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Stratified-random trawl survey for northern shrimp (*Pandalus borealis*) in NAFO Subarea 0+1, in 1999

by

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Introduction

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

This document presents the results of the 1999 survey, and compares them with previous results in the survey series.

The sampling data from the whole survey series since 1988 have been reviewed and checked over the last year, and the biomass estimates from earlier years (Carlsson & Kanneworff, 1998a and 1998b) have been recalculated. The revised estimates for earlier years are also presented in this report, which therefore supersedes its predecessors.

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 traditionally high shrimp densities in order to get a more precise biomass estimate. In order to optimise the sampling and in accordance with results from a study group (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.

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 (Appendix; Kingsley et al., 1999).

From 1988 through 1998 stations have been selected at random by re-placing sampling sites for each year. We wished to study the stability of the stock distribution and assess the performance of a fixed-station design relative to that of resampling. Therefore about 50 % of the stations from the survey in 1998, randomly chosen, were repeated as fixed stations in the 1999 survey. 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 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 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.

Following the recommendations from a study group (Carlsson et al., 1998) the tow duration was reduced. In the 1998 survey about 25 % of the offshore hauls lasted 30 minutes instead of the former 60 minutes. In the 1999-survey it was planned to tow for 60 minutes at 50 % of stations, 30 minutes at 25 % and 15 minutes at 25 % of the hauls.

Compared with earlier years more trawl hauls per day at sea have been taken and thus a better mean coverage of the areas: in 1999, 230 trawl hauls were taken (Fig. 1) compared with 167 in 1997 and 211 in 1998. Each haul represented on average 490 km² and 439 km² in 1998 and 1999 (region W) against 692 km² (overall mean) from 1988 through 1997.

Biological Samples

From each haul a sample of about 4 kg of shrimp was taken. Shrimp were sorted by species and sex, and for *Pandalus borealis* and *P. montagui* 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 *Pandalus borealis* by sex and length group for each stratum and for the total area.

All fish by-catch was sorted to species or species group and weighed.

In overall length distributions of *Pandalus borealis* from both offshore and inshore areas modes were identified by visual inspection and by application of the deviation method (Skúladóttir, 1981). Distributions were thereafter analysed for size components by modal analysis (Macdonald and Pitcher, 1979).

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 track length multiplied by the mean wingspread.

Revision of past survey data.

A revision of data from the whole survey series has been made over the last year. Corrections for occurrence of other species (e.g. *Pandalus montagui*) have been applied to the database. Samples from all years have been checked by means of length-weight keys, and some adjustments to the earlier given weight of some of the sample components have been introduced. Based on information from the 'trawleye' on the headrope of the trawl, used since 1995, a correction factor to the recorded durations for the hauls has been applied to the data before 1995. Finally, some other errors of different kinds (e.g. keying errors) were also corrected for.

Unweighted estimates of biomass (tow duration).

Three different target tow durations were used in 1999. Overall, 29 % of the tows lasted for about 60 minutes, 44 % for 30, and 23 % for 15 minutes. There were also a few tows that lasted 45 minutes (3 %) and 5 experimental zerolength tows. Analyses have so far not found that shorter tows are more variable (Kingsley et al., 1999). Therefore, no weighting was applied to tows of different durations. 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.

End-error.

The analysis of 1999 catches relative to tow duration indicates a positive end error (Kingsley et al., 1999). The true swept area appears to be about 3400 m^2 (SE 1540 m^2) greater than the nominal. This is about 14.9 % of the area of a 15-min tow, 3.7 % at 60 min. End error is more important when tows are shorter. It has not been allowed for in any of the calculations in this document. Owing to this effect alone, the 1999 result presented here is estimated to be biased upward by about 7½ %, relative to one-hour-tow surveys by about 3¾ %, and approximately unbiased relative to half-hour-tow surveys.

Variance and standard error calculations.

Stations were placed randomly in strata, but not independently. Buffered sampling spreads stations more evenly than independent random sampling, and is expected to increase precision, i.e. to reduce the true standard error of the biomass estimate. No unbiased estimate of true error variance exists; the conventional expression probably overestimates it. Preliminary analyses indicate that the difference is small, so the conventional expression has been used here. I.e. the survey is slightly more precise than calculated.

Satterthwaite's approximation for d.f. of SE.

In some regions, single strata have contributed most of the uncertainty in total biomass; and one region dominates the uncertainty of the overall result. For calculating the degrees of freedom appropriate to the sums of unequal variances, and resulting confidence intervals, Satterthwaite's (1946) approximation has been used.

Fixed stations.

The fixing of some stations from 1998 for the 1999 survey 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 previous years.

Results and Discussion

Biomass, Total Estimate

The database for the survey period 1988-99 has been revised, and all shrimp samples have been checked with length-weight keys and corrected for possible errors. Various adjustments for earlier inclusions of other species (a.o. *Pandalus montagui*) have been applied. These revisions caused major changes of the biomass estimates in some strata, but overall trends through the period have not changed significantly. The revised total estimates (Fig. 2) indicate less variation than the earlier given figures. The estimates for 1991 and 1997 are, however still considerably lower than other years' estimates.

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 1999 are:

REGION	BIOMASS ESTIMATE	NO. OF HAULS	CONFIDENCE LIMITS (95 %)
Disko	61,183	37	18,759
North	14,442	20	37,315
Canada	11,901	11	120,483
West	136,192	153	39,744
South	63,384	9	90,974
OVERALL	287,402	230	92,022

The very low biomass estimate for 1997 was followed by record highs in 1998 and 1999 (Table 2). In some years (especially in 1996-97) a more southerly distribution is indicated along the coast. High concentrations of shrimp have been detected in region S in the last three years. In 1999, the biomass in region S accounts for 22 % of the total estimated for all regions, but this estimate should be treated with caution as 68 % of the total error variance originates from this area. The sampling for that area may not be adequate. This may be the cause of the 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 for a much smaller proportion than the former.

For the 1997 and 1998 biomass estimates, higher than normal coefficients of variation for the region W were observed (Carlsson and Kanneworff, 1998a). This was explained by a more uneven distribution of the biomass than normal. The distribution of the biomass in 1999 (Fig. 1), however, seems to be more like the period before 1997, agreeing well with the observed lower coefficients of variation through the years (Table 3).

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-August), and seasonal variations are therefore assumed to be minimised. Fig. 4 and 5 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. In 1998 and 1999 the total biomass is estimated to be in the same area of magnitude, however with some decline in areas W3 and W4, counterweighted by increase in the northern areas, and especially in the stratum S1.

During the later years (1996-99) the biomass is indicated to be gradually more distributed towards shallower water compared to the period 1990-95 (Fig. 3). Also in 1988 and 1989 a large proportion of the biomass was observed in more shallow areas. In both periods small shrimp were more abundant in the survey catches. When the large 1985-yearclass entered the catches it first showed up in areas W4 and W5 in shallow water (Fig. 6 and 7).

Fig. 6 shows the biomass estimates in depth strata in the main areas W1-W7 from all years of surveys. Until 1994 the area W1 constituted a large proportion (> 10 %) of the estimated total biomass. Most of the biomass was found in the depth layer 300-400 m. Again in 1999 some increase is observed. However, this area is very large and the density of shrimp has consistently been low compared with other areas (Fig. 7), and the area has therefore been of low interest for the commercial fleet through most of the years.

In the main areas W1, W3 and W4 a general decline of the biomass is seen from 1993(-94), discontinued by a significant increase in W3 and W4 in 1998 and in W1 in 1999. In W3 higher concentrations in 1998 than in the preceding seven years were found in the depth interval 200-300 m. Extremely high densities were in the same year met in depths > 300 m in W4. In 1999, fairly high densities of shrimp were observed in many of the strata, and in general, a more even distribution of the biomass was seen than in the preceding year.

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 general good stability in the average density. In the areas around St. Hellefiskebanke (W2-W4) a development in the depth distribution from shallow to deeper water was observed 1988-97. In the latest two years a larger part of the biomass has again been observed in shallower water (200-300 m). In the area W5 the biomass seems to have been fairly stable, even with an increasing tendency in 1992-97. In 1998 and 1999, however, a significantly lower biomass is indicated. The southern 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 has apparently mainly taken place from the northern and western areas (W1, W3 and W4) to W5. Further southward displacement to W6 was seen only in 1993 and 1996.

The region South has exhibited very large between-year variation in the estimated biomass (1994-99, 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 1e).

Stock Composition

Total abundance

Estimated total number of shrimp in the survey area (including both inshore and offshore areas) from 1988 to 1999 are given in Table 4. Total number of shrimp was at the same high level as in 1998, higher than all other years. While number of female shrimp decreased insignificantly compared to 1998, the number of male shrimp in 1999 is the highest on record (Table 4 and Fig. 8).

Size group abundance by areas

Overall length distributions for the offshore survey area from 1988-99 are shown in Fig.s 9a and 9b, and for the inshore survey area from 1991-99 in Fig.s 10a and 10b. Fig.s 11(a-b) and 12(a-b) show total length frequencies by areas in 1999 offshore and inshore, respectively. Offshore areas north of 69º30'N are combined in area NW (N1-N4) and area NS (N5-N9), areas on the Canadian side of the midline are combined into region C (C1 and C3), while the southermost areas S1 and S2 are combined in area S.

The overall length-frequency distribution for the offshore area in 1999 show a number of distinct male modes (at 9, 15, 19-20 and 22 mm CL), a mode of primiparous females at 24 mm CL and one of multiparous females at 26 mm CL. Compared to the distribution from the same area in 1998, where a group of males around 20 mm totally dominated the male group (Carlsson and Kanneworff, 1998a), the 1999 data show several significant size groups. For both years, however, the presence of several male groups are promising in terms of recruitment to the female group in coming years.

The overall length-frequency distribution for the inshore area in 1999 show similar male and multiparous modes as in the offshore area, however with a higher proportion of smaller males. As primiparous females in this context are defined as pre-first-spawning females, they are almost absent in the inshore area, because the survey is performed at a time when most spawning has taken place.

Length distributions for offshore stratification areas in 1999 (Fig. 11a and 11b) show dominance of the larger male groups in all areas, smaller males, however, being relatively more abundant in the southern strata W4, W5, and W6, as it normally has been the case in the past (Carlsson and Kanneworff, l.c.). In the southermost strata (area S) the distribution is dominated by large males, while shrimp below 17 mm CL are almost absent. Similar modes of males as in the offshore areas can be found in length distributions for inshore stratification areas (Fig. 12a and 12b), but there is too much noise in these figures because sample size has been too small.

Length-at-age interpretation

A length-at-age key for the West Greenland offshore northern shrimp stock was established by Savard et al. (1994) and has been applied since then in the analysis of length distributions from this area. According to this interpretation the male component consisted of six size groups, considered to by age group one to six. Sex reversal would generally take place at age seven. This key has also been found relevant for the analysis of age structure of inshore shrimp, as basically the same size groups occurred in shrimp samples from this area.

However, over the last few years significant modal groups moved through the length frequency distributions from the inshore areas, occurring not to be in agreement with the offshore length-at-age interpretation. Inshore length distributions from recent surveys were therefore reanalysed, and a new length-at-age interpretation was established (Carlsson, 1997; Carlsson and Kanneworff, 1998a), identifying five modal groups of males, around 9, 13-14, 17, 20-22, and 22-24 mm carapace length.

In 1998, visual inspection of length-frequency distributions from the offshore survey areas in 1997 indicated that the new inshore length-at-age interpretation might be more applicable than the old model in these areas also. By modal analysis using the MIX program five male modes resulted in a better fit than six modes, and these modes were similar to those found in survey data from inshore Disko Bay areas in 1997 (Carlsson l.c.) and were especially prominent in the areas off the Disko Bay (areas W1, W2, and W3).

In 1999, visual inspection of length-frequency distributions from both the inshore and the offshore survey again indicated a new growth pattern in both areas, as the male modes at 13 and at 16-17 mm carapace length appeared to be missing and replaced by one mode at 15 mm CL. To elucidate this problem, overall distributions from both areas from 1993 (after the shift from 44 mm to 20 mm mesh size in the cod-end) to 1999 were examined by the deviation method (Skúladóttir, 1981): the mean distribution for all years are subtracted from the annual distributions, which makes it possible to follow significantly abundant or small year classes from year to year. Deviation diagrams for the offshore and inshore survey areas are shown in Fig. 14 and 15 (Fig. 13 show deviation diagrams for the offshore areas from 1988 to 1992 and clearly indicate the progression of the '1985 year-class').

For the offshore areas (Fig. 14) there seems to be too much noise to draw obvious conclusions on the progress of cohorts from year to year, and the analysis should probably be based on smaller areas. For the inshore areas (Fig. 15) data indicate that the five-male-mode model is applicable from 1993 to 1997, and that a change in growth pattern takes place between 1997 to 1998. A preliminary analysis of both offshore and inshore overall length distributions from 1998 and 1999 indicate faster growth and a change of sex at age five in both years. This change may be the result of a change in the temperature regime between 1997 and 1998 as described by Carlsson and Kanneworff (1999).

Conclusions

During the period of stratified random surveys in the offshore areas of shrimp distribution the biomass estimates have indicated a good stability, ranging from 170 to 290 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. Some areas account for a large proportion of the variances of the estimated biomasses. The survey design has been evaluated and adjusted in order to reduce the sampling variation and to study and optimise the performance of the sampling.

Total number of shrimp in 1999 is at the same high level as in 1998. While the number of female shrimp is similar to 1998, number of males is at the highest level recorded, and recruitment to the female group appears to be secured for the coming years.

Inspection of overall length-frequencies the deviation method and a preliminary modal analysis of offshore and inshore length distributions indicate a change between 1997 and 1998 to faster growth. At the same time age at sex reversal appears to have changed from six years to five years.

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Table 1a. Estimated trawlable biomass and sampling statistics for strata in region W, 1999.

AREA	STRATUM	SQKM	HAULS	TONS	STD	CV
W1	150-200 M	2416	2	2	3	139
	200-300 M	5295	14	5650	9710	172
	300-400 M	9239	24	15699	18010	115
	400-600 M	752	2	1	1	141
W2	150-200 M	1857	2	5	5	103
	200-300 M	3026	7	7484	12566	168
	300-400 M	2158	4	1838	13384	71
	400-600 M	1723	2	6505	2806	43
W3	150-200 M	2215	2	15	16	108
	200-300 M	4810	14	7945	8565	108
	300-400 M	2714	7	5043	3539	70
	400-600 M	3361	8	6757	5102	76
W4	150-200 M	4252	5	216	245	113
	200-300 M	1791	9	3081	4592	149
	300-400 M	812	4	2995	2656	89
	400-600 M	1967	5	34	34	100
W5	150-200 M	1995	3	6510	11272	173
	200-300 M	3454	9	20072	21133	105
	300-400 M	1797	4	2765	5310	192
	400-600 M	2806	7	230	442	192
W6	150-200 M	1095	2	544	766	141
	200-300 M	1491	4	16835	23059	137
	300-400 M	1300	4	8467	6601	78
	400-600 M	884	2	494	128	26
W7	150-200 M	2419	2	3	4	121
	200-300 M	985	3	2	2	112
	300-400 M	239	2	0	0	141
OVERALL			Standard Error	18684	Error CV	14

Table 1b. Estimated trawlable biomass and sampling statistics for strata in region C, 1999.

AREA	STRATUM	SQKM	HAULS	TONS	STD	CV
C1	300-400 M	655	2	950	790	83
	400-600 M	312	1	8	8*	100*
C3	200-300 M	660	2	10244	13385	131
	300-400 M	1192	4	691	338	49
	400-600 M	623	2	8	11	138
OVERALL			Standard Error	9482	Error CV	80

*) Estimated from STD = biomass * 0.985

Table 1c. Estimated trawlable biomass and sampling statistics for strata in region D, 1999.

AREA	SQKM	HAULS	TONS	STD	CV
D1	819	3	2053	759	37
D2	566	2	5314	1486	28
D3	1124	4	10312	11993	116
D4	1834	7	14998	5763	39
D5	612	3	5974	3643	61
D6	1014	4	7169	5791	81
D7	1447	6	5991	3616	60
D8	652	3	3371	3079	91
D9	1296	5	6012	7295	121
OVERALL		Standard Error	8414	Error CV	14

Table 1d. Estimated trawlable biomass and sampling statistics for strata in region N, 1999.

AREA	SQKM	HAULS	TONS	STD	CV
N1	3664	2	1967	842	43
N2	11740	4	21	34	161
N3	368	1	624	615*	100*
N4	2257	2	6628	9213	139
N5	2985	2	237	14	6
N6	10830	3	4274	7310	171
N7	1029	2	0	1	141
N8	3237	2	165	198	120
N9	2407	2	527	732	139
OVERALL		Standard Error	7803	Error CV	54

*) Estimated from STD = biomass * 0.985

Table 1e. Estimated trawlable biomass and sampling statistics for strata in region S, 1999.

STRATUM	SQKM	HAULS	TONS	STD	CV
S1	1993	5	63665	73268	115
S2	4526	4	19	23	126
OVERALL		Standard Error	32766	Error CV	51

Table 2. Biomass estimates 1988-99 (thousand tons) in combined areas from north to south. Standard errors and error percentages are also given.

Area	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
N1-N9	21.7	11.3	11.1	5.8	20.6	8.0	8.0	8.2	10.0	7.2	8.3	14.4
D1-D9	-	-	-	50.6	47.4	33.6	40.0	47.3	54.3	52.3	61.9	61.2
W1-W2	58.6	48.2	82.1	30.9	52.0	103.1	107.7	43.7	53.8	40.1	42.2	54.2
W3-W4	74.4	79.6	54.2	52.4	35.0	41.3	49.7	58.6	34.9	15.1	107.1	26.1
C1+C3	9.6	3.9	11.1	4.8	24.1	3.4	6.8	4.4	1.7	0.2	0.4	11.9
W5-W7*	19.0	38.6	23.3	28.1	46.1	67.5	37.7	53.0	90.5	66.5	50.9	55.9
S1-S2	-	-	-	-	-	-	20.7	1.7	3.7	24.9	22.3	63.7
Total	183.3	181.5	181.8	172.6	225.1	256.8	270.6	217.1	248.9	206.2	293.3	287.4
SE	24.7	32.3	32.6	22.8	30.4	30.1	53.0	29.2	40.1	30.6	55.6	40.6
%	13.5	17.8	17.9	13.2	13.5	11.7	19.6	13.5	16.1	14.8	18.9	14.1

*) 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 1988-99.

			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

Table 4. Numbers (billions) of male and female northern shrimp in over-all length distributions from the total survey area (including region S and inshore areas; mean values for inshore areas 1991-1999 used in 1988-1990).

Year	males	females	total	males, %	females, %
1988	25.5	10.0	35.5	71.9	28.1
1989	36.2	7.6	43.9	82.6	17.4
1990	29.8	10.1	39.8	74.7	25.3
1991	17.4	6.2	23.6	73.8	26.2
1992	29.7	7.3	36.9	80.3	19.7
1993	35.6	9.9	45.4	78.3	21.7
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	83.7	16.3
1997	29.5	7.6	37.0	79.6	20.4
1998	42.9	11.5	54.5	78.8	21.2
1999	44.8	11.3	56.2	79.9	20.1
Average	33.0	9.0	42.0	78.2	21.8

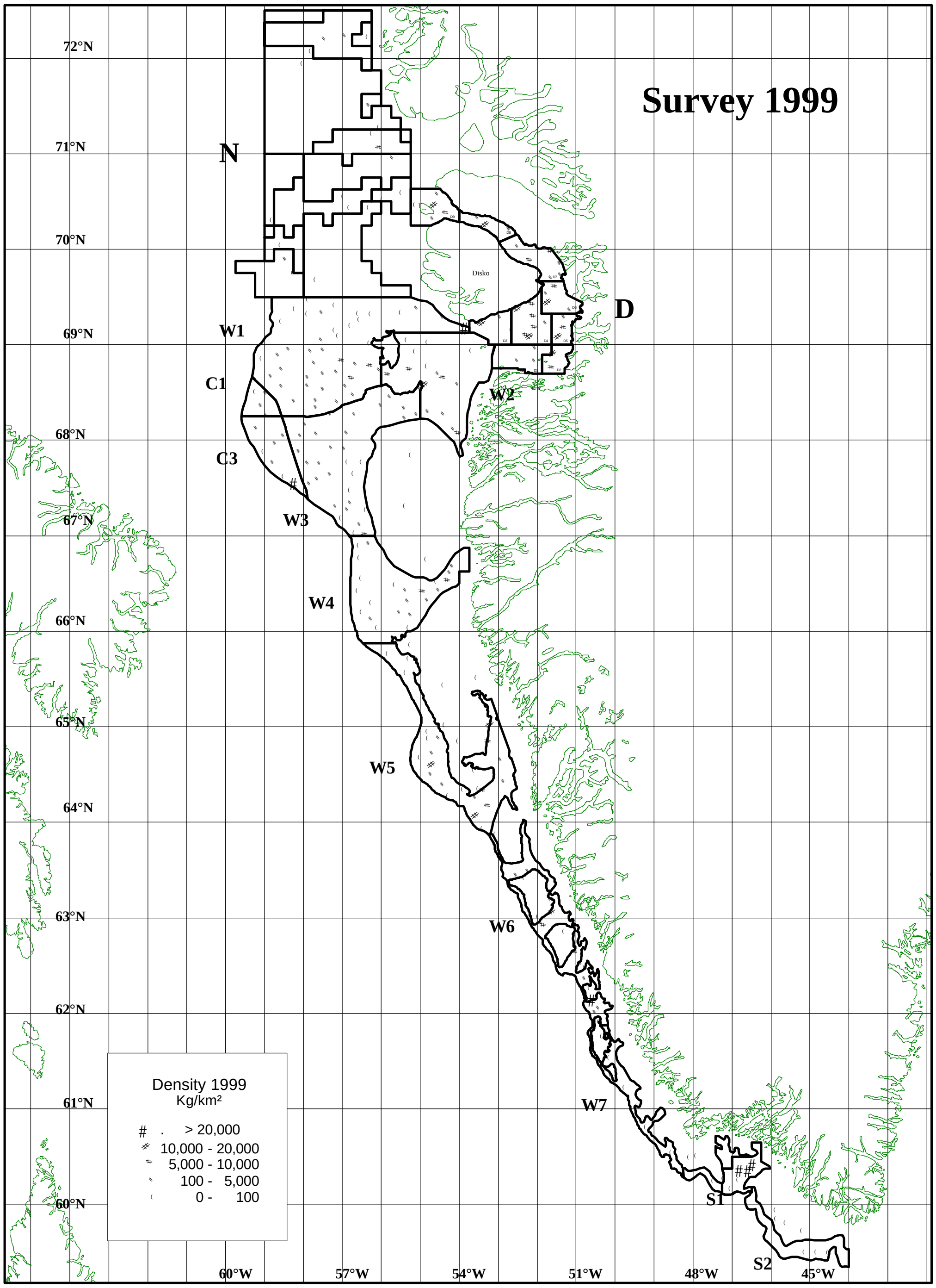


Figure 1. Sampling sites and shrimp densities in the trawl survey 1999.

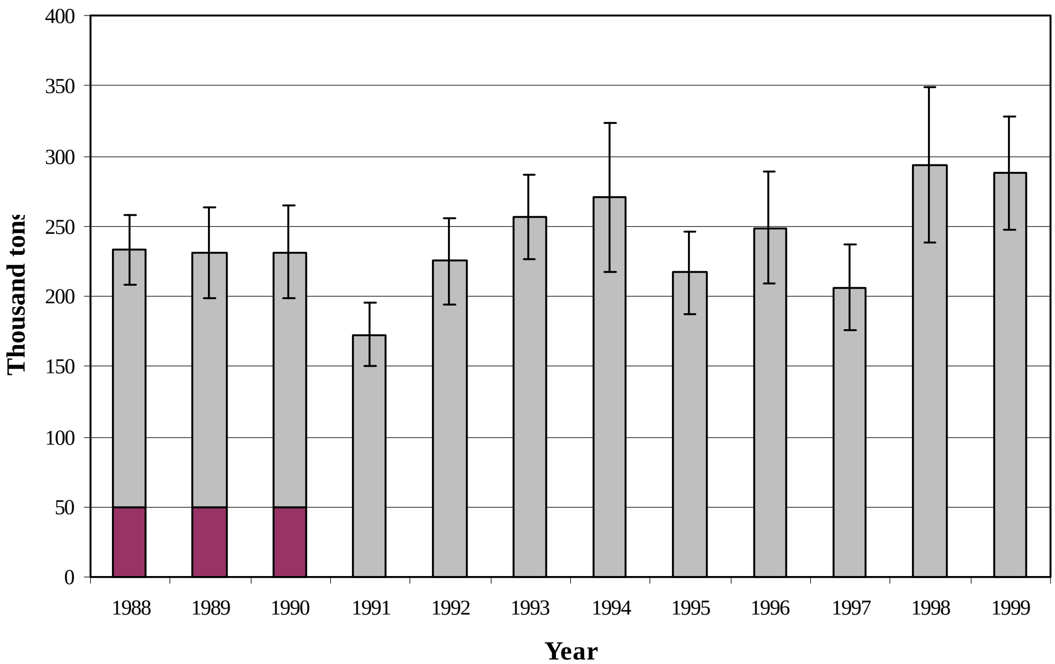


Figure 2. Estimated total yearly biomass 1988-99 with standard errors. Average biomass estimate for inshore areas 1991-1999 is inserted in 1988-1990 to facilitate between-year comparisons.

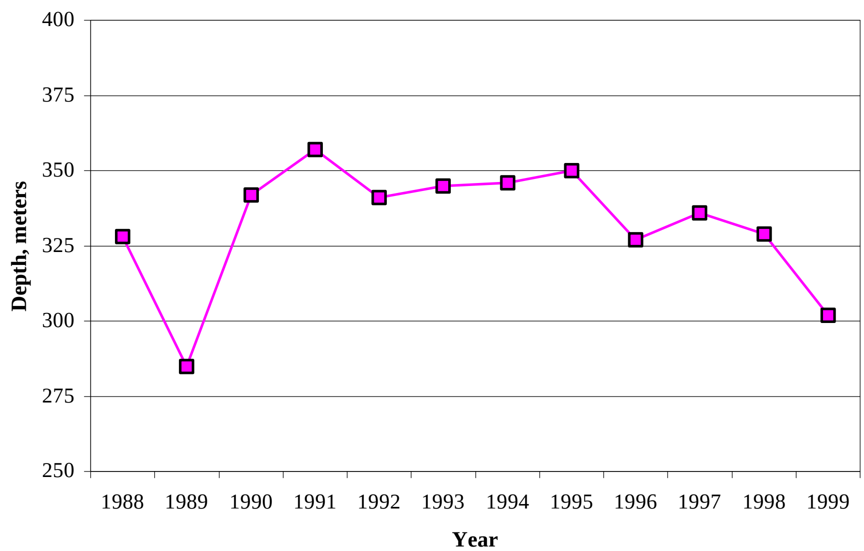


Figure 3. Mean depths with observed highest densities (kg per sq.km) in the survey catches 1988-99 for the central strata in Davis Strait (regions W and C).

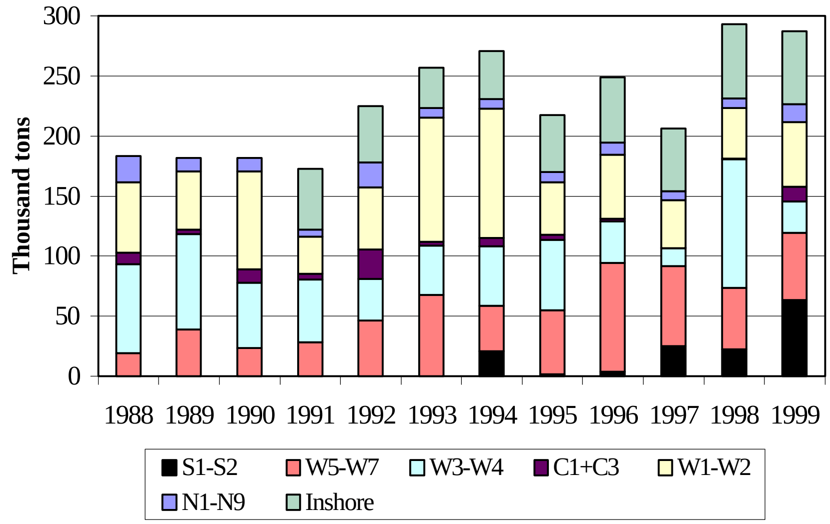


Figure 4. Estimated biomass in groups of strata for surveys in SA0+1, 1988-99. Note that surveys in inshore areas were carried out from 1991 only.

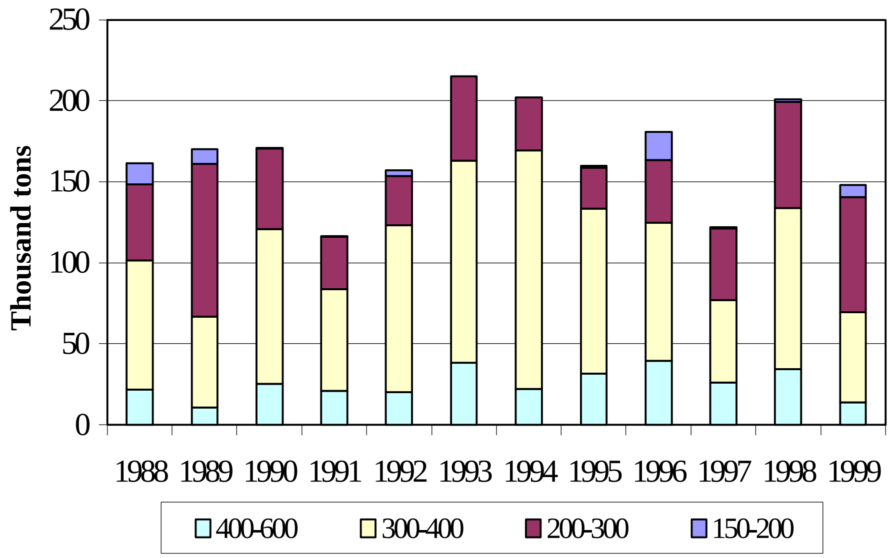


Figure 5. Estimated biomass in depth strata (regions W and C only) for surveys in SA0+1 offshore, 1988-99.

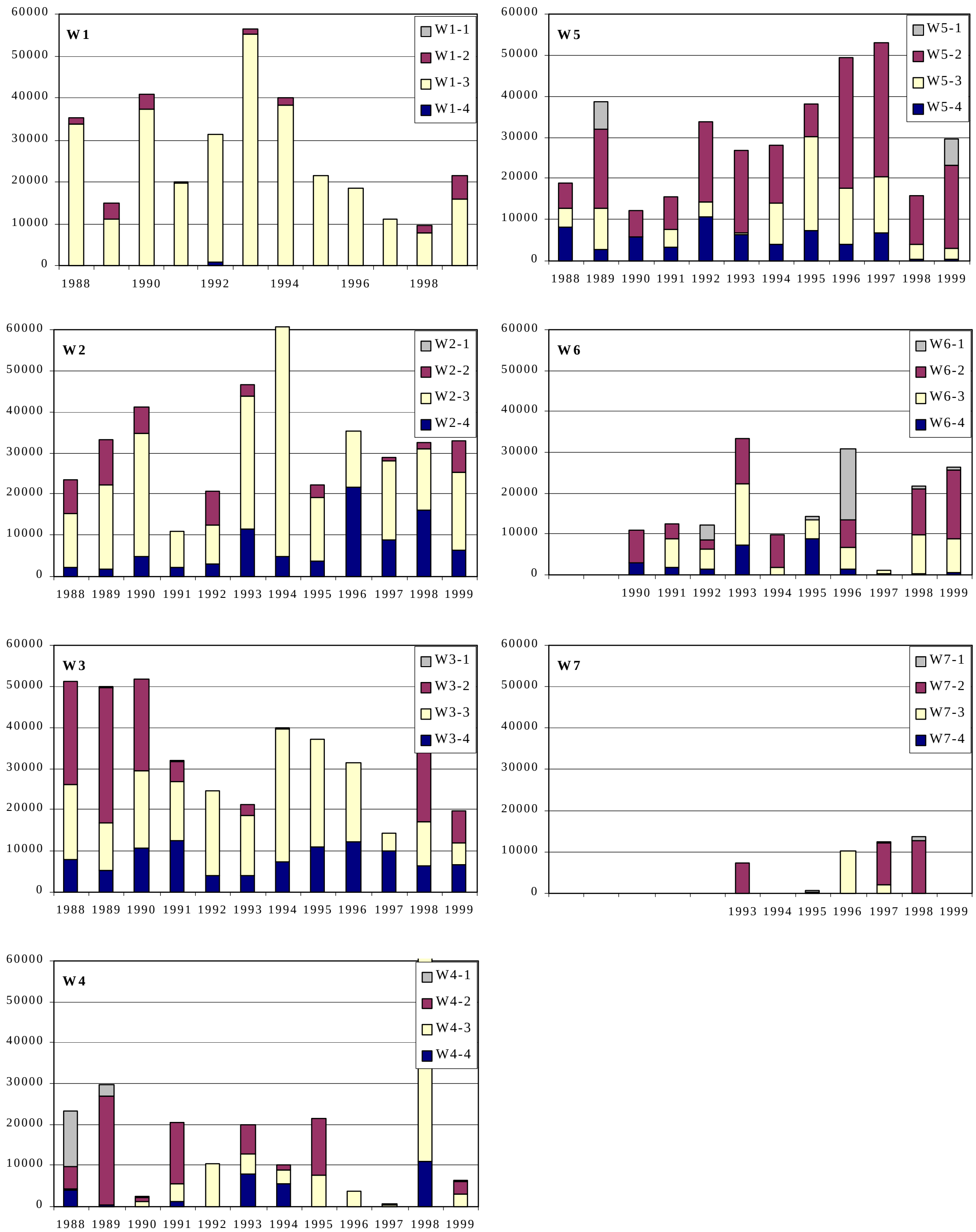


Figure 6. Biomass estimates of shrimp (tons) in region W in depth strata, 1988-99.

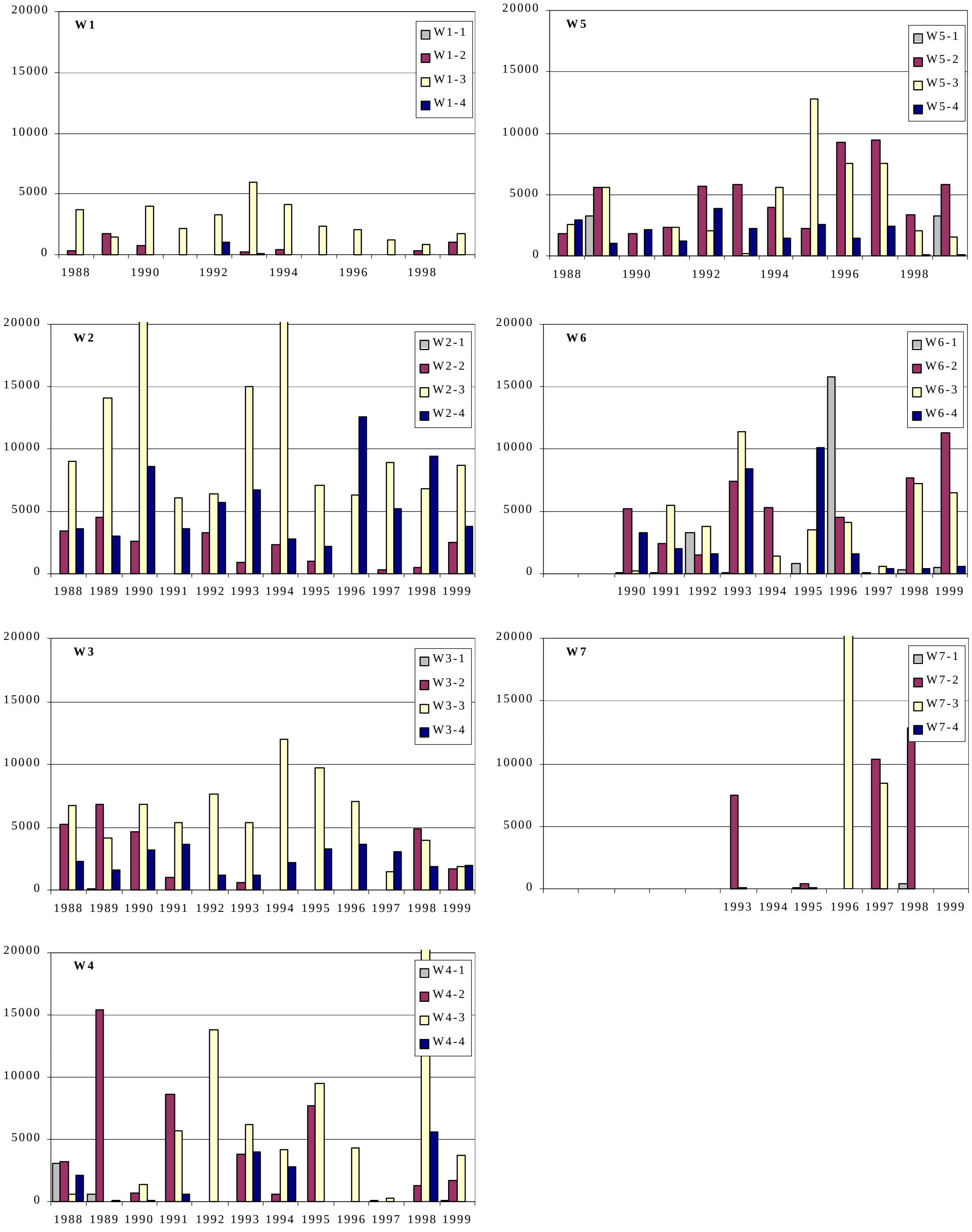


Figure 7. Estimated densities of shrimp (kg/km²) in region W in depth strata, 1988-99.

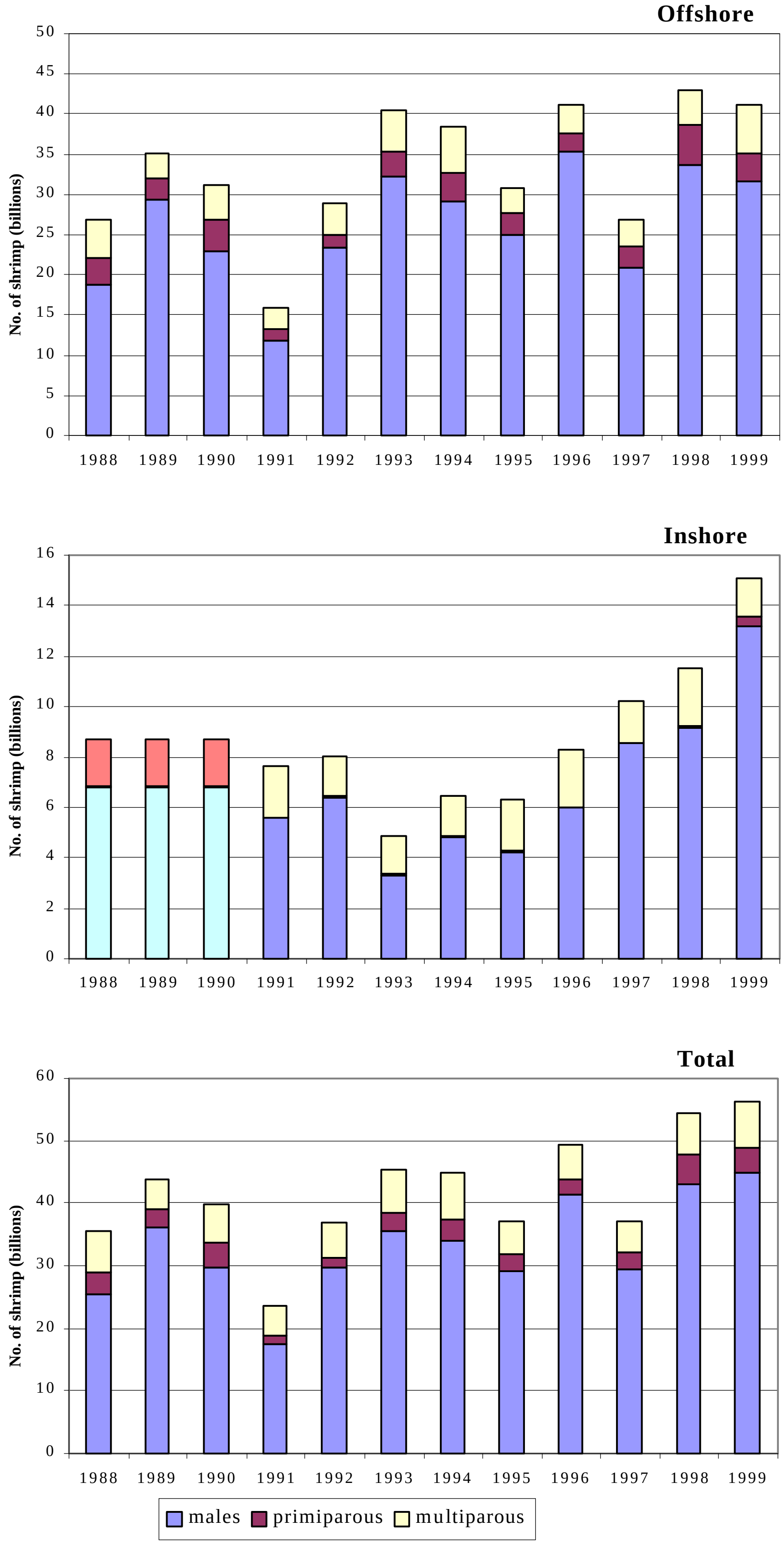


Figure 8. Estimated total number of northern shrimp in offshore, inshore and total survey area by sexual stage (mean values for inshore areas 1991-1999 inserted for 1988-1990 for comparison).

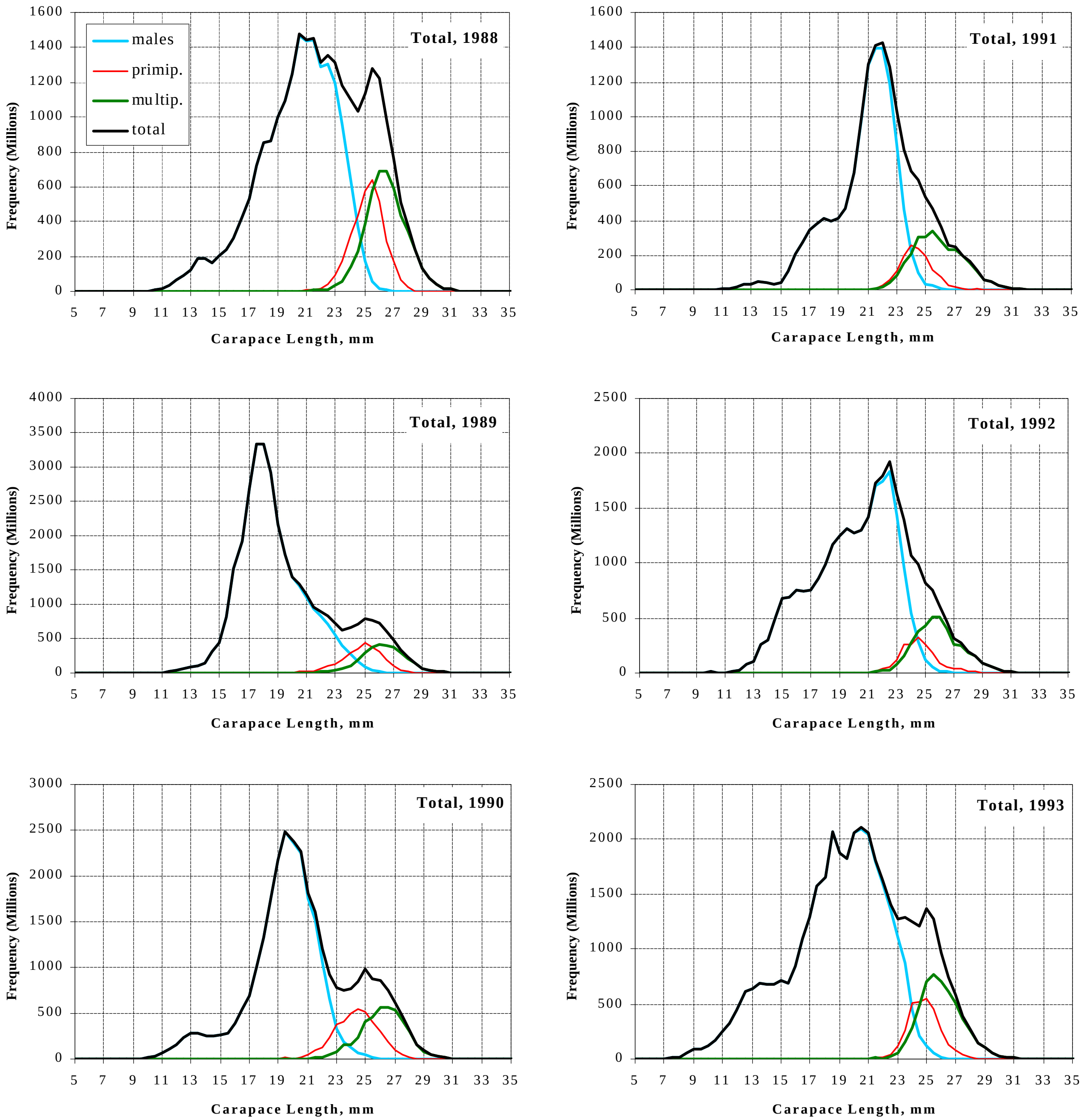


Figure 9a. Numbers of shrimp by length group (CL) in total offshore survey area (excluding region S) in 1988-93.

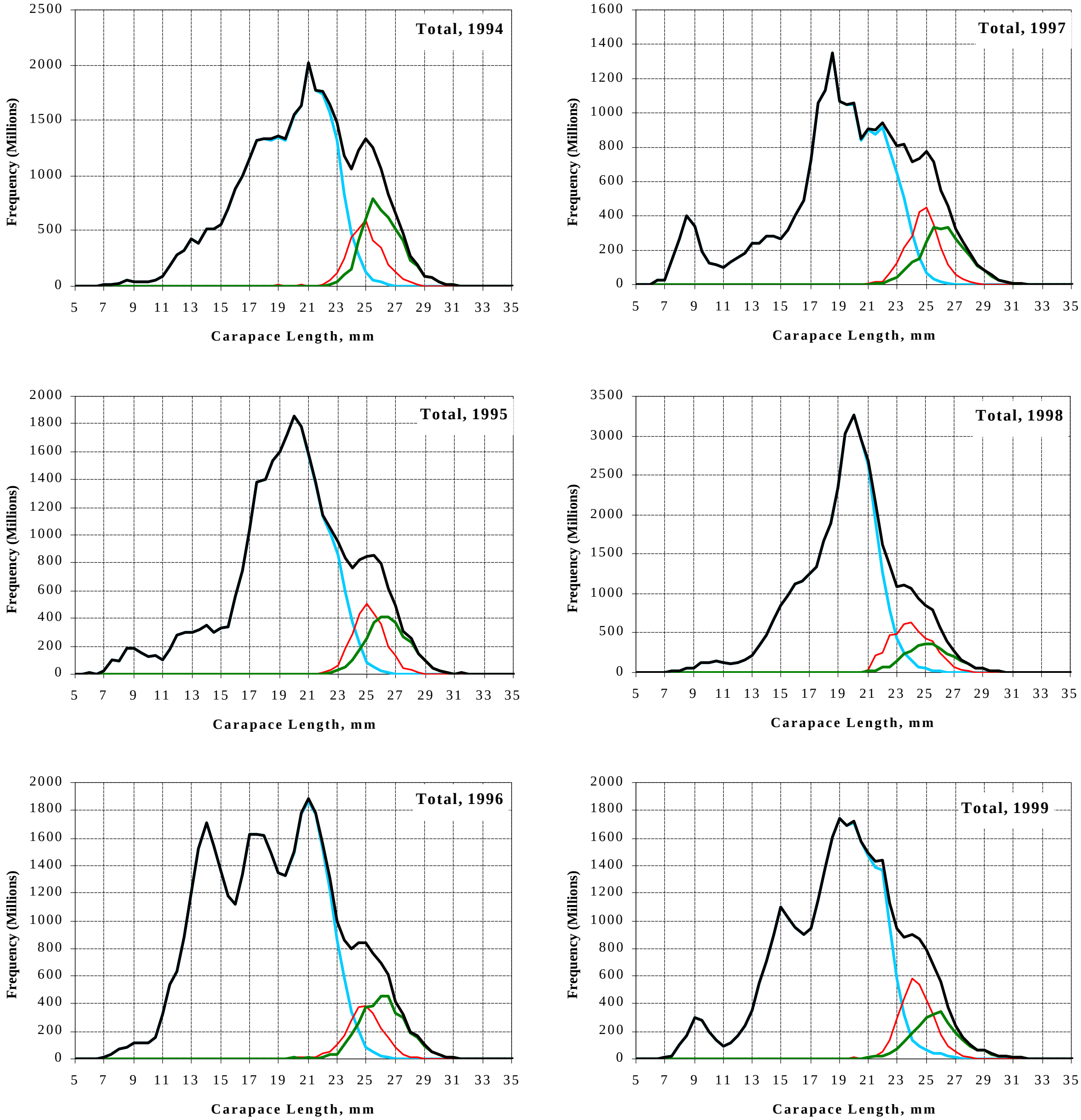


Figure 9b. Numbers of shrimp by length group (CL) in total offshore survey area (excluding region S) in 1994-99

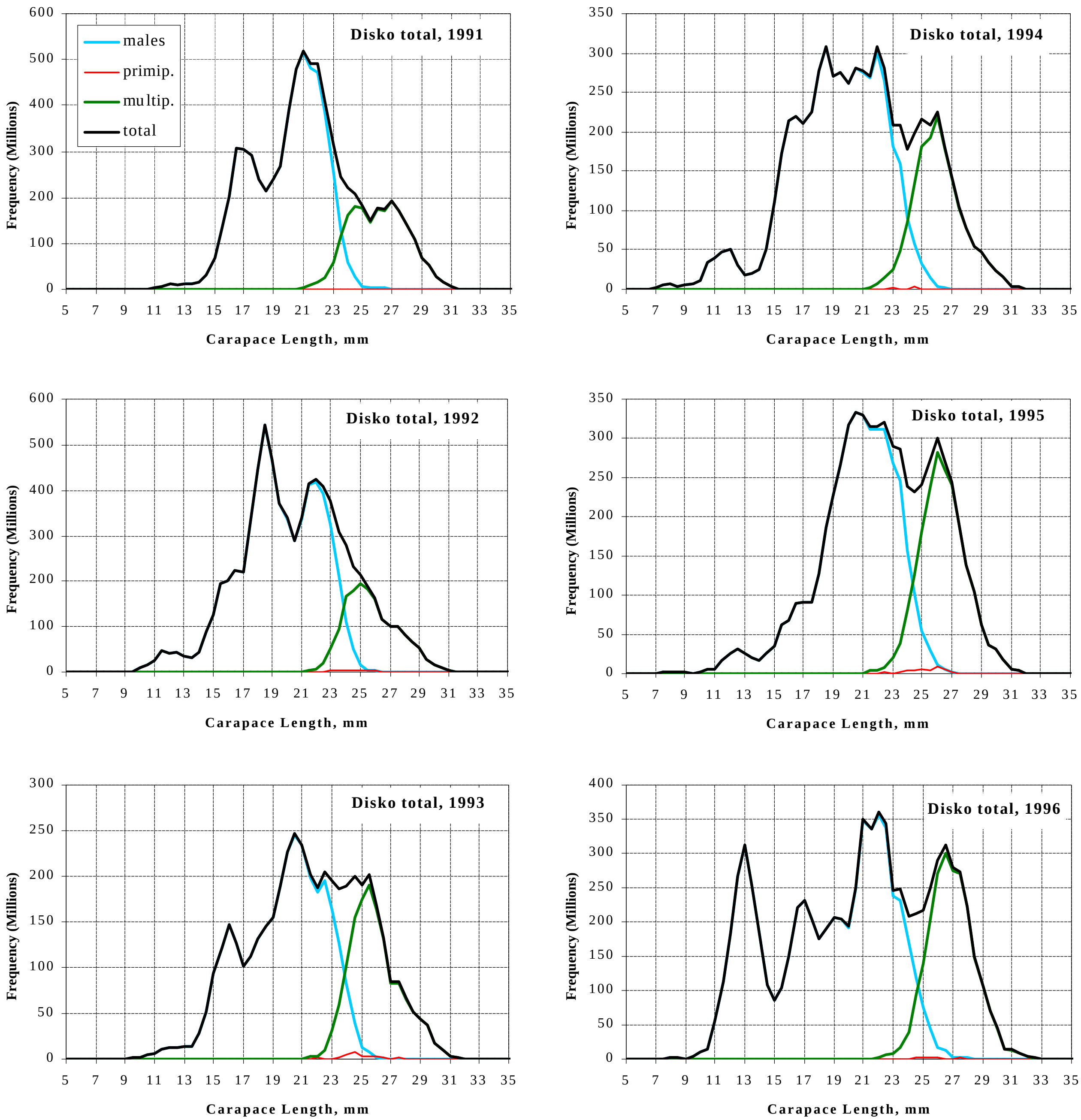


Figure 10a. Numbers of shrimp by length group (CL) in total inshore survey area in 1991-96.

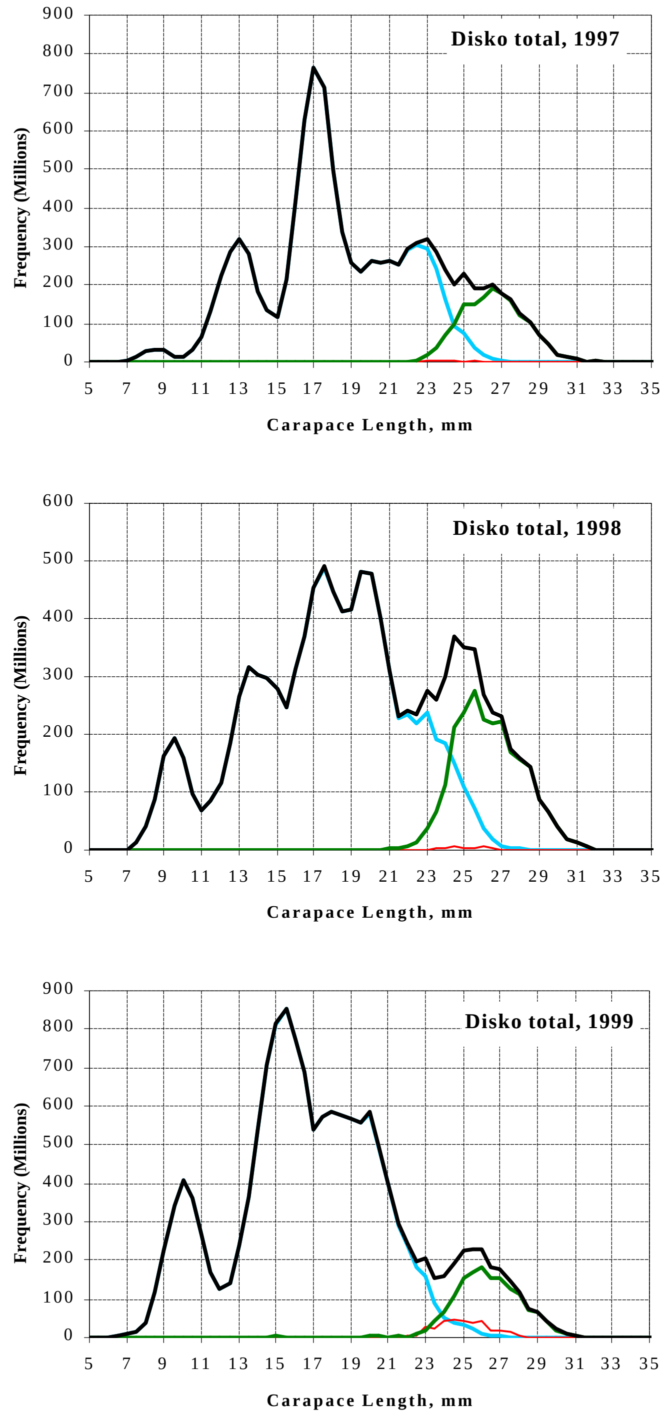


Figure 10b. Numbers of shrimp by length group (CL) in total inshore survey area in 1997-99.

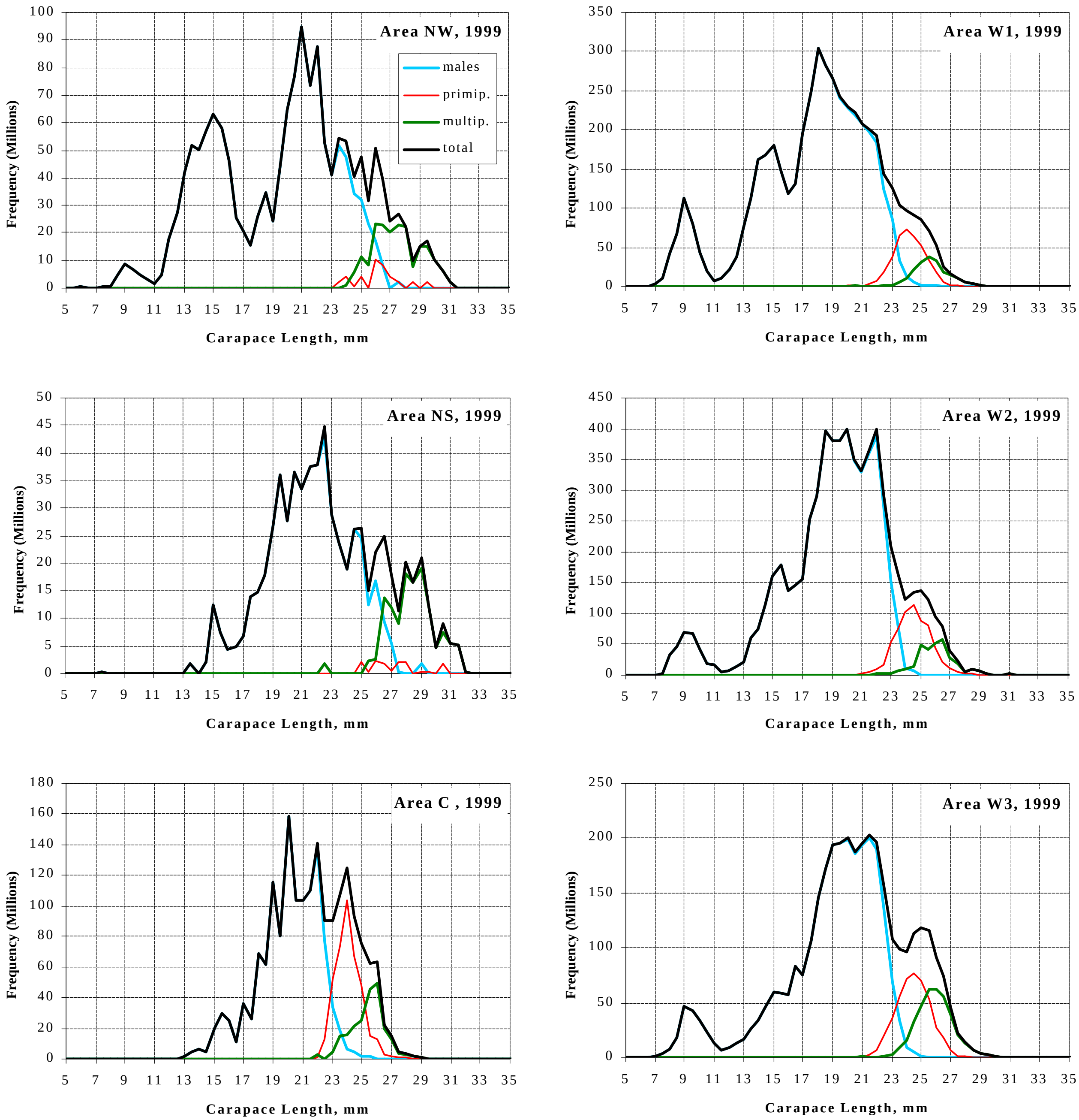


Figure 11a. Numbers of shrimp by length group (CL) in areas NW, NS, C, W1, W2 and W3 in 1999.

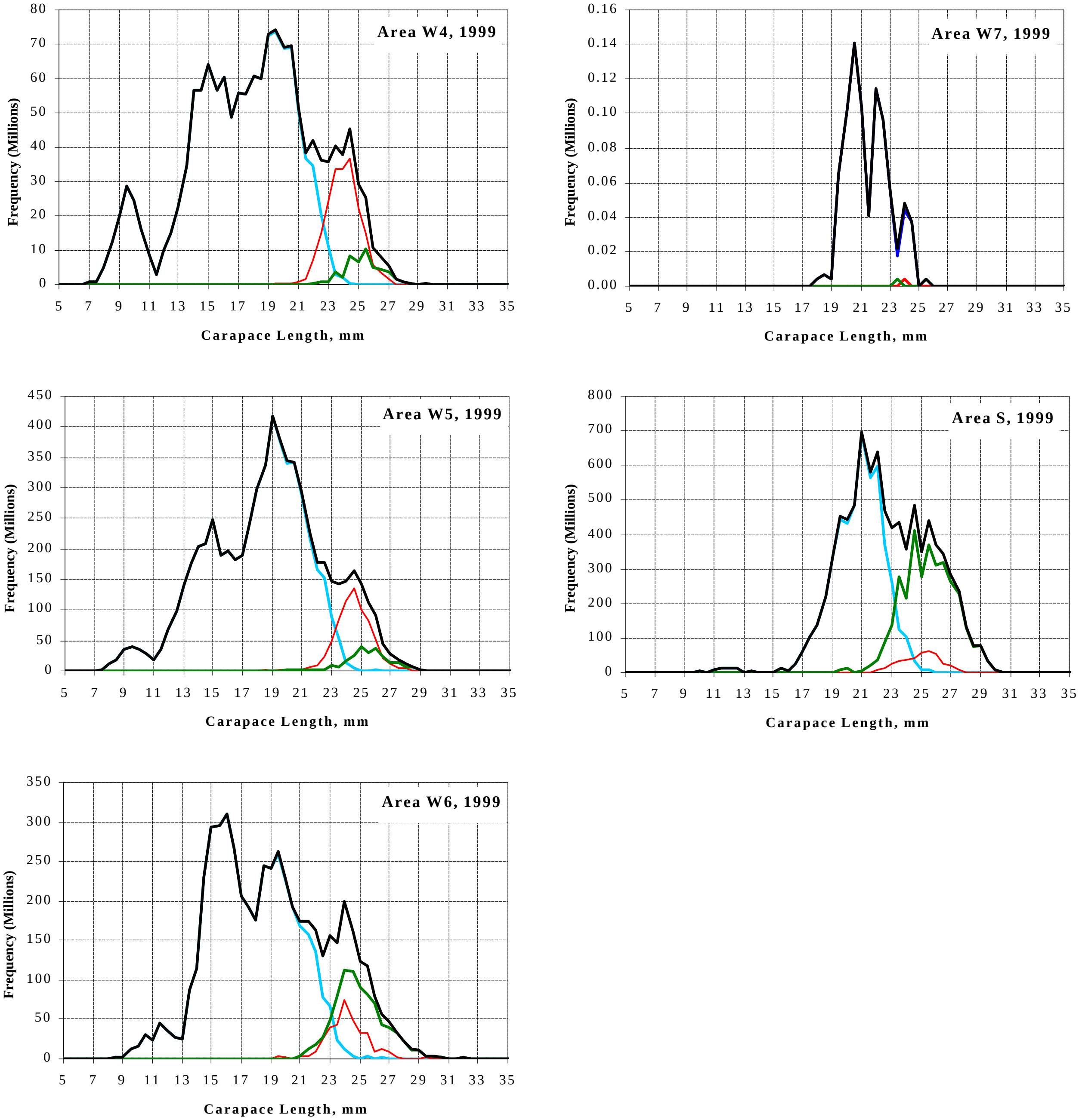


Figure 11b. Numbers of shrimp by length group (CL) in areas W4, W5, W6, W7 and S in 1999.

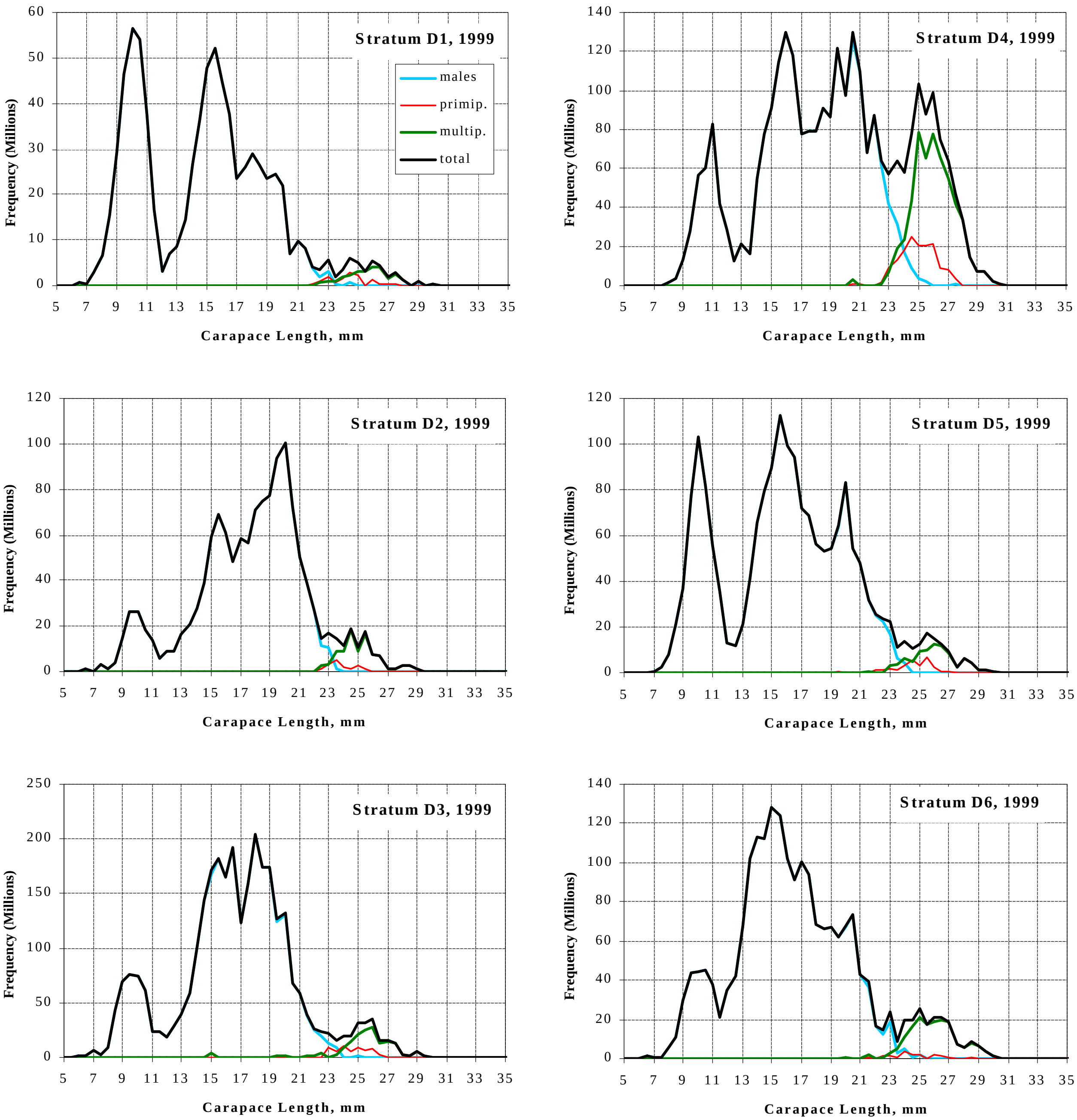
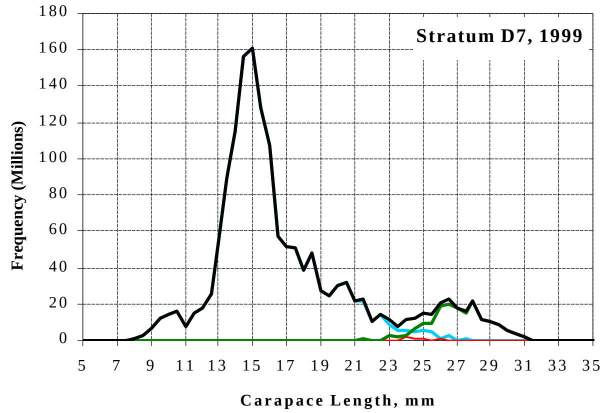
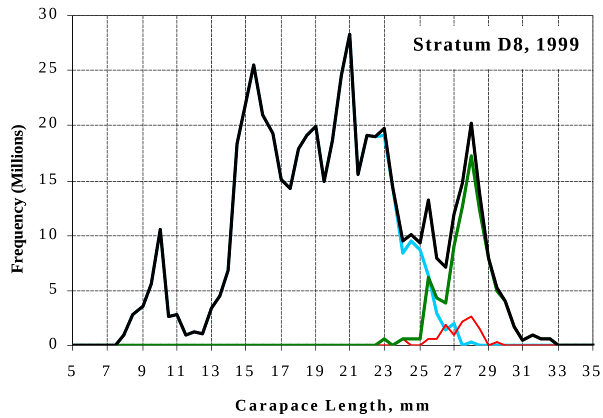


Figure 12a. Numbers of shrimp by length group (CL) in strata D1-D6 in 1999.





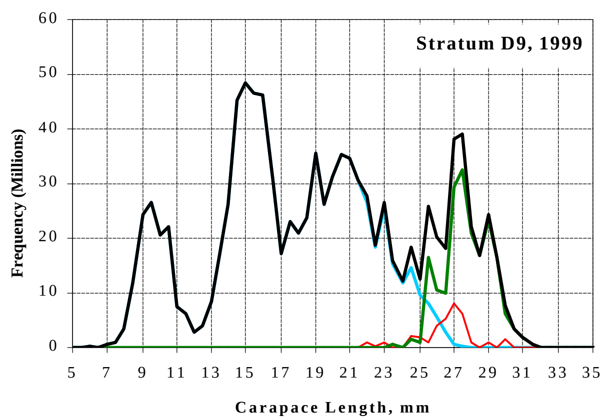


Figure 12b. Numbers of shrimp by length group (CL) in strata D7-D9 in 1999.

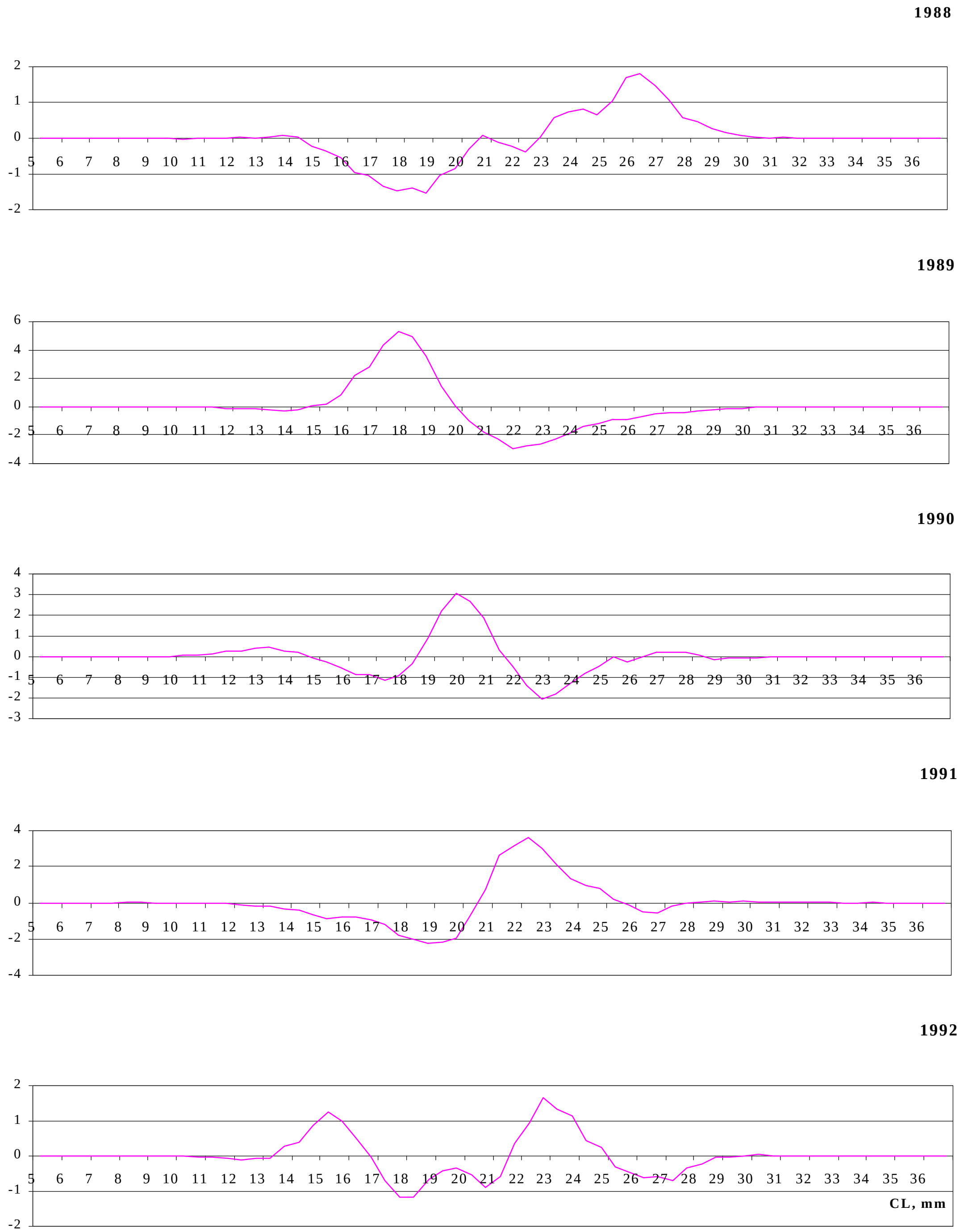


Figure 13. Plots of offshore length-frequency deviations 1988 to 1992 from mean distribution for the same period.

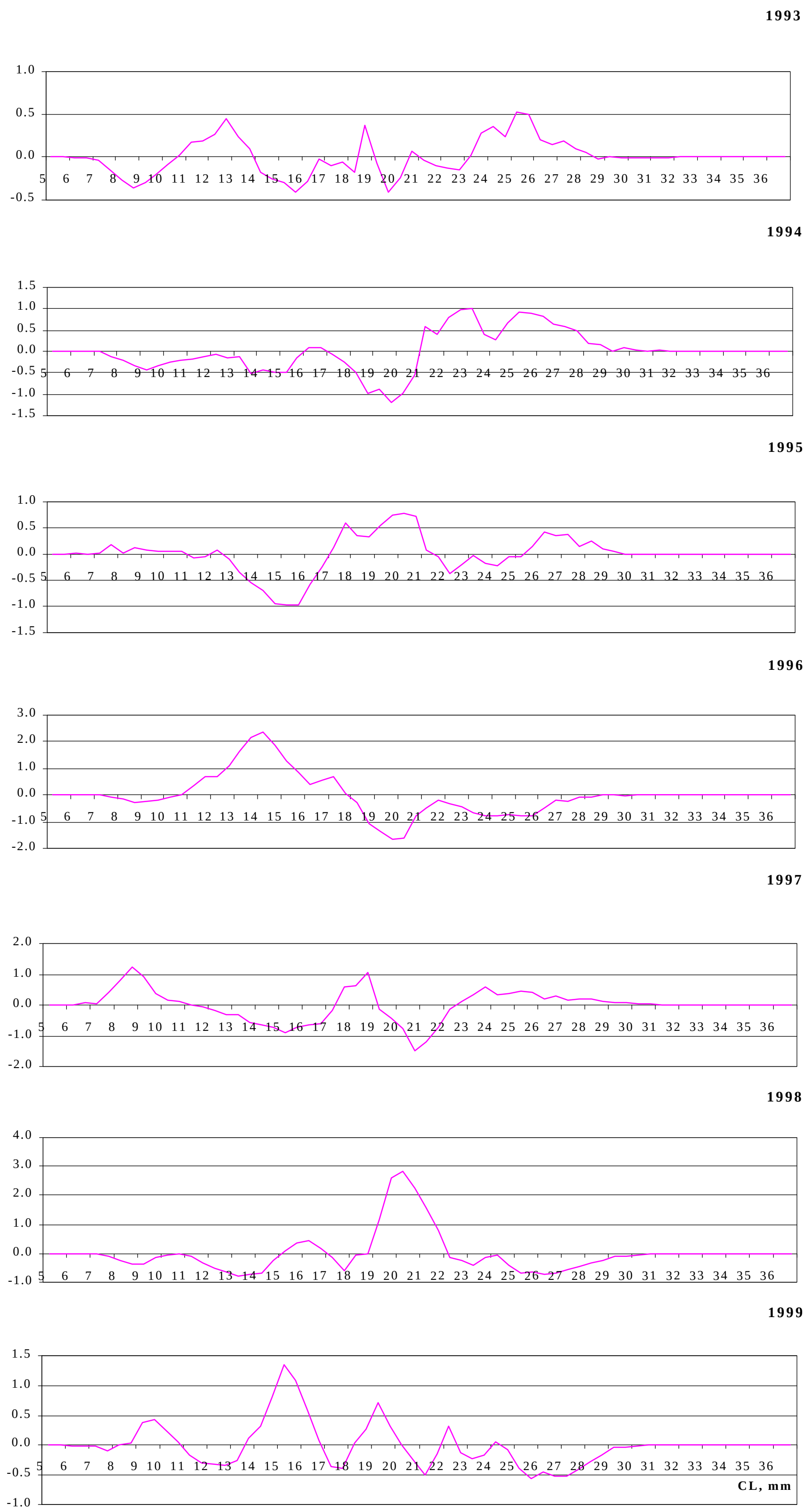


Figure 14. Plots of offshore length-frequency deviations 1993 to 1999 from mean distribution for the same period.

Figure 15. Plots of inshore length-frequency deviations 1993 to 1999 from mean distribution for the same period.

Appendix: Buffered sampling

In earlier years trawl stations were selected according to the guidelines given by Doubleday (1981), where stations are being selected at random, but at the same time with some mechanism to avoid aggregation of the selected stations. For the survey in 1999 a new method of choosing trawling sites was introduced. This procedure is intended to ensure randomness in placing stations and at the same time respect an adequate geographic distribution (Kingsley et al., 1999). A buffer zone around retained stations is constructed, where there can not be retained new stations. The bufferzones are different for each stratum, based on the stratum area (A) and the count of stations (n) that shall be placed in stratum. The bufferzones are circular with radius (r) figured from:

$$A = n * \pi * r^2$$

Around each stratum is laid a buffer area of at least double the figured radius. Bufferzones around stations shall secure an acceptable spreading of these. The buffer areas around strata shall secure that all points in strata have the same possibility to be selected. If these are not used, there will, because of the bufferzones around the stations, be a tendency that the selected stations are placed in boundary areas of the stratum.

Strata are ordered after decreasing size of their bufferzones. Selection of stations starts in the stratum, which has the biggest bufferzone, and closes with the stratum that has the smallest bufferzone.

The stations in a stratum are selected randomly within that stratum and its buffer area. All selected stations are retained, also those in the buffer area outside around the stratum, so long as the minimum clearance to the nearest previously selected station is respected. Stations are selected according to this method, until the wished-for number of stations in the stratum is found.

After that all stations taken in the buffer area outside the applicable stratum are deleted. The chosen stations inside the stratum are retained and function as buffer-stations for the selection of stations in the following strata.

Selection of stations is continued as described, until all strata are treated.

The selection of sampling stations by this new method is carried out by means of a computer program, while station lists by the old method were made manually. This has reduced the preparation time for the survey considerably.