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Stratified-random trawl survey for northern shrimp (*Pandalus borealis*) in NAFO Subareas 0+1 in 2001

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-September 2001.

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 years, however, after a low in 1997 the biomass has increased to a record high amount of about 350 thousand tons, the estimates for the last four years being the highest on record.

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 (Carlsson and Kanneworff, 2000).

This document presents the results of the 2001 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.

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.

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, 2001 a) about 50% of the stations from the surveys in 1998-2000, 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.

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* trawleye 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 2001-survey tow durations of 30 and 15 minutes were applied in the proportion 2:1.

Due to the recent changes in stratum coverage and reduction of haul duration a higher number of hauls per day have been obtained in the surveys. The total survey time was cut down six days in 2000 and 2001 compared to 1999. However, the reduction of tow time and the concentration of stations to certain strata made it possible to reduce the total planned stations with five stations only, from 235 in 1999 to 230. The further changes introduced in 2001 increased the planned number of stations to 240 for the same number of working days.

As earlier, a number of planned trawling sites had to be skipped for various reasons. As a large part 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 sites. Three stations had to be skipped in the inner part of Holsteinsborg Deep (area W4, see Fig. 1) as this area was occupied by fixed fishing gear for snow crab. The rest of the trawling sites were skipped due to bottom conditions.

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 was measured by slide calliper to nearest 0.1 mm for *Pandalus borealis* and *P. montagui*. The samples were weighted by catch and stratum area to obtain estimates of total number of *Pandalus borealis* by sex and length group (0.5 mm intervals) for each stratum and for the total area. These data were thereafter used to calculate indices of recruitment, spawning stock biomass (SSB), and fishable biomass (FB). 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 equal and greater than 17 mm converted to weight.

For the conversion of numbers to weight a relationship was used, which was established during previous surveys (Carlsson and Kanneworff, 2000):

$$W = 0.000669 * CL ** 2.96$$

where W is the weight in grams and CL is oblique carapace length in mm.

Furthermore, maps of geographical distribution of mean size of *Pandalus borealis* were created from the observations at each sampling location by interpolation using ordinary point kriging with a spatial resolution of 1 × 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.

Unweighted estimates of biomass (tow duration and end error).

Two different target tow durations were used in 2001 (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 *et al*., 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 2000 and 2001 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 2001 are:

REGION	BIOMASS ESTIMATE	NO. OF HAULS	CONFIDENCE LIMITS (95%)
Disko	82,738	23	31,507
North	38,991	18	21,269
Canada	4,190	11	3,846
West	203,495	152	75,561
South	19,744	20	19,183
OVERALL	349,158	224	86,132

Since the very low observed biomass estimated for 1997 (206 thousand tons) the biomass has increased significantly to a record high estimate for the two most recent years of 350 thousand tons. The estimate for 2001 is the fourth annual estimate with record highs above the observations from the period 1988-97 (Table 2). The biomass in 2001 had a fairly normal distribution (Fig. 1) with traditional 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. The exceptionally high biomass in the southernmost region (S: Julianehåb Bay) found in 1999 (however, with very high error variance) was not observed again in the following years. Due to the large observed variance in this area a high number of sampling sites were planned for the surveys in 2000 and 2001. The observed biomass for this region was in the two years estimated to be of the same magnitude as in most of the earlier years (1994, 1997, and 1998). This region has exhibited frequent large coefficients of variation of the biomass estimate (Table 3). 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 2001, 18% for regions C, N and S combined).

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 2001, the total estimate is reduced by 11.5% to about 309 thousand tons.

Biomass, geographical and depth distribution

Large variations in the distribution of this stock are indicated, both from year to year and seasonally. The stratified-random trawl surveys during the time series have been carried out at the same period of the year (July-September), and seasonal variations are therefore, assumed to be minimized. Fig. 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 the total biomass estimate indicate a gradual increase through the last ten years, apart from somewhat lower figures in 1995 and 1997. Most of the increase in biomass from during the recent four years is seen in the northernmost regions (North of about 67°N), including the Disko Bay area, and mainly in the 200-300 m depth layers. A decline in biomass is in the same period observed for the shallow areas (150-200 meters). As the inner part of Holsteinsborg Deep (part of area W4) could not be reached due to commercial fishing for snow crab, and as very good catches were taken near the closed area (Fig. 1) the biomass in the area W4, and especially stratum W4-3 is considered to be somewhat underestimated for 2000 and 2001.

The distribution of the shrimp stock over the various strata has varied much over the years (Fig. 5 and 6), 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 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 84 and 83 thousand tons in 2000 and 2001, respectively (24% of the total in both years). Estimated shrimp densities in the Disko Bay area are high compared to the offshore areas (Table 4), having more than 8 grams shrimp per square meter, nearly four 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 some increase is observed, and in the recent two years more than 10% of the biomass is again found in this area, in which depths between 200 and 300 meters seem to be more attractive than before. However, this area is very large and the density of shrimp has consistently been low compared with other areas (Fig. 6), 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).

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 more pronounced in 2000 and 2001.

Area W5, which accounts for 9% of the total biomass estimate, has been an area with high variations in all depth layers. Like in most other regions the 2001-biomass is indicated to be concentrated in the depth stratum 200-300 m.

Stock composition

Size distribution by areas in 2001

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 most of the areas, but not in areas NN, C, and W1 where smaller (11-17 mm CL) individuals prevailed or were equally abundant (Fig. 7). Males smaller than 11 mm CL were only found in areas W1 to W6, and relative high numbers of large (> 23 mm CL) females were observed in areas C, W3 and W7. 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. 8).

Figure 9 shows the geographical distribution of mean size for males, for primiparous and multiparous females, and for all sexual groups pooled. Low mean size (< 17 mm CL) of males was found in several distinct areas, in particular the northern part of strata N and D, southwest off Disko Island (eastern part of stratum W1 and north-western part of stratum W2), as well as in strata W3 and W4. Small (< 24 mm mean CL) primiparous females occurred predominantly in the central part of stratum W1 and in the Holsteinsborg Deep (coastal part of stratum W4) and between the fishing banks and in the coastal waters in strata W5 and W6. High values of mean size (> 26 mm mean CL) of multiparous females were almost exclusively observed in the southern-eastern part of stratum N and adjacent offshore waters in strata C1, small parts in the vicinity of strata W3 and W4, offshore waters in stratum W5, and between the fishing banks in stratum W7. The geographical distribution of all sexual stages pooled revealed mainly a combination of those for the males and the primiparous females, in particular concerning the location of areas with values below 17 mm mean CL. The geographical distribution of size agrees largely with those of the past years (Wieland and Carlsson, 2001), except for the wider extension of areas with values below 17 mm mean CL in Disko Bay observed in 2000.

Annual size distribution

Overall length distributions for the offshore and the inshore (Disko Bay and Vaigat) survey areas in 1988 to 2001 are compared in Fig. 10a-c. Visual inspection of the offshore length frequency for 2001 indicates a number of distinct males modes (appr. at 7.5, 13.5, 18.5 and 20.5 mm CL), a mode of primiparous females at about 24.5 mm CL and one of multiparous females around 25.5 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 13.5 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 general situation of the past years rather than its exceptional strength observed in 2000.

Fig. 11 shows overall length frequencies combined for the offshore and the Disko area for 1999 to 2001. A progression of the '1998 year-class' from 10 mm CL in 1999 to 15 mm in 2000 and further to 18 mm in 2001 and a progression of the '1999 year-class' from 9 mm CL in 2000 to about 13.5 mm CL in 2001 are clearly visible. The actual presence of several size groups of males and, in particular, the high numbers at modes of 13.5 and 18 mm CL are promising in terms of recruitment to the females group in coming years.

Total abundance, recruitment and spawning stock biomass

Total number and proportion 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 2001 was the second highest on record exceeding considerably the long term average while the proportion of males and females has not changed very much compared to the past years. 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%) and 1992 (- 5.7%).

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 2001 is the second highest in time series (1.7 times the long term average) although being about 17% lower than for the preceding year.

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 6), and the direct estimates of survey biomasses (Table 2) are given in Table 8. The total SSB for the 2001 survey exceeds that for 2000 by 8% and is the highest on record.

The contribution of the inshore component of the stock to total recruitment and SSB differed substantially through the years and is actually 34% in terms of recruitment and 24% in terms of SSB (Tables 7 and 8).

Table 9 shows the estimated fishable biomass calculated from number of shrimp equal to or above 17 mm CL. In contrast to the significant increase in total estimated biomass from 1999 to 2000 a reduction in fishable biomass is seen. Small shrimp around 9 mm CL (about 10% of the total in numbers) were the main contributors to the increase in juvenile biomass in 2000. In 2001, this mode was still below 17 mm CL, and the increase in fishable biomass from 2000 to 2001 was thus mainly carried by growth from about 15 mm CL in 2000 to about 18 mm CL in 2001 (Fig. 11).

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 250 thousand tons, apart from somewhat lower values in 1991, 1995 and 1997. From 1998 a significant increase is observed with record high biomass in 2000 and 2001 of 350 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. Both, recruitment and SSB indices are well above long term average and the present length distribution indicates that progression of males to the female group appears to be secured for the coming year.

References

Carlsson, D.M., O. Folmer, C. Hvingel and P. Kanneworff, 1995. Offshore trawl survey for shrimp (*Pandalus borealis*) in NAFO Subareas 0 and 1, in 1995. NAFO SCR Doc. 95/113. Serial No. N2652.

Carlsson, D.M., O. Folmer, C. Hvingel, P. Kanneworff, M. Pennington and H. Siegstad, 1998. A review of the trawl survey of the shrimp stock off West Greenland. NAFO SCR Doc. 98/114. Serial No. N4023.

Carlsson, D.M., P. Kanneworff and M.C.S. Kingsley, 1999. Stratified-random trawl survey for Northern shrimp (*Pandalus borealis*) in NAFO Subarea 0+1, in 1999. NAFO SCR Doc. 99/109. Serial No. N4189.

Carlsson, D.M. and P. Kanneworff, 2000. Stratified-random trawl survey for shrimp (*Pandalus borealis*) in NAFO Subarea 0+1, in 2000. NAFO SCR Doc. 00/78. Serial No. N4335.

Kingsley, M.C.S., P. Kanneworff and D.M. Carlsson, 1999. Modifications to the design of the trawl survey for *Pandalus borealis* in West Greenland waters: effects on bias and precision. NAFO SCR Doc. 99/105. Serial No. N4184.

Kingsley, M.C.S., D.M. Carlsson, P. Kanneworff and M. Pennington, in press. Spatial structure of the resource of *Pandalus borealis* and some implications for trawl survey. Fisheries Research 00:000-000.

Kingsley, M.C.S., 2001 a.. Effect in 2001 of recent modifications to the design of the West Greenland shrimp survey. NAFO SCR Doc. 01/176. Serial No. N4565.

Kingsley, M.C.S., 2001 b. Studies in 2001 on the end effect of the Skjervøy 3000 trawl in the West Greenland shrimp survey. NAFO SCR Doc. 01/177. Serial No. N4566.

Wieland, K. and D.M. Carlsson, 2001. Geographical distribution and mean size of different life stages of Northern shrimp (*Pandalus borealis*) off West Greenland. NAFO SCR Doc. 01/178. Serial No. N4567.

Table 1a. Estimated trawlable biomass and sampling statistics for strata in region W, 2001.

AREA	STRATUM	SQKM	HAULS	TONS	STD	CV
W1	150-200 M	2416	1	27	27*	100
	200-300 M	5295	3	14343	22221	155
	300-400 M	9239	16	17578	12980	74
	400-600 M	752	2	7	1	8
W2	150-200 M	1857	2	304	415	137
	200-300 M	3026	4	33109	38082	115
	300-400 M	2158	10	14511	14612	101
	400-600 M	1723	6	3222	1630	51
W3	150-200 M	2215	2	76	105	138
	200-300 M	4810	19	40906	102711	251
	300-400 M	2714	6	2001	2457	123
	400-600 M	3361	3	6581	2441	37
W4	150-200 M	4252	4	149	173	116
	200-300 M	1791	4	1224	765	63
	300-400 M	812	8	1715	3413	199
	400-600 M	1967	5	5	4	68
W5	150-200 M	1995	3	2452	3993	163
	200-300 M	3454	15	26196	33140	127
	300-400 M	1797	5	1034	1427	138
	400-600 M	2806	4	2957	5452	184
W6	150-200 M	1095	4	234	248	106
	200-300 M	1491	7	8133	8715	107
	300-400 M	1300	4	6650	5039	76
	400-600 M	884	2	1435	352	25
W7	150-200 M	2419	2	3	3	99
	200-300 M	985	8	18605	40430	217
	300-400 M	239	2	34	46	137
	400-600 M	273	1	8	8*	100
OVERALL			Standard Error	37781	Error CV	19

*) calculated from STD = biomass * 0.985

Table 1b. Estimated trawlable biomass and sampling statistics for strata in region C, 2001.

AREA	STRATUM	SQKM	HAULS	TONS	STD	CV
C1	300-400 M	655	2	1032	44	4
	400-600 M	312	2	16	12	75
C3	200-300 M	660	3	1160	325	28
	300-400 M	1192	2	1956	2706	138
	400-600 M	623	2	26	37	140
OVERALL			Standard Error	1923	Error CV	46

Table 1c. Estimated trawlable biomass and sampling statistics for strata in region D, 2001.

AREA	SQKM	HAULS	TONS	STD	CV
D1	819	3	6003	1418	24
D2	566	1	11692	11517*	100
D3	1124	4	4403	4182	95
D4	1834	3	10032	4961	49
D5	612	2	6651	5241	79
D6	1014	2	6584	2142	33
D7	1447	2	9321	9813	105
D8	652	2	9182	6759	74
D9	1296	4	18870	14112	75
OVERALL		Standard Error	15754	Error CV	19

*) calculated from STD = biomass * 0.985

Table 1d. Estimated trawlable biomass and sampling statistics for strata in region N, 2001.

AREA	SQKM	HAULS	TONS	STD	CV
N1	3664	2	13651	9224	68
N2	11740	4	4463	5096	114
N3	368	1	1595	1571*	100
N4	2257	1	7216	7108*	100
N5	2985	2	1159	1099	95
N6	10830	3	2871	4828	168
N7	1029	2	1	0	28
N8	3237	1	144	142*	100
N9	2407	2	7891	5740	73
OVERALL		Standard Error	10635	Error CV	27

*) calculated from STD = 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	16	14212	31359	221
S2	4526	2	5532	11052	200
OVERALL		Standard Error	9592	Error CV	49

Table 2. Biomass estimates 1988-2001 (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

[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 1988-2001.

Year	Region				
	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

Table 4. Estimated shrimp densities in groups of strata in 1988-2001. Densities are given in t/km² (or g/m²).

Area	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
D1-D9	-	-	-	5.401	5.060	3.589	4.269	5.052	5.801	5.582	6.612	6.534	8.917	8.836
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
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
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
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
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
S1-S2	-	-	-	-	-	-	3.979	0.265	0.565	3.814	3.428	9.769	3.761	3.029
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

Table 5. Numbers (billions) of male and female Northern shrimp in overall length distributions from the total survey area (mean values for inshore areas 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
Average	37.1	9.6	46.7	79.5	20.5

Table 6. Biomass estimates of male and female shrimp (thousand tons) in total survey area, based on weight-at-length keys applied to overall length-frequency distributions (mean values for Disko Bay 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	65.6	34.4
1990	124.3	97.9	222.2	55.9	44.1
1991	89.9	60.1	150.0	60.0	40.0
1992	141.3	71.7	213.0	66.3	33.7
1993	150.3	97.9	248.3	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	214.8	128.0	342.7	62.7	37.3
Average	150.5	94.0	244.4	61.6	38.4

Table 7. Recruitment index (number of males < 17 mm CL, billions) in offshore, Disko 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
Average	9.31	4.22	13.53

Table 8. SSB index (female biomass, thousand tons) in offshore, Disko and total survey area.

Year	Offshore	Disko	Total
1988	88.1	17.7	105.9
1989	59.7	18.8	78.6
1990	83.0	17.6	100.6
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	79.6
1998	88.6	22.8	111.4
1999	93.2	18.8	112.0
2000	88.5	32.3	120.8
2001	99.0	31.4	130.4
Average	77.0	20.8	104.3

Table 9. Fishable biomass index (for shrimp >= 17 mm CL) in offshore, Disko and total survey area.

Year	Offshore	Disko	Total
1988	174.8	42.0	216.8
1989	157.5	42.0	199.6
1990	171.8	42.0	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	201.1
1996	163.8	48.2	211.9
1997	140.7	44.7	185.3
1998	209.3	53.7	263.1
1999	204.6	47.0	251.5
2000	171.8	64.9	236.7
2001	238.3	70.9	309.2
Average	175.9	46.9	237.9

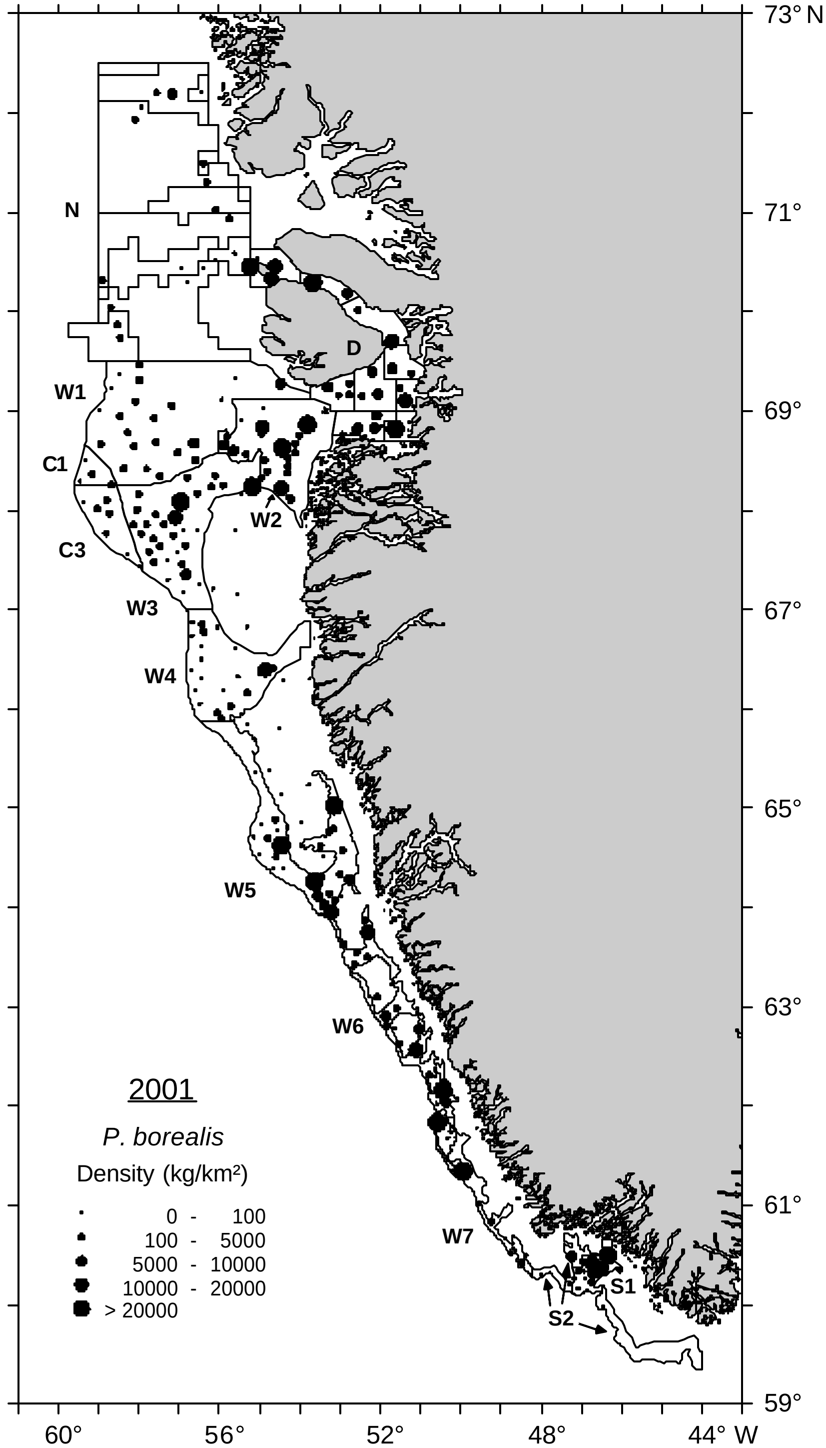

Fig. 1. Sampling sites and shrimp densities in the trawl survey 2001.

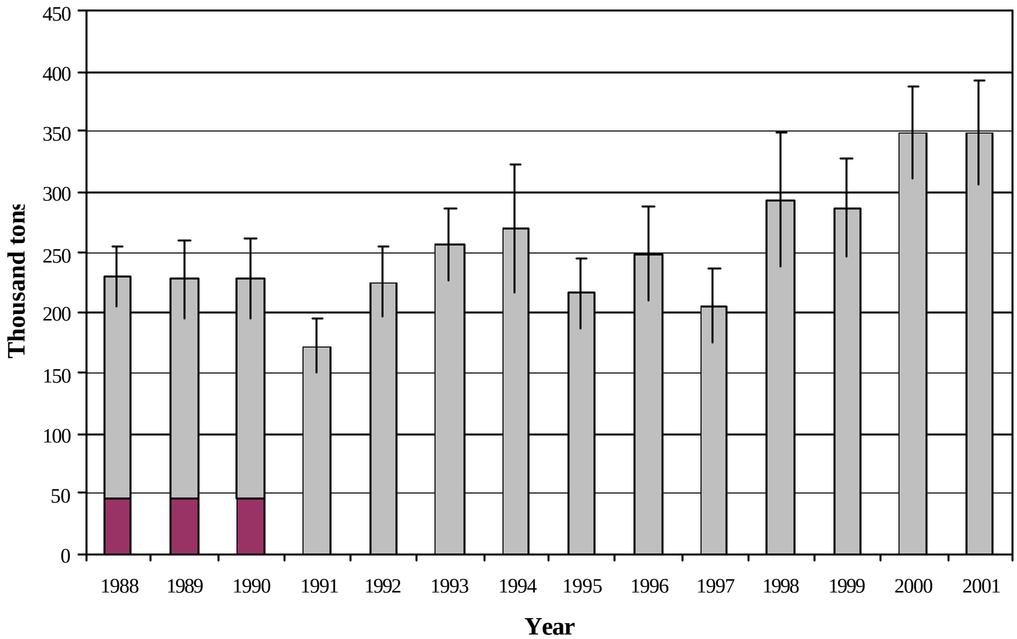

Fig. 2. Estimated total yearly biomass 1988-2001 with standard errors. Average biomass estimate for inshore areas 1991-1999 is inserted in 1988-1990 to facilitate between-year comparisons.

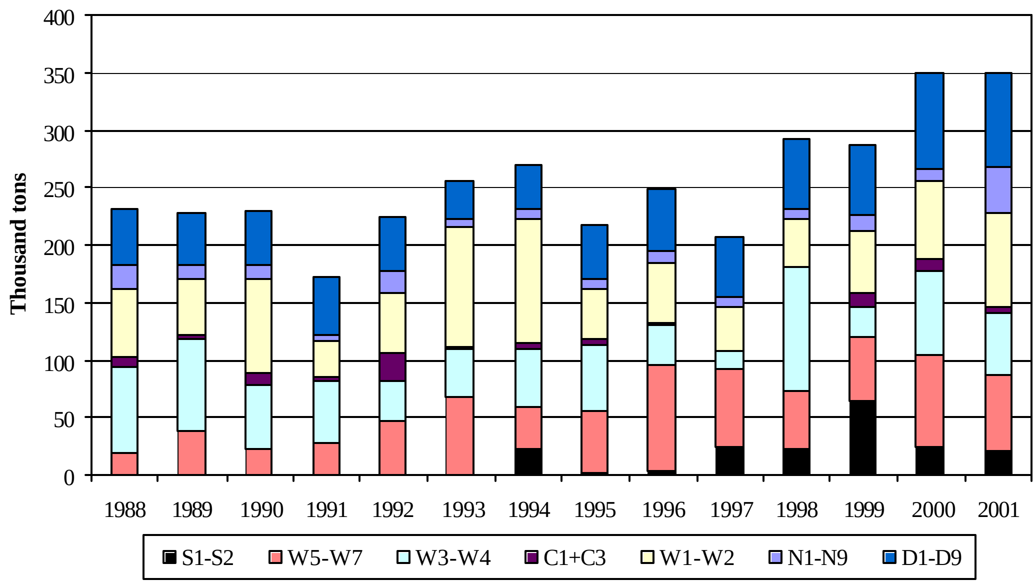

Fig. 3. Estimated biomass in groups of strata for surveys in SA0+1, 1988-2001. Note that surveys in inshore areas were carried out from 1991 only.

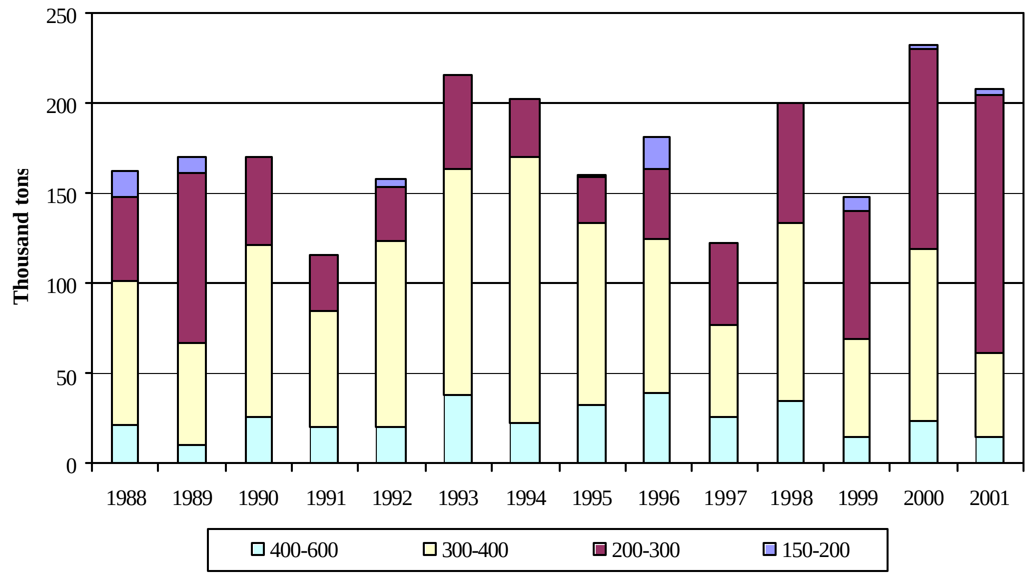

Fig. 4. Estimated biomass in depth strata (regions W and C only) for surveys in SA0+1 offshore, 1988-2001.

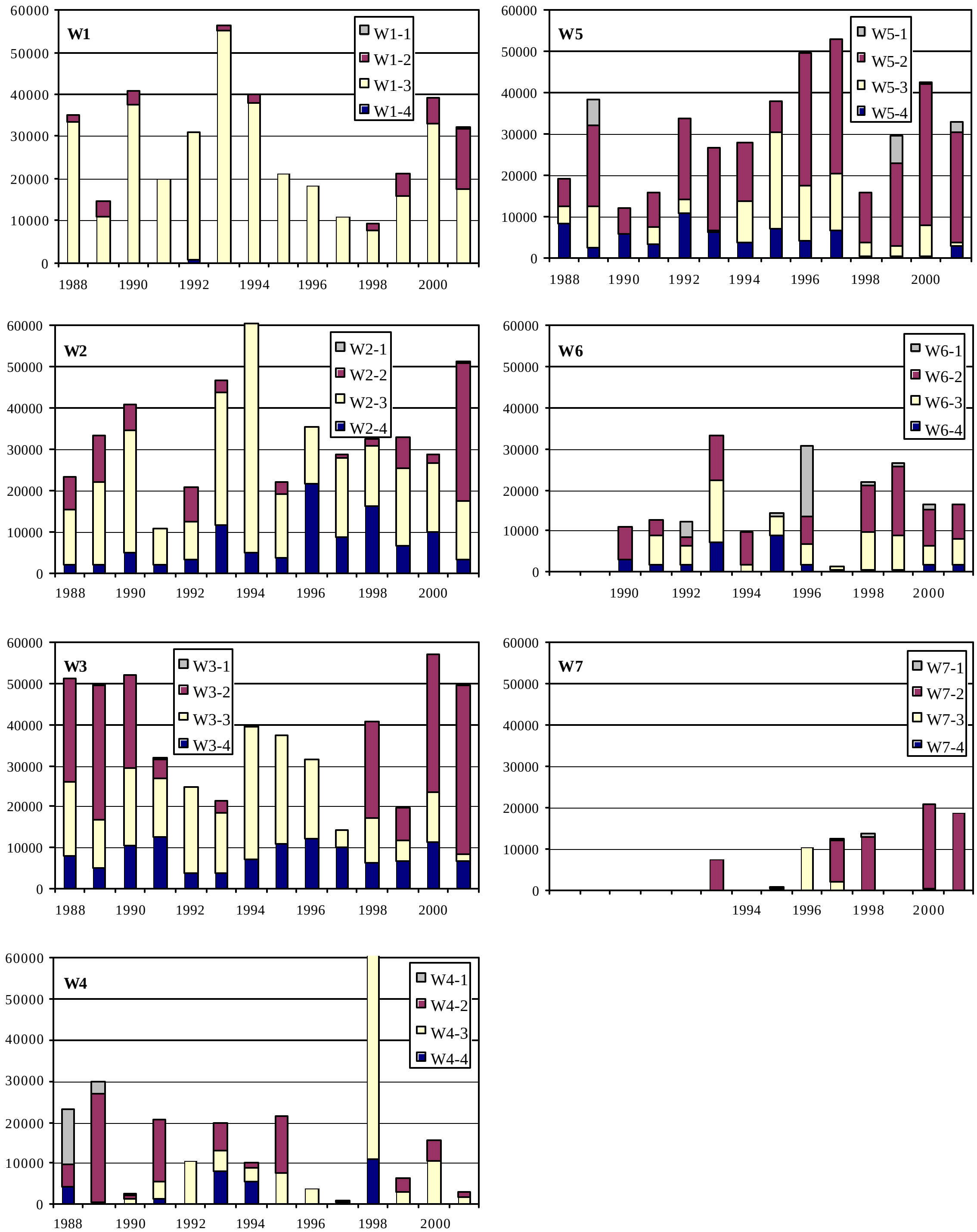

Fig. 5. Biomass estimates of shrimp (tons) in region W in depth strata, 1988-2001.

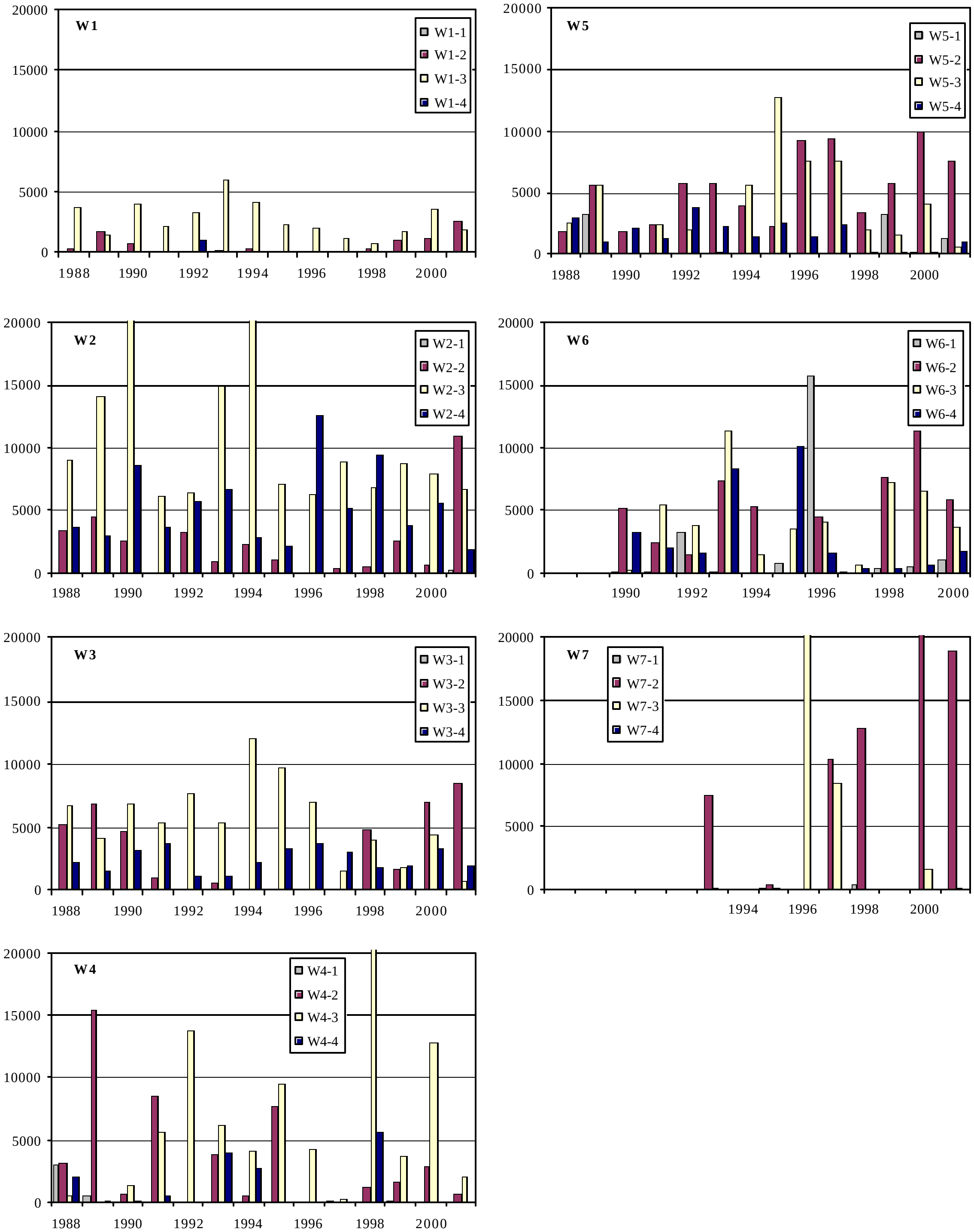

Fig. 6. Estimated densities of shrimp (kg/km²) in region W in depth strata, 1988-2001.

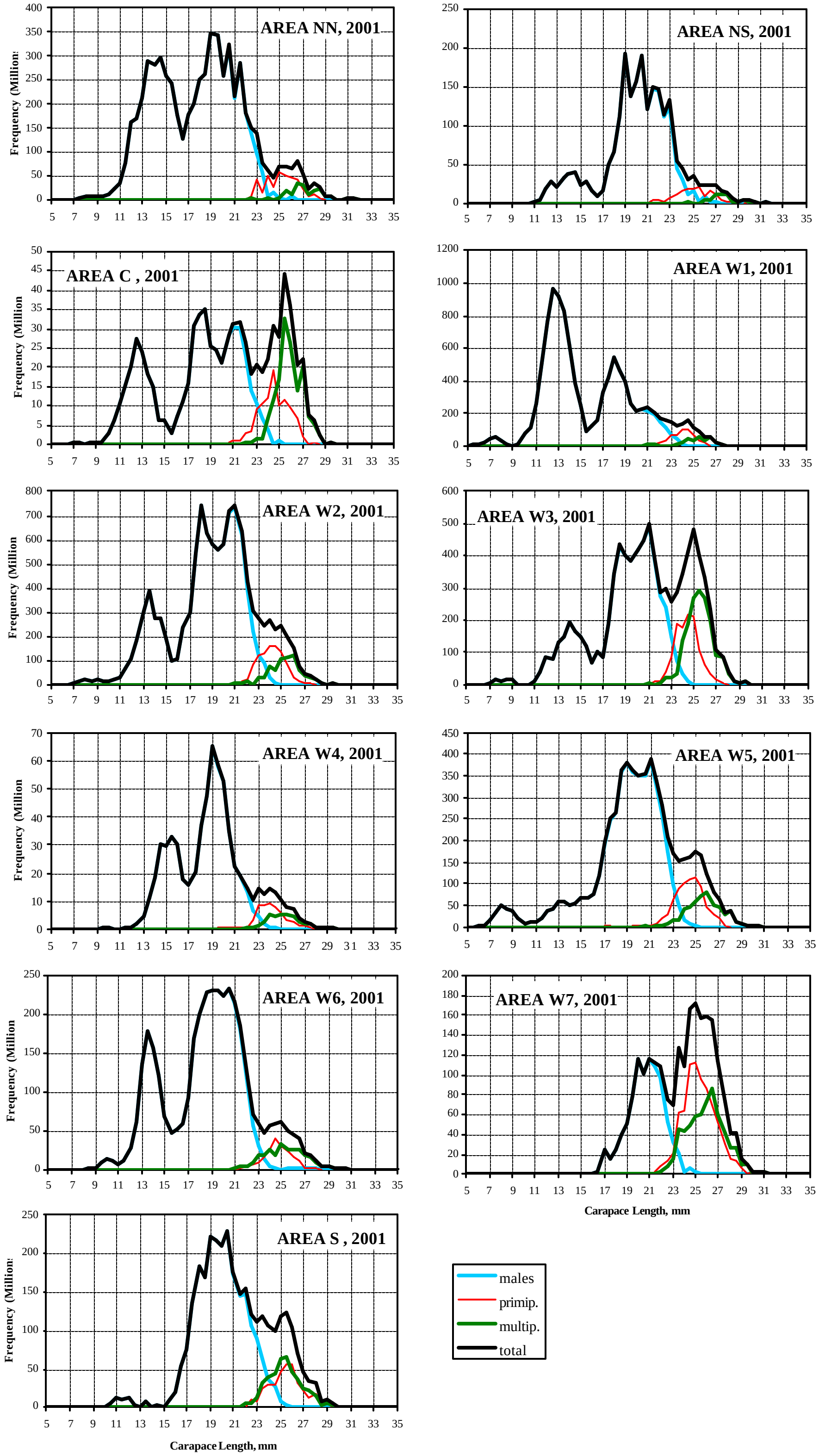

Fig. 7. Numbers of shrimp by length group in offshore areas NN, NS, C, W1 – W7 and S in 2001.

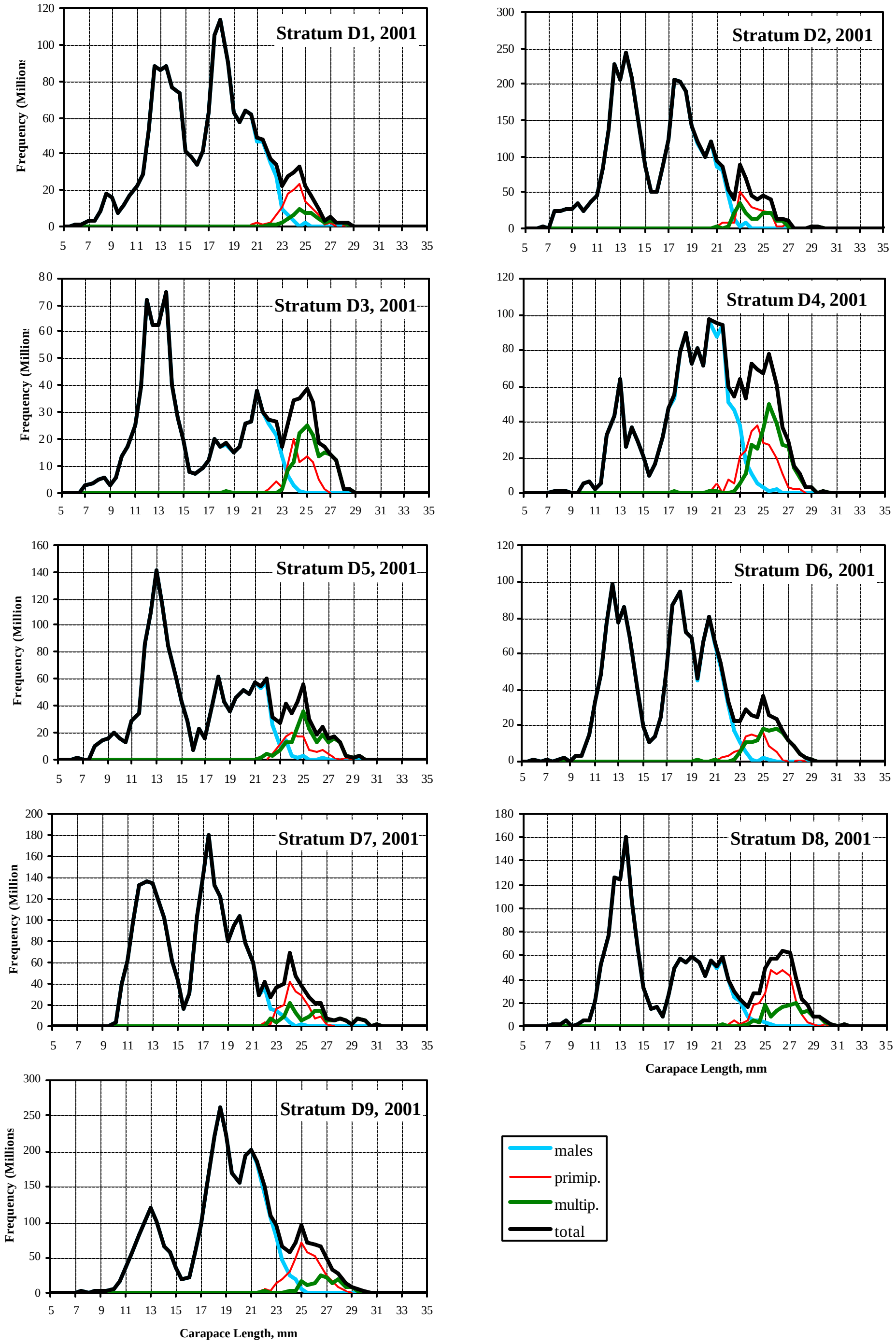

Fig. 8. Numbers of shrimp by length group in inshore strata D1-D9 in 2001.

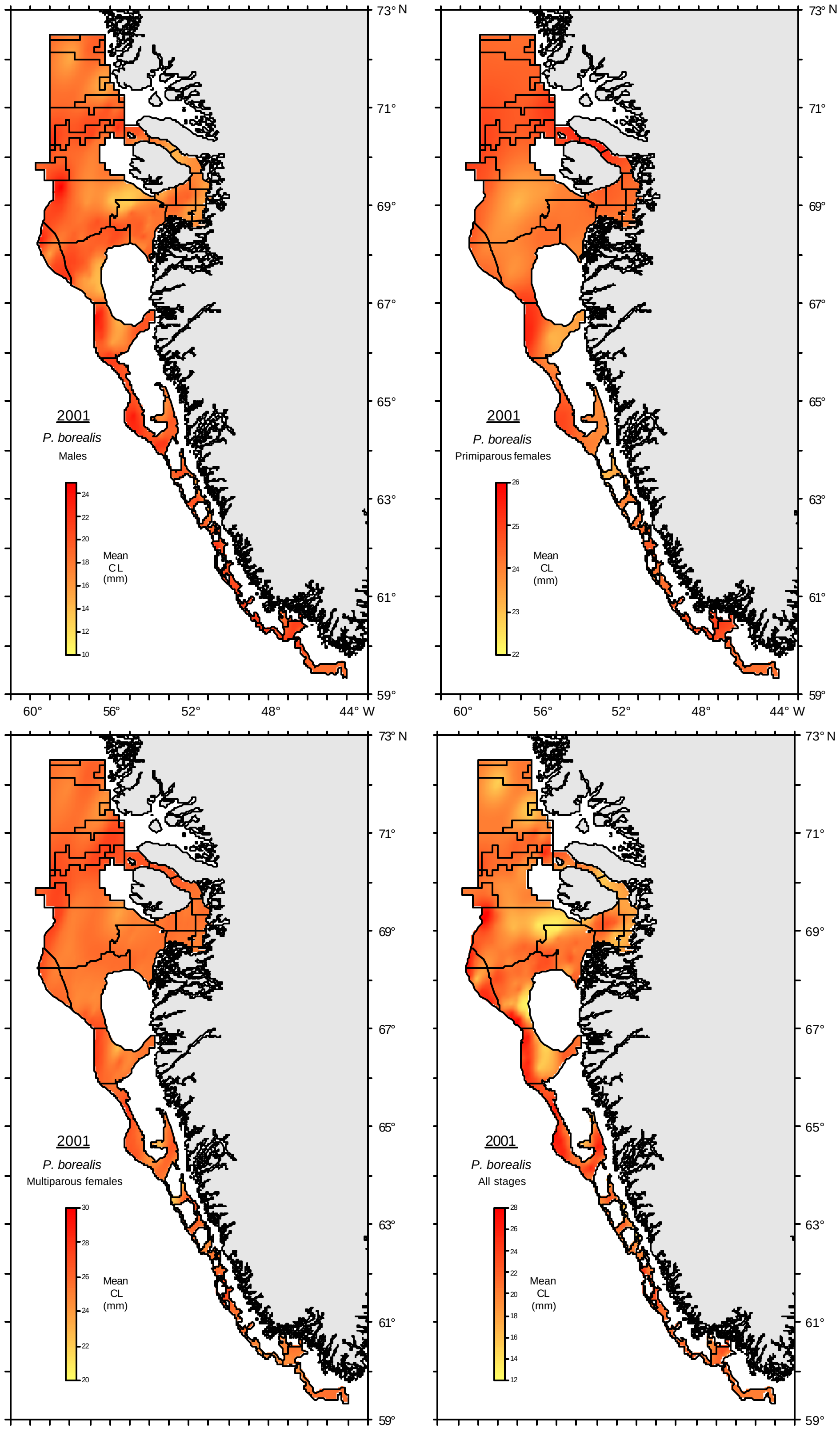

Fig. 9. Geographical distribution of mean size of shrimp, 2001.

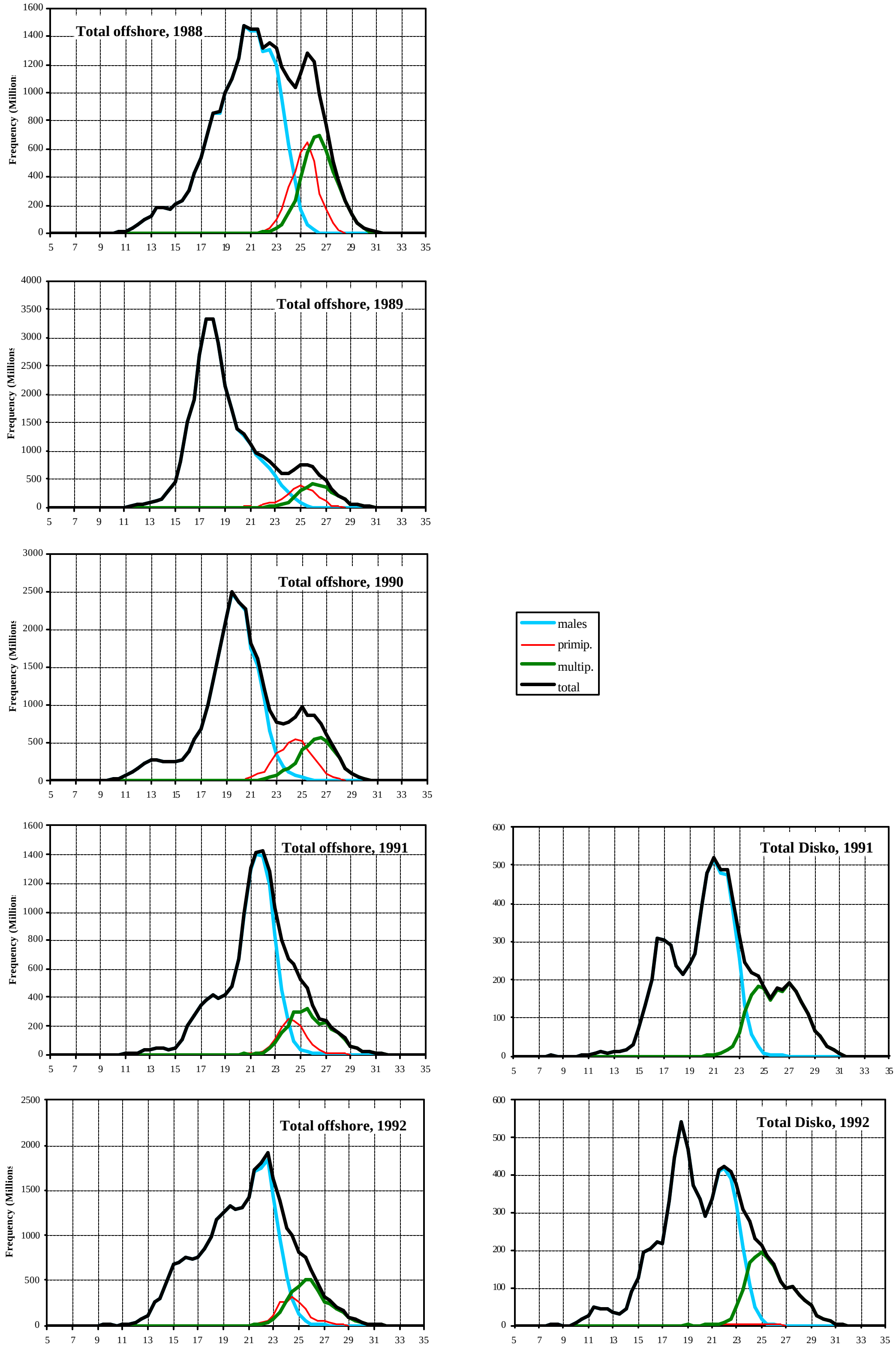

Fig. 10a. Numbers of shrimp by length group in total offshore area 1988-1992 and in total Disko area 1991-1992 (mesh size in the cod-end 44 mm stretched, no surveys in Disko area 1998-1990).

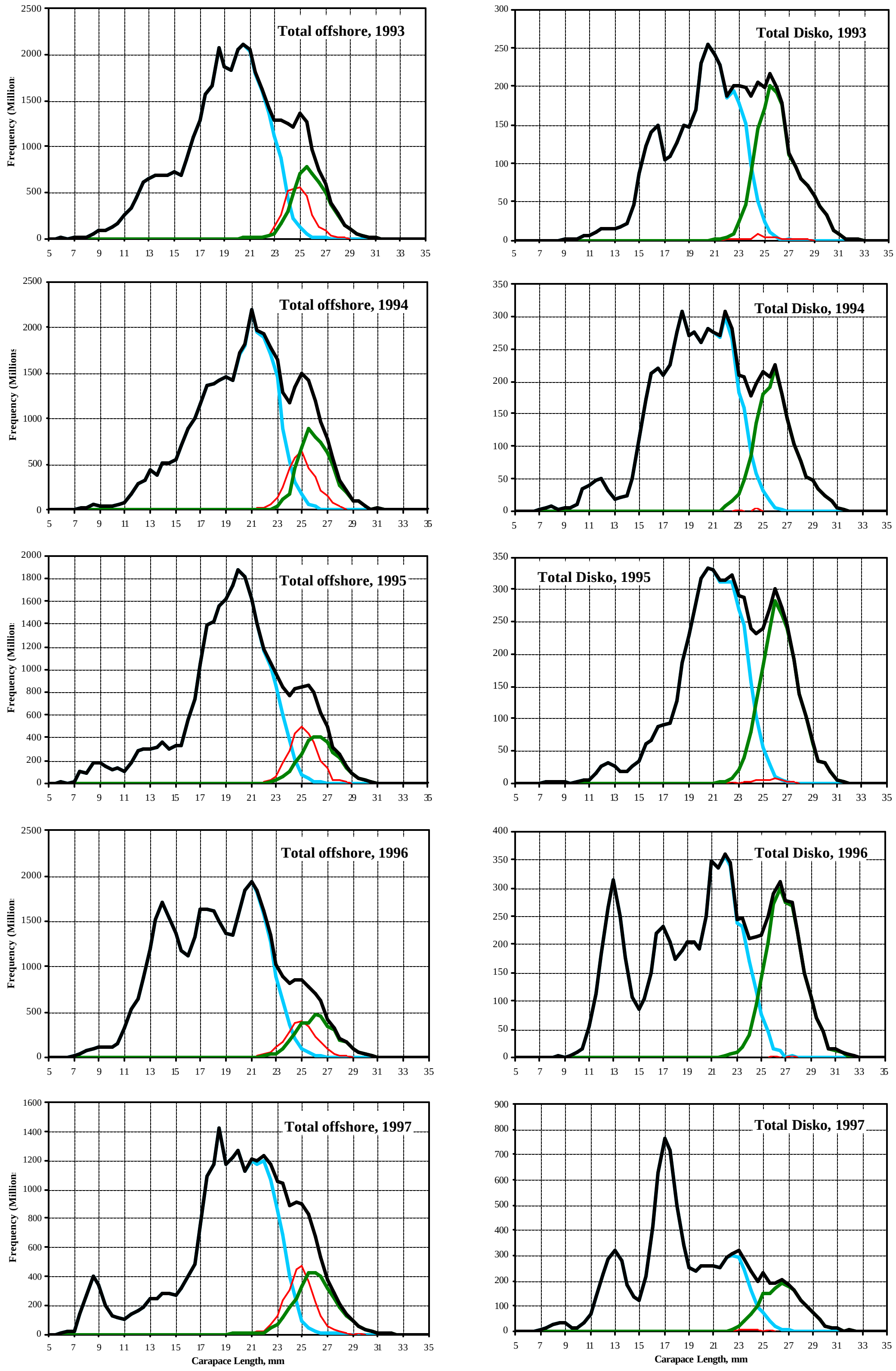

Fig. 10b. Numbers of shrimp by length group in total offshore and Disko area 1993-1997 (mesh size in the cod-end 20 mm stretched).

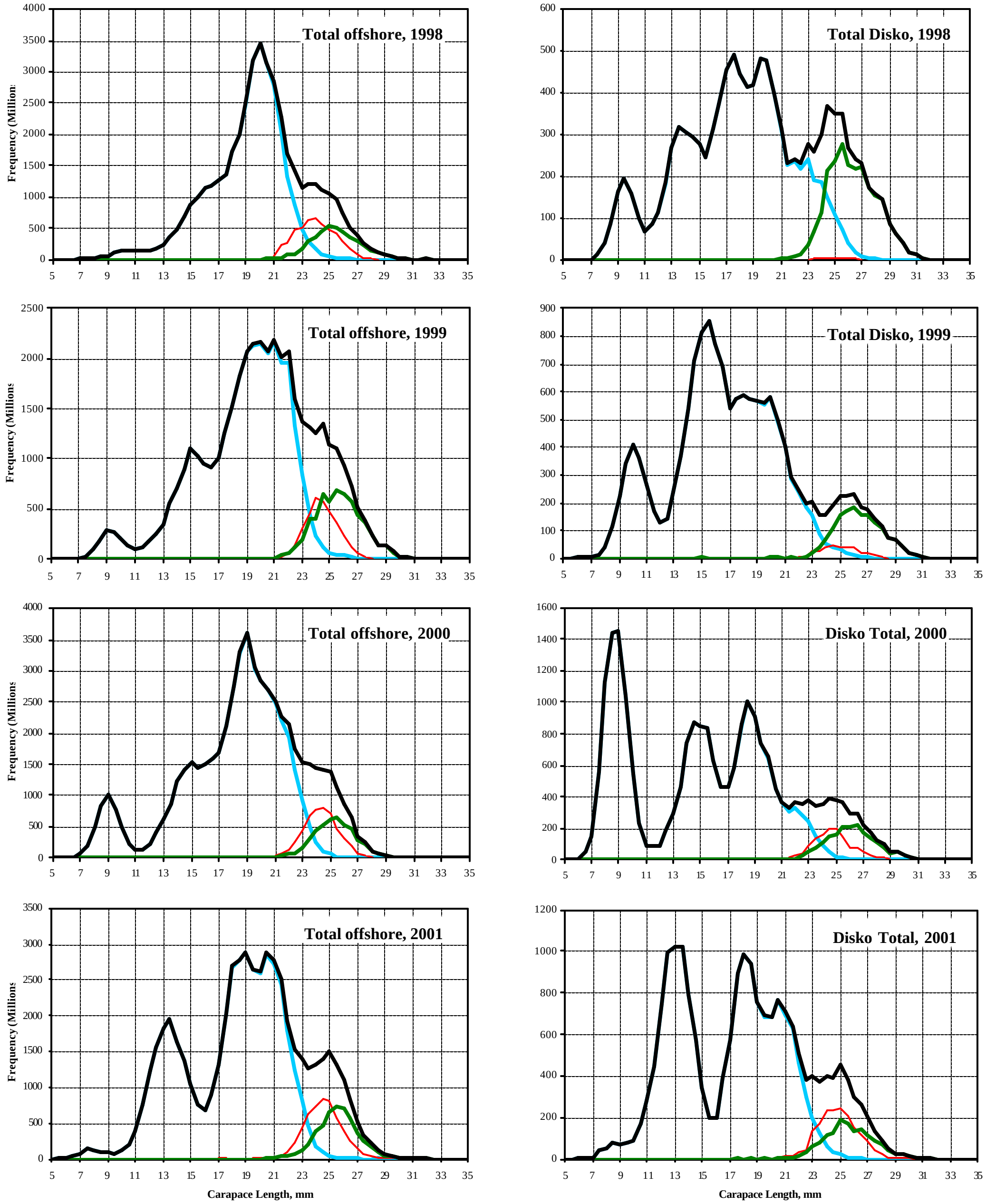

Fig. 10c. Numbers of shrimp by length group in total offshore and Disko area 1998-2001 (mesh size in the cod-end 20 mm stretched.

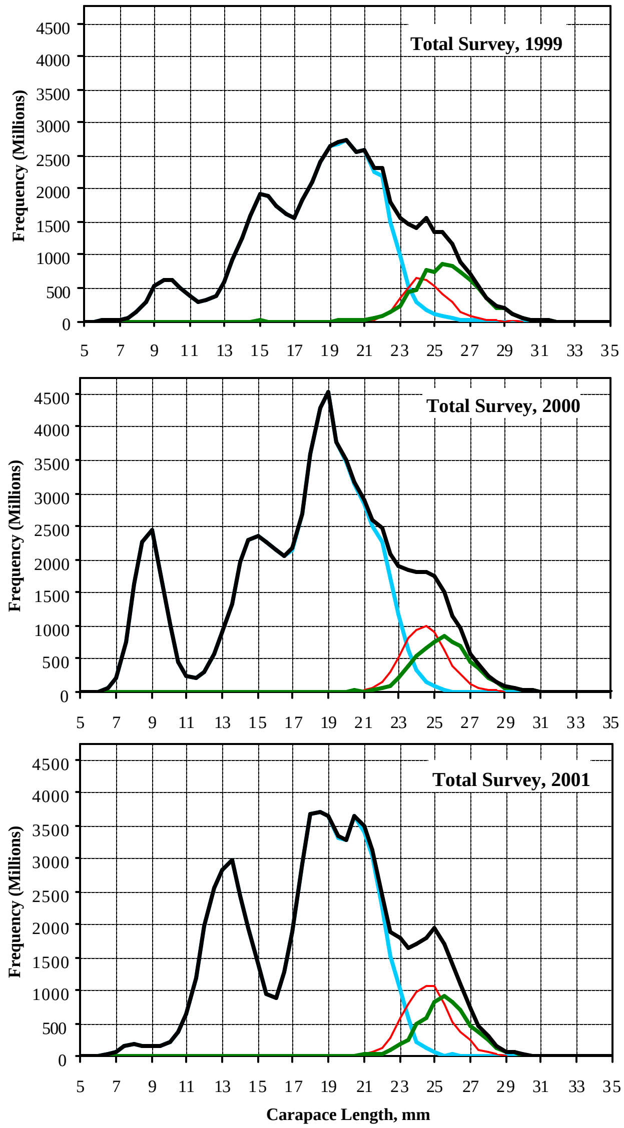

Fig. 11. Numbers of shrimp by length group in total survey area (offshore and Disko combined) 1999-2001.