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BIOMASS OF SHRIMP (PANDALUS BOREALIS) IN NAFO SUBAREA 1 IN 1977-80 ESTIMATED BY MEANS OF BOTTOM PHOTOGRAPHY

by
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ABSTRACT

A photographic survey in NAFO div 1A and 1B was carried out in August 1980 using the same sampling technique as in previous years. The density figures obtained by the bottom photography in the period 1977-80 are used in a mathematical model to produce biomass estimates covering the observed area between 66:00N and 69:30N.

INTRODUCTION

Since 1977 bottom photography has been used as a tool for estimating shrimp density in the offshore area in NAFO SA1. In earlier papers (Kanneworff, 1979a; 1979b) the use of the method was discussed, and biomass estimates for the shrimp population in the area from 66:00'N to 69:00'N were given in relation to estimates derived from a stratified trawl survey in 1976 (Horsted, 1978).

The present paper introduces a mathematical model for the distribution of shrimp in the photographic material, and biomass estimates for the period 1977-80 are derived from this model. The biomass estimates are calculated by means of stratum areas given by Carlsson and Kanneworff (1979).

MATERIAL AND METHODS

The method of sampling by means of bottom photography and the techniques for handling the equipment has been described by Kanneworff (1979a). From 1977 this sampling has been carried out in the offshore area of Div. 1A-1C, between 66:00'N and 69:30'N. The same standard of exposure has been used every year, i.e. each photograph covers 3.39 squaremeters. Two photographs per minute has been used as a standard exposure rate, giving an estimated average distance between photographs of 5-15 meters dependent on the speed of the current and of the wind.

The sampling sites have been chosen so as to cover most of the strata within 66:00'N and 69:30'N with respect to both the geographic and the depth distribution of the shrimp (Fig. 1). Depths within the range 100-600 m have been examined. Some of the sites have been occupied in two or more of the years in order to make a direct year-to-year comparison possible. One of the sites in the central area has been occupied in all four years. This station has been chosen as a reference point being located inside the most heavily fished area.

It should be pointed out that the sampling in 1980 has been concentrated in the northern part. This has been done because earlier material indicated that shrimps of smaller size groups could be widely distributed in the area northwest of Store Hellefiskebanke.

In 1980 a total of 17 sampling sites were occupied during the month of August. The number of photographs taken in the four succeeding years 1977-80 are 1067, 1544, 158 and 1795 respectively, the 1979 sampling season being very much influenced by extreme bad weather conditions.

In order to obtain an indication of the average individual weight the shrimps were as previously classified during the reading of the photographs by the three size categories: small (less than 18-20 mm carapace length, with a mean weight of 3.5 g), large (greater than 28-30 mm carapace length, with a mean weight of 13 g), and medium (all others, with a mean weight of 7.5 g). On some occasions the size distributions as read from the p-hotographs have been compared to samples from catches taken by shrimp trawl in connection with the photographic samp-ling.

The use of a mathematical model in the analysis is the result of an attempt to describe the biomass dependency of some easily measurable parameters in the simplest possible way. A multiple regression analysis was used to sort out those of the available parameters which best describe the biomass figures from the photographic material.

The analysis was carried out by means of a 'General Linear Model' procedure included in the 'Statistical Analy-sis System' (SAS) programme package in the computercentre of the Danish Technical Highschool (NEUCC).

In the final version of the model it was chosen to incorporate only year, depth and latitude, being the three most significant parameters and being parameters which are directly 'at hand'.

The input values to the analysis were biomass indices (grams per squaremeter) from all sampling sites collected in 30-minutes periods (up to six periods per station) during the years 1977-80. All values were weighted by the number of photographs in each 30-minute period.

The material from the photographic sampling was as-sumed to be lognormal distributed, and thus the following model was established:

$$B_{i,j,k} = e^{(a_0 + a_1 y_i + a_2 y_i^2 + a_3 d_j + a_4 d_j^2 + a_5 l_k + a_6 l_k^2 + a_7 y_i d_j + a_8 y_i l_k + a_9 d_j l_k)} \times \Delta_{i,j,k}$$

Δ is a stochastic varable with a lognormal distribution around $(\mu, \frac{\sigma^2}{n})$ dependent of year, depth and latitude, and it includes a dependency of all other parameters which are not included in the model. The easiest way of treating Δ here is to regard it as being a pure sampling inaccuracy. Δ is lognormal distributed, which means that if the expectation of Δ is equal to 1, the equation:

$$E(\Delta) = 1 = e^{\mu + \frac{\sigma^2}{2n}} \quad \text{or} \quad \mu + \frac{\sigma^2}{2n} = 0$$

is valid. If n is large,

$$E(\log \Delta) = \mu = -\frac{\sigma^2}{2n}$$

Including this into the former equation, the model now looks:

$$B_{i,j,k} = e^{(a_0 + a_1 y_i + a_2 y^2 + a_3 d_j + a_4 d_j^2 + a_5 l_k + a_6 l_k^2 + a_7 y_i d_j + a_8 y_i l_k + a_9 d_j l_k - \frac{\sigma^2}{2n} + \varepsilon)}$$

In this equation, ε is normal distributed around $(0, \sigma^2)$.

RESULTS AND DISCUSSION

During the four sampling years most of the strata relevant for the shrimp distribution between 66:00'N and 69:30'N have been sampled (Fig. 1). The coverage in the different years, however, has been very much influenced by the weather, ice conditions, technical problems with the equipment and in one of the years limitations in the use of the research vessel due to request for work with higher priority than the shrimp work.

In the 1980 season the sampling was concentrated in the northern part of the area, because this area was expected to be of a special interest, possibly being nursery areas for the younger shrimps.

This change in sampling coverage is likely to introduce some bias into the use of the density figures from the photographic material. A bias in the biomass estimates introduced by a selection of sampling sites to areas in which little commercial fishing has taken place and in which younger yearclasses or higher densities are to be found will tend to overestimate the values for the biomass in the whole area incorporated in the analysis. In Tab. 1 it can be seen that many of the stations north of 68:00'N in 1980 did show very high densities, but that only two of them were dominated by smaller sized shrimps.

During the cruise in 1980 some discrepancies between the charts used for establishing the depth strata (Carlsson and Kanneworff, 1979) and the real depths measured with the echo sounder onboard the research vessel were encountered in the northwestern part of the sampling area. A major discrepancy was found in the area LH440 (Fig. 1), which area was expected to be well inside the depth range 300-400 m, but neither in the area LH440 nor in the eastern part of the neighbour area LH439 any depths beyond 300 m could be found. The error in the biomass estimate for this block (block no. 11217, Fig. 2) leads to an overestimate of about 10-15 percent. The values used for the areas of the different strata do thus need some revisions, but they are still the only available figures.

In order to get a check of the size compositions derived from the photographic reading some comparisons can be made with samples obtained from trawl catches taken in connection with the photographic sampling. Table 3 shows the size compositions from seven sampling sites in 1980 together with the estimated weights. Five of the stations show a very good correlation in the size distributions. In the last station of the table the size group 'small' seems to be very underrepresented in the trawl sample. The 'small' shrimps in the photographic material were in fact very small on this station and may well be somewhat underestimated being close to the resolution of the photographic system. Most of this size group is supposed to have passed through the meshes in the trawl. In the samples from the other stations tabulated any influence from mesh selection is not likely, most of the shrimps in the samples being greater than 13 mm carapace length.

The values for the average weights seem to be underestimated in the photographic material as compared to the samples from trawl catches. A revision of these weights is thus needed, being very sensitive input parameters in the biomass calculations.

The development in the size composition of shrimp in the main fishing area, south of 68:00'N, as described by means of the reference sampling site (area code KRU04), is shown in Fig. 3. A decrease in mean size through 1977-79 with a reduction in estimated mean weight from 7.3 g to 6.0 g is obvious, while the material from 1980 seems to indicate a moderate increase in mean size as compared to 1979.

Using the established model with the input data, i.e. estimates of grams per squaremeter, the regression analysis showed (Table 4) that the biomass dependency of the chosen parameters may be described by a model of this kind. There is, however, a very low correlation coefficient and a very high variance involved. This means that another correlation than the linear might be a better approach, and thus the use of this model must be carried out with great caution.

The formulae for calculating the variance in the material have not yet been worked out, but it is essential to include very wide confidence limits in the use of the biomass estimates derived from this model. Of the same reason it is not possible to extrapolate to parameter values outside the observed (e.g. to areas south or north of the area sampled).

Despite the very high variance the authors find this new way of approaching a direct biomass estimate better than the method formerly used, in which an estimate was obtained relative to an estimate from a trawlsurvey in 1976 (Kanneworft, 1979b).

By means of the model estimated biomass values for all 100 m depth strata within the 100-600 m depth interval in the area from 66:00'N to 69:30'N and for all four years involved have been obtained. The total biomass for the area is estimated to be 202, 115, 110 and 177 thousand tons in the four years 1977-80. The magnitude of the biomass estimates in some of the strata are visualized in Fig. 4 together with the total figures.

The estimates given seem to indicate a major increase in the biomass in 1980 relative to 1979 but as mentioned above the figures for 1980 may be overestimated due to selection of special sampling sites. The decrease from 1977 to 1978, however, is in good agreement with earlier estimates given by Ulltang and Torheim (1979), and the same applies for the apparent stable level between 1978 and 1979.

The interaction between the different parameters in the model, given in Table 4, are shown in Figures 5a-5b. It is clearly seen that the parameter latitude (BR) has a very heavy effect on the estimates. The highest biomass seem to be concentrated in the depth interval 150-400 m with peak values close to 300 m. The depths with the highest concentrations according to the model are in good agreement with the preferred fishing depths for the commercial trawlers.

CONCLUSION

Taking very high variances into account values for total biomass of shrimp obtained by means of a mathematical model may be used to examine the fluctuations in the stock. As stated earlier (Kanneworff, 1978) values for biomass obtained through photographic sampling should be regarded as minimum figures, as they take into consideration only that part of the stock which during sampling time is near or on the bottom. In order to reduce the effect of the fluctuations caused by vertical migrations to a minimum the sampling has been carried out only during the daytime and only in July-August in all four years. The biomass estimate from 1980, however, may be somewhat overestimated as long as a model of the present kind is used.

Due to the possible underestimate of the mean weights in the size groups the overall biomass values for the four years in question may be underestimated up to 10-15 percent.

A reduction in mean shrimp size in the period 1977-79 is indicated, and a minor increase seems to have taken place from 1979 to 1980.

Noting the low correlation coefficient and the very high variances it is obvious that the model needs some revision and that another dependency that the linear is likely to be expected.

ACKNOWLEDGEMENT

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Table 1. List of photographic stations with calculated shrimp densities, mean weight and estmated biomass per squaremeter. The estimates are based on average weights in three size groups as follows:

small: 3.5 g (<18-20 mm carapace length)
medium: 7.5 g (between 18-20 and 26-28 mm carapace length)
large: 13.0 g (>26-28 mm carapace length)

Strata are defined by 100 m depth intervals within the blocks

Div	Stratum No.	Stratum Area	Date	No.of Phot.	Density (no/sqm) Small	Medm.	Large	All	Mean Weight	Biomass Estimate grams/sqm
1B	12414090	690	770724	54	0.000	0.104	0.082	0.186	9.9	1.85
1B	12414090	690	770724	35	0.000	0.084	0.101	0.185	10.5	1.94
1B	12416070	1542	770725	17	0.017	0.190	0.000	0.207	7.2	1.48
1B	12317050	631	770726	82	0.000	0.363	0.004	0.367	7.6	2.77
1B	12317070	1543	770726	64	0.000	0.207	0.000	0.207	7.5	1.56
1B	12316050	1822	770727	116	0.031	0.674	0.003	0.707	7.3	5.20
1B	12015090	122	770804	282	0.001	0.111	0.000	0.112	7.5	0.84
1B	12115110	358	770805	23	0.000	0.038	0.000	0.038	7.7	0.29
1B	12415090	727	770805	204	0.014	0.129	0.010	0.153	7.5	1.15
1B	12417070	1662	770806	190	0.000	0.107	0.002	0.109	7.6	0.82
			1977						7.6	
1B	12316050	1822	780721	154	0.061	0.511	0.006	0.579	7.1	4.13
1B	12216090	209	780722	162	0.000	0.113	0.000	0.113	7.5	0.85
1B	12215030	1395	780724	126	0.000	0.000	0.000	0.000	****	
1B	12215050	643	780724	107	0.006	0.069	0.000	0.074	7.2	0.54
1B	12115070	234	780724	172	0.000	0.005	0.000	0.005	7.7	0.04
1B	12115030	850	780725	174	0.005	0.097	0.002	0.103	7.4	0.76
1C	13414050	250	780725	3	0.100	0.400	0.000	0.500	6.8	3.40
1B	12015110	260	780725	21	0.014	0.085	0.014	0.113	7.8	0.87
1C	13414050	250	780726	178	0.106	0.363	0.003	0.473	6.6	3.14
1C	13012070	120	780727	181	0.205	0.391	0.002	0.598	6.1	3.67
1B	12416090	517	780802	59	0.000	0.155	0.005	0.160	7.7	1.23
1B	12416070	1542	780802	169	0.832	0.640	0.009	1.482	5.3	7.83
1B	12516070	1396	780803	38	0.070	0.178	0.008	0.256	6.6	1.68
			1978						6.1	
1B	12415050	590	790723	6	0.000	0.500	0.000	0.500	7.5	3.75
1A	11214050	919	790730	49	1.096	0.849	0.000	1.946	5.2	10.21
1A	11115050	185	790731	11	0.865	0.676	0.027	1.568	5.4	8.46
1B	12316050	1822	790801	36	0.008	0.123	0.000	0.131	7.3	0.95
1B	12316050	1822	790801	16	1.222	2.093	0.000	3.315	6.0	19.98
1B	12413050	627	790805	7	0.083	0.917	0.000	1.000	7.2	7.17
1B	12414090	690	790805	16	0.019	0.241	0.074	0.333	8.5	2.83
1B	12515070	994	790810	12	0.927	0.293	0.000	1.220	4.5	5.44
1B	12417070	1662	790810	5	0.059	0.235	0.000	0.294	6.8	2.00
			1979						5.7	
1B	12317050	631	800810	116	0.008	0.122	0.003	0.132	7.4	0.98
1B	12316050	1822	800811	167	0.115	0.343	0.004	0.461	6.5	3.02
1B	12415050	590	800811	49	0.018	0.096	0.000	0.114	6.9	0.79
1B	12515070	994	800811	39	0.273	0.409	0.008	0.689	6.0	4.12
1B	12413050	627	800812	110	0.056	0.861	0.003	0.920	7.3	6.69
1B	12414090	690	800812	188	0.009	0.126	0.002	0.137	7.3	1.00
1B	12514050	724	800813	71	0.041	0.734	0.000	0.776	7.3	5.66
1A	11115050	185	800813	62	0.396	1.014	0.004	1.414	6.4	9.04
1A	11213050	424	800815	134	0.081	2.293	0.007	2.381	7.4	17.57
1A	11214050	919	800817	189	2.200	1.053	0.016	3.268	4.8	15.80
1B	12517070	1525	800810	167	0.000	0.065	0.000	0.065	7.5	0.49
1B	12416070	1542	800821	40	0.184	4.081	0.000	4.265	7.3	31.25
1B	12416090	517	800821	116	0.511	0.392	0.003	0.906	5.3	4.76
1A	11217050	45	800822	68	0.000	1.338	0.017	1.355	7.6	10.26
1A	11216050	1628	800822	22	0.040	0.507	0.013	0.560	7.4	4.12
1B	12517070	1525	800823	89	0.000	0.017	0.000	0.017	7.6	0.13
1B	12416070	1542	800823	148	1.426	0.283	0.004	1.713	4.2	7.17

Table 2. Percentage size distribution and average weights of shrimps in photographic material. The samples are taken from the same site (area code KR004) in four succeeding years.

YEAR	percentage small	percentage medium	percentage large	average weight
1977	4.3	95.3	.4	7.3
1978	10.6	88.4	1.0	7.1
1979	36.9	63.1	.0	6.0
1980	24.9	74.3	.8	6.5

Table 3. Percentage size distribution and average weight of shrimp in photographic material and samples from trawl catches in 1980.

Stratum no.	Area code	type	% small	% medium	% large	Average weight
12317050	KP440	photo	5.8	92.3	1.9	7.4
		trawl	5.5	93.4	1.2	8.9
12316050	KR004	photo	24.9	74.3	.8	6.5
		trawl	21.0	78.1	.9	7.4
12413050	KZ014	photo	6.1	93.6	.3	7.3
		trawl	14.2	85.0	.8	8.9
12414090	KZ012	photo	6.9	92.0	1.1	7.3
		trawl	8.0	89.1	2.9	11.1
12517070	LA438	photo	.0	100.0	.0	7.5
		trawl	3.4	93.2	3.4	10.3
11217050	LH440	photo	.0	98.7	1.3	7.6
		trawl	1.3	95.1	3.6	9.3
12416070	KZ002	photo	83.3	16.5	.2	4.2
		trawl	19.6	80.3	.2	11.4

Table 4. Output from the multiple linear regression analysis showing the fitness of the model to the input values. The calculated parameters to the equation on page 3 (a_o through a_9) are shown in the lower part of the table. The parameter U corresponds to G^2 in the equation.

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: LNBIMS
WEIGHT: EILLNO

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	10	4740.38410438	474.03841044	9.24	0.0001	0.328302	2598.4594
ERROR	189	9698.70918970	51.31592164		STD DEV		LNBIMS MEAN
CORRECTED TOTAL	199	14439.09329408			7.16351322		0.27568310

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
YEAR	1	1363.07240650	26.56	0.0001	1	98.41526368	1.92	0.1677
YEAR*YEAR	1	371.37318280	7.24	0.0078	1	157.02014583	3.06	0.0819
DEPTH	1	67.19245350	1.31	0.2540	1	65.52916132	1.28	0.2599
DEPTH*DEPTH	1	1557.98521631	30.36	0.0001	1	467.66885147	9.11	0.0029
BR	1	49.50856202	0.96	0.3272	1	226.92225488	4.42	0.0368
BR*ER	1	1227.46712283	23.92	0.0001	1	797.00616650	15.53	0.0001
U	1	56.99897797	1.11	0.2933	1	66.52160176	1.30	0.2563
YEAR*DEPTH	1	17.72744329	0.35	0.5574	1	0.00014750	0.00	0.9986
YEAR*BR	1	0.34321406	0.01	0.9349	1	7.76109101	0.15	0.6978
DEPTH*BR	1	28.71552510	0.56	0.4554	1	28.71552510	0.56	0.4554

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	2419.77760401	1.87	0.0629	1293.25371543
YEAR	-35.42199413	-1.38	0.1677	25.57807422
YEAR*YEAR	0.25960540	1.75	0.0819	0.14840964
DEPTH	0.13047047	1.13	0.2599	0.11545719
DEPTH*DEPTH	-3.8682058E-05	-3.02	0.0029	0.00001281
BR	-31.64532980	-2.10	0.0368	15.04863635
BR*BR	0.28713743	3.94	0.0001	0.07285931
U	-3.31735123	-1.14	0.2563	2.91364190
YEAR*DEPTH	2.3530712E-06	0.00	0.9986	0.00138791
YEAR*BR	-0.07823776	-0.39	0.6978	0.20117829
DEPTH*BR	-0.00159342	-0.75	0.4554	0.00213009

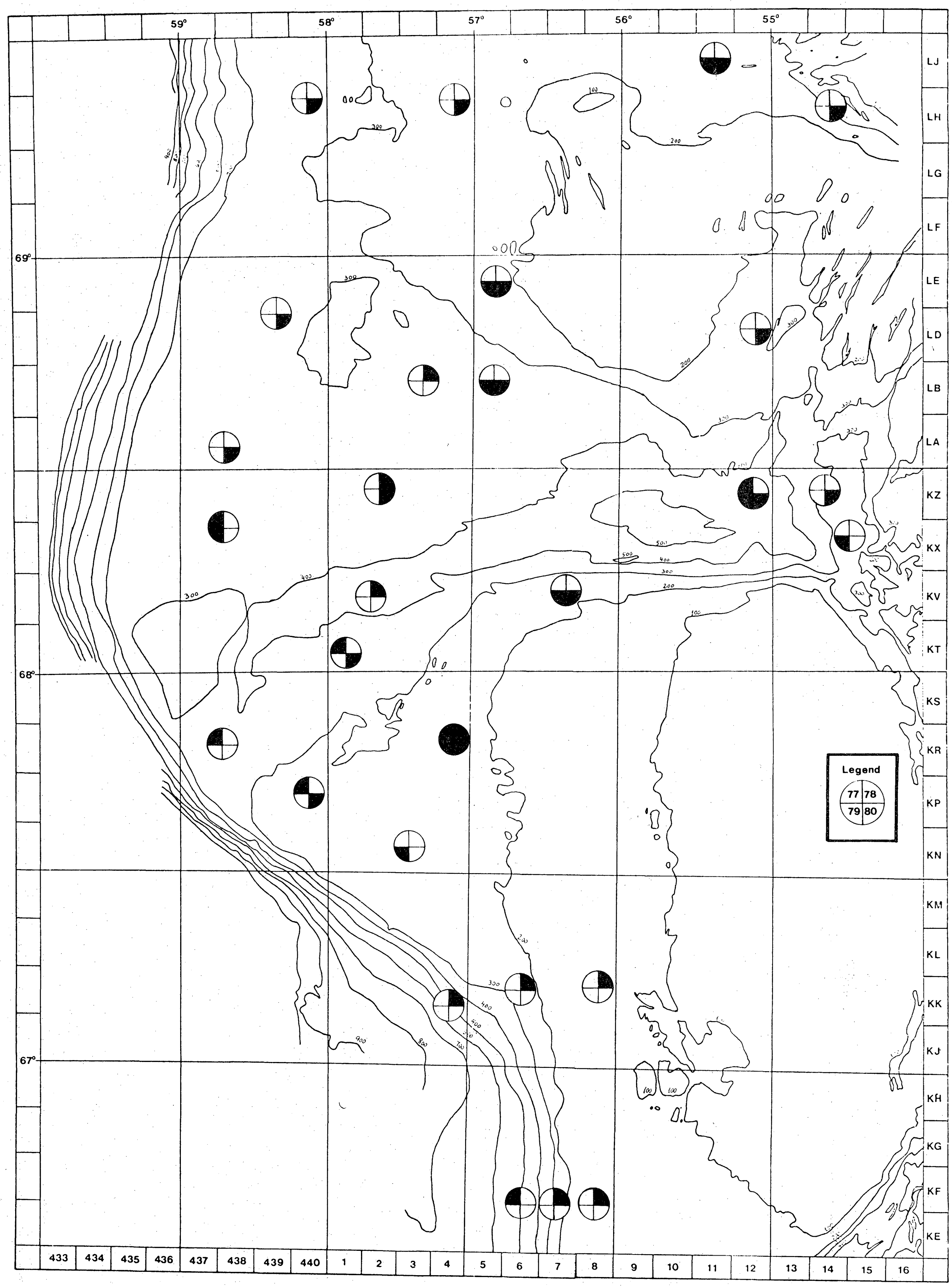


Fig. 1. Map showing the sampling stations in years 1977-80. Three stations south of the map, occupied during 1977-78, were included in the analysis.

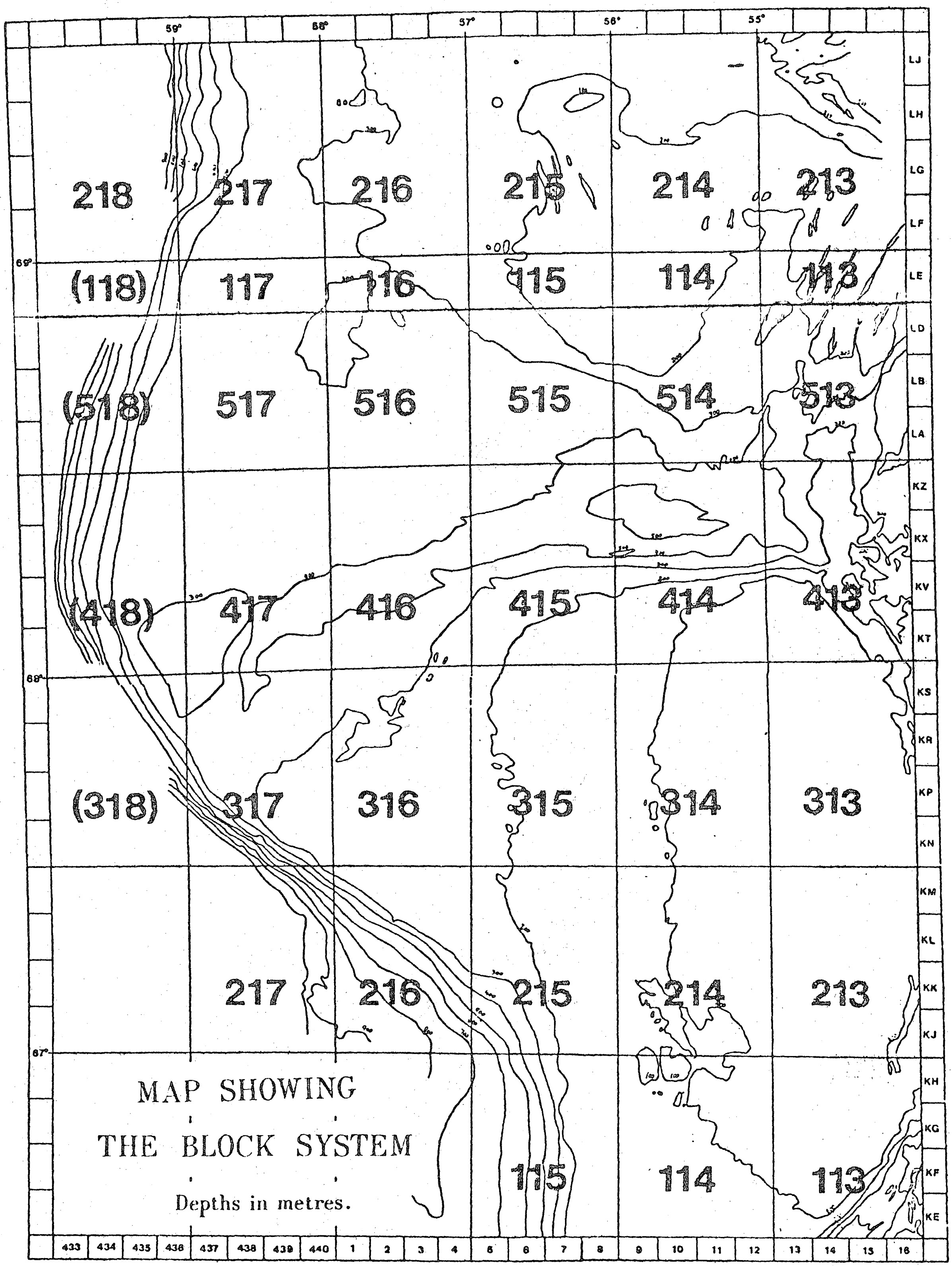


Fig. 2. Block numbers in the stratification system for Div. 1B and the southern part of Div. 1A. Block numbers in brackets west of 59°W are numbers extended to SAO from SA1 for practical use in the ADP system.

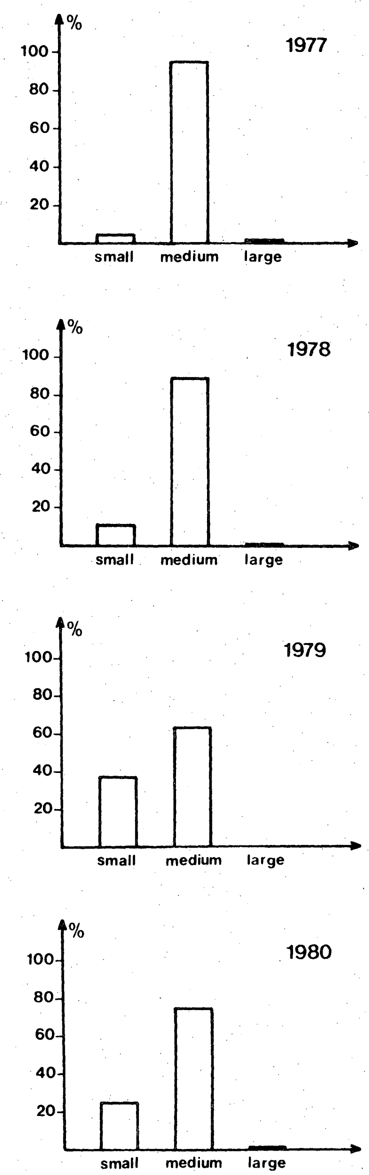


Fig. 3. Size composition of shrimps from photographic samples in the commercially most important area west of St. Hellefiskebanke.

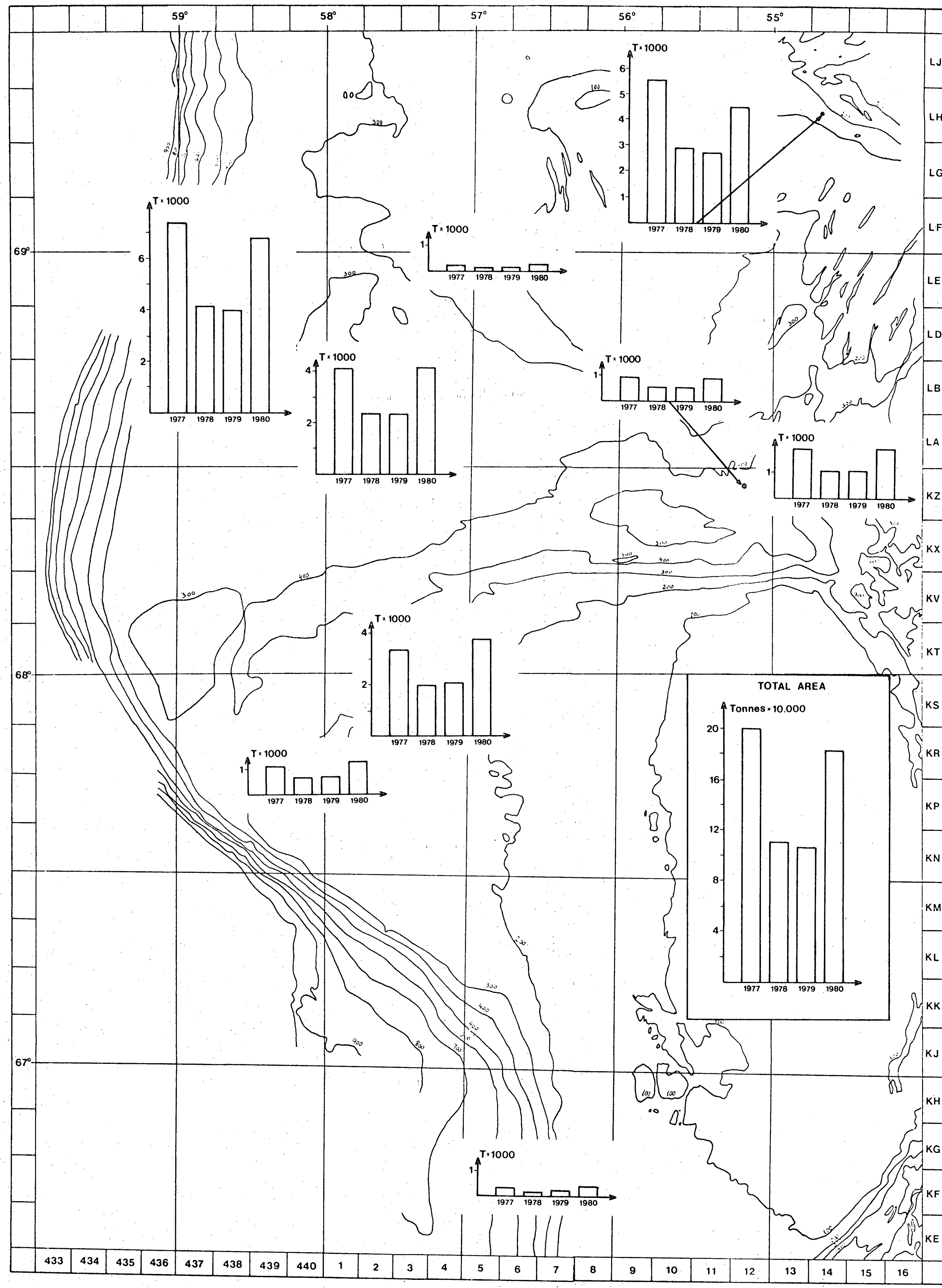


Fig. 4. Map showing biomass estimates for some selected strata together with the total biomass estimate for the whole area between 66°00'N and 69°30'N.

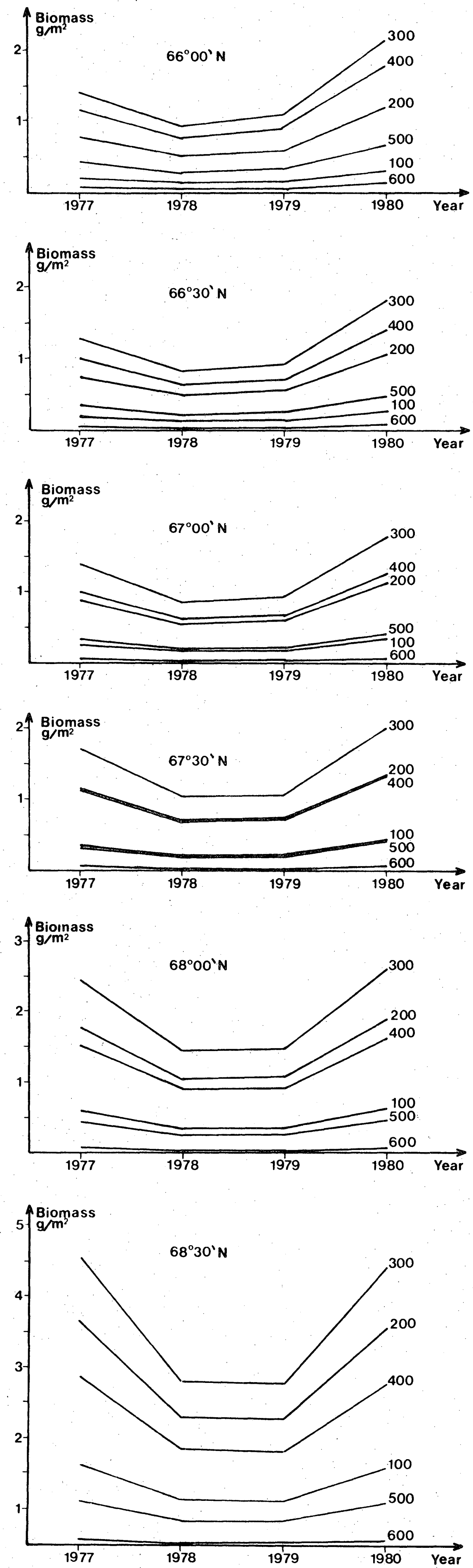
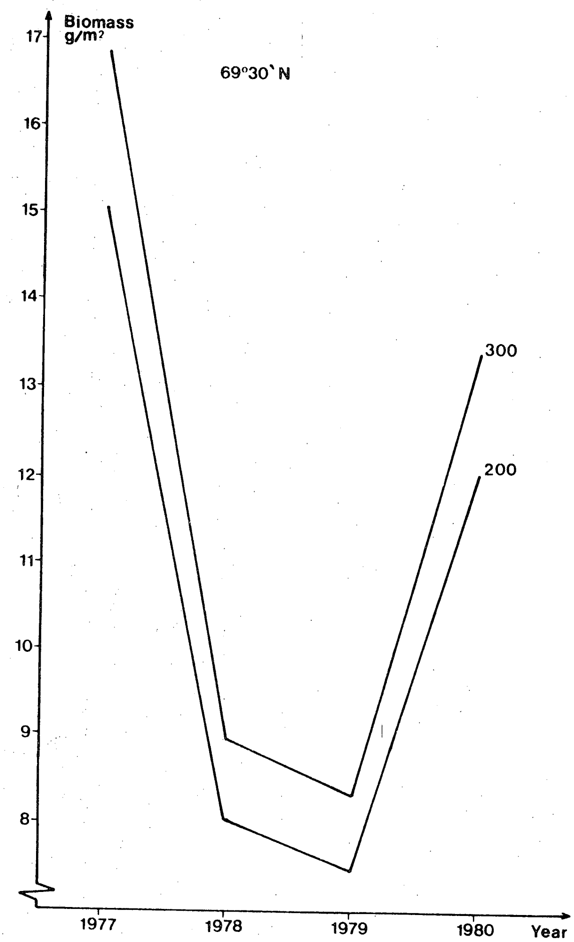
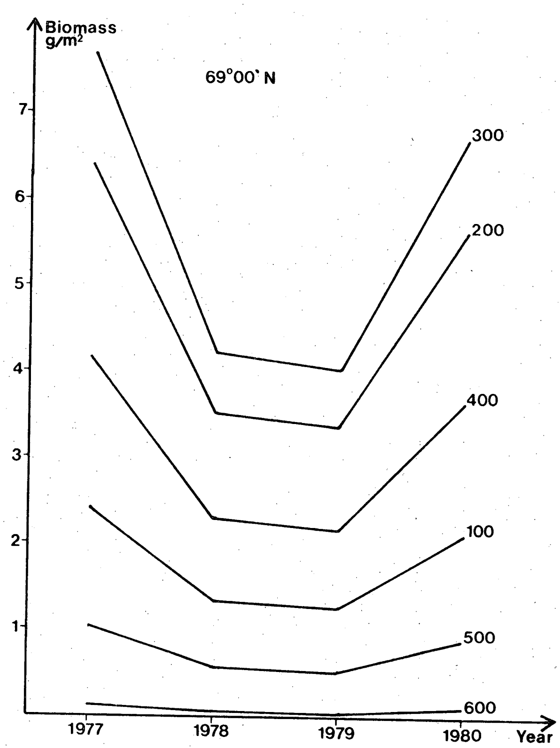


Fig. 5a. Figs. 5a-5b show the estimated shrimp biomass per squaremeter in different depths and at latitudes between 66°00'N and 69°30'N.





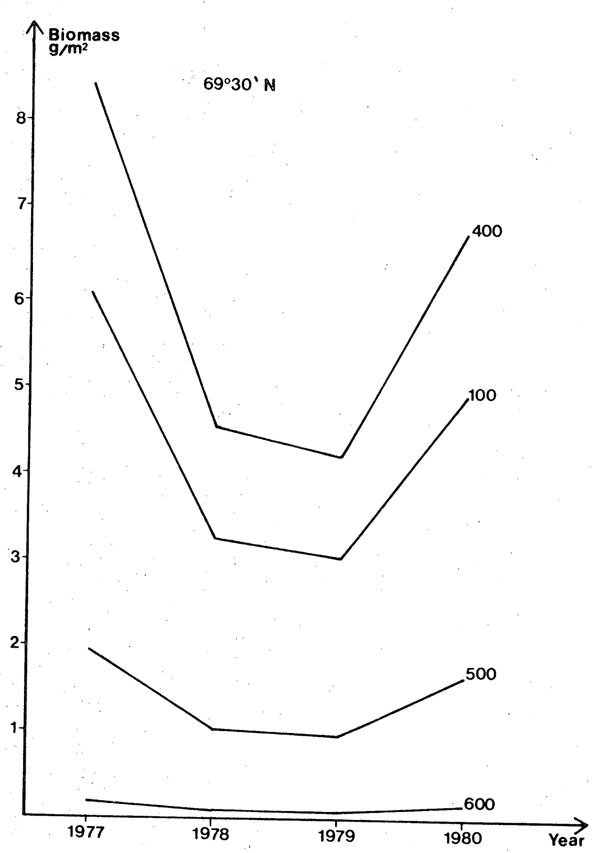


Fig. 5b. Figs. 5a-5b show the estimated shrimp biomass per squaremeter in different depths and at latitudes between 66°00'N and 69°30'N.