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Offshore Stratified-random Trawl Survey for Shrimp (*Pandalus borealis*) in NAFO Subarea 0+1, in 1997

by

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Introduction

Since 1988, Greenland Institute for 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 NAFO Subarea 1 and a small part of Div. 0A in the depth interval 150-600 meters. As in the preceeding years (1994-96) the survey in 1997 was carried out as a two-phase survey allocating extra trawl hauls to strata with high shrimp densities to reduce the variance of the biomass estimates.

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 minimize 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: 150-200m, 200-300 m, 300-400 m, and 400-600 m. The

stratification of the various areas have earlier been described in detail (Carlsson et al., 1995) as has the two phase sampling method.

During the survey period in July to September 157 trawl hauls were taken in the offshore area (Fig. 1). Of these 23 were taken as additional hauls in the second phase of the two-stage survey.

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 1997 was separated in age groups by modal analysis (Macdonald and Pitcher, 1979) after identification of modes by visual inspection of individual samples from a survey design project in area W3 (Carlsson, 1997a) and combined length frequencies from survey strata. Results were compared to results from modal analysis of total distributions from earlier years.

Results and Discussion

The sampling scheme for the first phase of the survey was established following the same guidelines as in previous years (Folmer et al., 1996) in accordance with Doubleday (1981). Trawl hauls were allocated to strata proportionally with their extension, the mean coverage being approximately 800 km² per haul. Some strata (in regions N and S) with known very low densities were, however, given about one third of this coverage. Station sites were chosen at random within the strata, however, some care has been taken to avoid obviously unbalanced coverage of strata with large geographical extensions. By mistake the distribution of sampling sites in some of the strata in the 1997 survey were not adjusted for this, e.g. C3-4, W3-3, and W3-4 (Fig. 2).

Biomass, total estimate

For all strata biomass estimates have been calculated (Table 1) by means of the swept area method. The estimated biomasses (in tons) for the four main regions are:

Region	Biomass estimate	No. of hauls	2 * standard deviation
North	7,120	29	4,930
Canada	255	10	300
West	106,019	105	36,893
South	26,108	13	22,643

In the biomass estimates from 1993 and onwards account has been taken for occurrence of *Pandalus montagui* in the survey catches (Folmer, 1996), and adjustment of the earlier given biomass estimates (Carlsson *et al.*, 1995) for this period has been introduced accordingly. For earlier years (1988-92) no correction has been made, partly because of the less extensive survey area, and partly because of the low proportion of *Pandalus montagui* in the catches at that time.

Since 1993 a downward trend in overall biomass is seen (Table 2 and Fig. 3), and the total biomass estimated for 1997 is the lowest recorded for the period of surveying this stock (1988-97). The total biomass for the offshore areas was estimated at 113.4 Kt, a significant decrease from the estimate of 186.4 Kt in 1996. The biomass is somewhat overestimated in the range of 1000 to 2500 tons for the years 1992-94 due to inclusion of *Pandalus montagui* in the calculations. This is most pronounced in the southermost areas, where larger concentrations have

been observed, e.g. in 1995 (Fig. 6b). An overall southward shift through the years is indicated with a downward tendency in regions N and C and in areas W1-W2 while the biomass in the areas W5-W7 has had an increasing proportion of the total biomass since 1992. This is in accordance with changes in distribution of the commercial fishery (Hvingel et al., 1996). Large variations in shrimp abundance estimates in the different areas from year to year is also observed (Fig. 4).

The region South has exhibited very large variations in the estimated biomasses (1992-97, 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).

A comparison of biomass estimates from the stratified-random method (S-R) with those calculated by means of the Spline method (SSD, Stolyarenko, 1987) based on the same sampling data shows a good correlation (Fig. 5). A comparison is only possible for the regions W and C, because the SSD method is only useable for areas with detailed depth information. As expected SSD estimates are consistently higher than S-R figures, especially for lower biomass values, as the sampling scheme does not satisfy both methods equally well. The SSD method prescribes that observed concentrations be delineated further during the survey by adding extra sampling sites around them. Without these secondary stations the biomass will be somewhat overestimated by this method.

The 1997 estimate calculated by the Spline method is 135.3 Kt, and the derived regression value for an S-R estimate is 107.6 Kt. This is very close to the original estimate from the S-R survey of 106.3 Kt for that area. Supposing that the distribution of stations in some of the strata have been less widespread in 1997 than in other years there would be a greater risk than normal of not detecting areas with higher concentrations, e.g. as seen in an area west of Store Hellefiskebanke (Fig. 2). In this area a special survey (Carlsson, 1997a) recorded some concentrations of shrimp. If catch figures from this survey are included in the SSD calculation, the biomass for the two regions concerned, W and C, is calculated to 166.9 Kt. Using the regression (Fig. 5) to estimate a corresponding value for an S-R estimate and with the assumption that the shrimp concentration west of Store Hellefiskebanke had been detected a biomass of 149.7 Kt is obtained. The figure derived via the SSD calculation is, however, still at the lower end of the range of estimates from the period. If this correction is applied the estimate for the total offshore area in 1997 (including region N) adds to 156.8 Kt (cf. Table 2).

Another way of correcting for a possible sampling error could be to include one or more of the stations from the special survey in the S-R calculation, disregarding that these stations are not chosen at random as part of the S-R design. If the station with the highest catch of shrimp from the special survey is included in stratum W3-3 the biomass estimate increases with 9.8 Kt. If the average of six of the stations with largest catches is included in the calculation as one additional station the biomass estimate increases with 5.3 Kt. Including stations in the same way in stratum W3-4 provides no significant changes for that stratum. In total, between 5 and 10 Kt might be added to the total offshore biomass estimate by this method.

Other areas with a lower than normal sampling coverage may be identified, e.g. Holsteinsborg Deep (Fig. 2). However, no further sampling data than the above are available and the final estimate for the total biomass must thus be regarded as a minimum for 1997, also if possible corrections (in the range of 5 to 43 Kt) are included.

Biomass, depth distribution

Large variations in the distribution of this stock can be observed, both from year to year and seasonally. The seasonal distribution pattern is observed by analysis of logbook data from the commercial fishery and described in Hvingel et al. (1996). The stratified-random trawlsurveys during the last ten years have been carried out at the same period of the year (July-August), and seasonal variations is therefore assumed to be suppressed. Fig. 6 (a and b) shows the biomass estimates in depth strata in the main areas W1-W7 from all years of surveys. In the main areas W1, W3 and W4 a general reduction of the biomass is seen, apart from somewhat higher values in 1993-94 in W1. However, the area W1 is very large and the density of shrimp has consistently been low compared to other areas. 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. Like in the other northern areas (W1 and W3-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 since 1992. The southermost areas, W6 and W7, however only sampled since 1990 and 1992, respectively, are indicated to have had occasional concentrations of shrimp in various depth strata.

Stock composition

Number of shrimp in overall length distributions for the survey area (excluding areas S1 and S2) from 1990 to 1997 were:

No. of shrimp (billions)	1990	1991	1992	1993	1994	1995	1996	1997
males	21.9	12.2	20.9	31.8	25.0	18.0	32.9	15.8
females	8.0	4.4	5.5	7.9	6.4	5.1	5.6	4.4
Total	29.8	16.6	26.5	39.7	31.4	23.1	38.5	20.2

Total number of shrimp decreased from 1996 to 1997 (about 48%), in accordance with the decrease in the biomass estimate. The decrease is based on a significant decrease of about 52% in number of males and a relatively minor decrease of about 20% in females. Numbers of shrimp in 1997 are the lowest on record except for 1991, where the number of males were even lower, while the number of females were at the same level. Number of males in 1991 may, however, be biased downwards due to the use of a 44 mm mesh size in the cod-end before 1993 (compared to 20 mm used since then).

Overall length distributions for the total survey area in 1992-97 are shown in Fig. 7, and Figures 6a and 6b show total length frequencies by stratum in 1997. Strata north of 69°30'N are combined into two strata NW (includes N1-N4) and NS (includes N5-N9), while strata on the Canadian side of the midline are combined into stratum C (includes C1 and C3).

By visual inspection of a number of male length frequencies of individual samples from a survey design project in area W3 (Carlsson, 1997a) a number of modes could be identified: 6-9 mm, 11-13 mm, 14.5-16.5 mm, 17-19.5 mm, 20-22 mm, and 22-24 mm carapace length (CL). These modes were in fair agreement with modes identified in pooled length frequencies by stratum and were used as input for modal analysis of the overall length frequency distribution.

Experiments with runs of the MIX program showed that a fixed coefficient of variation at 0.06 was appropriate. Attempts to run the model with 6 modes (means) as inferred from the visual inspection did not succeed in the sense that it was necessary to keep the two largest modes fixed to get a reasonable von Bertalanffy growth (Fig. 9a), while running the model with only 5 modes as input (by combining the two largest modes) gave a good fit, but increasing growth by age. In both models standard errors of proportions and means were acceptable (below .02 and .2, respectively).

Results of length frequency analysis of composition of survey catches are shown in Table 3 (for 1997 results of the six-mode run for males are given). Results from 1988-1994 were taken from Don Parsons (pers. comm.) and NAFO (1995).

The estimated proportion of the two largest modes in the first run and the last mode in the second run are both about 40%; the proportion of the dominant male group at 17.4 mm CL are also at 40% in both runs. In both cases a lower than ever observed recruitment to the female group may be expected in 1998, and the group of males around 17.4 mm CL may not be expected to recruit to the female group until year 2000 or year 1999, depending on which scenario is correct. The growth of the dominant group around 17.4 mm CL in the coming years may help to clarify this problem.

A general length-at-age key for the West Greenland offshore shrimp stock was established by Savard et al. (1994) and 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. Based on this the mode at 17.4 mm CL represents the 1993 year class. However, changes in growth patterns seem to have occurred in 1997, as the mean CL of this year-class is larger than observed earlier for that age.

The same length-at-age key has been applied with fair results on survey samples from the Disko Bay. Reanalysis of survey samples from 1995 to 1997, however, indicate a different growth pattern in recent years (Carlsson, 1997b), and a similar reanalysis of offshore survey samples seems appropriate, especially as differences in growth patterns between strata is apparent. The optimal situation would be if biological data on the growth of shrimp could be obtained.

The male group around 17.4 mm CL (the 1993 year class according to the present interpretation) is evident in most strata and dominates at 18-19 mm CL in the southern part of the main survey area (strata W4-W7) and in W1 and W2 at 17-19 mm CL. Larger males are most abundant in strata W1-W3. Modes of smaller males are present in most strata, but small shrimp are most abundant in the southern stratum W5, where the 1996 year class is evident at 8.5 mm CL.

As in earlier years female modes are found at 25 mm (primiparous) and 26 mm CL (multiparous). The primiparous distribution is assumed to consist primarily of transitioned shrimp from the 1990 year class, which occurred in the male distribution at 21.4 mm CL in 1996 as a year class of mean strength. Females are most abundant in stratum W5, concurrent with the high biomass estimate in this area.

Conclusions

During the period of stratified random trawl surveys in the shrimp distribution area in NAFO SA0+1 the biomass estimates have shown a fair stability most of the years. However, a general decline is indicated since 1993, and the 1997 estimate is the lowest on record. The areas north of approximately 66°N have exhibited the largest declines, while an increase in the southern areas is indicated from the low value in 1991 to 1996. A decline from 1996 to 1997 is seen both in the northern and the southern areas. Large variations from year to year in the distribution of the biomass over the various depth strata and main areas may suggest that the stock is highly migratory.

Due to an unbalanced coverage of certain strata in 1997 the biomasses for these are supposed to be somewhat underestimated in the range of 5 to 43 thousand tons. Taking this into consideration the observed decrease from 1996 to 1997 is somewhat reduced, but the total biomass for 1997 is still relatively low.

In accordance with the low biomass estimate, abundance of shrimp is the lowest on record except for 1991. Overall length distributions and results from modal analysis indicate a relatively strong 1993 year class, although only at average size, but otherwise recruitment forecast is poor. The 1996 year class is indicated as more abundant than normal, but it is to early to judge its actual size. Recruitment prospects to the female group in 1998 and probably also in 1999 are the lowest on record, depending on the growth of the 1993 year class.

Different from earlier years, where concentrations of female shrimp were found in the northern strata of the main area, this year they are most abundant in the southern stratum W5, where also the highest biomass is found.

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

STRATUM	SQKM	TONS	HAULS	STD	STDERR	MIN	MAX
AREA W1							
150-200 M	2416	0.5	3	0.8	0.5	0	1
AREA W1							
200-300 M	5295	35.2	7	56.1	21.2	1	139
AREA W1							
300-400 M	9239	11451.9	12	12619.1	3642.8	0	34976
AREA W1							
400-600 M	752	3.1	2	2.2	1.6	2	5
AREA W2							
150-200 M	1857	0	2	0	0	0	0
AREA W2							
200-300 M	3026	917.8	5	1171	523.7	6	2503
AREA W2							
300-400 M	2158	13752.6	6	9646.3	3938.1	3156	29635
AREA W2							
400-600 M	1723	11756.6	4	6193.2	3096.6	2932	16608
AREA W3							
150-200 M	2215	0.1	3	0.2	0.1	0	0
AREA W3							
200-300 M	4810	213.7	6	345.1	140.9	0	905
AREA W3							
300-400 M	2714	4136.1	3	4025.7	2324.2	147	8198
AREA W3							
400-600 M	3361	10488.8	4	3978.1	1989	6658	15681
AREA W4							
150-200 M	4252	395.5	5	535.5	239.5	0	1163
AREA W4							
200-300 M	1791	94.3	2	20.8	14.7	80	109
AREA W4							
300-400 M	812	216.1	2	226	159.8	56	376
AREA W4							
400-600 M	1967	31	3	16.1	9.3	13	43
AREA W5							
150-200 M	1995	57.3	3	98.2	56.7	0	171
AREA W5							
200-300 M	3454	26750.4	8	39966.1	14130.2	178	101564
AREA W5							
300-400 M	1797	9799.3	4	12541.4	6270.7	2	28056
AREA W5							
400-600 M	2806	7088	4	8986.5	4493.2	906	20432
AREA W6							
150-200 M	1095	112.7	1	.	.	113	113
AREA W6							
200-300 M	1491	2.6	2	1.8	1.3	1	4
AREA W6							
300-400 M	1300	804.6	2	80.9	57.2	747	862
AREA W6							
400-600 M	884	327	2	129.8	91.8	235	419
AREA W7							
150-200 M	2419	91.2	3	155.7	89.9	0	271
AREA W7							
200-300 M	985	5386	4	10685.6	5342.8	1	21414
AREA W7							
300-400 M	239	2104	2	2973.5	2102.5	1	4207
AREA W7							
400-600 M	273	2.6	1	.	.	3	3

Table 1b. Estimated trawlable biomass and sampling statistics in strata in the areas C1-C3.

STRATUM	SQKM	TONS	HAULS	STD	STDERR	MIN	MAX
AREA C1							
300-400 M	655	5	2	7.1	5	0	10
AREA C1							
400-600 M	312	7	2	5.4	3.8	3	11
AREA C3							
200-300 M	660	10.3	2	4.5	3.2	7	13
AREA C3							
300-400 M	1192	228.4	2	212.1	150	78	378
AREA C3							
400-600 M	623	4.6	2	2.5	1.7	3	6

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

STRATUM	SQKM	TONS	HAULS	STD	STDERR	MIN	MAX
AREA N1	3664	803.7	5	1761.8	787.9	0	3955
AREA N2	11740	2046.6	5	4571	2044.2	0	10223
AREA N3	368	107	2	109.5	77.5	29	184
AREA N4	2257	1133.4	3	779.8	450.2	474	1994
AREA N5	5766	2576	3	1665.6	961.6	759	4030
AREA N6	3237	440.6	4	756.5	378.2	15	1574
AREA N7	1029	0.6	1			1	1
AREA N8	8063	6.1	3	7.5	4.3	1	15
AREA N9	2407	5.9	3	6.9	4	2	14

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

STRATUM	SQKM	TONS	HAULS	STD	STDERR	MIN	MAX
AREA S1	1993	26081.4	10	35801.6	11321.5	1	102963
AREA S2	4526	27.1	3	25.1	14.5	0	49

Table 2. Biomass estimates 1988-97 in combined areas from north to south (thousand tons).

Area	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
N1-N4	12.8	8.1	8.8	4.1	14.2	8.2	3.3	3.1	7.5	4.1
N5-N9	9.1	3.2	2.9	1.9	7.0	0.3	5.2	6.7	1.6	3.0
W1-W2	57.7	56.6	78.4	38.8	55.6	103.2	81.1	44.9	54.5	37.9
W3-W4	65.9	81.5	48.3	41.1	37.8	40.8	45.1	43.3	30.3	15.6
C1+C3	9.3	3.8	11.4	4.7	16.8	3.6	7.0	5.1	1.7	0.3
W5-W7	16.8	38.4	24.7	28.6	47.7	66.5	36.0	41.9	90.8	52.5
S1-S2	-	-	-	-	0.5	19.9	23.7	1.8	3.8	26.1
Total	171.6	191.6	174.5	119.2	179.6	242.4	201.4	146.9	190.2	139.5

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+W1-W7) 1988-1997.

Males, lengths-at-age

Age	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	mean
1						9.3	8.5	8.5	8.5	8.6	8.7
2	12.3	12.6	12.0	12.7	13.2	11.9	11.9	10.9	11.6	11.8	12.1
3	14.7	15.4	14.0	15.8	15.1	14.1	14.3	13.7	13.8	14.3	14.5
4	17.4	17.3	16.8	17.3	17.2	16.9	16.8	17.1	16.8	17.5	17.1
5	19.9	19.5	19.2	19.8	19.3	19.3	19.5	19.7	19.2	20.3	19.6
6	22.3	22.1	21.2	21.5	22.0	21.8	22.0	22.3	21.4	22.0	21.9

Males, percents-at-age

Age	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	mean
1						1.6	1.0	2.9	2.2	4.5	2.4
2	2.3	1.4	3.8	1.3	3.4	6.8	5.3	2.7	5.8	4.9	3.8
3	4.7	14.5	4.8	5.2	11.8	10.7	9.6	6.3	24.2	10.3	10.2
4	19.0	50.1	14.4	14.1	15.1	22.5	26.4	20.0	21.3	38.4	24.1
5	39.2	21.9	53.4	18.1	27.1	32.1	27.9	42.1	18.2	19.5	30.0
6	34.8	12.1	23.6	61.3	42.7	26.3	29.8	26.0	28.3	22.3	30.7
Total	100.0	100.0	100.0	100.0	100.1	100.0	100.0	100.0	100.0	99.9	101.2

Abundance-at-age, all shrimp (billions)

Age	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	mean
1						0.5	0.3	0.5	0.7	0.7	0.5
2	0.4	0.4	0.8	0.2	0.7	2.2	1.3	0.5	1.9	0.8	0.9
3	0.9	4.6	1.1	0.6	2.5	3.4	2.4	1.1	8.0	1.6	2.6
4	3.4	16.0	3.2	1.7	3.2	7.2	6.6	3.6	7.0	6.1	5.8
5	7.1	7.0	11.7	2.2	5.7	10.2	7.0	7.6	6.0	3.1	6.7
6	6.3	3.9	5.2	7.5	8.9	8.4	7.5	4.7	9.3	3.5	6.5
7+	7.7	6.0	8.0	4.4	5.5	7.9	6.4	5.1	5.6	4.4	6.1
Total	25.8	37.9	29.9	16.6	26.4	39.7	31.4	23.1	38.5	20.2	29.2

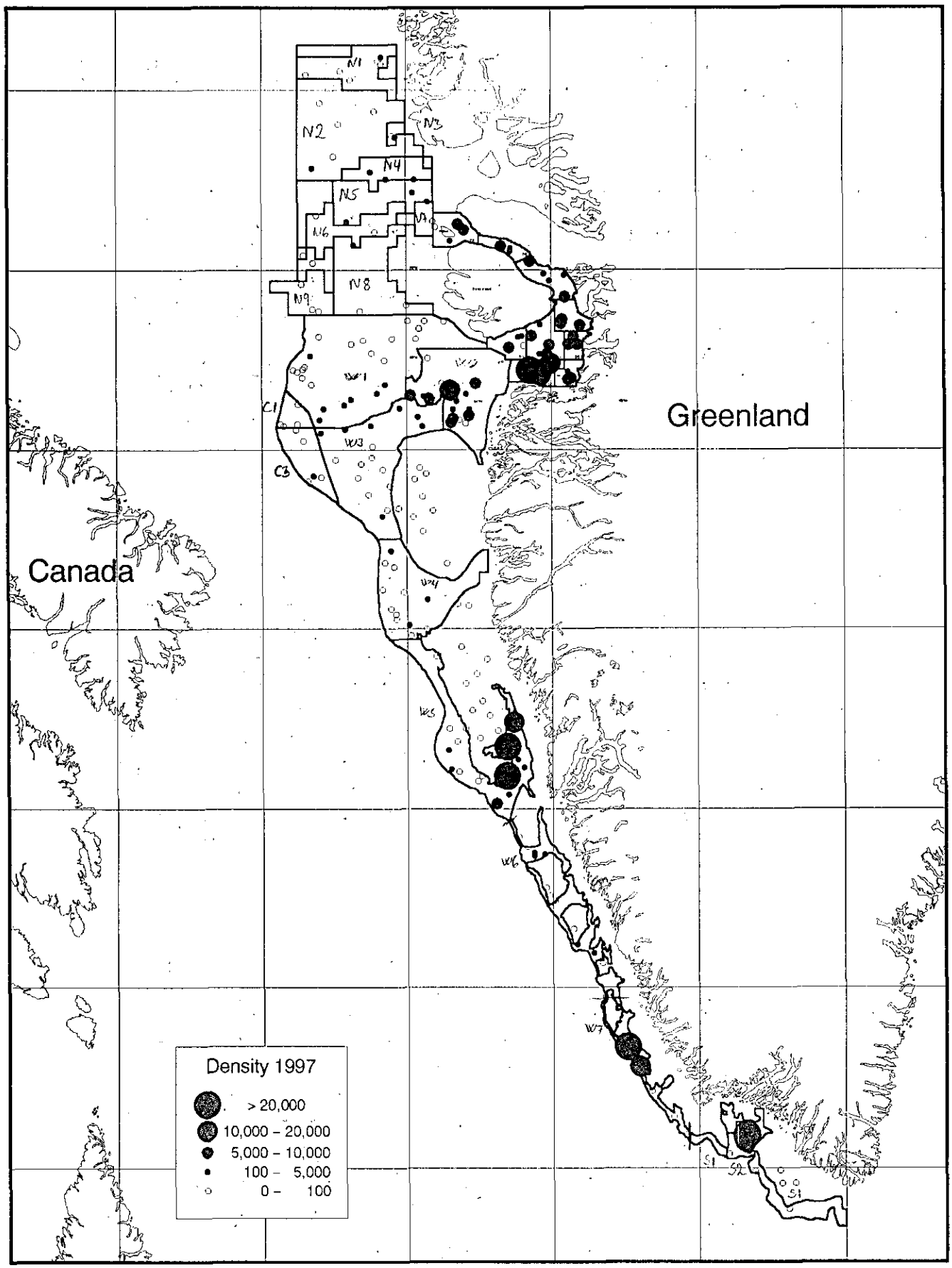

Figure 1. Sampling sites and shrimp densities (catch per km² swept area) in the trawl survey in 1997. Inshore sampling stations (Disko Bay area) are also shown, but material from this survey is reported separately (Carlsson and Kanneworff, 1997).

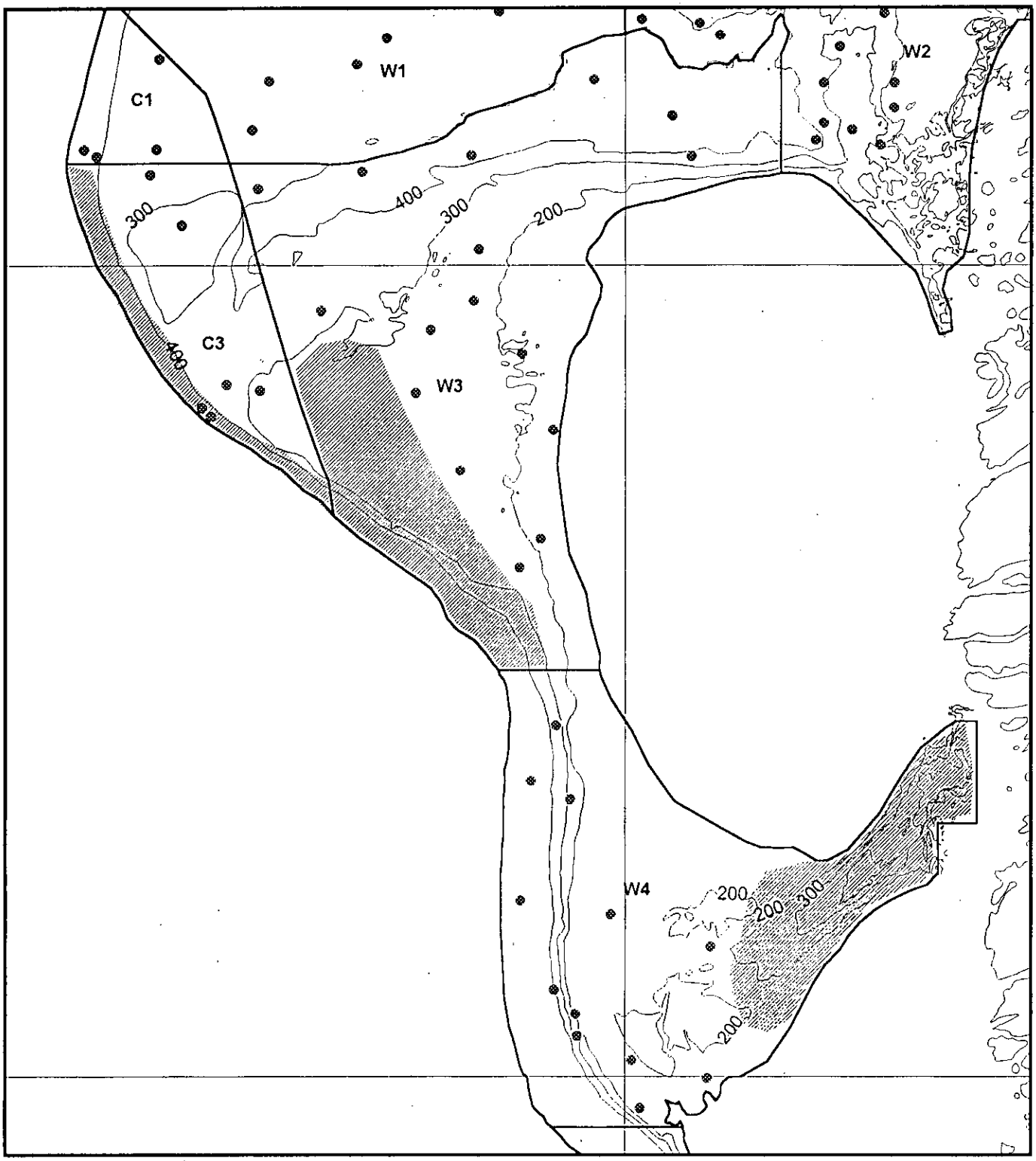

Figure 2. Distribution of stations in part of the survey area. Note the unbalanced coverage in stratum C3-4, the southern parts of W3, and in Holsteinsborg Deep (hatched areas, see text).

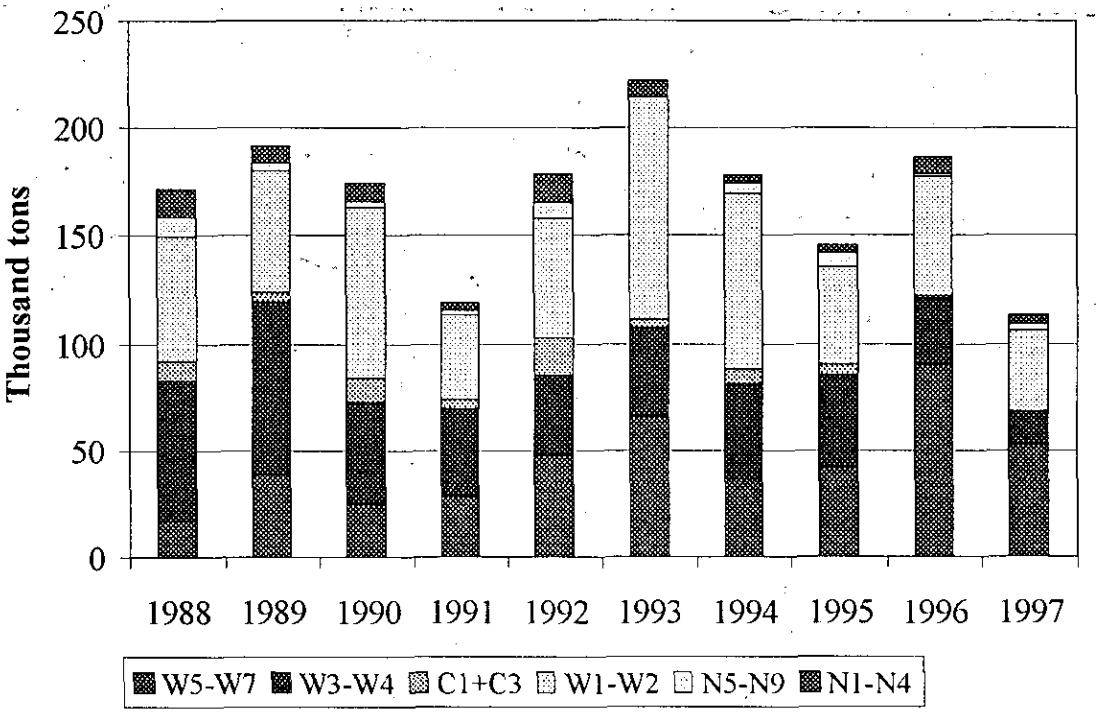

Figure 3. Estimated biomass in groups of strata for surveys in SA0+1 offshore, 1988-97.

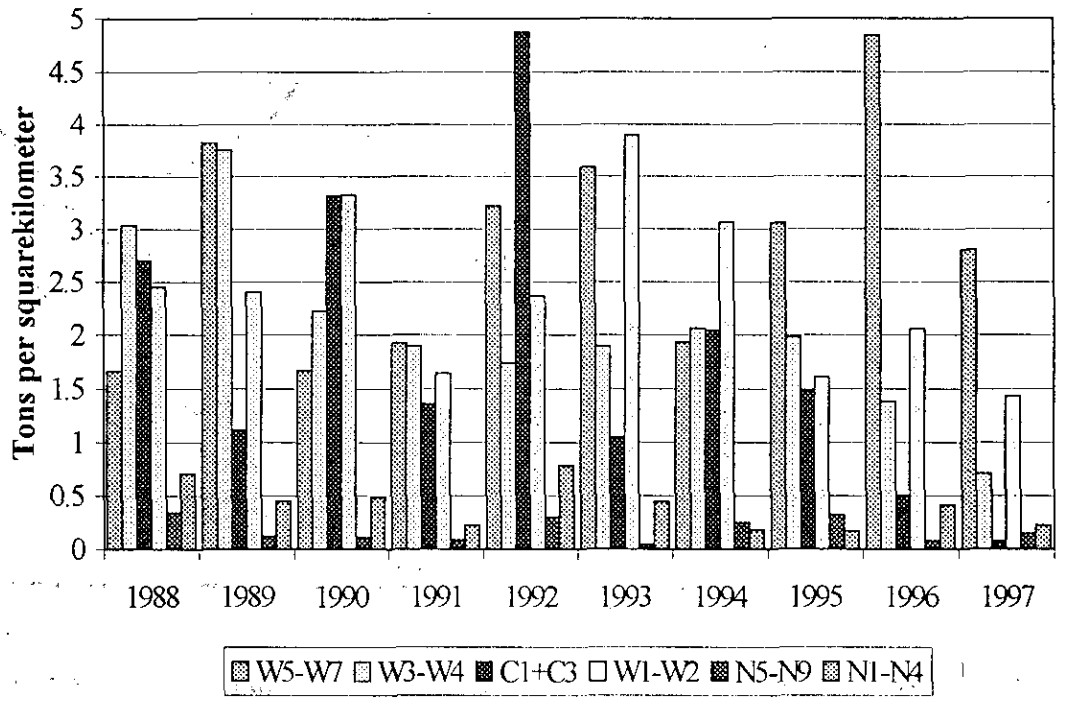

Figure 4. Estimated densities (tons per km²) in groups of strata for surveys in SA 0+1 offshore, 1988-97.

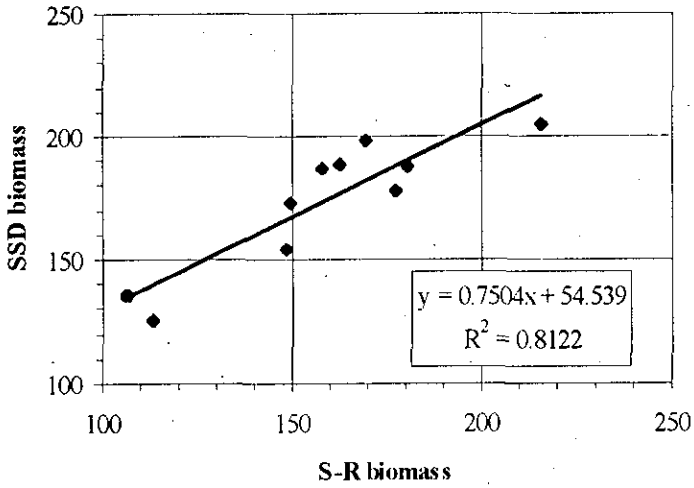

Figure 5. Comparison of two methods for calculating biomass estimates. The 1997 value is shown as a filled circle.

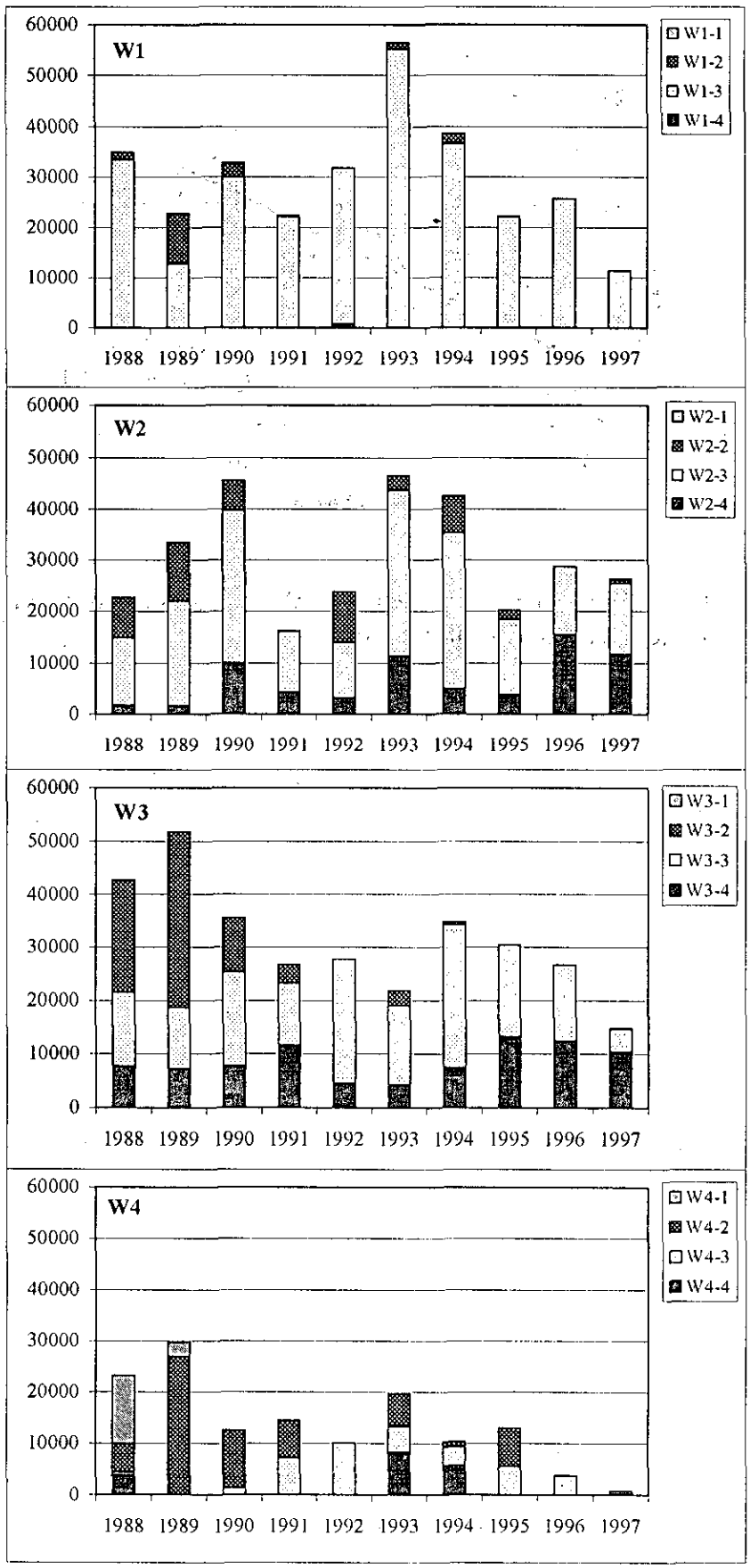

Figure 6a. Biomass estimates in depth strata for areas W1-W4, 1988-97.

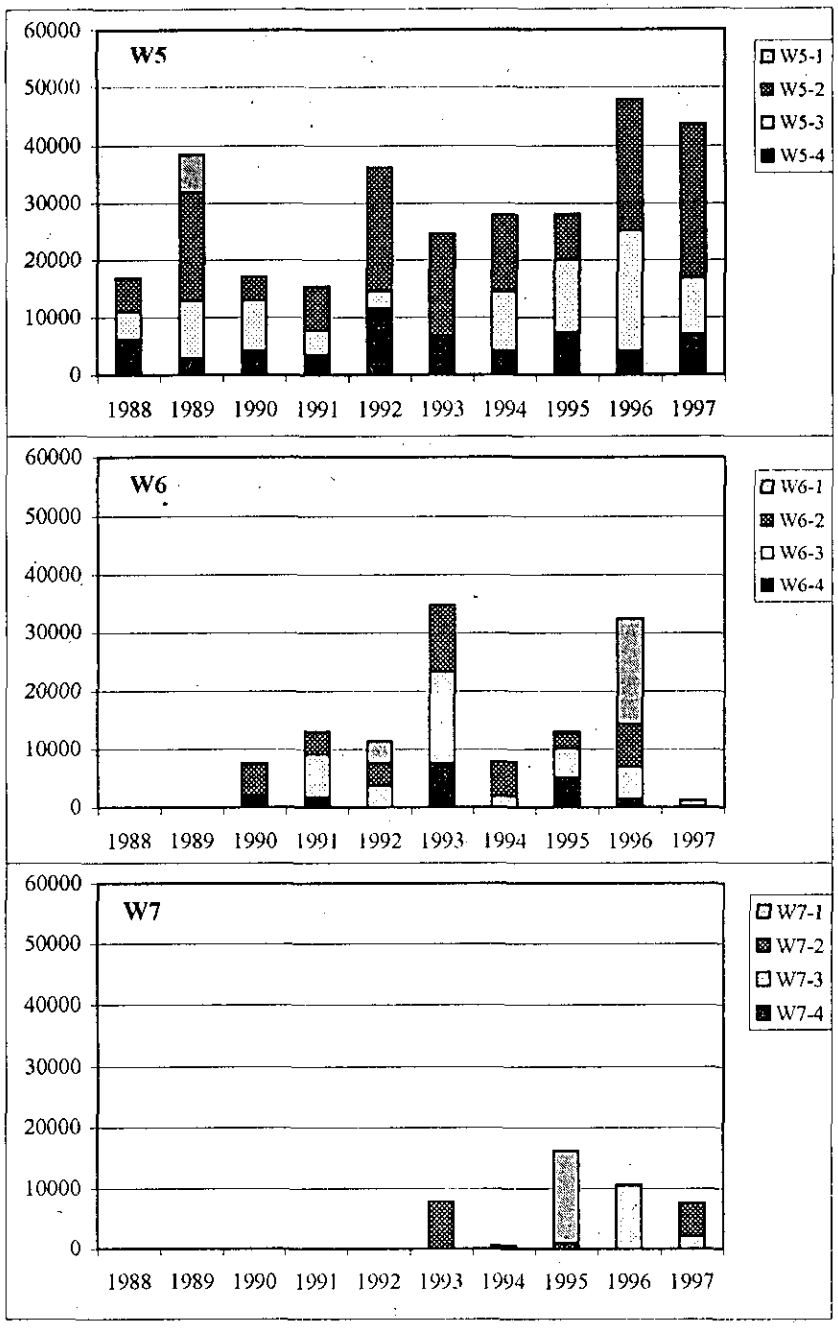

Figure 6b. Biomass estimates in depth strata for areas W5-W7, 1988-97.

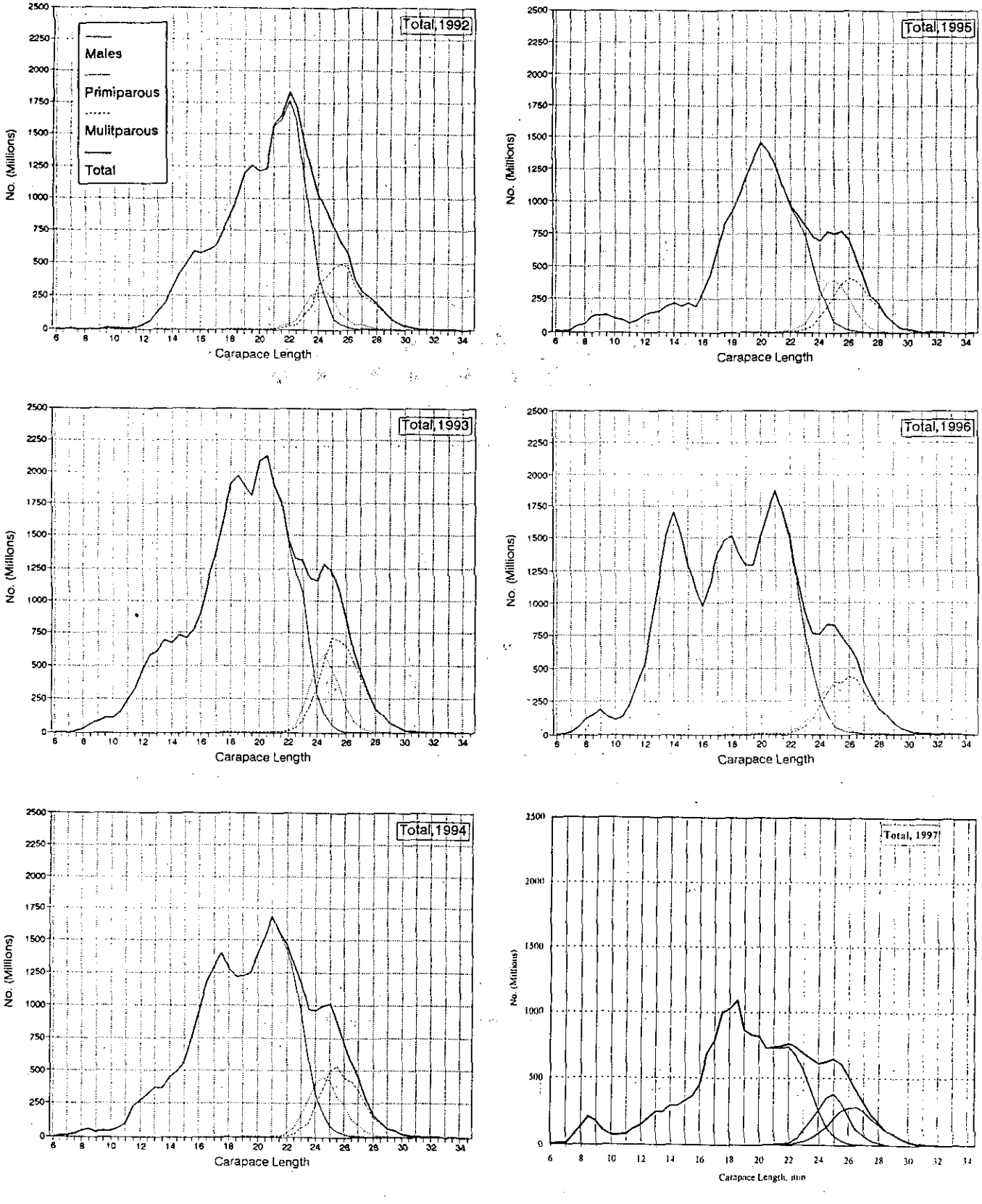

Figure 7. Numbers of shrimp by length group (CL) in total survey area (excluding area S) in 1992-97.

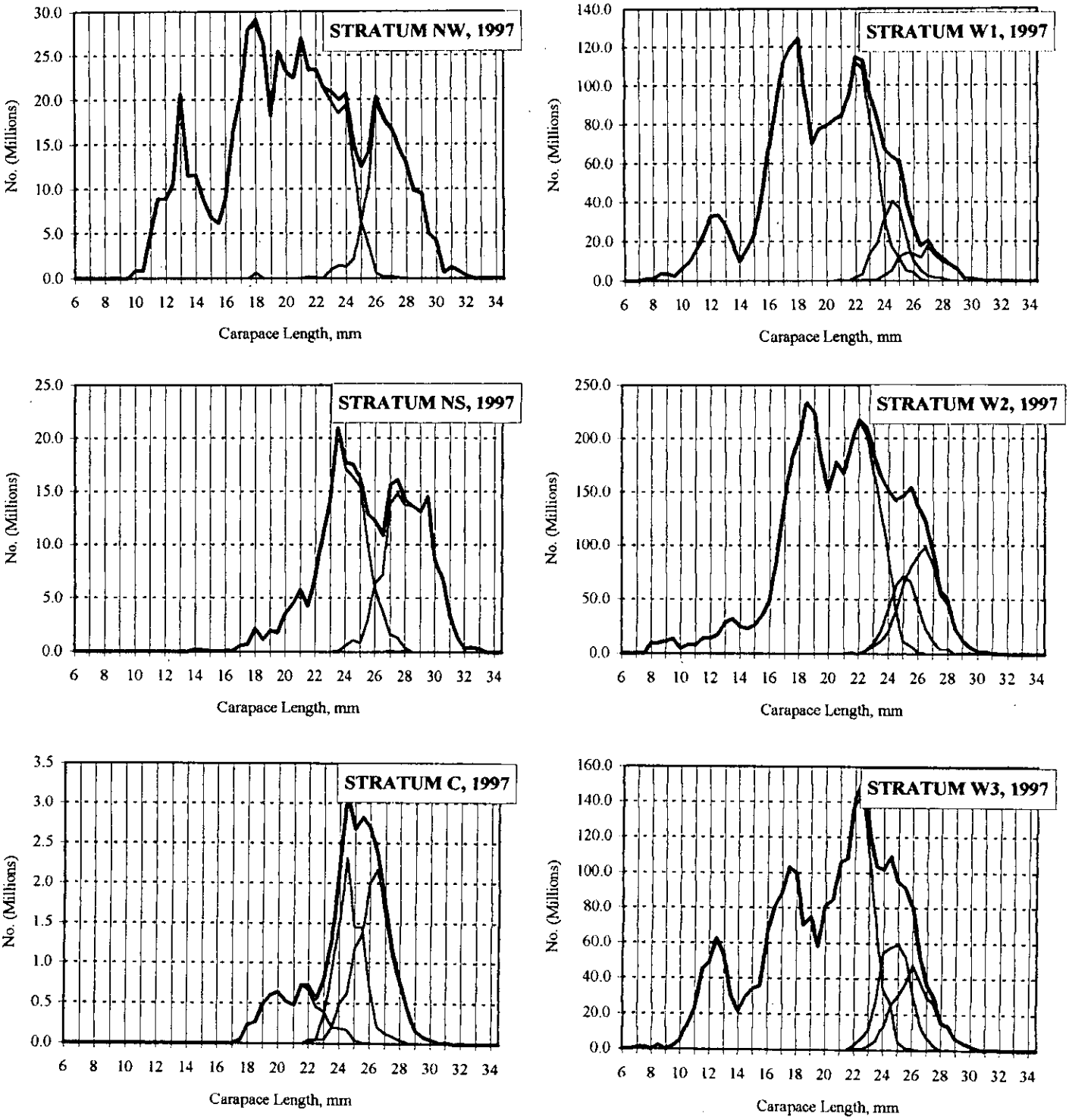

Figure 8a. Numbers of shrimp by length group (CL) in areas NW, NS, C and W1-W3 in 1997.

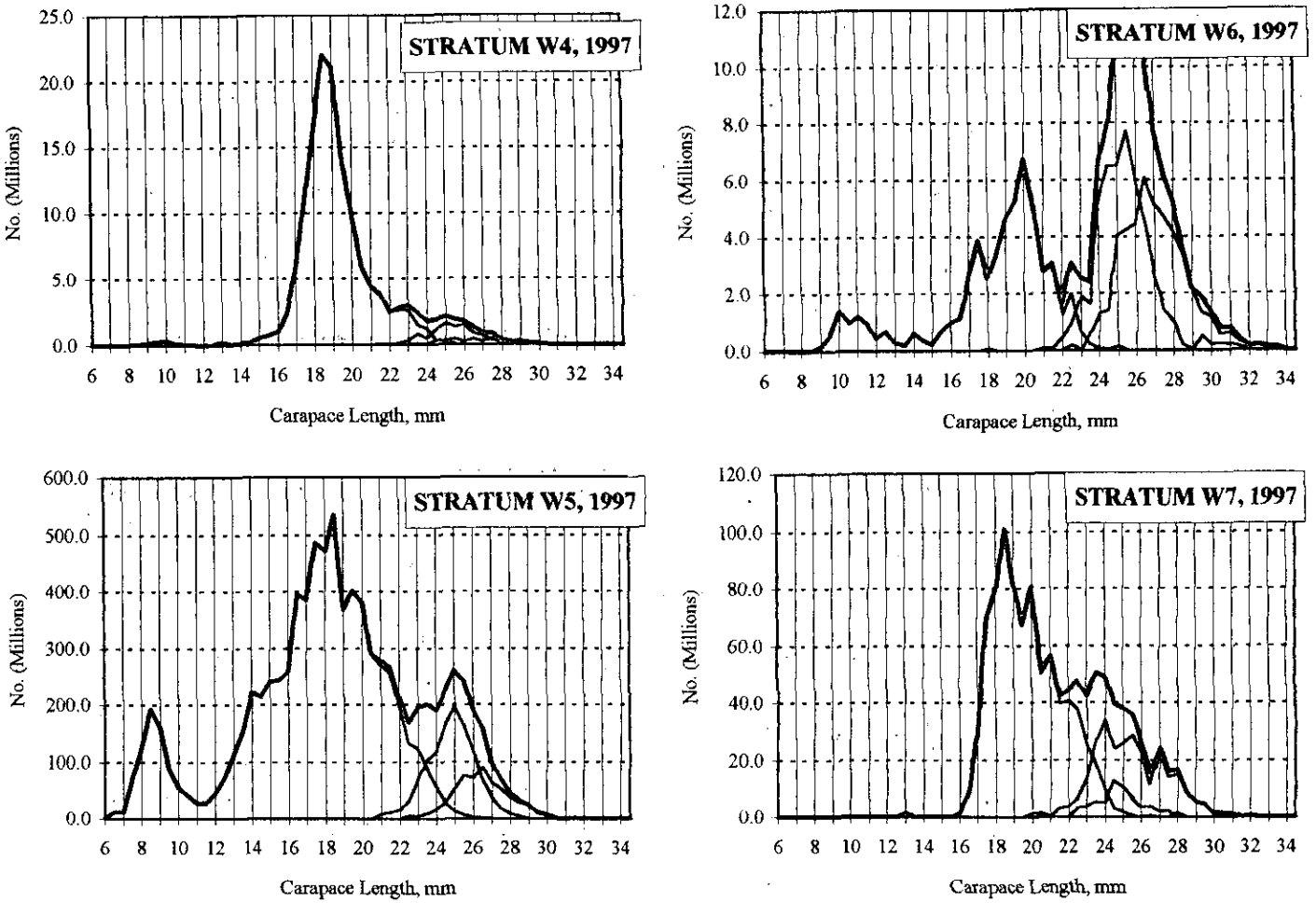

Figure 8b. Numbers of shrimp by length group (CL) in areas W4-W7 in 1997.

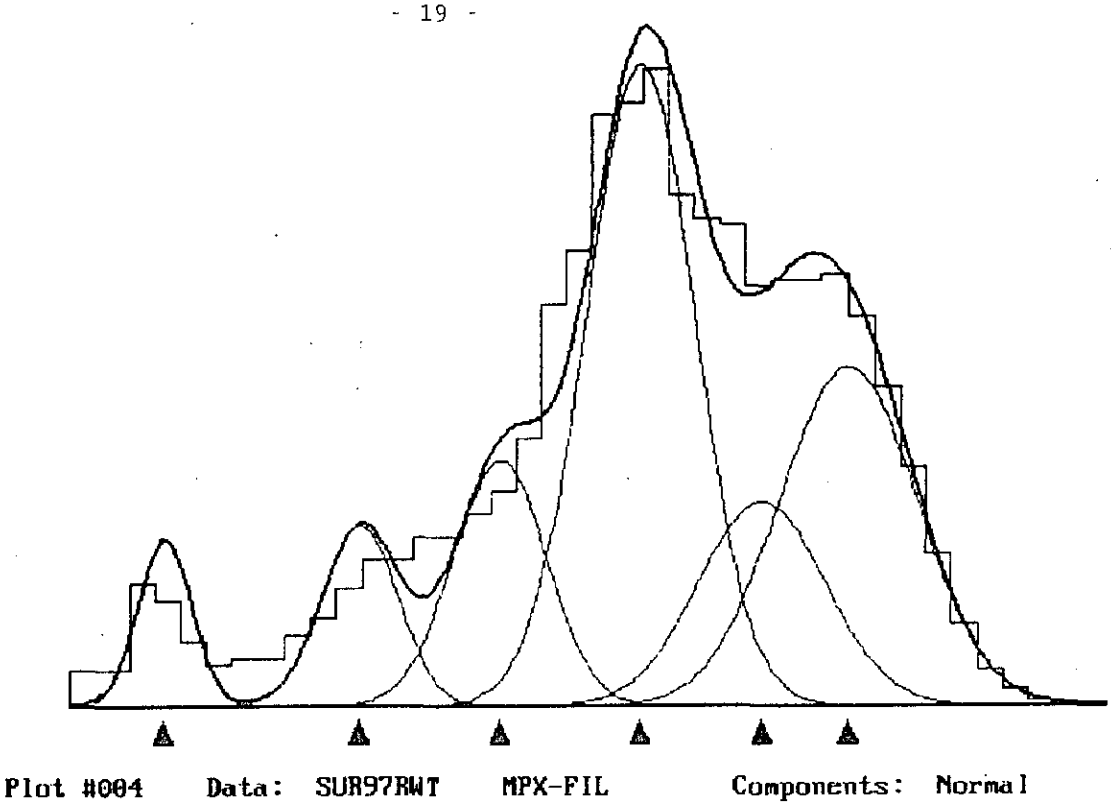

Figure 9a. Separation of cohorts in total length-frequency distribution (excluding region S). Six mode model.

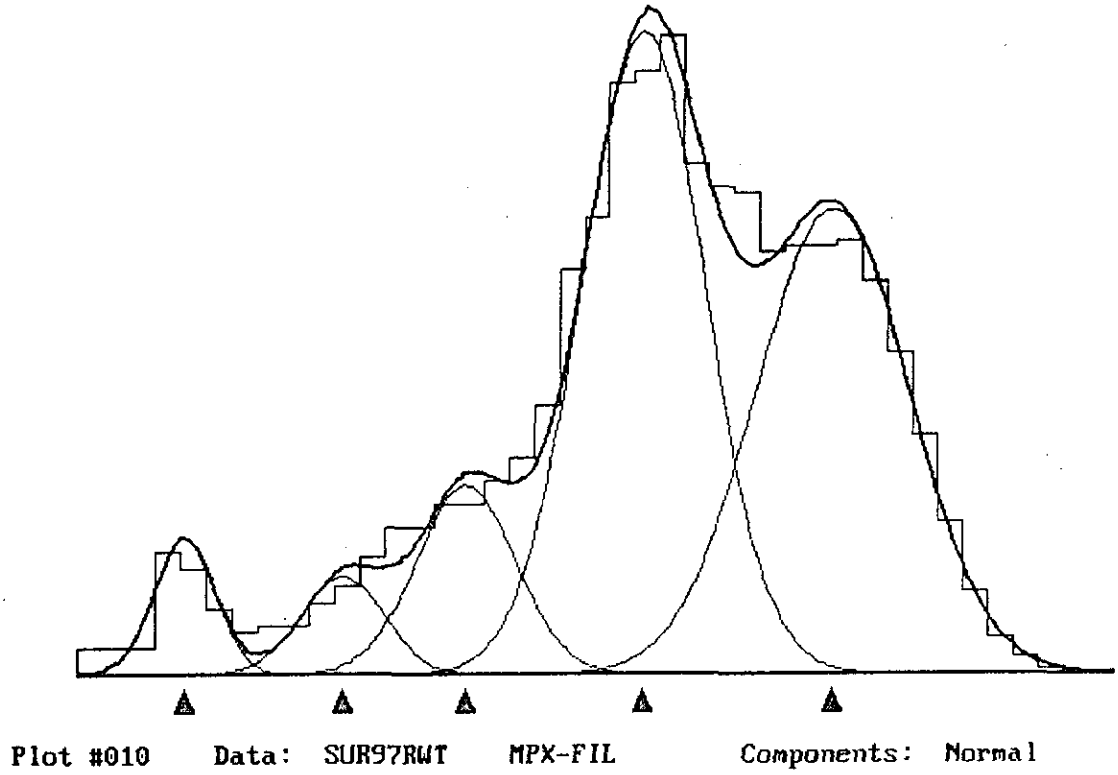

Figure 9b. Separation of cohorts in total length-frequency distribution (excluding region S). Five mode model.