each.

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. Trawl doors were *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.

Following recommendations from a study group (Carlsson *et al*., 1998) the tow duration was reduced. The reduction was introduced stepwise as a precaution against possible loss of information. In 1998 about 25% of the offshore hauls were reduced to 30 minutes instead of the former 60 minutes. In the 1999-survey 50% of the stations were reduced: 25% to 30 minutes and 25% to 15 minutes. Further reductions were made in the 2000-survey, where half of the stations were scheduled to be of 45 minutes length while the rest were planned as 30 and 15 minutes' hauls in equal numbers. In the surveys in 2001 and 2002 tow durations of 30 and 15 minutes were applied in the proportion 2:1.

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. 19 stations had to be skipped, mainly due to bottom conditions, and 8 stations in region N north of 71°N were skipped due to time constraint. In total, samples and data from 218 trawl stations were used to describe the stock situation in 2002.

Biological samples

From each haul a sample of about 4 kg of shrimp was taken. Shrimp were sorted by species and sexual characteristics, and oblique carapax length (CL) was measured by slide calliper to nearest 0.1 mm for *Pandalus borealis* and *Pandalus montagui*.

The samples of *Pandalus borealis* were weighted by 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 indices for recruitment, spawning stock biomass (SSB), and fishable biomass.

The recruitment index was defined as the total number of shrimp below 17 mm CL. The 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 was derived from the total number of shrimp with a length equal to and greater than 17 mm CL converted to weight.

For the years prior to 2001 a relationship for converting numbers to weight was used, which was established during previous surveys (Carlsson and Kanneworff, 2000). For the years 2001 and 2002 a new length-weight relationship based on data collected during the surveys in these two years was used (Wieland, 2002a).

The geographical distribution of mean size of *Pandalus borealis* was mapped using ordinary point kriging with a spatial resolution of 1 nautical mile.

All fish by-catch was sorted to species or species group and weighted. Analyses of these data will be presented elsewhere.

Data management and analysis

Swept area

The distance between the doors was recorded 5 times in each haul, 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 2002 (30 and 15 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. 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.

Results and Discussion

Biomass, total estimate

For all strata biomass estimates have been calculated (Tables 1a-1e) on the basis of the nominal swept area. The biomass estimates (in tons) for the five main regions in 2002 are:

REGION	BIOMASS ESTIMATE	NO. OF HAULS	CONFIDENCE LIMITS (95 %)
Disko	100,166	24	35,928
North	21,764	12	25,499
Canada	5,995	10	5.515
West	307,931	152	97,851
South	37,614	20	33,882
OVERALL	473,470	218	118,162

Since the low observed biomass estimated for 1997 (206 thousand tons) the biomass has increased significantly to a record high estimate for 2002 of 473 thousand tons. The estimate for 2002 is the fifth annual estimate with record highs above the observations from the period 1988-97 (Table 2, Fig. 2). The biomass in 2002 had a fairly traditional distribution (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. Also, in the area north of Store Hellefiskebanke (about 68-69°N) very good concentrations were found this year. Compared to the preceding year a doubling of the biomass in the southernmost region (S: Julianehåb Bay) was found in 2002, however well below the record high biomass observed in 1999 (Table 2). Due to the large observed variance in this area a high number of sampling sites were planned for the surveys since 2000. This region has exhibited frequent large coefficients of variation of the biomass estimate (Table 3). It is not known if this area truly has a naturally high variation of the biomass or if a revision of the stratification and hence the sampling pattern would reveal higher stability. Also for the estimates for regions C and N large coefficients of variation are normally observed, but the biomass estimates from these regions account only for a small proportion of the total (in 2002, 15 % for regions C, N and S combined). Due to missing coverage of the northern part of region N in 2002 this region might have been somewhat underestimated, the average biomass for strata N1-N3 1994-2001 being about 5,000 tons.

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 2002, the total estimate is reduced by 9.3 % to about 430 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. Figures 3 and 4 show the variations in biomass distribution over various geographical areas and over the depth intervals used. 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 (Fig. 3). Fig. 4 shows that since 1995 the biomass has gradually moved from the deeper layers to the depth layer 200-300 m, which in 2002 had more than 60 % of the observed biomass.

The increase in biomass during the recent five years has mainly been observed in the northern part of region W (W1-W3, Fig. 5) and in Disko Bay area. In all areas the largest increase has taken place in the depth layer 200-300 m. In 2002, higher shrimp densities than normal were found in the shallow areas (150-200 m), especially in W3 and W5. These concentrations are traditionally connected with recruitment of a large year class of shrimp.

The distribution of the shrimp stock over the various strata has varied much over the years (Fig. 5), and no clear trends can be seen. The major part of the biomass has, however, consistently been observed in areas W2, W3, W5, and in Disko Bay (Table 2). The distribution of the biomass over the main depth layers (200-300 and 300-400 m) show clear trends through the years of observation (Fig. 6). A movement of the biomass during the period 1988-1994 towards deeper strata is indicated while a movement in the opposite direction seems to have taken place since 1995.

The Disko Bay 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 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 100 thousand tons in 2002 (21 % of the total). Estimated shrimp densities in the Disko Bay area are high compared to the offshore areas (Table 4), having more than 10 grams shrimp per. square meter, about three times the average density offshore.

Figure 5 shows the biomass estimates in depth strata in the central areas W1-W7 from all years of surveys. Until 1994 the area W1 constituted a large proportion (>10%) of the estimated total biomass. Nearly all the biomass was found in the depth layer 300-400 m. Since 1999 an increase is observed, and in the recent three years more than 10% of the biomass is again found in this area, in which depths between 200 and 300 meters seem to be increasingly attractive. However, this area is very large and the density of shrimp has consistently been low compared with other areas, and the area has therefore been of low interest for the commercial fleet through most of the years.

Area W2 has generally been of high interest for the commercial fisheries, and has in the survey material exhibited high shrimp densities in most of the years. In 2001 a significant change towards a very high abundance in the 200-300 m depth layer was observed (Fig. 5). In 2002, high densities were again observed in this depth layer, but at the same time a significant increase was observed in the depth layer 300-400 m

The area W3 was in the early days of the commercial offshore fishery of high importance. In good agreement with this the observed biomass in the first years of the survey series was fairly large and relatively stable, but from 1991 the biomass in the depth stratum 200-300 meters decreased sharply and remained nearly absent in the following six years. A sudden reverse to a distribution like that prior to 1991 was seen in 1998 and since then the biomass has been concentrated in depth layer 200-300 m with high densities. In 2002, a high incidence of shrimp was found for the first time in the upper depth zone.

Area W5, which in 2002 accounts for 14 % of the total biomass estimate, has been an area with high variations in all depth layers. Like in most other regions the 2002-biomass is indicated to be concentrated in the depth stratum 200-300 m. However, as in area W3 a large amount of shrimp was this year found in the shallow depth layer (150-200 m). Through the years of surveys similar incidences of sudden concentrations of shrimp in the shallow areas have been observed (e.g. in W4 in 1988, W5 in 1989 and 1999, W6 in 1996). These concentrations are traditionally connected with recruitment of year classes above average size.

In order to study further the temporal and spatial variations of the observed shrimp biomass a preliminary simple linear regression model was used to test the (logarithm of) shrimp density dependency of the variables year, depth layer, geographical region and time of the day. The model included survey data from the period 1994-2002, 8 depth zones, each of 50 meters intervals from 150 m to 600 m, 5 regions (see text table p. 3) and 11 one-hour periods from 9 a.m. to 20 a.m. (UTC). All variables but time of the day were significant in the model that explained 33 % of the variations in the observations. Fig. 7 shows index values of the significant model variables. The yearly indices follow the independently observed estimates well (cf. Fig. 2) apart from the index for year 2000 (that was not significant to the model). The distribution pattern over the depth layers is surprisingly broad, however, large changes over the years have been observed, often connected with variations in distribution of different size groups and incoming large year classes. The relative densities in the four of the five regions seem to have been remarkably stable; only region S (the southernmost region) has shown large variations through the period (cf. Table 4).

Stock composition

Size distribution by areas in 2002

Length distributions for the offshore areas NN (strata N1-N4), NS (strata N5-N9), C (strata C1+ C3), W1 to W7, and S (strata S1+ S1) show dominance of males between 19 and 23 mm CL in some of the areas, but not in areas NS, W1 to W3, W5 and W6 where smaller (15-19 mm CL) individuals prevailed or were equally abundant (Fig. 8). Males smaller than 11 mm CL were only found in areas C, W2, W5 and W6 as well as in area S, and relative high numbers of large (> 23 mm CL) females were observed in areas W4 to W6 and S. 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 between 11 and 17 mm CL (Fig. 9).

Figure 10 shows the geographical distribution of mean size all sexual groups pooled. Low mean size (< 17 mm CL) of males was found in several distinct areas, in particular in the Disko Bay (stratum D1-D9), southwest off Disko Island (eastern part of area W1 and north-western part of area W2), as well as between the fishing banks and the coast at about 62 to 64 °N (area W6). The geographical distribution of mean size agrees in general with those of the past years (Wieland and Carlsson, 2001, Kanneworff and Wieland, 2001), except for the wider extension of areas with values below 17 mm mean CL in the Disko Bay and the coastal offshore areas between 62 and 64 °N.

Annual size distribution

Overall length distributions for the offshore and the inshore (Disko Bay and Vaigat) survey areas in 1988 to 2002 are compared in Fig. 11a-c. Visual inspection of the offshore length frequency for 2002 indicates a number of distinct males modes (appr. at 9, 13, 17.5 and 20.5 mm CL), a mode of primiparous females at about 24 mm CL and one of multiparous females around 25 mm CL. The same peaks can be detected in the corresponding inshore length frequency with some shifts of the location of the modes and a higher relative abundance of males at 12 and, especially, at 16.5 mm CL. In both, the offshore and the inshore part of the survey area, the abundance of the smallest size group of males reflects more the average condition rather than its exceptional strength observed in 2000.

Figure 12 shows overall length frequencies combined for the offshore and the Disko Bay area for 1999 to 2002. A progression of the '1998 year-class' from about 10 mm CL in 1999 to 15 mm in 2000 and further to 18 mm in 2001 and to 20 mm CL in 2002 is clearly visible. Even more pronounced is the progression of the '1999 year-class' from 9 mm CL in 2000 to about 13.5 mm CL in 2001 and to 17.5 mm CL in 2002. Here, the pronounced 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. Several processes, which include mesh selection of the trawl especially for shrimp smaller 11 mm CL (Wieland, 2002c), 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. However, the actual presence of several size groups of males and, in particular, the high number at the mode of 17.5 mm CL is promising in terms of recruitment to the female group in the coming year.

Total abundance, recruitment, spawning stock biomass and fishable biomass

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 2002 was the highest on record exceeding considerably the long term mean with a higher proportion of males than the average of the time series. 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 calculation of recruitment indices, defined as the total number of shrimp below 17 mm CL, was limited to the period 1993 to 2001 (Table 7). This was done because before 1993 a wider mesh size in the cod-end has be used which would not have retained the smallest size group of males in any proper relation to its actual abundance. The total recruitment index for 2002 is the highest in time series (more than two times the long term average). However, a change to faster growth related to an increase in bottom temperature observed in the most recent years (e.g. Wieland, 2002b) makes it difficult to assess changes in recruitment based on the fixed size limit used here.

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 8. The total SSB for the 2002 survey exceeds that for 2001 by 15 % and is the highest on record.

Table 9 shows the estimated fishable biomass (FB) calculated from the number equal to and above 17 mm CL, which 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 2002 survey indicated a substantial increase and is by far the highest on record, which can mainly attributed to the progression of a large part of the '1999 year-class' beyond 17 mm CL (Fig. 12).

The contribution of the inshore (Disko Bay and Vaigat) component of the stock to total recruitment, SSB and FB differed substantially through the years (Tabs. 7-9) and is actually 39 % in terms of recruitment, 19 % in terms of SSB, and 20 % in terms of fishable biomass.

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 1998 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 2002 of 473 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 recruitment, spawning stock biomass 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 and sampling statistics for strata in region W, 2002.

AREA	STRATUM	SQKM	HAULS	TONS	STD	CV
W1	150-200 M	2416	2	216	228	105.6
	200-300 M	5295	3	44204	17402	39.4
	300-400 M	9239	12	17873	24700	138.2
	400-600 M	752	2	0	0	65.9
W2	150-200 M	1857	2	205	284	139.1
	200-300 M	3026	6	26938	29261	108.6
	300-400 M	2158	7	36966	32911	89.0
	400-600 M	1723	5	1995	1376	69.0
W3	150-200 M	2215	2	11277	14249	126.4
	200-300 M	4810	30	25532	33342	130.6
	300-400 M	2714	4	3717	2366	63.7
	400-600 M	3361	3	2165	2062	95.2
W4	150-200 M	4252	2	1161	1641	141.3
	200-300 M	1791	4	24108	33733	139.9
	300-400 M	812	9	2496	3880	155.4
	400-600 M	1967	4	10	5	56.2
W5	150-200 M	1995	2	32464	45912	141.4
	200-300 M	3454	16	33480	52194	155.9
	300-400 M	1797	3	18	32	173.2
	400-600 M	2806	3	223	380	170.9
W6	150-200 M	1095	3	496	251	50.6
	200-300 M	1491	6	28132	39705	141.1
	300-400 M	1300	4	6290	5824	92.6
	400-600 M	884	2	1767	2250	127.3
W7	150-200 M	2419	2	2	1	33.7
	200-300 M	985	11	6197	13731	221.6
	300-400 M	239	2	0	0	141.4
	400-600 M	273	1	0	.	.
OVERALL			S.E.:	48926	Err. CV:	15.9

Table 1b. Estimated trawlable biomass and sampling statistics for strata in region C, 2002.

AREA	STRATUM	SQKM	HAULS	TONS	STD	CV
C1	300-400 M	655	2	1023	335	32.8
	400-600 M	312	2	8	3	43.9
C3	200-300 M	660	2	3822	3705	97.0
	300-400 M	1192	2	1112	1169	105.2
	400-600 M	623	2	31	44	141.4
OVERALL			S.E.:	2758	Err. CV:	46.0

Table 1c. Estimated trawlable biomass and sampling statistics for strata in region D, 2002.

AREA	SQKM	HAULS	TONS	STD	CV
D1	819	3	9658	2532	26.2
D2	566	2	9972	4068	40.8
D3	1124	3	4392	2510	57.2
D4	1834	4	15806	3390	21.4
D5	612	2	4518	1227	27.2
D6	1014	2	6556	892	13.6
D7	1447	3	14406	21138	146.7
D8	652	2	2355	165	7.0
D9	1296	3	32505	21718	66.8
OVERALL		S.E.:	17960	Err. CV:	17.9

Table 1d. Estimated trawlable biomass and sampling statistics for strata in region N, 2002.

AREA	SQKM	HAULS	TONS	STD	CV
N4	2257	1	14361	14146*	99*
N5	2985	2	224	12	5.2
N6	10830	3	3322	4822	145.1
N7	1029	2	6	3	40.4
N8	3237	2	1890	2657	140.5
N9	2407	2	1960	2552	130.2
OVERALL		S.E.:	21901	Err. CV:	100.6

*) Calculated from Biomass*0.985

Table 1e. Estimated trawlable biomass and sampling statistics for strata in region S, 2001.

AREA	SQKM	HAULS	TONS	STD	CV
S1	1993	15	23309	35209	151.1
S2	4526	5	14305	31965	223.5
OVERALL		SE.:	16941	Err CV:	45.0

Table 2. Biomass estimates 1988-2002 (thousand tons) in combined areas from north to south. Standard errors and error percentages are also given.

Year	**N1-N9**	**D1-D9**[1]	**W1-W2**	**W3-W4**	**C1+C3**	**W5-W7**[2]	**S1-S2**	**Total**	**SE**	**%**
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	100.2	128.4	70.5	6.0	109.1	37.6	473.5	59.1	12.5

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

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

Table 3. Error coefficients of variation for the biomass estimates in the five main regions 1988-2002.

			Region		
Year	C	D	N	S	W
1988	37	-	30	-	16
1989	44	-	23	-	16
1990	44	-	42	-	20
1991	25	23	40	-	17
1992	77	16	17	-	17
1993	54	21	51	-	14
1994	19	26	48	99	24
1995	45	17	47	84	18
1996	91	10	52	95	22
1997	59	14	37	16	24
1998	41	18	41	59	26
1999	80	14	54	51	14
2000	7	13	37	56	15
2001	46	19	27	49	19
2002	46	18	101	45	16

Table 4. Estimated mean shrimp densities in groups of strata in 1988-2002. 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
D1-D9	-	-	-	5.401	5.060	3.589	4.269	5.052	5.801	5.582	6.612	6.534	8.917	8.836	10.697
N1-N9	0.524	0.252	0.247	0.140	0.497	0.192	0.209	0.213	0.261	0.186	0.214	0.375	0.249	1.012	0.565
C1+C3	2.788	1.119	3.233	1.391	6.995	0.982	1.975	1.284	0.491	0.071	0.129	3.457	3.388	1.217	1.742
W1-W2	2.489	2.659	3.484	1.310	2.206	3.895	4.069	1.653	2.032	1.514	1.596	2.047	2.568	3.140	4.851
W3-W4	3.429	3.668	2.499	2.416	1.611	1.882	2.269	2.674	1.593	0.687	4.888	1.190	3.317	2.402	3.214
W5-W7	1.885	3.842	1.575	1.899	3.113	3.602	2.013	2.831	4.828	3.551	2.719	2.984	4.247	3.615	5.821
S1-S2	-	-	-	-	-	-	3.979	0.265	0.565	3.814	3.428	9.769	3.761	3.029	5.770
Average	1.829	1.850	1.678	1.509	1.969	2.115	2.188	1.737	1.991	1.650	2.347	2.299	2.796	2.793	3.788

Table 5. Numbers (billions) of male and female shrimp in overall length distributions from the total survey area (mean values for Disko Bay 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
Average	40.7	10.1	50.8	79.1	20.9

Table 6. Biomass estimates of male and female shrimp (thousand tons) in total survey area, based on length-weight relationship applied to overall length-frequency distributions (mean values for Disko Bay 1991-1997 used in 1988-1990, new length-weight relationship used for 2001 and 2002).

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
Average	160.4	97.3	257.7	61.8	38.2

Table 7. Recruitment index (number of males < 17 mm CL, billions) in offshore, Disko Bay 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
Average	10.37	5.08	15.46

Table 8. SSB index (female biomass, thousand tons) in offshore, Disko Bay and total survey area (mean values for Disko Bay 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	100.7	32.0	132.7
2002	123.8	28.4	152.2
Average	80.2	21.5	101.7

Table 9. Fishable biomass index (for shrimp >= 17 mm CL) in offshore, Disko Bay and total survey area (mean values for Disko Bay 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
Average	189.3	48.8	238.2

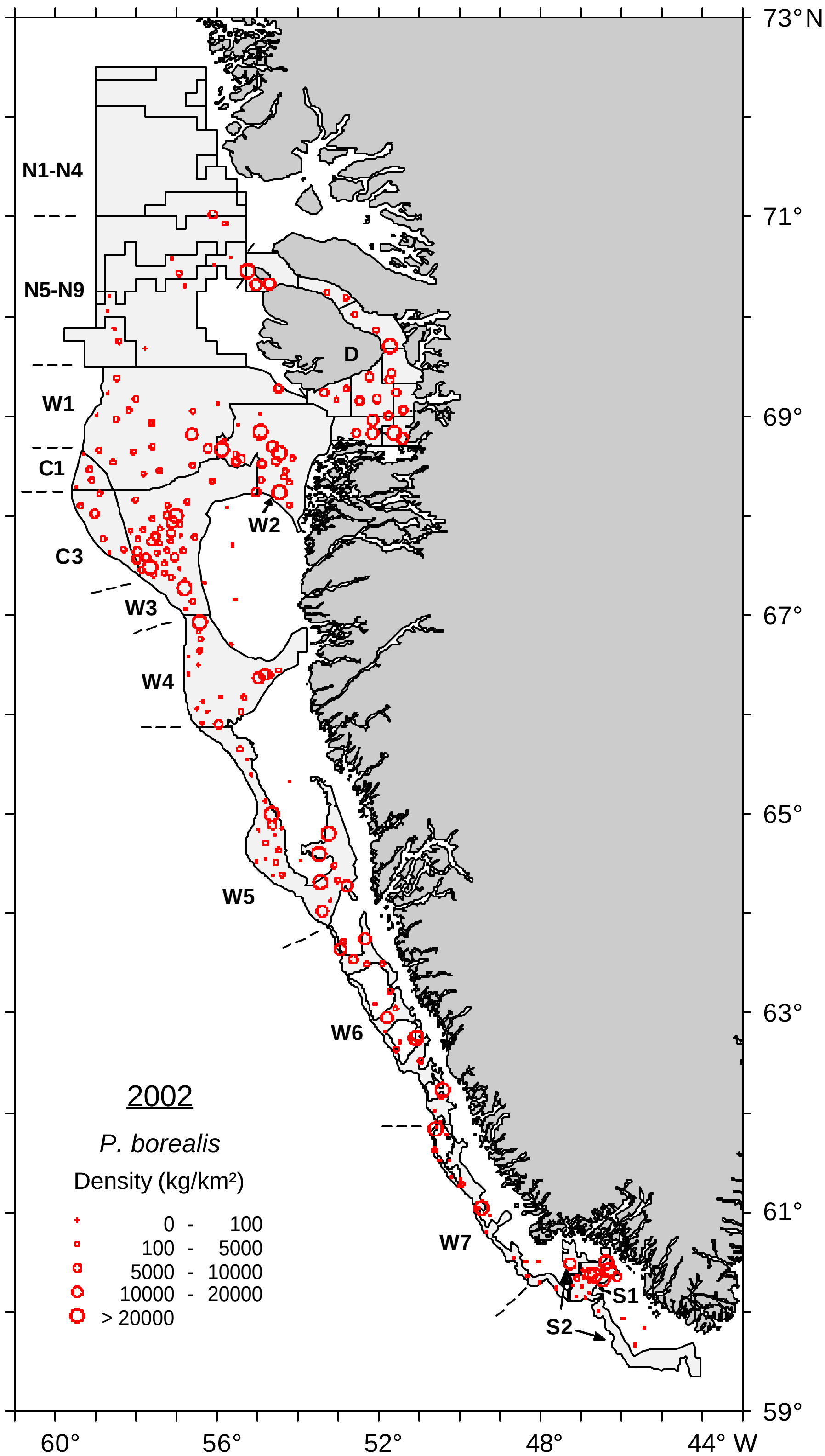

Fig. 1. Sampling sites and shrimp densities in the trawl survey 2002.

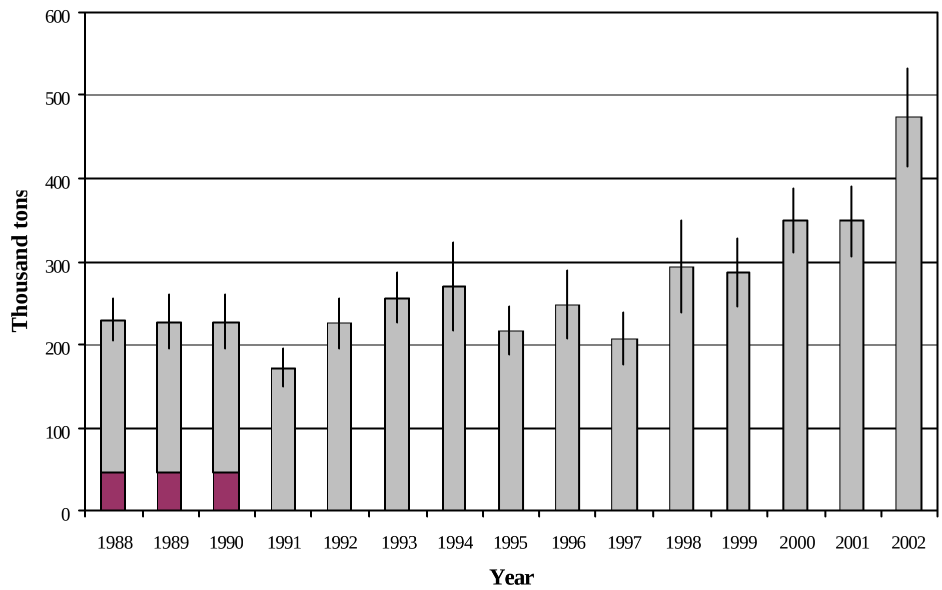

Fig. 2. Estimated total yearly biomass 1988-2002 with standard errors. Average biomass estimate for inshore areas 1991-1997 is inserted in 1988-1990 to facilitate between-year comparisons.

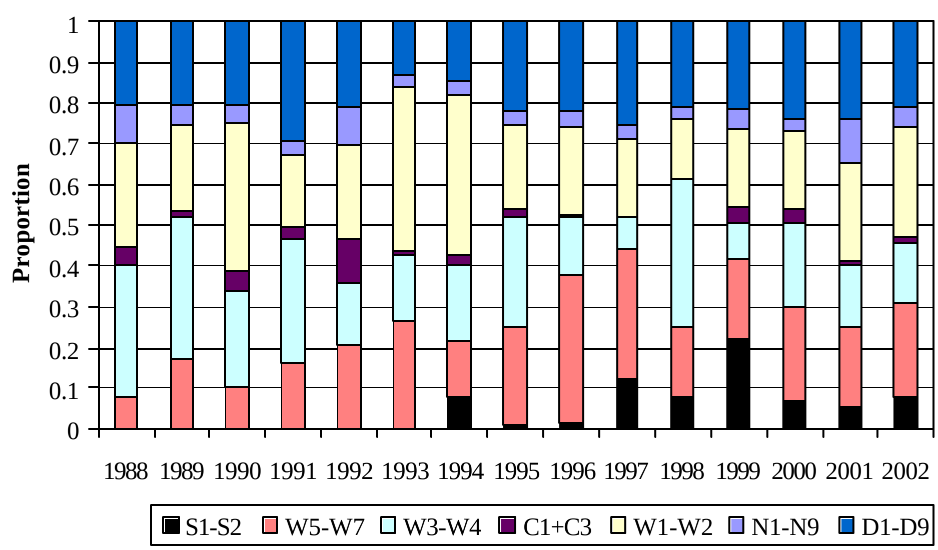

Fig. 3. Proportionate contribution to the total biomass of groups of strata for surveys in SA0+1, 1988-2002. Data for inshore areas (D1-D9) 1988-90 estimated as described above (Fig. 2).

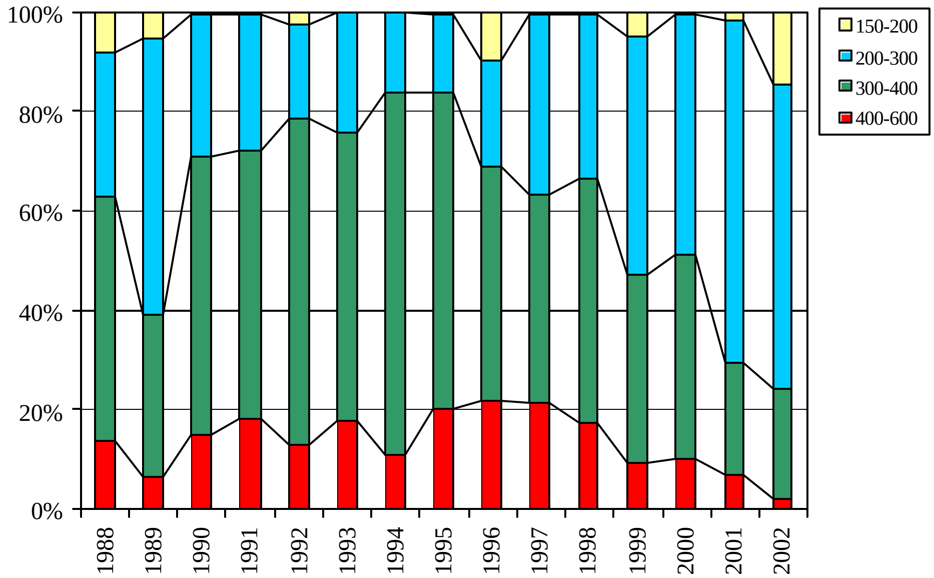

Fig. 4. Proportionate distribution of estimated biomass in depth strata (regions W and C only) for surveys in SA0+1 offshore, 1988-2002.

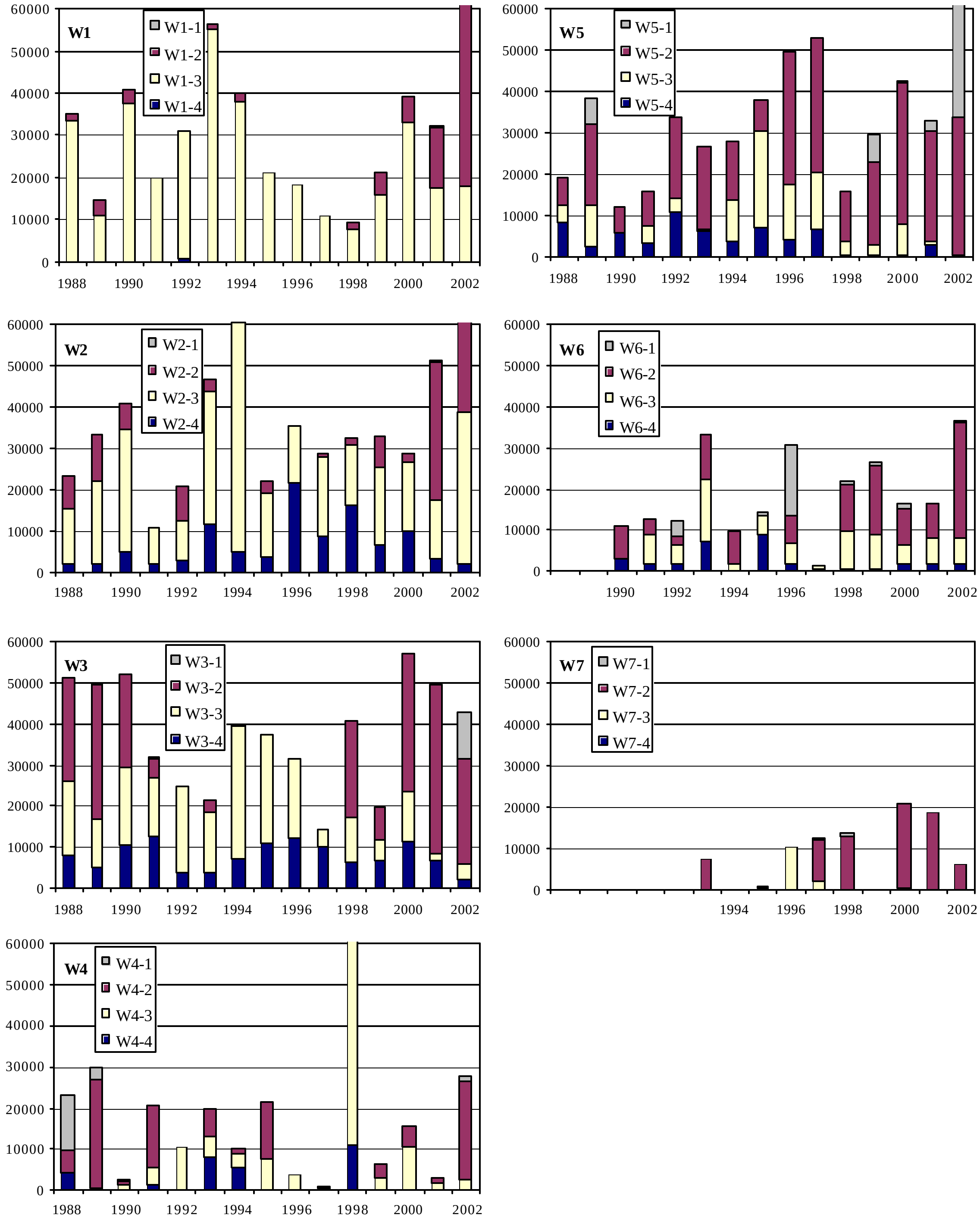

Fig. 5. Biomass estimates of shrimp (tons) in region W in depth strata, 1988-2002.

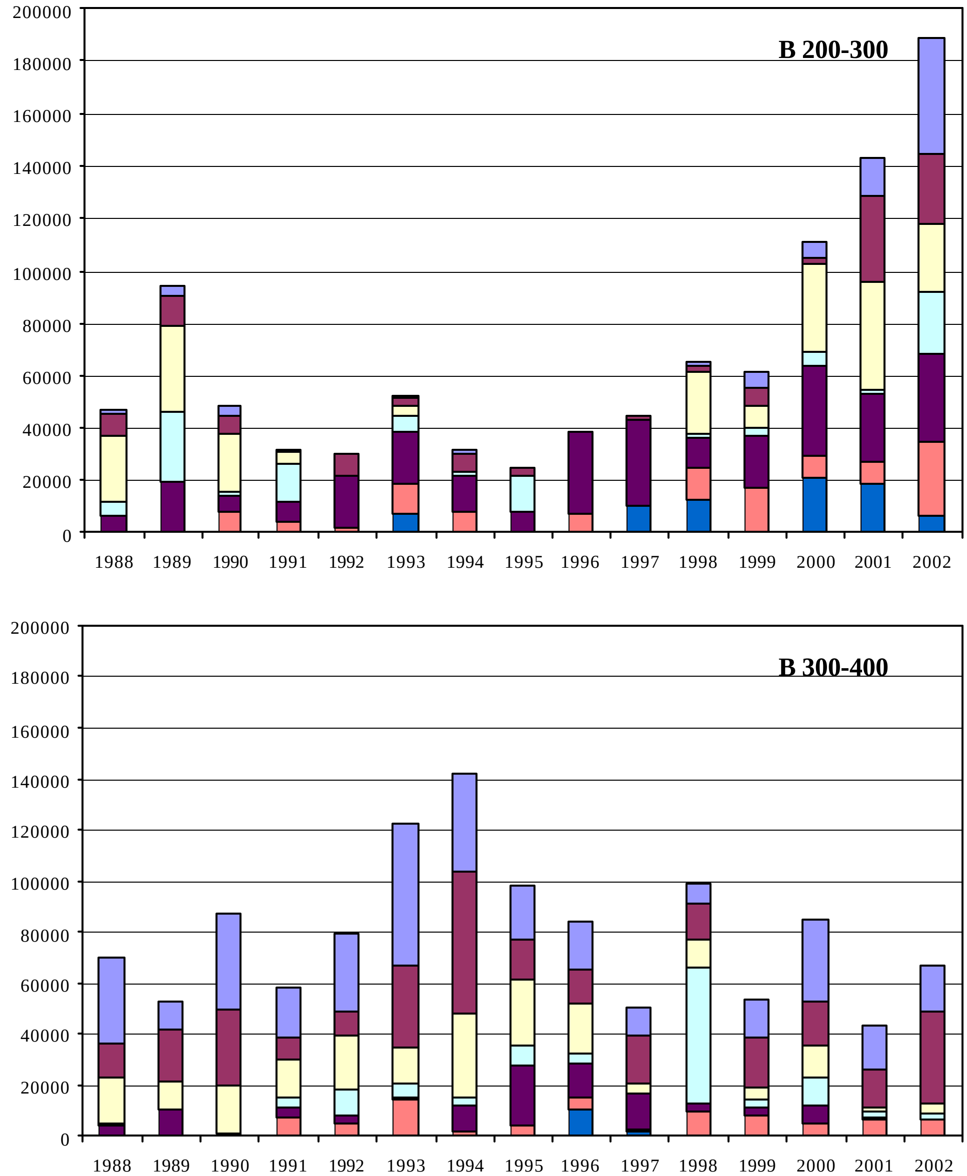

Fig. 6. Estimated biomass of shrimp in region W in depth strata 200-300 m (upper panel) and 300-400 m (lower panel), 1988-2002. The shadings dividing the columns represent the seven areas (W1-W7, top to bottom) in the region.

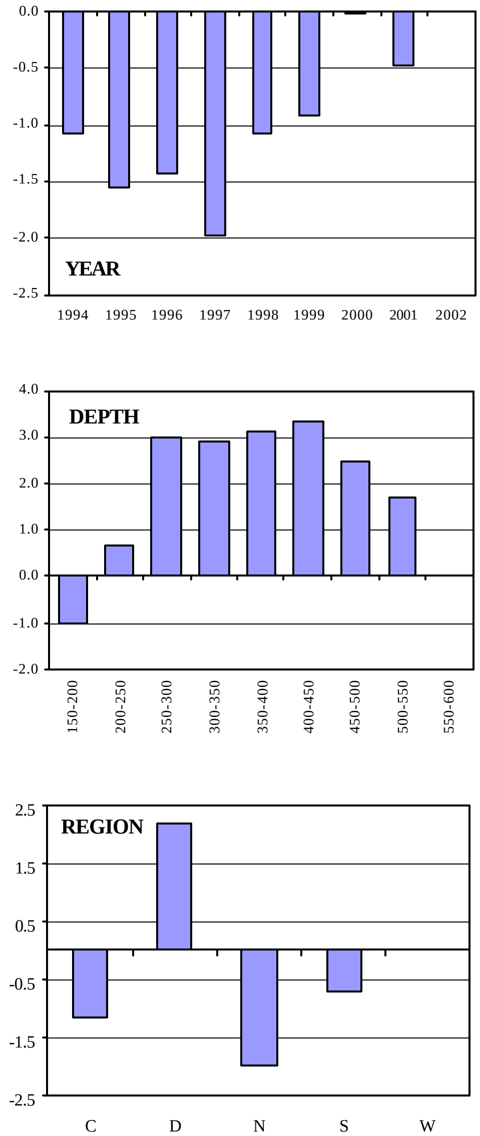

Fig. 7. Parameter indices from a regression model for survey data 1994-2002.

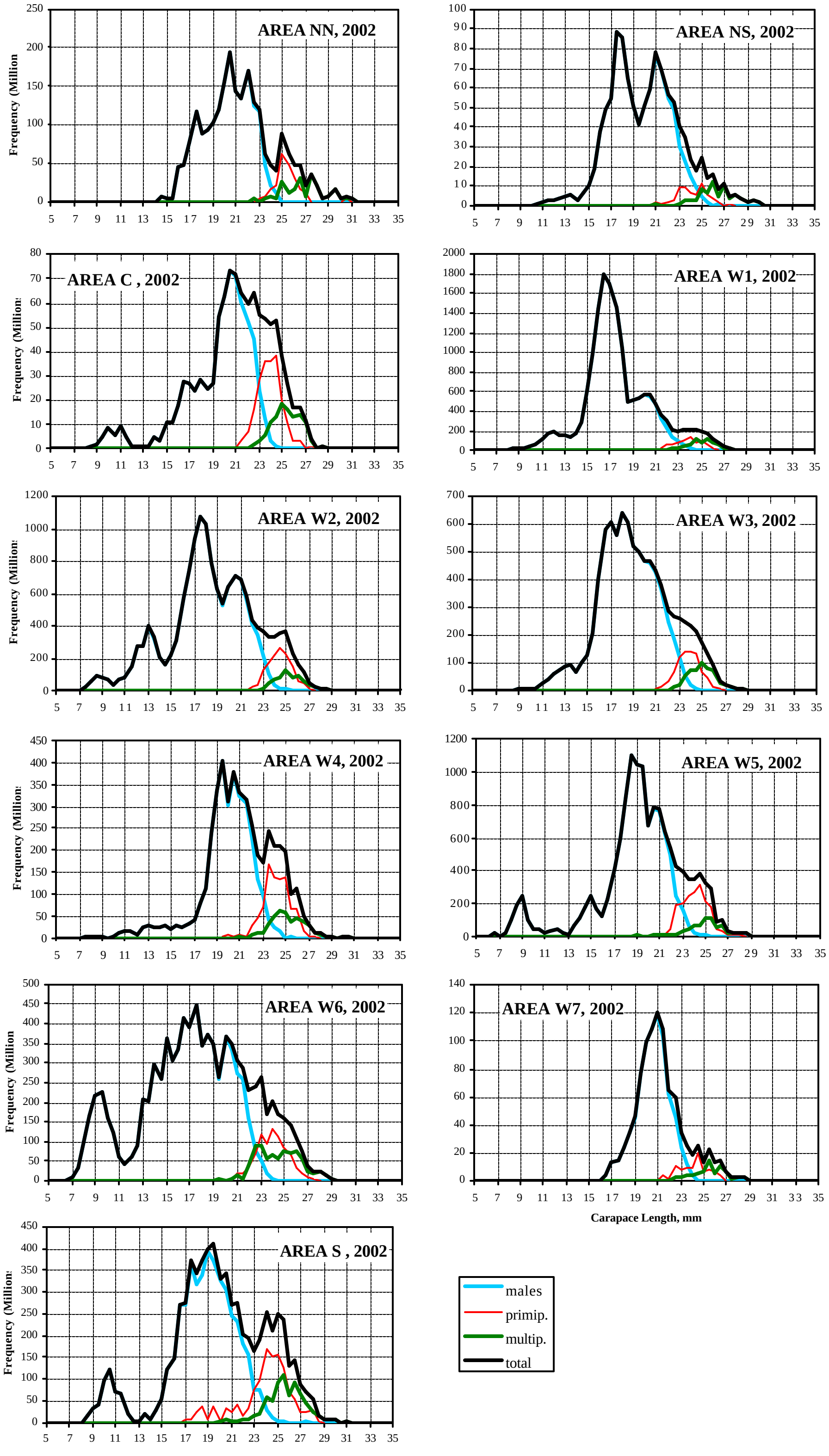

Fig. 8. Numbers of shrimp by length group in offshore areas NN (N1-N4), NS (N4-N9), C, W1 – W7 and S in 2002.

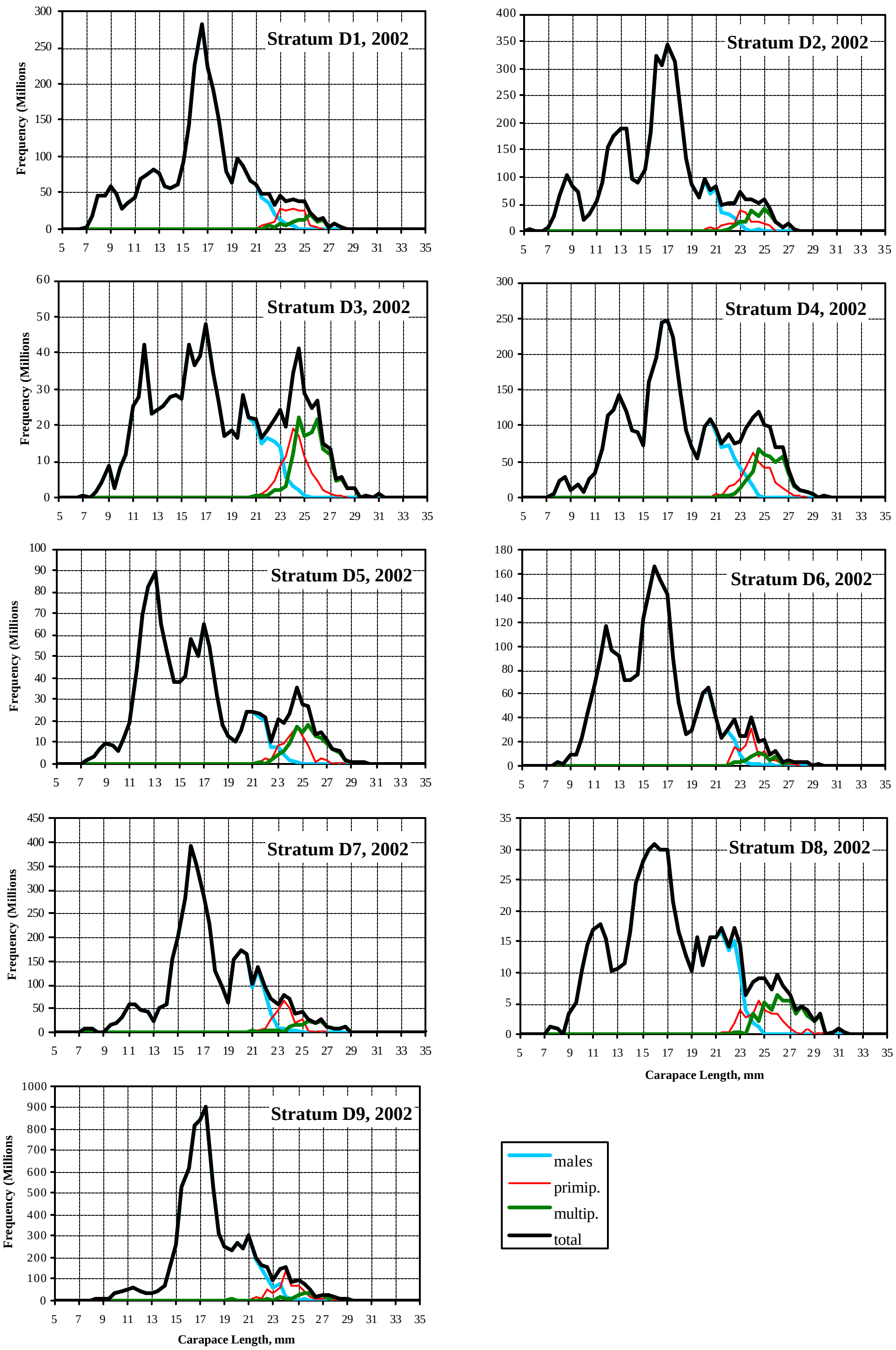

Fig. 9. Numbers of shrimp by length group in inshore strata D1 – D9 in 2002.

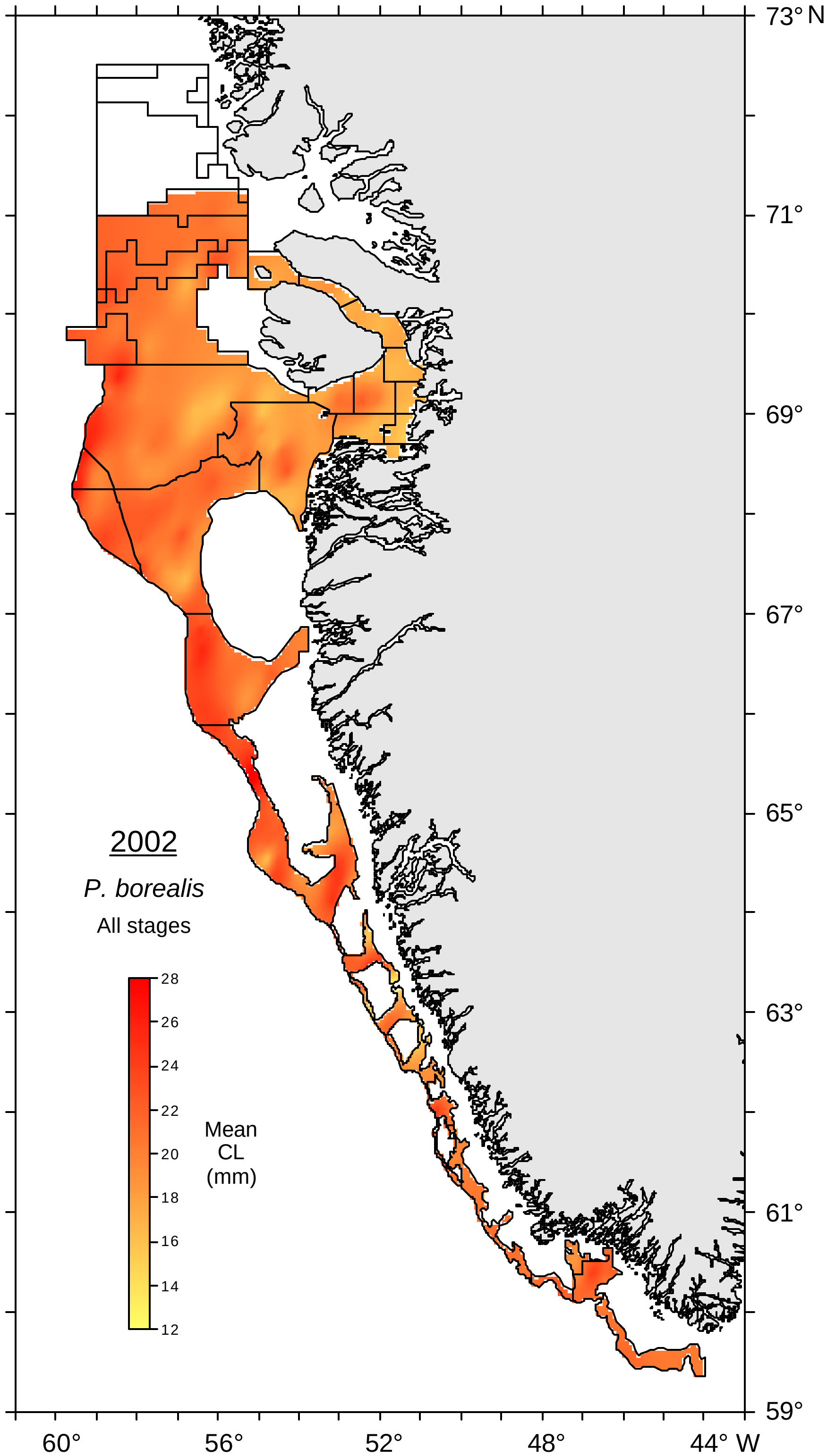

Fig. 10. Geographical distribution of mean size of shrimp in 2002.

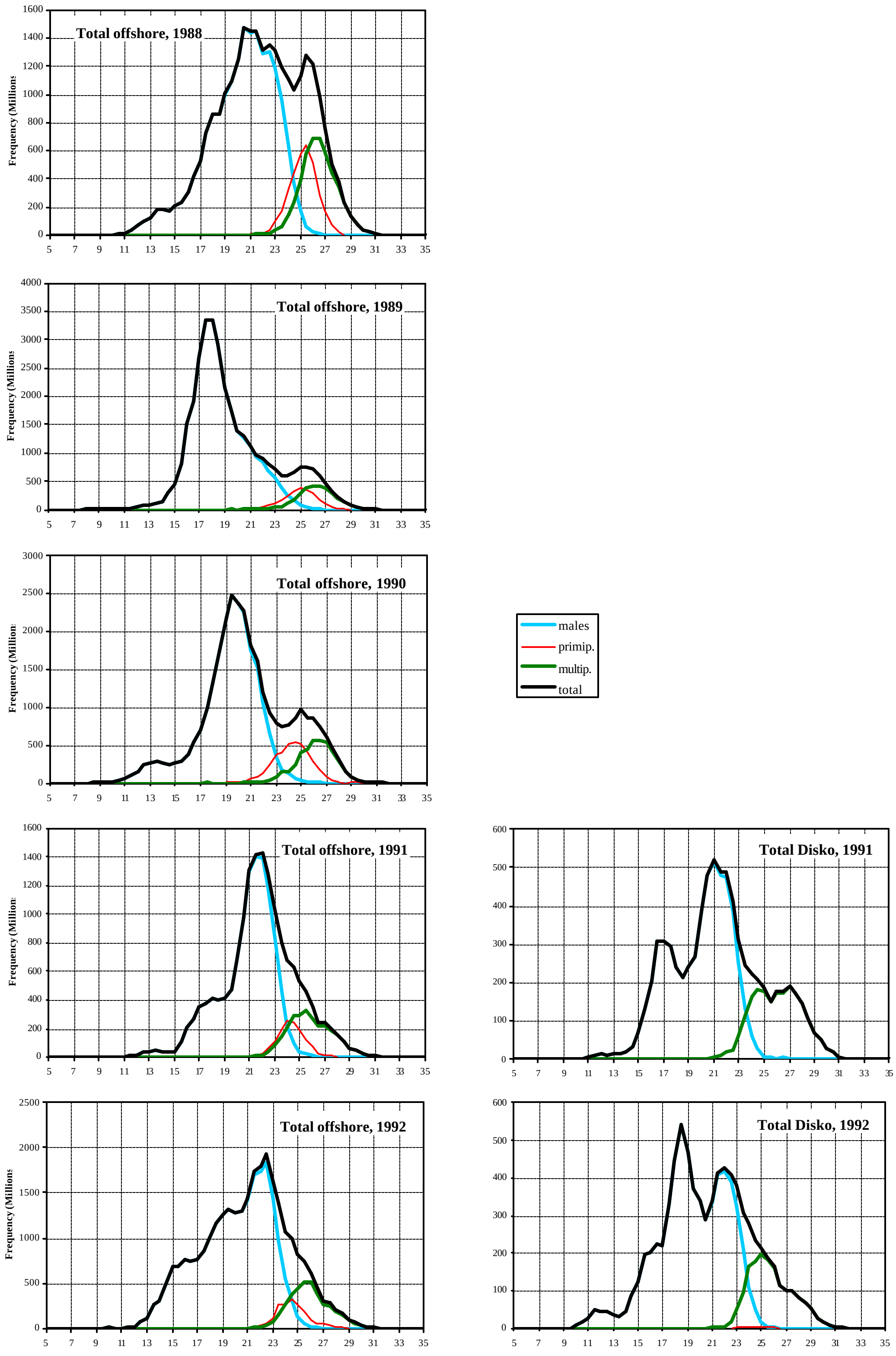

Fig. 11a. Numbers of shrimp by length group in total offshore area 1988-1992 and in total Disko Bay area 1991-1992 (mesh size in the cod-end 44 mm stretched, no surveys in Disko area 1998-1990).

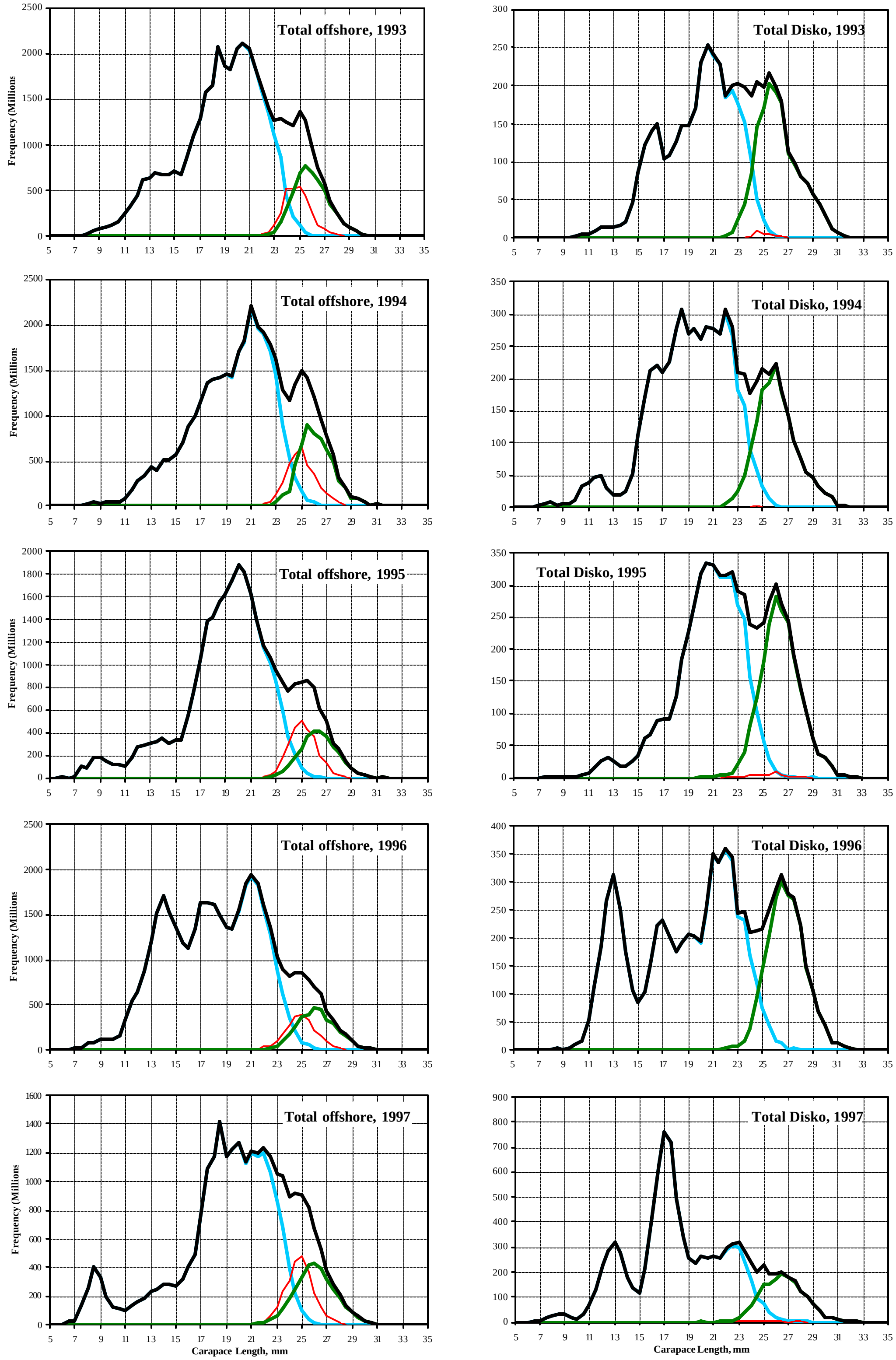

Fig. 11b.Numbers of shrimp by length group in total offshore and Disko area 1993-1997 (mesh size in the cod-end 20 mm stretched).

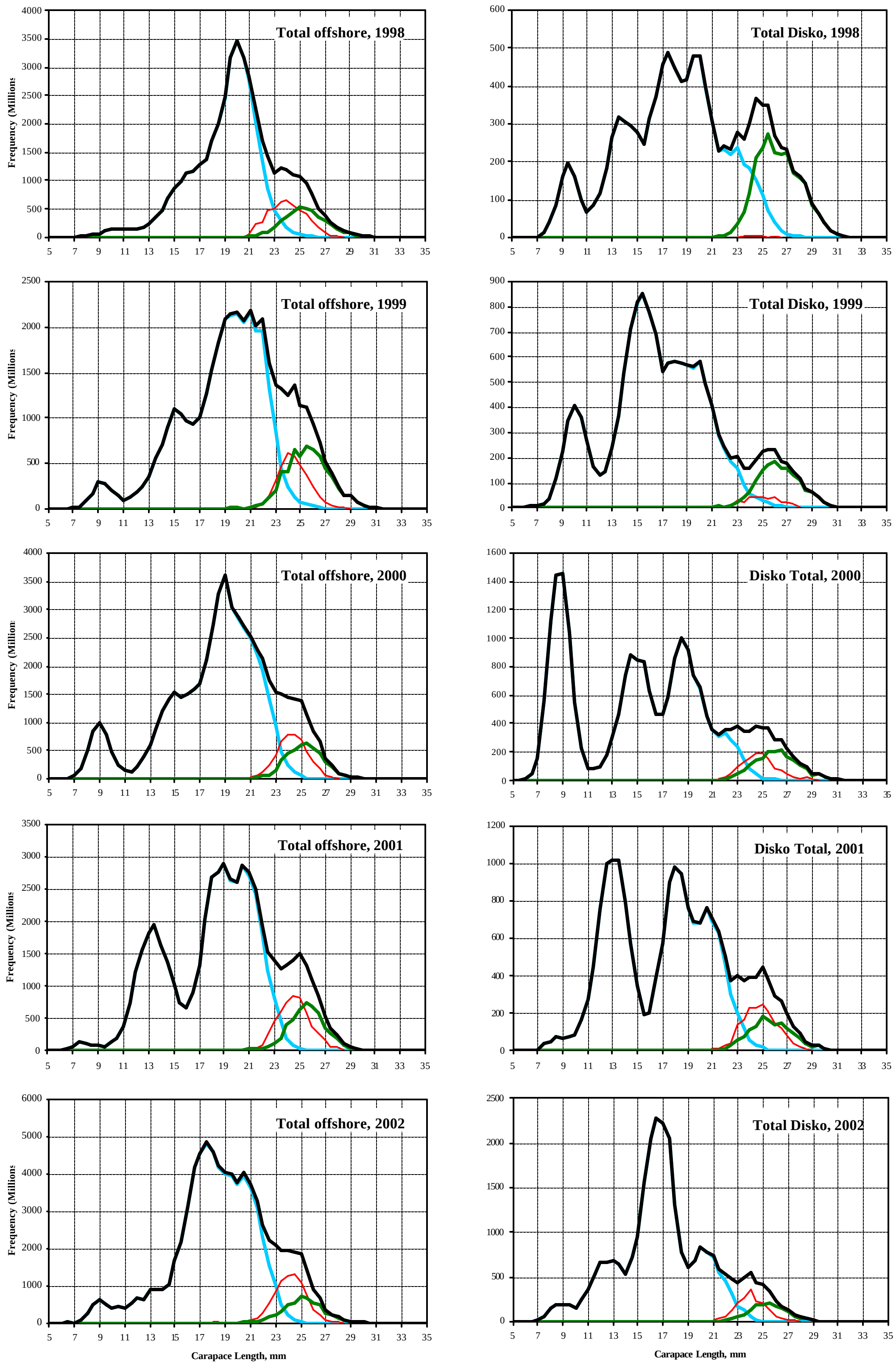

Fig. 11c. Numbers of shrimp by length group in total offshore and Disko Bay area 1998-2002 (mesh size in the cod-end 20 mm stretched).

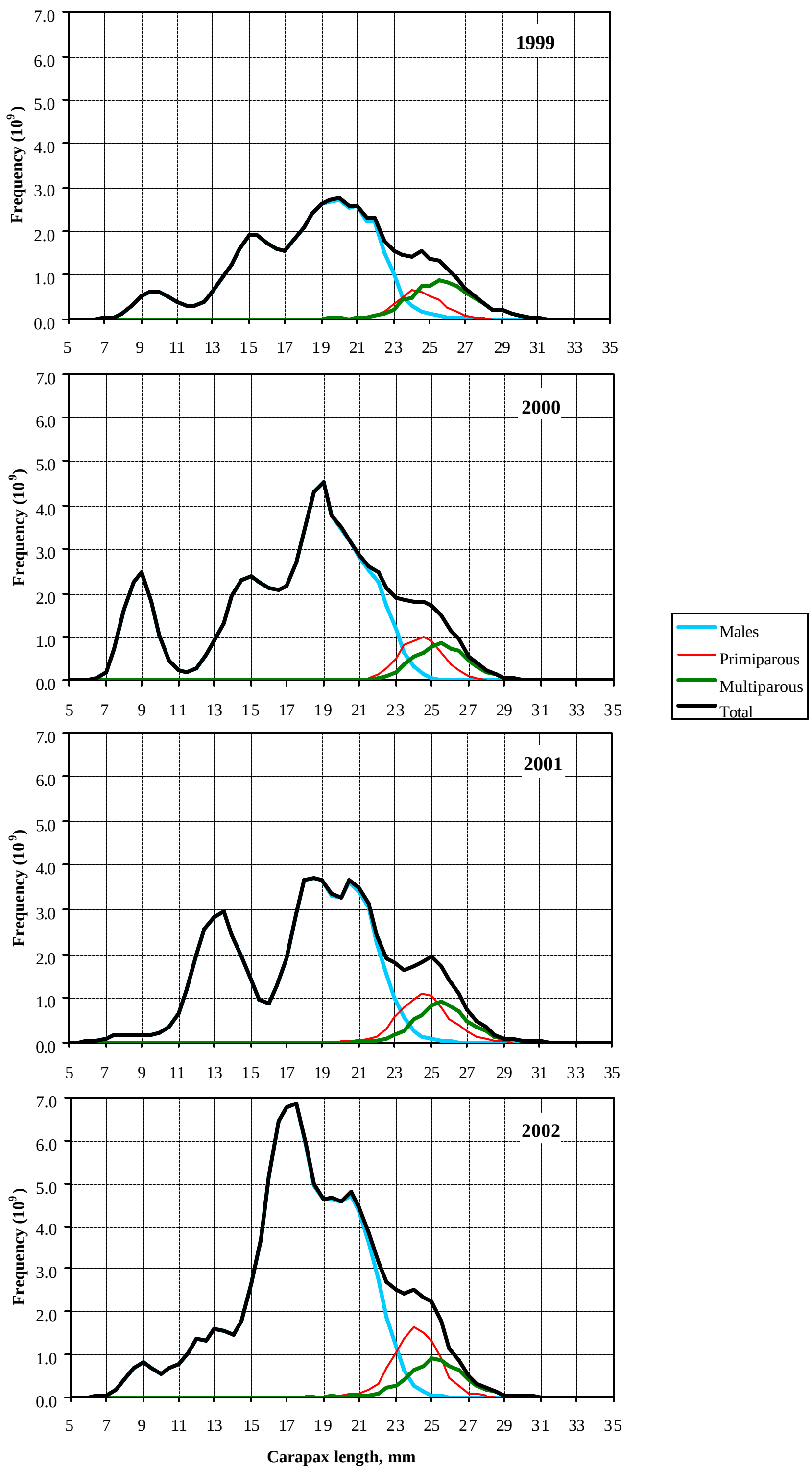

Fig. 12. Numbers of shrimp by length group in total survey (offshore and Disko Bay combined) 1999-2002.