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Offshore Stratified-random Trawl Survey for Shrimp (*Pandalus borealis*) in NAFO Subarea 0+1, in 1998

by

D. M. Carlsson and P. Kanneworff

Greenland Institute of Natural Resources
Box 2151, DK-1016 Copenhagen K., Denmark

Introduction

Since 1988, Greenland Institute of Natural Resources has conducted annual stratified-random trawl surveys in the shrimp distribution area in Davis Strait during the months July-September to assess the *Pandalus borealis* stock biomass and to obtain information on the biology of the stock.

The surveys cover the offshore areas of shrimp distribution in the depth interval 150-600 meters in NAFO Subarea 1 and a small part of Div. 0A. In contrast to earlier years the allocation of trawl stations in 1998 has been weighted in favour of strata with traditionally high shrimp densities in order to optimise the sampling effort.

The survey was carried out in connection with a corresponding survey covering the inshore distribution areas in Disko Bay – Vaigat (Carlsson and Kanneworff, 1998).

Material and Methods

The survey was conducted with the 722 GRT trawler *Paamiut*, using 3000/20 meshes *Skjervøy* bottom trawl with a twin cod-end. Mesh size in the cod-end was 20 mm (stretched). 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 *Furuno* trawleye on the headrope.

In order to minimise the influence of diel vertical migrations of shrimp, the trawl operations were carried out only in the daytime (0900-1900 UTC). The position (GPS) of the vessel at the beginning and end of each tow was used to determine the length of the track.

The mean wingspread was calculated for each haul, based on the measured distance between doors. Swept area was calculated as the distance between starting and ending position, multiplied by the mean wingspread.

Wherever possible the stratification of the survey area is based on depth contours. In regions without reliable depth information the stratification is based on the distribution of the commercial fishery. Where reliable depth information exists four depth zones are applied: 150-200 m, 200-300 m, 300-400 m, and 400-600 m. The stratification of the various areas has earlier been described in detail (Carlsson et al., 1995).

In contrast to the preceding years (1994-97), in which the surveys were carried out as two-phase surveys with amplified sampling effort in phase two in strata with observed high shrimp densities (and thus high variability), the survey in 1998 was carried out in one step only. In order to optimise the sampling and in accordance with results from a study group addressing this topic (Carlsson et al., 1998) a reduced coverage in depth strata with traditional low shrimp densities was applied concurrently with an increased coverage in other strata. Also, following the recommendations from the study group the tow duration was reduced to 30 minutes from the formerly used 60 minutes in about 25 % of the offshore hauls in depths between 200 and 400 meters. If no negative effect of this reduction is seen a stepwise further reduction of the duration of hauls will be scheduled in the future.

Compared to earlier years more trawl hauls per day at sea have now been obtained and thus a better mean coverage of the areas: 490 km² per haul in 1998 (region W) against 650 km² per haul at average for the period 1988-97. During the survey period in July-September 176 trawl hauls were taken in the offshore area (Fig. 1).

In the northern offshore area (region N) all hauls in 1998 were reduced to 30 minutes.

From each haul a sample of 4-5 kg of shrimp was taken. Shrimp were sorted by sex, and oblique carapax length was measured by slide calliper to nearest 0.1 mm. The samples were weighted by catch and stratum area to obtain estimates of total number of shrimp by sex and length group for each stratum and for the total area.

The total catch was sorted and weighed by species.

The overall length distribution of shrimp in 1998 was separated in size components by modal analysis (Macdonald and Pitcher, 1979) applying the hitherto used length-at-age key for this stock. Results were compared to results from modal analysis of total distributions from earlier years. The suitability of a new length-at-age interpretation found for shrimp in the Disko Bay in 1997 (Carlsson 1997) was investigated by modal analysis of both combined area length distributions and the total length distribution from 1998, after identification of modes by visual inspection of combined area length frequencies.

Biomass, total estimate

For all strata biomass estimates have been calculated (Tables 1a-1d) by means of the swept area method. The estimated biomass (in tons) for the four main regions is:

Region	Biomass estimate	No. of hauls	Confidence limits (approx. 95%)
North	7,760	20	5,979
Canada	460	10	373
West	209,220	138	110,018
South	23,106	8	27,391

The very low biomass estimate for 1997 is followed by a high estimate for 1998, which is among the highest recorded in the series (Table 2). However, very uneven concentrations of shrimp compared to earlier have been observed in the surveys in 1997 and 1998, and a higher degree of uncertainty must therefore be expected. Fig. 2 shows the yearly biomass estimates for region W (areas W1-W7) along with the approximate 95 % confidence limits. The 1998 estimate exhibits much higher variance than any other year. If the distribution of the stock in 1998 had been equal to earlier years more narrow confidence limits would have been expected, as the average number of stations per area unit this year was higher than earlier.

For the period 1988-92 the biomasses may be somewhat overestimated, as the catches are not corrected for presence of *Pandalus montagui*. However, the proportion of *P. montagui* in the catches at that time was fairly low, partly because the survey area did not extend as far south as in the later years. The estimates for 1993-98 do not include *Pandalus montagui*.

Biomass, geographical and depth distribution

Large variations in the distribution of this stock can be observed, 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-August), and seasonal variations are therefore assumed to be minimised. Fig. 3 and 4 show the variations in biomass distribution over various geographical areas and over the depth intervals used. It is indicated that the large increase in estimated biomass from 1997 to 1998 has mainly taken place in the areas W3 and W4, in depths between 200 and 400 meters.

Fig. 5 shows the biomass estimates in depth strata in the main areas W1-W7 from all years of surveys. Until 1996 the area W1 constituted a large proportion (> 20 %) of the estimated total biomass. However, this area is very large and the density of shrimp has consistently been low compared to other areas (Fig. 6), and the area has thus been of lesser interest for the commercial fleet through most of the years.

In the main areas W1, W3 and W4 a general reduction of the biomass is seen from 1993-94, discontinued by a significant increase in W3 and W4 in 1998. In W3 higher concentrations than normal were found in the depth interval 200-300 m, especially in the southern part. Extremely high densities were met in depths > 300 m in W4, but in only two of the six hauls taken there.

W2 has – apart from the situation in 1991 where the stock may have been heavily underestimated (Carlsson et al., 1995) – shown some variation in the total biomass estimates, but with a good stability in the average density. In the areas around St. Hellefiskebanke (W2-W4) a distinct shift in the depth distribution from shallow to deeper water is observed. In the area W5 the biomass seems to have been fairly stable, even with an increasing tendency in 1992-97. In 1998, however, a significant decrease is indicated. The southernmost areas, W6 and W7, however only sampled since 1990 and 1993, respectively, are indicated to have had occasional concentrations of shrimp in various depth strata.

The earlier observed 'southward shift' in the biomass through the years 1993-97 (Carlsson and Kanneworff, 1997) has apparently mainly taken place from the northern and western areas (W1, W3 and W4) to W5. Further southward displacement to W6 is seen only in 1993 and 1996. In 1998 an increase of biomass is recorded in all areas in region W, except W1 and W5 (Fig. 5).

The region South has exhibited very large variations in the estimated biomass (*1994-98, Table 2*). Also, extreme variations are seen between hauls during the same survey, and the total biomass estimate is thus determined with a very high degree of uncertainty (Table 1d).

Stock composition

Total abundance

Number of shrimp in length distributions for the total survey area (excluding region S) from 1988 to 1998 were:

No. of shrimp (billions)	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Males	18.1	31.9	21.9	12.2	20.9	31.8	25.0	18.0	32.9	15.8	32.9
Females	7.8	6.0	8.0	4.4	5.5	7.9	6.4	5.1	5.6	4.4	7.7
Total	25.9	37.8	29.8	16.6	26.5	39.7	31.4	23.1	38.5	20.2	40.6

Total number of shrimp increased from 1997 to 1998 (about 100%) to the same level as in 1996, in accordance with the increase in the biomass estimate. Compared to 1996 the number of males is the same, while the number of females is even bigger, and the total number of shrimp in 1998 is thus the highest found during the years of surveys.

Size group abundance by areas

Overall length distributions for the total survey area in 1988-98 are shown in Fig.s 7a and 7b, and Fig.s 8a and 8b show total length frequencies by area in 1998. Areas north of 69°30'N are combined in area NW (includes N1-N4) and area NS (includes N5-N9), while areas on the Canadian side of the midline are combined into region C (includes C1 and C3).

A length-at-age key for the West Greenland offshore shrimp stock was established by Savard et al. (1994) and has been used since then in analysis of length distributions of shrimp. This length-at-age interpretation was used in modal analysis of the total combined length distribution of males for the survey area in 1998 (excluding region S). Experimental runs of the MIX program showed that a fixed coefficient of variation at 0.06 was appropiate, and apparently reasonable results were easily obtained after a few runs. The final model ran smoothly with no other constraints, and with acceptable standard errors of proportions and means (below .02 and .2, respectively).

Results of modal analysis of length distribution of survey catches from 1988 to 1998 are shown in Table 3. Data for the years 1988 to 1994 originate from Don Parsons (pers. comm.) and NAFO (1995). Data for 1998 show the highest proportion of a single size component of males, namely age group 5 shrimp at about 20 mm CL. The only other components of similar size in this survey series are age groups 5 and 6 in 1990 and 1991, respectively, when the '1985' year class dominated the biomass estimates in several years. But the abundance of the age group 5 component in 1998 is far above abundance of all other age groups in Table 3, reflecting the very high level of the biomass estimate this year.

Length distributions for stratification areas in 1998 (Fig. 8a and 8b) show dominance of the about 20 mm CL group in all areas except areas NS and W6. In area NS, however, biomass is very low and the available two shrimp samples are very poor in terms of indications of clean modes. In area W6 a modal group (age 4 according to this interpretation) at 16.5 mm CL dominates, and this group is also evident in areas W1, W3 and W5. Female modes are found around 25-26 mm CL in all samples. Females are most abundant in areas W4, W6 and W7.

<u>Investigation of a new length-at-age interpretation</u>

The length-at-age key used for the offshore shrimp stock has been found relevant in the analysis of age structure of inshore shrimp in the Disko Bay area. However, over the last few years significant modal groups moved through length frequency distributions from the inshore, that occurred not to be in agreement with the offshore length-at-age interpretation. Inshore length distributions from recent surveys have therefore been reanalysed, and a new length-at-age interpretation has been established (Carlsson, 1997, Carlsson and Kanneworff, 1998).

In analysis of all length distributions fitting of six modes in the male distribution has often been troublesome, and as some similarity between modal groups in the inshore and offshore areas have been found over the years it was felt applicable to reanalyse size compositions from the offshore areas also. Initially areal and total length distributions from 1988 were investigated.

By visual inspection of length distributions of individual samples and of pooled length distributions by area a number of modes could be identified, around 9 mm, 14 mm, 17 mm, 20-22 mm, and 22-24 mm carapace length (CL). These modes were similar to those found in survey data from inshore Disko Bay areas in both 1997 and 1998 (Carlsson l.c.) and were especially prominent in the areas off the Disko Bay (areas W1, W2, and W3).

Results from the modal analysis using the MIX program are shown in Table 4. For most areas reasonable runs could be made without other constraints than a coefficient of variation of 0.06. In areas NW and W6 growth pattern seemed to differ from other areas, and the new length-at-age structure was not directly applicable. Fig. 9 shows a comparison of abundance af modal groups based on areal analysis with abundance from analysis of the overall distribution.

The general length-at-age key for the West Greenland offshore shrimp stock was confirmed in survey result during the years, especially by the occurrence of the very abundant '1985' year class, which occurred in the length frequencies at modes in accordance with the key from 17.5 mm CL and larger. Based on this length-at-age key the mode at 17 mm CL represents shrimp of age 4. Due to a larger mesh size (44 mm stretched) used in trawl surveys before 1993 the vey abundant year class was not traced before 1989 and can not be used to determine whether there are two or three cohortes smaller than 17.4 mm CL.

Conclusions

During the period of stratified random surveys in the offshore areas of shrimp distribution the biomass estimates have shown a good stability ranging from 160 to 220 thousand tons, apart from somewhat lower values in 1991 and 1997. Large variations from year to year both geographically and over depth zones are observed and may suggest that the stock is highly migratory. Higher than normal variance of the 1998 mean biomass estimate is indicated, possibly explained by a more uneven distribution of shrimp than earlier seen.

Modal analysis of the overall length distribution of shrimp in the survey area in 1998 show occurrence of a very abundant year class of large males both when using the traditional and the new length-at-age interpretation, and promising recruitment to the female stock can be foreseen in the short term. Also abundance of the female stock component appears high, and there is no concern for the spawning potential of the population.

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Table 1a. Estimated trawlable biomass and sampling statistics for strata in the areas W1-W7, 1998.

	STRATUM	SQKM	TONS	HAULS	STD	CV
AREA W1	150-200 M	2416	2	2	3	141
	200-300 M	5295	1898	11	4710	248
	300-400 M	9239	8023	21	8769	109
	400-600 M	752	20	2	28	141
AREA W2	150-200 M	1857	3	2	4	121
	200-300 M	3026	1663	7	1968	118
	300-400 M	2158	15272	5	12454	82
	400-600 M	1723	16775	4	20135	120
AREA W3	150-200 M	2215	2	2	2	129
	200-300 M	4810	16080	11	24353	151
	300-400 M	2714	11102	7	5318	48
	400-600 M	3361	6616	7	4260	64
AREA W4	150-200 M	4252	159	5	159	100
	200-300 M	1791	9278	6	17150	185
	300-400 M	812	54811	2	68111	124
	400-600 M	1967	14267	4	28359	199
AREA W5	150-200 M	1995	4	3	6	163
	200-300 M	3454	12177	8	13802	113
	300-400 M	1797	3789	4	4135	109
	400-600 M	2806	292	6	397	136
AREA W6	150-200 M	1095	416	2	414	100
	200-300 M	1491	12076	4	15951	132
	300-400 M	1300	9881	3	8182	83
	400-600 M	884	384	2	428	112
AREA W7	150-200 M	2419	994	3	1231	124
	200-300 M	985	13234	3	20673	156
	300-400 M	239	4	2	5	136

Table 1b. Estimated trawlable biomass and sampling statistics for strata in the areas C1+C3, 1998.

	STRATUM	SQKM	TONS	HAULS	STD	CV
AREA C1	300-400 M	655	74	2	76	102
	400-600 M	312	1	2	1	141
AREA C3	200-300 M	660	164	2	68	41
	300-400 M	1192	220	2	243	111
	400-600 M	623	1	2	1	44

Table 1c. Estimated trawlable biomass and sampling statistics for strata in the areas N1-N9, 1998.

STRATUM	SQKM	TONS	HAULS	STD	CV
AREA N1	3664	3234	2	2345	73
AREA N2	11740	83	4	125	150
AREA N3	368	487	1	.	.
AREA N4	2257	2114	2	2945	139
AREA N5	5766	50	2	19	39
AREA N6	3237	667	3	1155	173
AREA N7	1029	0	2	0	141
AREA N8	8063	1115	2	1569	141
AREA N9	2407	10	2	14	141

Table 1d. Estimated trawlable biomass and sampling statistics for strata in the areas S1-S2, 1998.

STRATUM	SQKM	TONS	HAULS	STD	CV
AREA S1	1993	22253	4	27381	123
AREA S2	4526	853	4	760	89

Table 2. Biomass estimates 1988-98 (thousand tons) in combined areas from north to south.

Area	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
N1-N9	21.9	11.3	11.7	6.0	21.2	9.1	8.5	9.8	9.1	7.1	7.8
W1-W2	57.7	56.6	78.4	38.8	55.6	103.2	81.1	42.6	54.5	37.9	43.7
W3-W4	65.9	81.5	48.3	41.1	37.8	41.5	45.2	43.5	30.3	15.6	112.3
C1+C3	9.3	3.8	11.4	4.7	16.8	3.6	7.0	5.1	1.7	0.3	0.5
W5-W7	16.8	38.4	24.7	28.6	47.7	67.3	36.2	57.4	90.8	52.5	53.3
S1-S2	-	-	-	-	-	-	23.7	1.8	3.8	26.1	23.1
Total	171.5	191.7	174.6	119.1	179.1	224.6	201.7	160.1	190.2	139.5	240.5

Table 3. Length- and percents-at-age of males, and abundance-at-age of all shrimp based on modal analysis of total length frequency distributions from the survey area (N+C+W), 1988-97 (old length-at-age interpretation).

Males, lengths-at-age

Age	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Mean
1						9.3	8.5	8.5	8.5	8.6	8.9	8.7
2	12.3	12.6	12.0	12.7	13.2	11.9	11.9	10.9	11.6	11.8	11.0	12.0
3	14.7	15.4	14.0	15.8	15.1	14.1	14.3	13.7	13.8	14.3	14.2	14.5
4	17.4	17.3	16.8	17.3	17.2	16.9	16.8	17.1	16.8	17.5	16.5	17.1
5	19.9	19.5	19.2	19.8	19.3	19.3	19.5	19.7	19.2	20.3	19.7	19.6
6	22.3	22.1	21.2	21.5	22.0	21.8	22.0	22.3	21.4	22.0	21.7	21.8

Males, percents-at-age

Age	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Mean
1						1.6	1.0	2.9	2.2	4.5	1.1	2.2
2	2.3	1.4	3.8	1.3	3.4	6.8	5.3	2.7	5.8	4.9	1.9	3.8
3	4.7	14.5	4.8	5.2	11.8	10.7	9.6	6.3	24.2	10.3	8.7	10.2
4	19.0	50.1	14.4	14.1	15.1	22.5	26.4	20.0	21.3	38.4	19.4	24.1
5	39.2	21.9	53.4	18.1	27.1	32.1	27.9	42.1	18.2	19.5	58.9	30.0
6	34.8	12.1	23.6	61.3	42.7	26.3	29.8	26.0	28.3	22.3	10.1	30.7
Total	100.0	100.0	100.0	100.0	100.1	100.0	100.0	100.0	100.0	99.9	100.1	101.0

Abundance-at-age, all shrimp (billions)

Age	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Mean
1						0.5	0.3	0.5	0.7	0.7	0.4	0.5
2	0.4	0.4	0.8	0.2	0.7	2.2	1.3	0.5	1.9	0.8	0.6	0.9
3	0.9	4.6	1.1	0.6	2.5	3.4	2.4	1.1	8.0	1.6	2.9	2.6
4	3.4	16.0	3.2	1.7	3.2	7.2	6.6	3.6	7.0	6.1	6.4	5.8
5	7.1	7.0	11.7	2.2	5.7	10.2	7.0	7.6	6.0	3.1	19.4	7.9
6	6.3	3.9	5.2	7.5	8.9	8.4	7.5	4.7	9.3	3.5	3.3	6.2
7+	7.7	6.0	8.0	4.4	5.5	7.9	6.4	5.1	5.6	4.4	7.7	6.2
Total	25.8	37.9	29.9	16.6	26.4	39.7	31.4	23.1	38.5	20.2	40.6	30.2

Table 4. Carapace length, proportions-at-age, and abundance-at-age (millions) of male shrimp in the West Greenland offshore area in 1998, based on modal analysis of length-frequency distributions from strata and total area (new length-at-age interpretation).

CL, mm	AGE						C.V.	Standard
STRATUM	1	2	3	4	5	6		error
NW	7.5	11.0	15.2	18.4	22.4		0.06	.02-.04
NS[1]								
C			17.3	20.7	23.4		0.06	.14-.28
W1	9.1	13.6	17.0	20.3			0.06	.04-.08
W2	9.8	14.0	16.5	19.9	21.9		0.06	.06-.16
W3		13.8	16.5	20.6			0.06	.02-.08
W4			15.7	19.5			0.06	.01-.03
W5		15.4	17.8	20.7			0.06	.05-.15
W6	10.7		15.8	19.5				.06-.08
W7			17.5	19.9	21.9		0.06	.10-.90
mean	9.3	13.6	16.6	19.9	22.4			
TOTAL	9.9	14.1	16.9	20.2			0.06	.01-.02

Proportions	AGE						Standard	TOTAL
STRATUM	1	2	3	4	5	6	error	MALES
NW	0.04	0.04	0.11	0.55	0.26	0.00	.002-.006	1100
NS[1]								179
C	0.00	0.00	0.06	0.43	0.51	0.00	.016-.048	56
W1	0.03	0.27	0.26	0.44	0.00	0.00	.003-.013	2269
W2	0.02	0.10	0.10	0.65	0.13	0.00	.002-.022	6002
W3	0.00	0.05	0.21	0.74	0.00	0.00	.003-.007	6406
W4	0.00	0.00	0.15	0.85	0.00	0.00	.004-.004	14560
W5	0.00	0.17	0.24	0.59	0.00	0.00	.015-.019	2744
W6	0.11	0.00	0.58	0.31	0.00	0.00	.005-.014	5208
W7	0.00	0.00	0.03	0.91	0.07	0.00	.027-.044	2034
mean	0.02	0.07	0.19	0.61	0.11	0.00		
TOTAL	0.02	0.10	0.23	0.65			.000-.003	40557

Abundance	AGE						SUM	TOTAL
STRATUM	1	2	3	4	5	6		MALES
NW	44.0	44.0	121.0	604.8	285.9	0.0	1100	1100
NS[1]								179
C	0.0	0.0	3.4	24.1	28.6	0.0	56	56
W1	68.1	612.6	589.9	998.3	0.0	0.0	2269	2269
W2	120.0	600.2	600.2	3901.4	780.3	0.0	6002	6002
W3	0.0	320.3	1345.3	4740.5	0.0	0.0	6406	6406
W4	0.0	0.0	2184.1	12376.3	0.0	0.0	14560	14560
W5	0.0	466.5	658.5	1618.9	0.0	0.0	2744	2744
W6	572.8	0.0	3020.4	1614.3	0.0	0.0	5208	5208
W7	0.0	0.0	61.0	1850.8	142.4	0.0	2054	2034
Sum	805	2044	8584	27729	1237	0	40399	40557
TOTAL	811	4056	9328	26362	0	0	40557	

[1]Not included in calculations due to very low biomass.

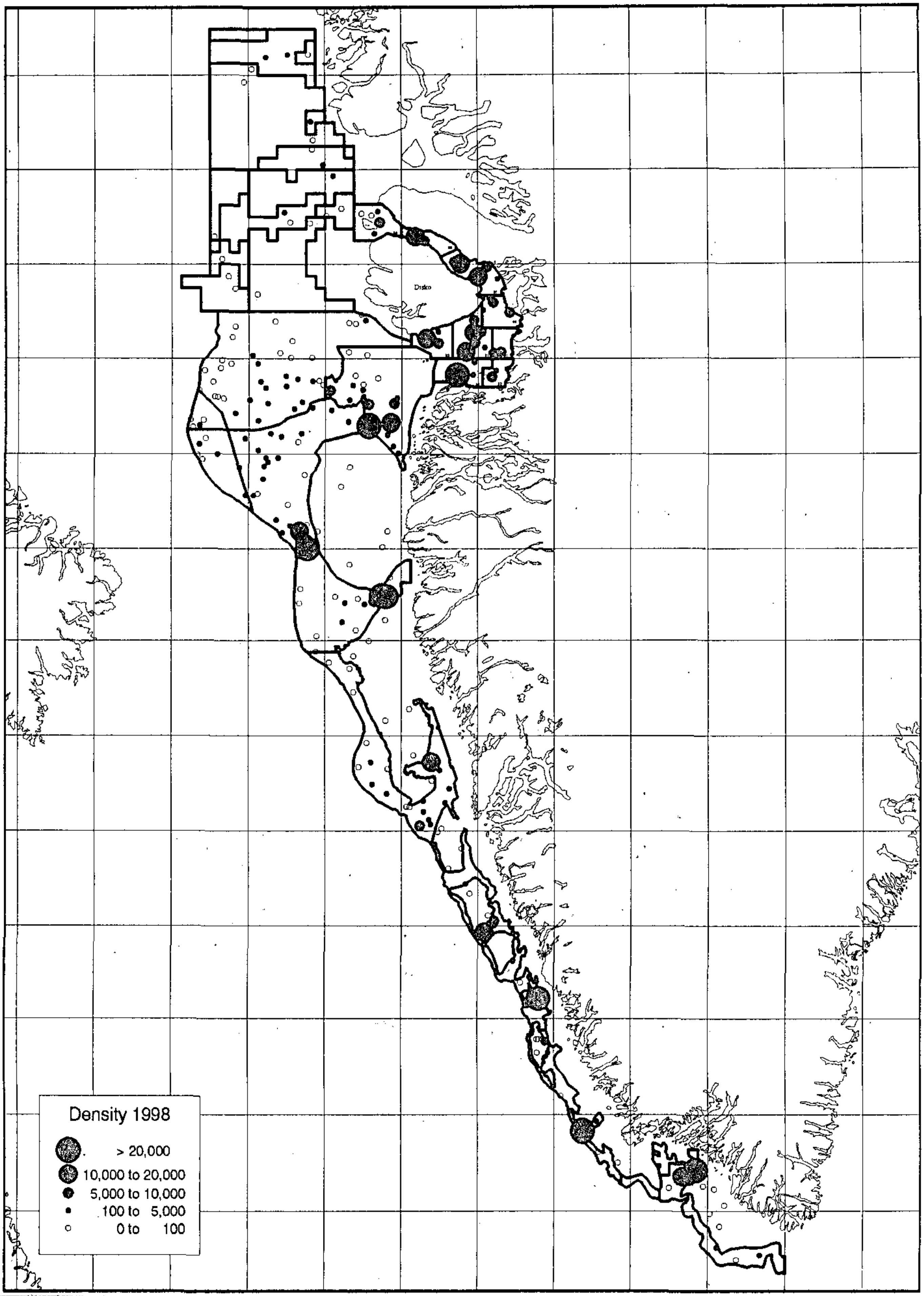

Figure 1. Sampling sites and shrimp densities (kg per km² swept area) in the trawl survey in 1998. Inshore sampling stations (in the Disko Bay area) are also shown, but material from this part of the survey is reported separately (Carlsson & Kanneworff, 1998).

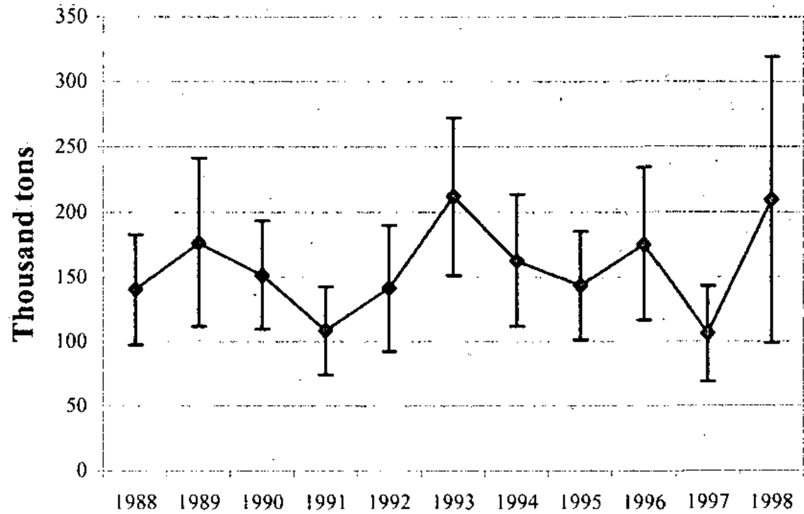

Fig. 2. Estimated yearly biomass 1988-98 for region W with 95 % confidence limits.

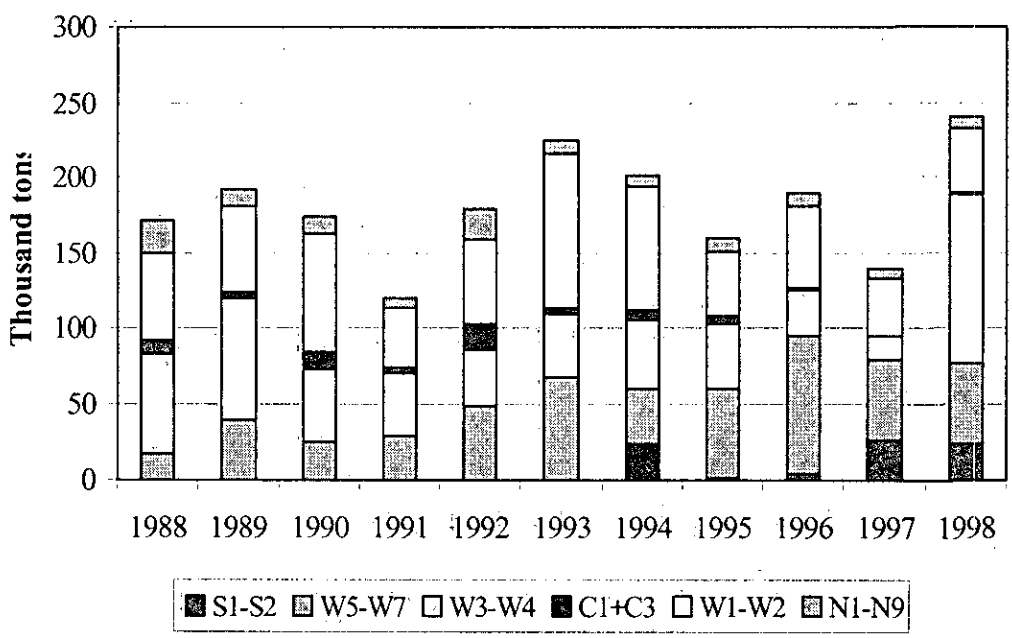

Fig. 3. Estimated biomass in groups of strata for surveys in SA0+1 offshore, 1988-98.

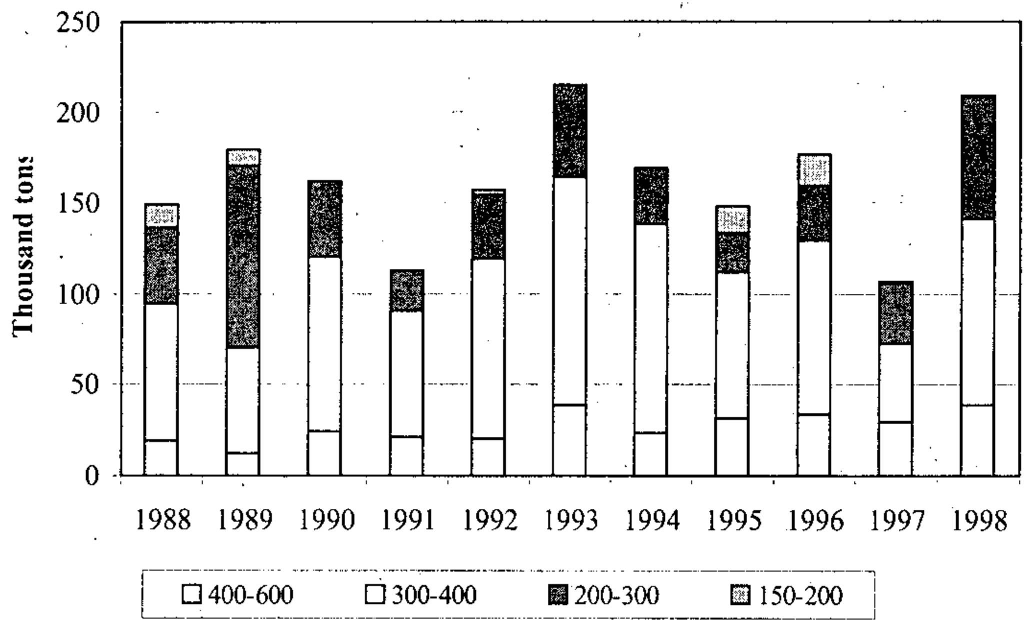

Fig. 4. Estimated biomass in depth strata (regions W and C only) for surveys in SA0+1 offshore, 1988-98.

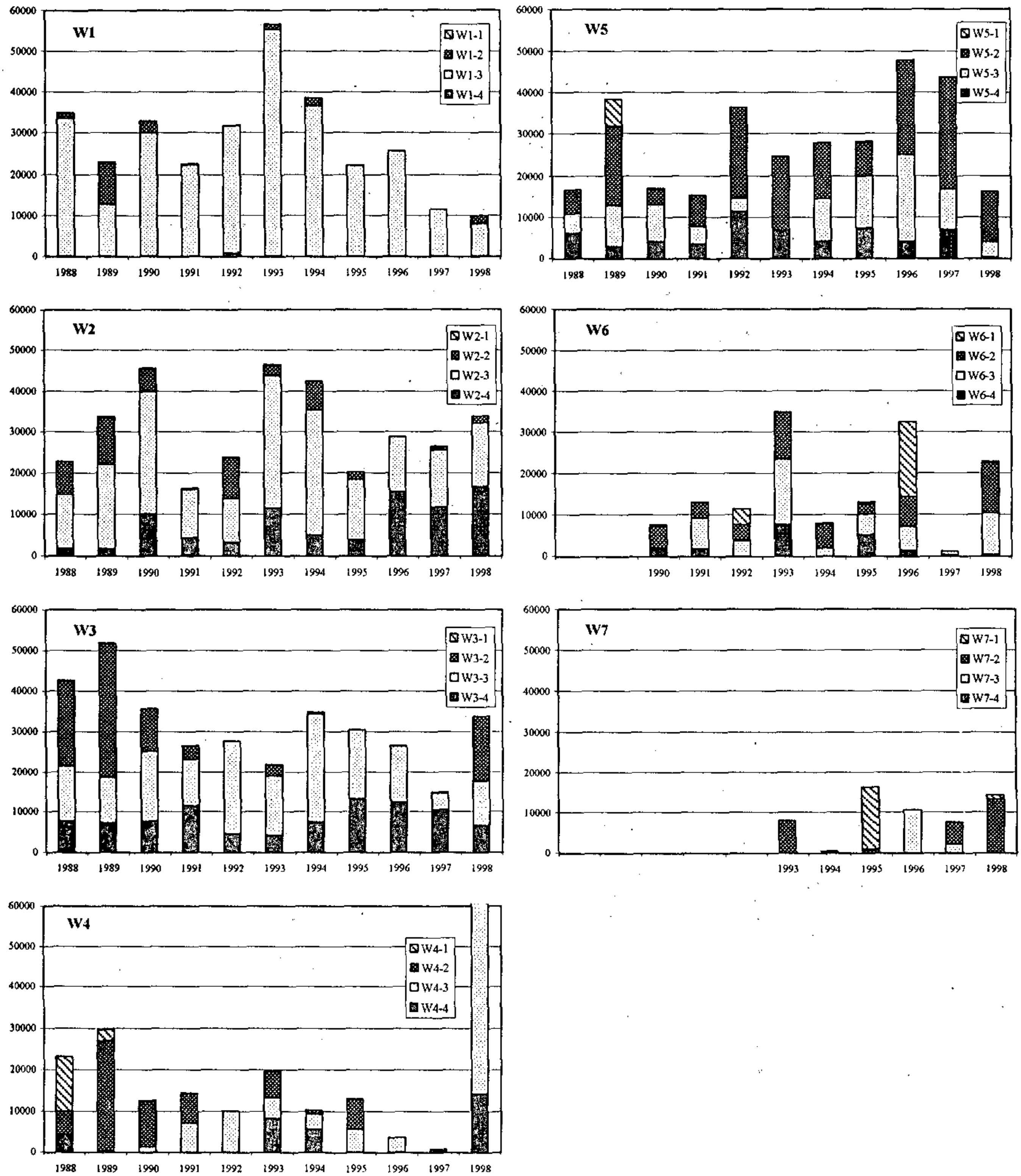

Figure 5. Biomass estimates (tons) of shrimp in region W in depth strata, 1988-98.

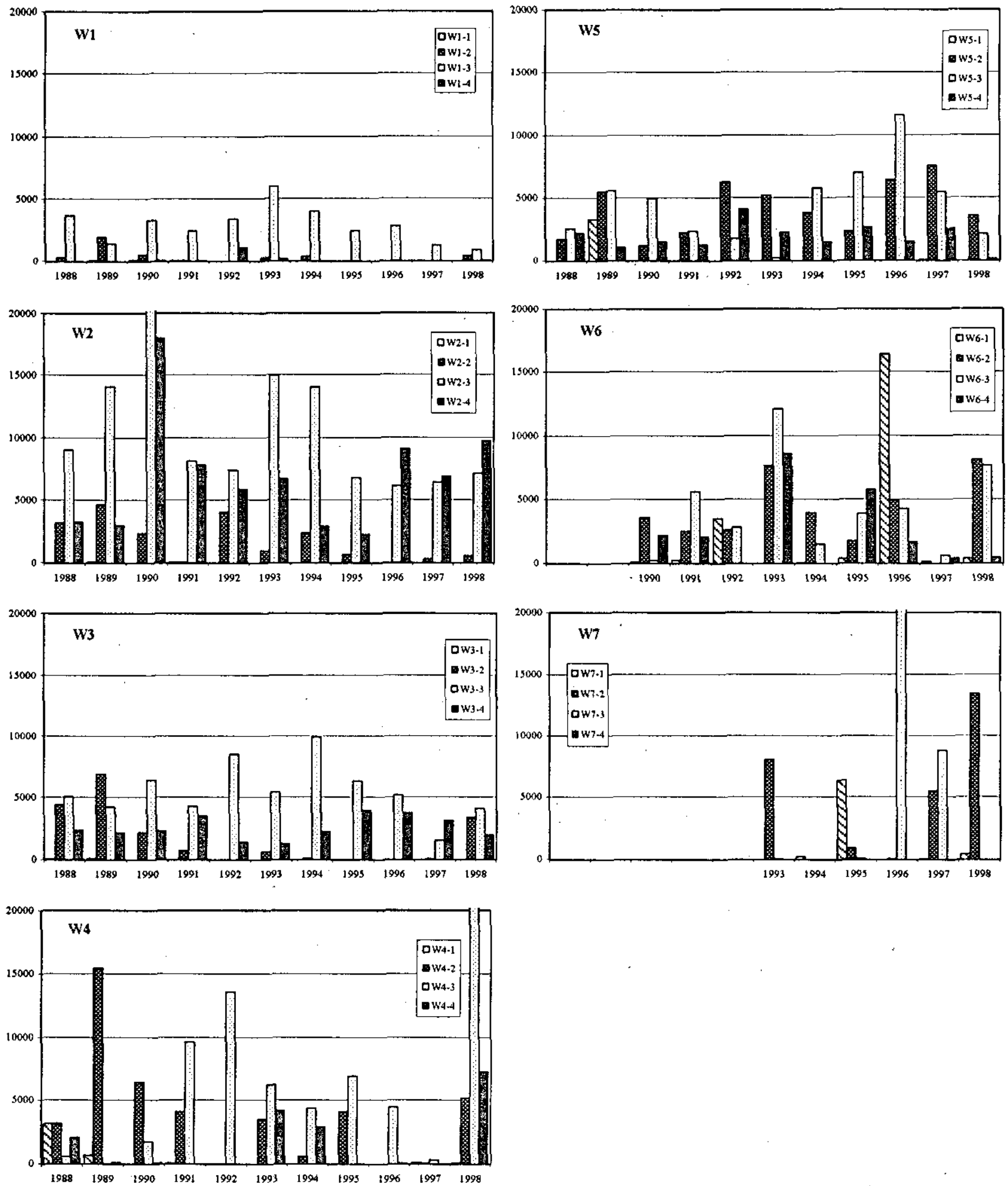

Figure 6. Estimated densities (kg per km²) of shrimp in region W in depth strata, 1988-98.

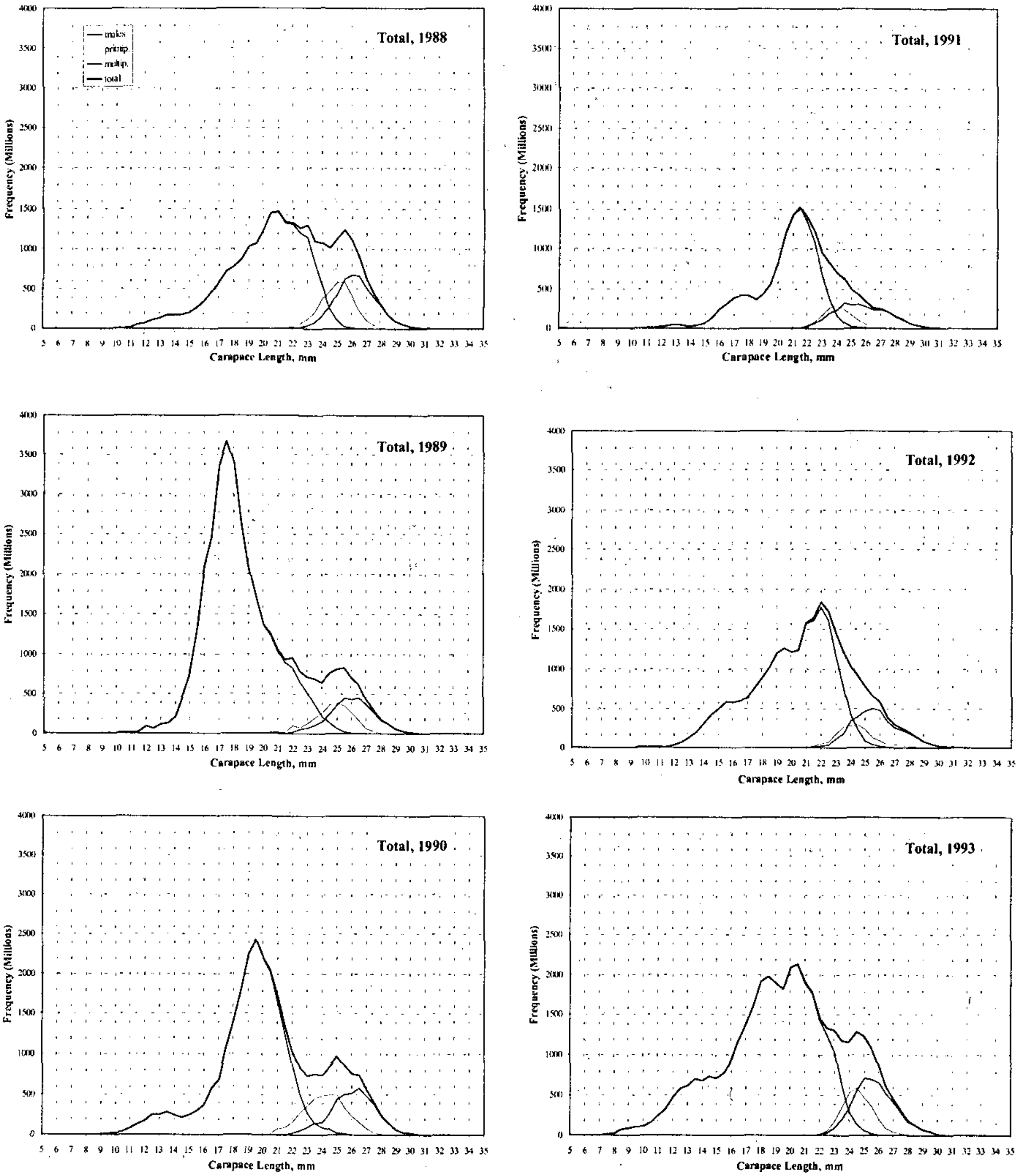

Fig. 7a. Numbers of shrimp by length group (CL) in total survey area (excluding règion S) in 1988-93.

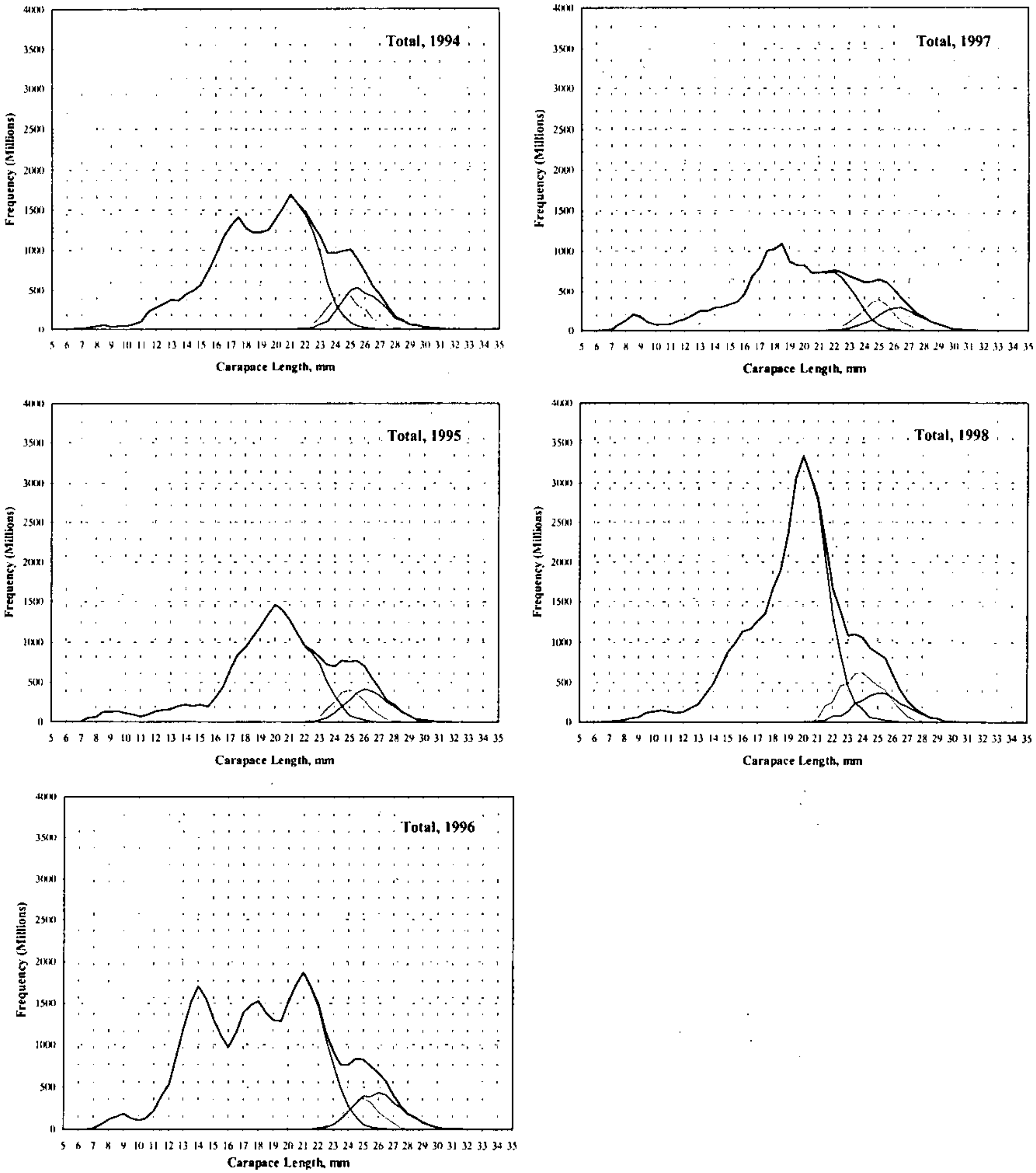

Fig. 7b. Numbers of shrimp by length group (CL) in total survey area (excluding region S) in 1994-98

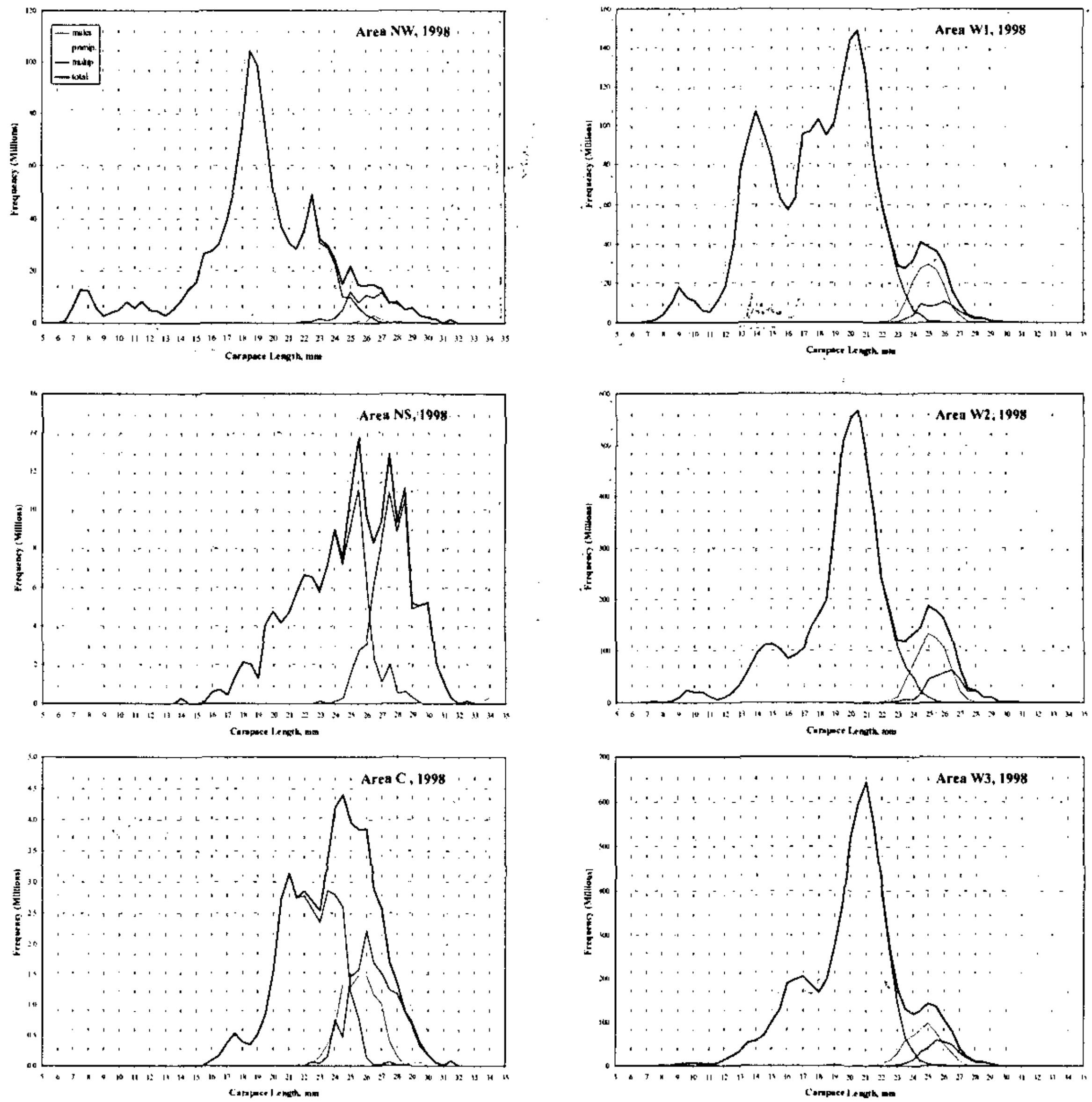

Fig. 8a. Numbers of shrimp by length group (CL) in areas NW, NS, C, W1, W2 and W3 in 1998.

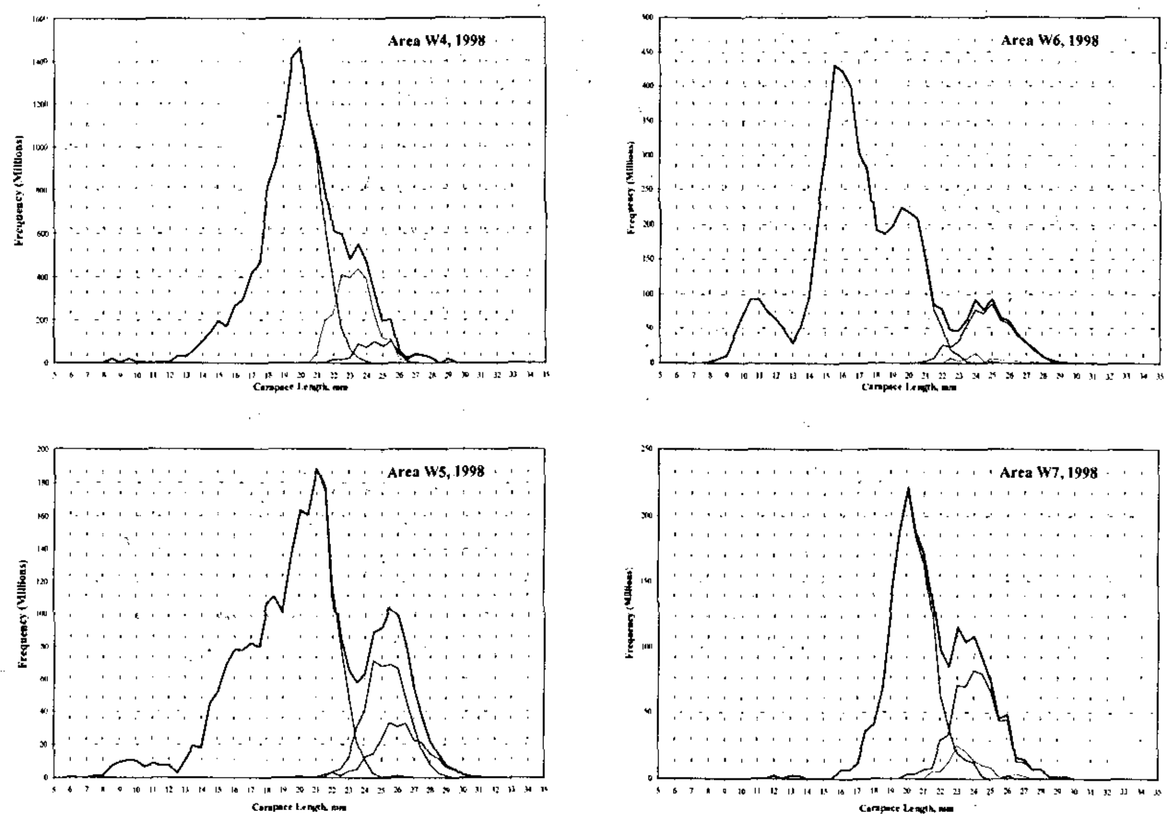

Fig. 8b. Numbers of shrimp by length group (CL) in areas W4, W5, W6 and W7 in 1998.

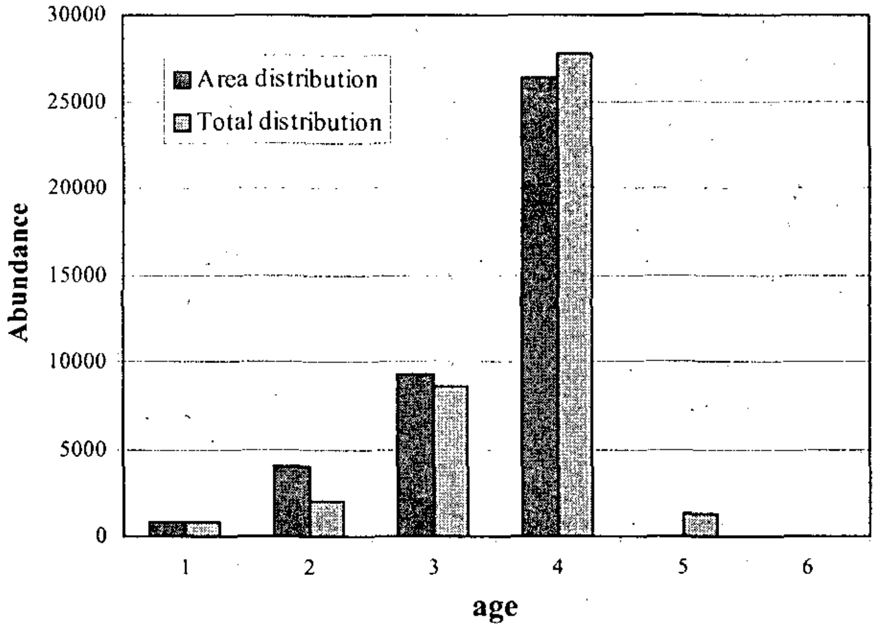

Fig. 9. Comparison of abundance of size groups based on modal analysis of length distributions from stratification areas and modal analysis of total area length distributions.