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Spatial Variability in Length Frequency Distribution and Growth of Shrimp (*Pandalus borealis* Krøyer 1984) in the Barents Sea

by

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Abstract

The length frequency distributions (LFDs) of shrimp (*Pandalus borealis*, Krøyer 1984) in the Barents Sea varies not only spatially but also over time. The stations are defined in four groups using a Spearman correlation analysis on the LFDs and then a cluster analysis. These groups are defined according to the size distribution so that the stations with many small shrimp make one group and the stations with the largest shrimp form the fourth group. The distribution is depth dependent for the first three groups while the largest shrimp occur in all depths and may be selected by strong current. To get a good picture of the growth performance in an area it is important to get a broad LFD where all length groups are present. This is a special challenge when planning the sampling design. Cohort analysis of LFDs for 1992 to 1998 show that shrimp in the southern Barents Sea grow faster than in the northern Barents Sea. On the basis of similar growth performance 14 sub-areas are defined. One may run further population analysis for each sub-area. However, this may get difficult due to grate variability especially in catch data when splitting into smaller areas. One should keep the high solution of data when preparing input data for further analysis. One may sum up e.g. the number of individuals in each year class in each area and then run production models or Multispecies virtual population analysis for the hole Barents Sea.

Key words: Barents Sea, shrimp, *Pandalus borealis*, spatial distribution, modal analysis, growth

Introduction

In the Barents Sea the shrimp fisheries are regulated by smallest allowable shrimp size (15mm carapace length), limited number of young commercial fish allowed in the catch and by number of vessel licenses given. One reason for not regulating the shrimp fisheries with a TAC has been a significant consumption of shrimp by cod (570.000 tons in 1994) (Bogstad and Mehl, 1997), while the fisheries never has exceeded this level (130.000 tons in 1984, 30.000 tons 1997) . Another reason has been the lack of knowledge about stock structure and problems in defining suitable management units. Genetic allozyme- and DNA- analyses have been conducted in this area with the aim to identify possible sub-populations in the Barents Sea (Drengstig & Fevolden, MS 1997; Martinez *et al.*, MS 1997). Though there are obvious genetic gradients in the material no distinct sub populations can be identified in the open Barents Sea. While the shrimp stock in the Barents Sea shows grate plasticity and variation in growth and maturity both spatially and over time, a definition of sub areas with shrimp showing the same growth and maturity performance would make the management of the stock easier.

Although management units can not be identified genetically they may be defined as areas with shrimp having the same life history. Therefore the aim of this study is to describe the spatial and historical variation in length frequency distributions (LDFs) of shrimp in the Barents Sea. Similar work on spatial patterns of LFDs has been done in the Gulf of St. Lawrence (Simard and Savard, 1990). General conclusions on life-history of shrimp has been presented by Shumway *et al.*(1985), Apollino *et al.*(1986) and Nilssen and Hopkins (1991). A presentation of the growth performance and age at sex change of shrimp in the neighbouring Svalbard area is given by Hansen and Aschan (submitted), and for the development of the shrimp stock in the Barents Sea Aschan *et al*. (1996) and Aschan and Godø (1999).

Material and Methods

Study area

The Barents Sea is delineated by the coastline of Northern Norway and Russia in the South, by Bear Island and Spitsbergen towards the West, and by Novaja Zemlja and Frans Josef Land at the East and the North. The northern part of the sea is covered by sea ice in winter, and is primarily under the influence of cold Arctic water masses. The southern part of the Barents Sea except for the easternmost region is ice-free the whole year and is characterised by the relative warm Atlantic Water masses. The temperature in the Barents Sea can vary greatly depending on the amount of Atlantic water flowing into the area from the Southwest. This has probably also consequences for growth, age at sex change and recruitment of the shrimp (Teigsmark 1983; Apollino *et al.* 1986; Nilssen and Hopkins 1991). The shrimp in this area occurs mainly on depths of 150 to 500 m, and the survey area is divided into six main areas including 24 strata (Fig. 1).

Sampling and laboratory measurements

Norway has conducted annual shrimp surveys in the Barents Sea in April–May since 1982. The data for 1991-1998 are used in this study. A Campelen 1800 survey trawl used and the stations were placed like a grid with 20-30 naut. mile distance between stations. The distance between stations was exceptionally only 10 naut. mile in the northern Barents Sea in 1996. Aschan and Sunnanå (1997) gave a detailed description of the surveys. Optimal effort allocation in this large stratified area was described and discussed by Harbitz *et al.* (1997).

To ensure the presence of small shrimp in the trawl samples an extra sub sample (10 l) was taken and small shrimp was sorted out at each station in 1992-1994. In 1995 a mesh bag (0.8 mm) with a 1 m^2 opening was attached to the under belly.

The biological development of shrimp is divided into several stages. Shrimp starts of as males (Stage 2) after the juvenile stage (Stage 1). Thereafter they become inter sex (Stage 3) before they develop into females with head-roe (Stage 4). When the females mate, the roe is spawned under the abdomen and kept there by the pleopodes (Stage 5), until hatched (Stage 6). Some females then take a resting period (Stage 7) while others start on a new cycle with head roe (Stage 8). The characters of shrimp, the Russian and the Norwegian coding of the stages are given in Table 1.

Crustaceans usually have no hard, bony tissue that they bring with them through moulting and therefore direct age reading is not possible. Therefore Mix 3.0 modal analysis of length frequencies, where modals of the distributions form the age groups, was used (Macdonald and Pitcher 1979). In order to obtain useful results the carapace length (CL) (from the posterior margin of eyestalk to the posterior mid dorsal edge) of approximately 300 individuals from each trawl station was measured to the nearest 0.1 mm with an electronic calliper (Mitutoyo, Japan).

Data and statistical analysis

Statistical analysis and some of the graphics were performed using different modules of SYSTAT® and SYGRAPH® (Wilkinson, 1990a,b). For the spatial distribution analysis the extra sub samples with small shrimp was excluded. The length-classes (0.1 mm) were filtered with a weighted 0.5 mm moving average to smooth out the measuring error $((n_1+2n_2+3n_3+2n_4+n_5)/9)$. The next step was to sort the samples according to their similarity in LDF, with Spearman correlation. The correlation matrix resaved was used as input for a cluster analysis and for Multidimensional Scaling (MDS). The analysis is a Monotonic Multidimensional Scaling where the data are analysed as similarities. Fitting is split between matrixes minimising Kruskal stress in 2 dimensions. The mean average cluster analysis gives the distance values, which tells how well correlated the stations are. Finally the values on the MDS axes (2-dimensions) are tested to environmental parameters such as light, time of the day, temperature, longitude, latitude, depth.

When running cohort analysis the extra sub sample with small shrimp was included in the LFDs. Then the frequencies were grouped in classes of 0.5 mm in order to run the cohort analysis. For the years 1993, 1995 and 1996 Mix 3.0 was run station by station. Stations in the same area with similar mean size at age were grouped together. 14 areas partly similar to the traditional strata division were found. Age analyses have been run for each area and year since 1991, and the growth pattern of single year-classes for 14 sub-areas in the Barents Sea were scrutinised.

Results

The cluster analyses identified four distinct groups at a distance of 0.15 (Fig. 2). The first group consists of small and medium sized shrimp, group two consists of small but mainly medium sized shrimp, group three consists of medium sized and large shrimp and group four consists mainly of large shrimp (Fig. 3) . The Monotonic Multidimensional scaling gave a stress of final configuration = 0.1459 after five interations and the proportion of variance (RSQ) was 0.917. A two dimensional plot from the MDS for 1996 showed in that the majority of variation between stations is explained by dimension 1 (Fig. 4). As seen from the map small shrimp were concentrated to the southern and eastern Barents Sea while large shrimp occurred in the North in the Barents Sea and in the West in the Bear Island trench (Fig. 5). The LFDs were mainly distributed according to depth (Fig. 6). In the 1996 material the correlation between values for dimension 1 and depth is good (r^2= 0.46) when the largest shrimp are excluded. The LFDs that consist mainly of large shrimp, are not distributed according to depth but occurs occasionally at any depth (200-500 m). Probably they are selected in areas and spots with strong currents.

The mean length with standard deviation (Sd) and percent of individuals in each year class for the years 1991 to 1998 showed no dramatic changes from year to year. However, there seem to be years with slower growth (Table 2-8). The growth pattern of single year-classes within the northern Barents Sea (stratum 15 and strata16 &17) seem fairly similar for the different year-classes a (Fig. 7). That is also the case within the southern Barents Sea (strata 3 & 4) (Fig 7). When the growth pattern of the 1992 year-class in the North (stratum 15 and strata 16 &17) is compared to the growth pattern in the South (strata 3 and 4) one can clearly see the difference in growth performance (Fig. 8). The growth curve gets gradually steeper as one moves from the North to the South. Old age groups are difficult to determine due to the lack of enough large individuals in the sample (strata 16 & 17 and 3 & 4) and thereby the growth curve indicate a growth stagnation.

Discussion

Though the Barents Sea is characterised as a relatively homogenous area according to depth, with no steep slopes, the depth is the main environmental factor explaining the spatial size distribution of shrimp. This is known from other areas such as Gulf of St. Lawrence (Simard and Savard, 1990), Iceland (Skuladottir *et al.*, 1991), Jan Mayen (Aschan *et al.*, 1996b) and Svalbard (Hansen and Aschan, submitted). Although a clear change in size distribution was found from South to North and West all four groups identified by the cluster analysis were present in the five main areas (A-E) while the first group with small and medium sized shrimp was not present in area F (Fig. 5).

Analysis of data from 1991-97 suggest that the shrimp in the southern Barents Sea grow faster than shrimp in the central and northern Barents Sea (Fig. 7 and Fig. 8). This supports earlier analysis conducted by Teigsmark in the period 1979-1981 (Tegismark, 1983). While the growth performance changes with distance (Tables 2-7) one has to define sub areas with similar growth pattern and with all modal groups present to be sure that the cohort analysis will be good. Both small (group one or two) and large (group three or four) shrimp should be present. It is tempting to combine strata into larger areas than the 14 sub-areas defined. However, it is necessary to keep a high solution on the data to ensure that changes in growth performance are recognised.

The life history of shrimp varies geographically, from the South to the North of the Barents Sea and over time. Nilssen and Hopkins (1991) showed that although significant latitudinal trends are clearly present, the effects of specific environmental conditions (e.g. “warm” or “cold” current systems at a given latitude, seasonal production cycles, and more recent trends towards increased fishing effort on previously unexplored stocks at high latitude) are important factors modifying “latitudinal life cycle strategies” of this species. In the 1980s, when the water was “cold”, the shrimp in the Barents Sea showed slow growth and they changed sex later than in the 1990s when the water was warmer (Teigsmark, 1983). Teigsmark (1983) identified three populations of *Pandalus borealis* in the Barents Sea that differed from each other by age at sex change and frequency of reproduction.

When comparing the mean length at age for 1997 to earlier years (Tables 2-7), one recognises very small shrimp (CL= 6.3) in the South in 1997. This may be shrimp that has been transported into the area from the North or it may be a sign of slower growth caused by to the suddenly colder water conditions in the Barents Sea in 1996 and 1997 (Aure *et al.*, 1999). The 1996 year class has since 1997 been absent in the Barents Sea. One explanation may be the high cod predation in the southern Barents Sea where the 1996 yearclass was found in 1997. The lower sea temperature seem to cause slowergrowth also in the 1997 year class (Table 8).

The year-class strength in shrimp is probably largely established during the pelagic larval stage, and it is assumed that the transport processes influence recruitment both directly as advectional loss of larvae and indirectly through temperature, food availability and predator-prey interactions. Results from the shrimp surveys in the Barents Sea conducted in 1995 and 1996 indicated that the 92-94 year-classes were strong (Tables 2-8).

Russian scientists concluded that several shrimp sub-populations in the Barents Sea, united into a large super population caused by larval drift (Berenboim, 1982, Berenboim and Lysy, 1987). This statement is supported by the recently published genetic work on allozymes by Drengstig and Fevolden(MS 1997) and RAPD-analysis by Martinez *et al.* (MS 1997). When in the future running production models and models for assessment one should consider the Barents Sea as one population. However, large variation in life history gives problems when running the Multispecies virtual population analysis (MS VPA) and other stock analysis based on time series as they require a fixed age for sex change and a fixed growth. The solution in the biological data has to be on a detailed level e.g. 14 sub areas for the Barents Sea. To run separate analysis for each of the 14 sub-areas is one solution. However, this may get difficult due to grate variability especially in commercial catch data when splitting the study area into small areas. One should keep the high solution of data when preparing input data for further analysis. One may sum up e.g. the number of individuals in each year class in each area and then run production models or MS VPA for the whole Barents Sea.

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TABLE 1. Sex stages of shrimp *Pandalus borealis* with characteristics and the Russian and the Norwegian codes in use.

Sex stage	Russian code	Norwegian code
Male	Male	2
Transitional (intersex, Norway) - no headroe - with spines	Transitional	3
Female, first time spawner (intersex, Norway) - headroe - with spines	Female 1+, 1-3	4
Female spawned - outroe - no headroe - no spines	Female 2, 0	5a
Female, eggs spawned - outroe - headroe	Female 2, 1-3	5b
Female, larvae just hatched - setae, eggrests - no headroe	Female 3, 0	6a
Female, larvae just hatched - setae, eggrests - headroe	Female 3, 1-3	6b
Female resting stage	Female 0	7
Female second time spawner - headroe - no spines	Female 1-, 1-3	8

TABLE 2 a. Modal group analysis (Mix 3.0) for each sub-area in the Barnets Sea, spring 1992. Standard deviation (Sd) mean carapace length (CL) and proportion (percent) in each year class (YC) are given for sub areas (strata).

Strata		YC 91		YC 90		YC 89		YC 88		YC 87		YC 86	
	Sd (mm)	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent
10, 11, 12		7.57	1	13.81	18	17.60	37	21.36	43	24.25	1		
1, 2, 3, 4		9.73	1	15.34	20	18.78	46	21.88	33				
14	1.65	6.84	1	13.30	7	17.26	57	21.70	36				
15	1.11	7.40	1	12.59	6	16.59	28	18.86	25	21.94	35	24.78	4
18	1.02	7.37	2	12.39	19	16.30	42	8.77	14	23.00			
19, 20,	1.31			11.58	5	16.12	24	19.15	37	21.37	35		
21	1.21			12.90	2	17.25	17	19.72	41	21.65	39		
22	1.18	6.46	1	11.85	3	16.68	16	19.01	38	21.33	42	24.04	1
5, 8	1.20	7.87		12.97	2	16.23	15	18.75	47	21.35	37		
6	1.11	8.65	1	13.75	4	15.87	16	18.90	47	21.23	32		
7	1.03	7.66	1	13.80	8	16.11	21	18.78	41	21.88	29	26.06	
9, 13,	1.10	7.48	1	11.94	4	15.81	10	18.45	38	21.21	42	23.10	6

TABLE 2 b. Modal group analysis (Mix 3.0) for each sub-area in the Barnets Sea, autumn 1992. Standard deviation (Sd) mean carapace length (CL) and proportion (percent) in each year class (YC) are given for sub areas (strata).

Strata		YC 91		YC 90		YC 89		YC 88		YC 87		YC 86	
	Sd (mm)	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent
15	1.58					17.53	21			22.70	79		
14	0.86			14.14	15	17.46	25	19.76	16	22.00	33	23.98	11
13				13.96	2	16.87	13	18.93	32	21.71	49	23.73	5
22	1.21	8.43	2	13.77	9	17.93	28	20.90	57	23.03	5		
21	1.35	8.70		13.89	2	18.09	31	21.18	64	22.91	3		
19, 20	1.18			13.83	7	17.91	41	20.98	34	22.42	18		
18	1.68			14.46	22	17.63	62	21.39	16				
16	0.89			14.61	8	17.30	45	20.16	13	22.51	27	24.58	7

TABLE 3. Modal group analysis (Mix 3.0) for each sub-area in the Barnets Sea, spring 1993. Standard deviation (Sd) mean carapace length (CL) and proportion (percent) in each year class (YC) are given for sub areas (strata).

Strata		YC 92		YC 91		YC 90		YC 89		YC 88		YC 87		YC 86	
	Sd (mm)	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent
24															
22	1.09			11.22	2	15.73	18	18.02	42	21.20	36	23.69	1		
21	1.12			12.07	2	16.19	15	18.10	35	21.13	38	23.02	10		
19, 20	1.27			11.27	1	16.13	37	18.61	30	21.33	30	24.27	2		
18	1.13	(6.43)		10.53	11	14.73	37	17.29	34	20.68	13	23.13	5		
16, 17	1.03	6.39	1	11.28	4	15.27	35	17.90	35	21.01	17	23.00	6	25.39	2
15	1.13			11.78	2	15.77	26	18.23	38	21.53	26	24.11	7		
14	1.05	(5.00)		11.87	2	15.74	32	18.15	44	21.16	17	23.53	5		
9, 13	1.27	(6.75)		10.92	1	15.29	14	18.04	51	21.27	33	24.60	1		
10, 11, 12	1.18	(6.50)		11.78	2	15.95	24	18.02	42	21.33	30	24.36	3		
5, 8	1.11	(7.35)		11.72	1	15.74	9	18.33	53	20.57	25	21.86	12		
7		8.14	1	11.90	2	15.86	20	17.92	40	20.49	25	22.40	9		
6		6.37	1	13.48	3	16.24	13	18.11	50	21.30	33	25.16	2		
3, 4		7.66	1	15.61	12	18.66	10	21.17	22	22.72	21				
1, 2		8.79	1	15.18	20	18.63	45	21.25	19	23.01	15				
1, 2, 3, 4		8.66	1	15.32	16	18.62	45	21.60	21	22.90	18				

TABLE 4. Modal group analysis (Mix 3.0) for each sub-area in the Barnets Sea, spring 1994. Standard deviation (Sd) mean carapace length (CL) and proportion (percent) in each year class (YC) are given for sub areas (strata).

Strata		YC 93		YC 92		YC 91		YC 90		YC 89		YC 88		YC 87	
	Sd (mm)	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent
24	1.25			10.44	15	14.58	24	17.02	38	20.11	22	23.53	1		
22	1.04	5.51	6	10.28	8	15.26	11	17.87	51	20.89	23	23.55	1		
21	1.14	5.64	4	10.62	2	15.29	9	17.85	52	20.96	30	23.45	3		
19, 20	1.04			10.53	2	15.37	16	17.92	64	21.02	17	24.01	1		
18	1.05	7.55	1	10.78	20	14.98	33	17.05	28	20.11	16	23.00	2		
16, 17	1.19			10.86	7	14.37	16	17.20	58	20.51	18	24.17	1		
15	1.05			11.04	2	15.13	8	17.84	47	21.02	33	23.72	9	25.96	1
14	1.06			10.79	1	15.40	10	17.75	51	20.91	32	24.03	6		
9, 13	1.05			10.48	1	14.63	3	17.76	53	20.78	36	23.60	7		
10, 11, 12	1.15			11.56	2	14.72	8	17.36	40	20.58	41	23.11	9		
5, 8	1.13	8.18	1	10.06	1	15.39	15	17.82	45	20.68	33	22.91	5		
1, 2, 7	1.08	7.69	1			14.84	34	17.53	33	20.26	25	22.24	7		
6	1.21			11.40	1	14.82	9	17.61	47	20.64	42	23.65	1		
3, 4	1.05	7.37	1	12.84	1	15.44	10	17.88	43	20.81	36	23.12	9		

TABLE 5. Modal group analysis (Mix 3.0) for each sub-area in the Barnets Sea, spring 1995. Standard deviation (Sd) mean carapace length (CL) and proportion (percent) in each year class (YC) are given for sub areas (strata).

Strata		YC 94		YC 93		YC 92		YC 91		YC 90		YC89	
	Sd (mm)	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent
24	1.02	5.71	1	10.87	13	15.03	35	17.52	29	20.60	21	24.20	1
22	1.17	6.38	1	11.32	6	15.50	12	18.08	42	20.92	37	23.73	2
21	1.07	5.88	1	11.67	4	16.12	18	18.32	47	20.92	29	23.73	1
19, 20	0.69	6.15	3	12.39	10	15.12	9	17.10	28	20.25	49	24.83	1
18	0.98	7.05	1	11.11	15	14.98	26	17.64	30	20.61	26	23.59	2
16, 17	1.10	6.25	5	11.12	7	15.10	19	17.53	38	20.78	28	23.96	3
15	1.11	7.08	1	11.36	4	15.12	16	17.41	50	20.78	25	22.96	3
14	1.11	6.26	1	11.28	5	15.62	21	17.86	40	20.72	30	24.28	3
9, 13	1.15	6.36	2	11.54	3	15.28	8	17.83	42	20.90	40	23.43	5
10, 11, 12	1.09	6.95	1	11.36	5	15.13	14	16.94	44	20.45	35	23.18	1
5, 8	1.40	7.68	3	12.61	8			17.20	74	20.14	15		
1, 2, 7	1.32	9.32	3	13.98	19	16.43	42	19.66	33	22.55	3		
6	1.24	7.95	1	12.65	4	16.64	56	20.25	38	24.16	1		
3, 4	1.38	8.16	2	13.57	11	16.88	38	19.37	41	22.33	8		

TABLE 6. Modal group analysis (Mix 3.0) for each sub-area in the Barnets Sea, spring 1996. Standard deviation (Sd) mean carapace length (CL) and proportion (percent) in each year class (YC) are given for sub areas (strata).

Strata		YC 95		YC 94		YC 93		YC 92		YC 91		YC 90		YC 89	
	Sd (mm)	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent
24															
22	1.05			12.31	2	16.58	28	18.57	46	21.26	24	23.72	1		
21	0.97			11.88	2	16.66	22	18.56	48	21.36	28	23.70	1		
19, 20				11.85	4	16.44	35	18.48	36	21.50	24	23.94	1		
18															
16, 17	1.10	6.50		11.80	4	15.85	39	17.82	35	21.06	21	24.28	1		
15	1.04			12.28	3	15.99	32	17.93	39	20.80	20	22.62	6	26.00	
14	1.09	8.00		12.17	2	16.34	29	18.01	46	21.19	22	23.66	2		
9, 13	1.02	7.50		12.25	2	16.02	18	18.01	53	21.31	25	23.64	2		
10, 11, 12	1.06			11.92	2	15.15	17	17.28	54	20.47	25	22.82	3		
5, 8	1.26	8.00		12.36	2	15.12	17	17.37	69	20.37	11	21.86	12		
6, 7	1.13			11.38	3	14.44	17	17.06	65	20.30	15				
6	1.16			12.19	4	14.71	13	17.02	69	20.30	13				
3, 4	1.22	8.50		13.83	9	17.42	55	20.74	27	24.27	7	27.87	2		
1, 2	1.17			14.68	36	17.90	44	20.70	16	22.80	5				

TABLE 7a. Modal group analysis (Mix 3.0) for each sub-area in the Barnets Sea, spring 1997. Standard deviation (Sd) mean carapace length (CL) and proportion (percent) in each year class (YC) are given for sub areas (strata).

Strata		YC 96		YC 95		YC 94		YC 93		YC 92		YC 91		YC 90	
	Sd (mm)	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent
24															
22	0.92			9.77	1	16.01	9	18.42	62	20.56	24	22.70	3		
21	0.96			10.27	10	15.92	7	18.32	51	20.92	33	22.97	7		
19, 20		4.07		10.48	1	15.21	7	17.81	45	21.38	45	24.19	2		
18	1.30	5.16		10.01	8	15.10	33	17.30	44	21.00	13	23.64	1		
16, 17	1.12	5.11	2	10.12	6	15.21	22	17.45	44	20.98	22	23.56	4		
15	1.16	6.13		10.80	2	15.49	13	17.67	53	20.55	24	22.93	7	26.21	0.3
14	1.18	5.39	1	10.28	3	15.03	6	17.13	66	20.33	20	22.62	6		
9, 13	1.28	5.70	1	9.53	1	13.33	1	17.72	73	21.07	24				
10, 11, 12	1.20	4.99	1	10.03	4	14.50	11	17.09	51	20.17	32	23.53	1		
5, 8						15.04		17.48		20.03					
6, 7	1.12	8.88		11.52	1	14.99	5	17.50	82	20.15	13				
6	1.07	6.99	2	11.81	3	14.90	18	17.26	50	19.57	18	21.05	8		
3, 4	1.13	7.15		11.70	1	15.15	6	17.81	65	20.33	25	22.8	4		
1, 2		7.01		9.50		14.71	7	18.04	62	20.23	25	22.57	5		
7	1.11	6.49	1	10.30	3	14.47	12	17.14	56	19.94	26	22.8	1		

TABLE 7b. Modal group analysis (Mix 3.0) for each sub-area in the Barnets Sea, autumn 1997. Standard deviation (Sd) mean carapace length (CL) and proportion (percent) in each year class (YC) are given for sub areas (strata).

Strata		YC 96		YC 95		YC 94		YC 93		YC 92		YC 91		YC 90	
	Sd (mm)	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent
24	1.30			13.25	25	17.39	46	20.51	25	23.35	1				
22															
21															
19, 20															
18	1.29			13.52	13	18.00	50	20.31	28	23.34	9				
16, 17	1.56			13.76	1	18.28	62	21.63	30						
15	1.45			12.50		15.06		18.58	50	21.19	41	24.32	1	28.00	
14	1.54	10.00		12.29	1	16.24	16	19.41	70	22.70	14	26.00			
9, 13															
10, 11, 12															
5, 8															
6, 7															
6	1.04			14.65		18.09	57	20.51	34	23.15	1	25.00			
3, 4															
1, 2															
17	1.17			13.95	9	16.88	23	18.70	41	20.85	18	22.86	1		
16	1.05			12.86		16.79	20	18.86	38	21.23	28	23.09	11		
11, 12	0.94	12.00		14.24		17.07	21	19.10	55	21.29	16	23.47			

TABLE 8. Modal group analysis (Mix 3.0) for each sub-area in the Barnets Sea, spring 1998. Standard deviation (Sd) mean carapace length (CL) and proportion (percent) in each year class (YC) are given for sub areas (strata).

Strata		YC 97		YC 96		YC 95		YC 94		YC 93		YC 92		YC 91	
	Sd (mm)	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent
21, 22	1.04	5.69	1	9.51	0	14.3	3	16.98	14	18.58	55	20.98	23	23.46	3
22															
21															
19, 20	1.16	*5.00*		*10.00*		14.64	4	17.86	62	20.67	30	23.48	5		
18	0.87					14.98	46	16.96	34	18.78	10	21.26	10		
16, 17	1.08	5.62	10	10.03	2	13.73	7	16.25	23	18.38	39	21.02	16	24.06	3
15	1.19	6.14	3	11.70	1	15.18	13	17.49	153	20.43	26	23.57	4	*26.00*	
14	1.00	5.72	1	12.44	0	16.1	17	18.08	49	20.74	30	23.47	4		
9, 13	1.14	*6.00*		11.13	1	15.18	4	18.11	53	20.58	39	23.51	3		
10, 11, 12	1.20	6.20	4	11.72	17	15.31	12	17.6	43	20.53	36	23.22	3		
5, 8	1.11	*6.00*		*10.50*		14.53	7	17.07	72	19.50	19	21.37	2		
6, 7	1.33	*6.00*		*10.00*		14.59	5	17.01	49	19.67	44	22.50	3		
6															
1, 2, 3, 4	1.25			10.21	0	13.72	7	17.67	51	20.80	36	22.52	6		
17	1.02	5.61	19	9.86	4	13.68	11	16.39	20	18.54	33	21.10	12	24.20	2
16	1.00	5.63	2	10.58	1	13.83	5	16.13	25	18.23	42	21.00	19	23.00	4

Table 9. Modal group analysis (mix 3.0) for each sub-area in the Barnets Sea, spring 1999. Standard deviation (Sd) maen carapace length (CL) and proportion (percent) in each year class (YC) are given for sub areas (strata).

Strata		YC 98		YC 97		YC96		YC 95		YC 94		YC93		YC 92		YC 91	
	Sd (mm)	CL (mm)	Percent	CL (mm)	Percent	CL(mm)	Percent	CL(mm)	Percent	CL(mm)	Percent	CL (mm)	Percent	CL (mm)	Percent	CL (mm)	Percent
24	1.06	6.00	8	9.22	18	13.72	10	16.79	42	20.26	18	22.95	4				
22	1.03	5.54	3	9.37	1			15.94	3	18.39	50	20.63	40	23.76	4		
21		*5.00*		*9.50*				*16.50*		18.2	65	20.67	30	23.03	5		
19,20		*5.50*				14.05	2	17.22	30	18.81	35	20.95	28	23.62	5	26.49	0
18	0.92	6.10	6	9.74	4	13.75	4	16.87	47	19.57	22	21.24	16	24.16	2		
16,17	1.05	6.02	6	9.53	6	13.79	3	17.11	45	19.98	33	22.43	8	25.67	1		
15	1.08	5.52	1	9.13	1	12.64	1	15.97	15	17.94	41	20.66	37				
14	1.03	5.68	2	8.99	1	13.49	1	17.22	26	18.75	33	20.98	34	24.02	4		
9,13	1.02	5.80	2	8.69	2	12.90	1	17.40	29	18.88	35	21.04	29	23.73	2		
10,11,12	1.35	5.31	3	9.72	3	13.40	2	17.49	58	20.69	25	24.23	1				
5,8	1.05	5.72	1	10.27	1	15.05	2	18.29	66	20.79	29	23.09	2				
6,7	1.30	6.75	0	9.99	1	13.08	2	17.53	62	20.43	30	22.58	4				
6																	
3,4	1.42	6.70	0	11.31	1	14.92	2	18.20	50	21.18	46						
1,2	1.18	7.21	1	13.47	6	15.84	10	18.16	57	21.38	26	24.29	1				

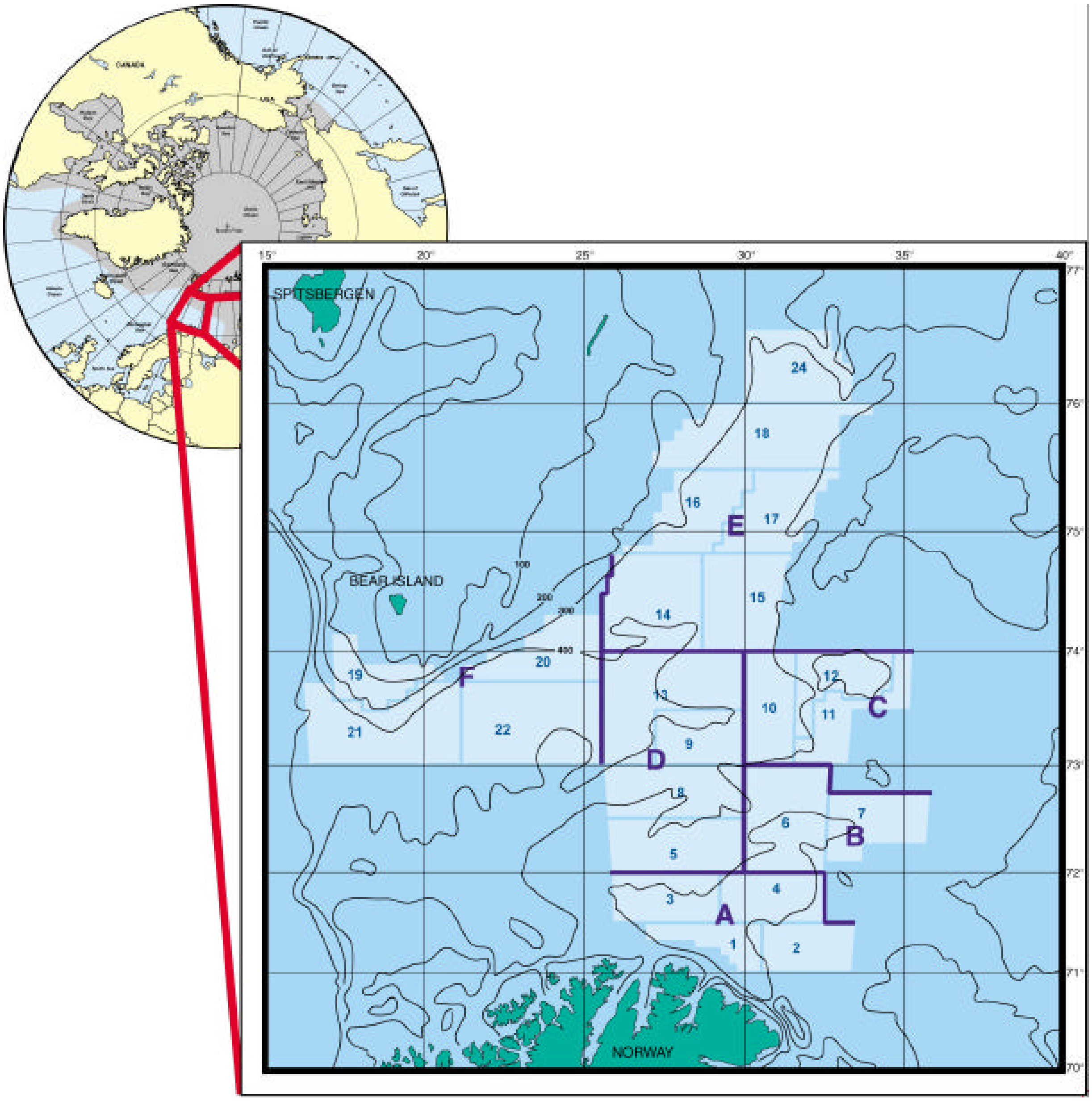


Fig. 1. Strata used in the Barents Sea for the shrimp surveys (1-24). Main areas are East Finnmark (A), Tiddly Bank (B), Thor Inersen Bank (C), Bear Island Trench (D), Hopen (D) and Bear Island (E).

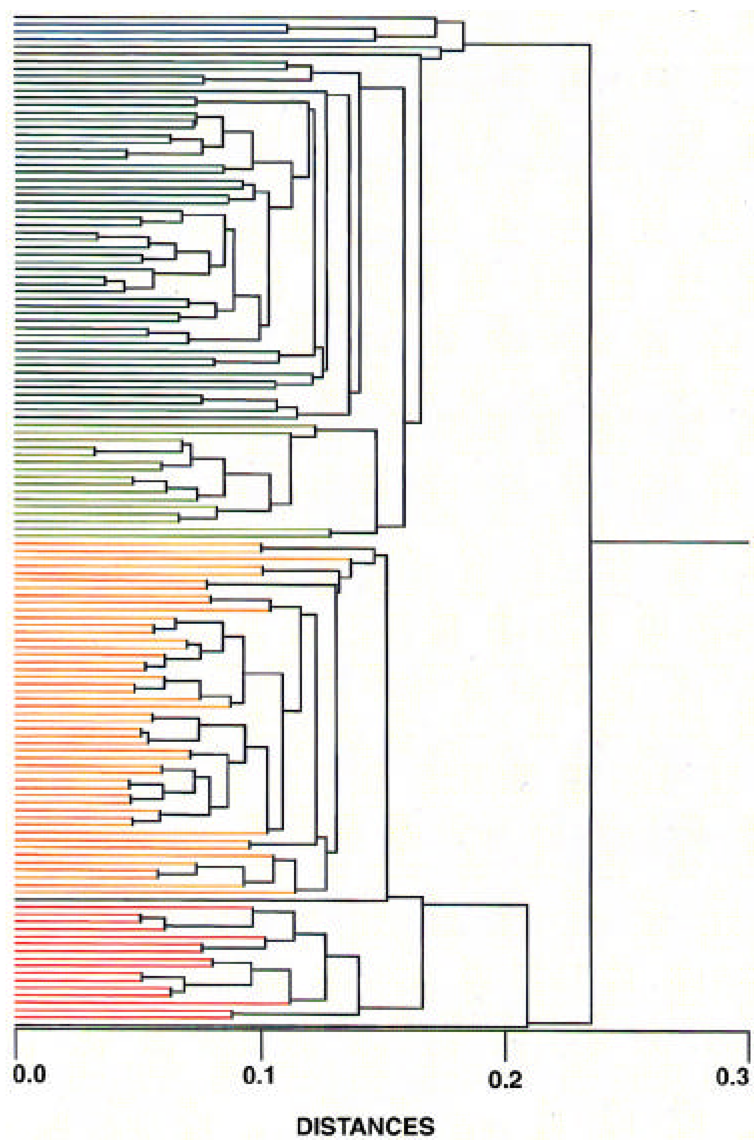
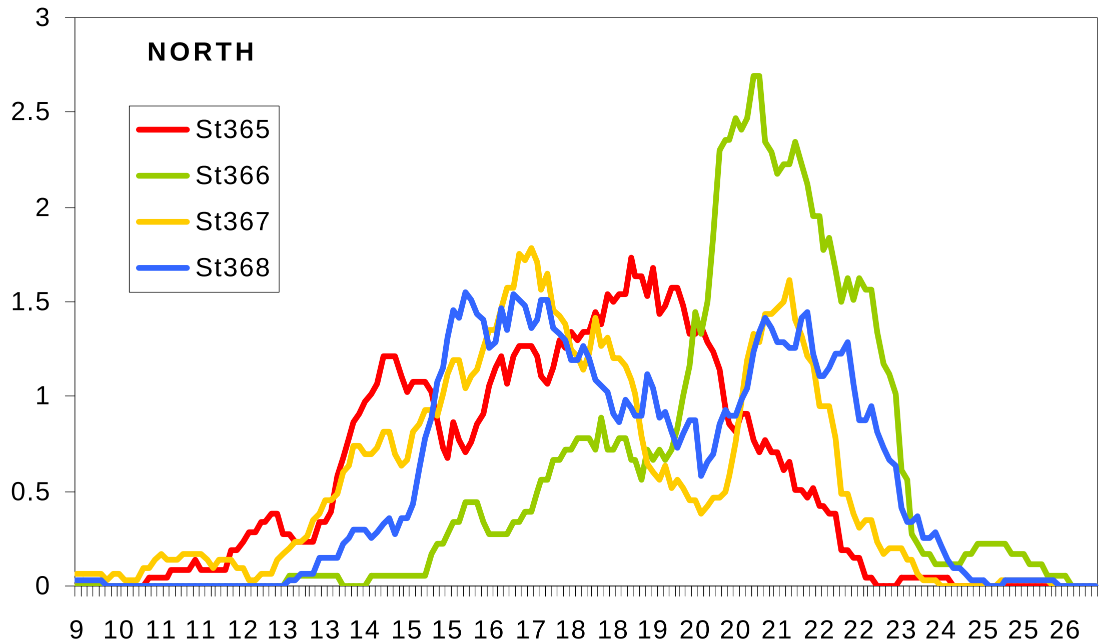


Fig. 2. Cluster of distance between stations in the Barents Sea in 1996 according to LFDs.



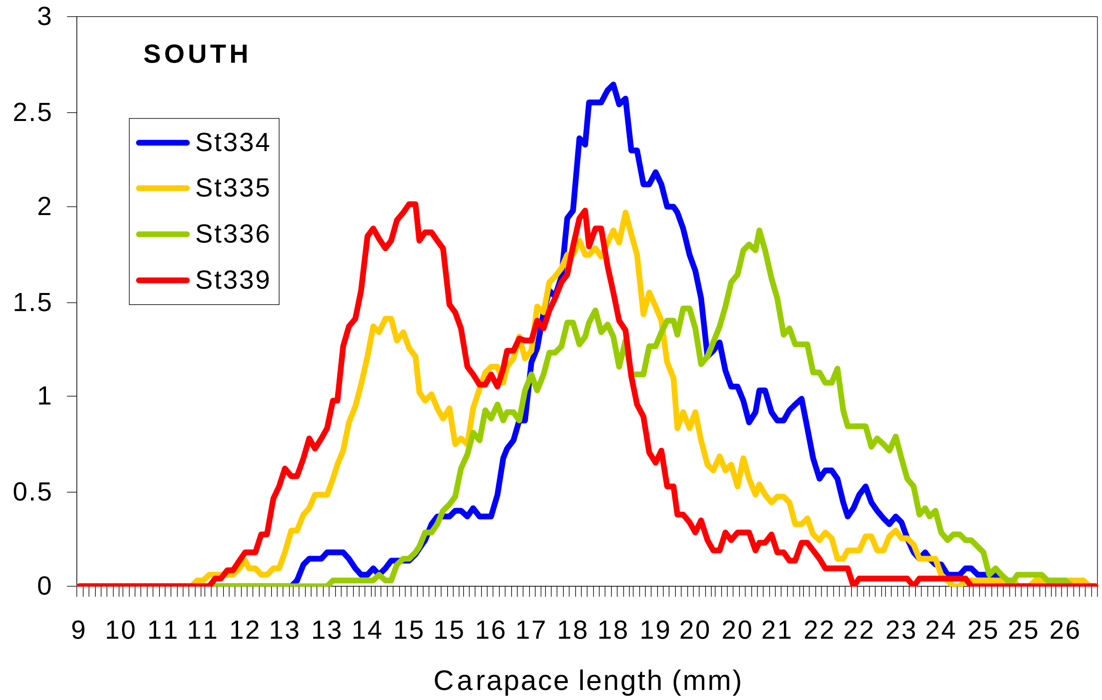


Fig. 3. LDFs of stations representing four groups in the northern (stations 365-368) and the southern (stations 334-336,369) Barents Sea in 1996.

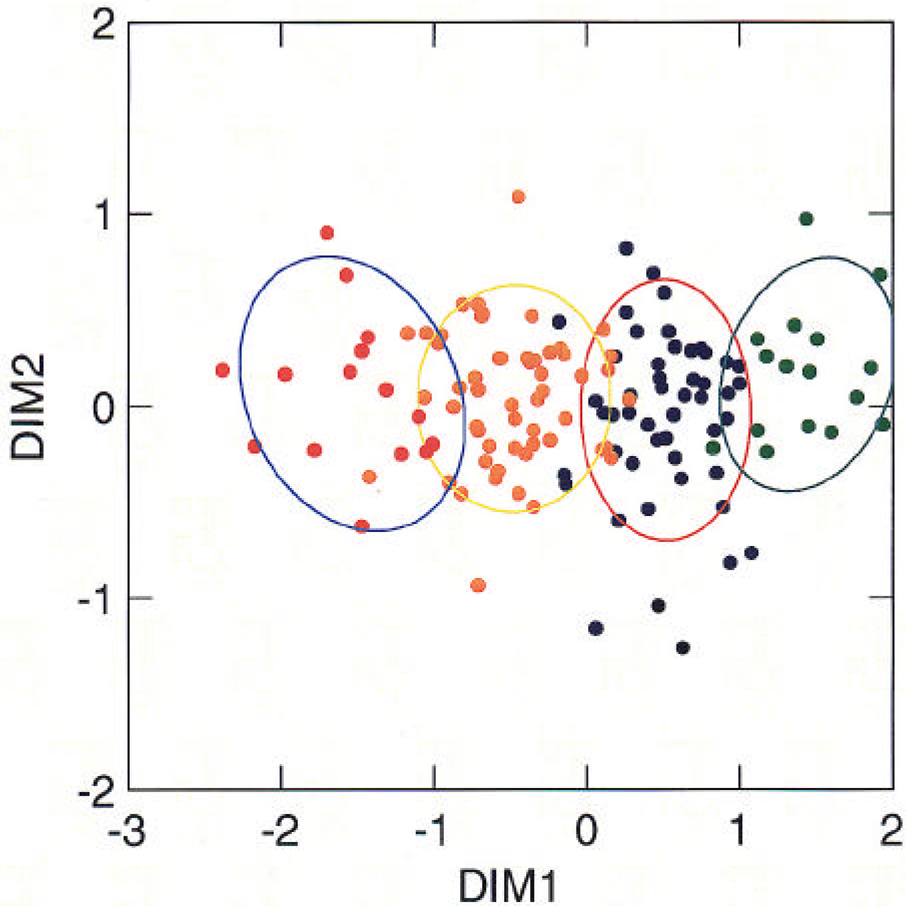


Fig. 4. Distribution of stations in the Barents Sea 1996 when analysed by Monotonic Multidimensional Scaling.

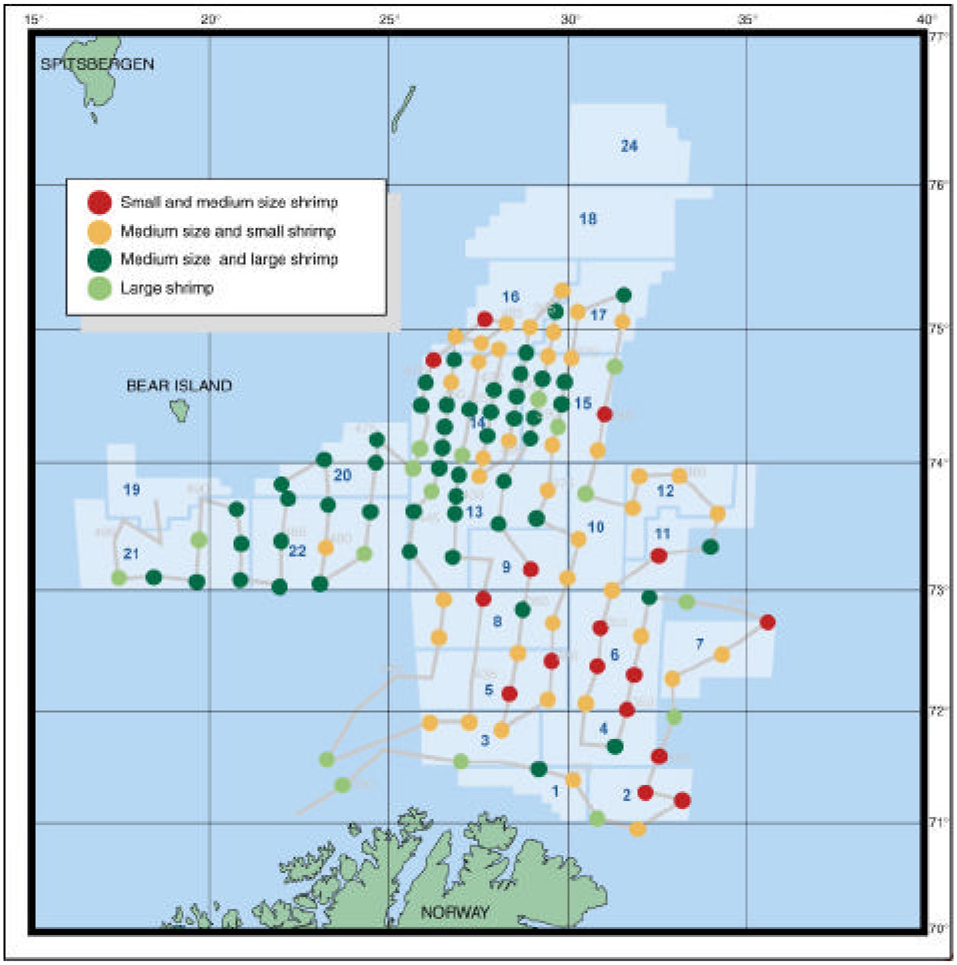


Fig. 5. Spatial distribution of four station groups characterised by LFDs in the Barents Sea in 1996. Survey track and every fifth station number marked with grey. Strata system with 24 strata.

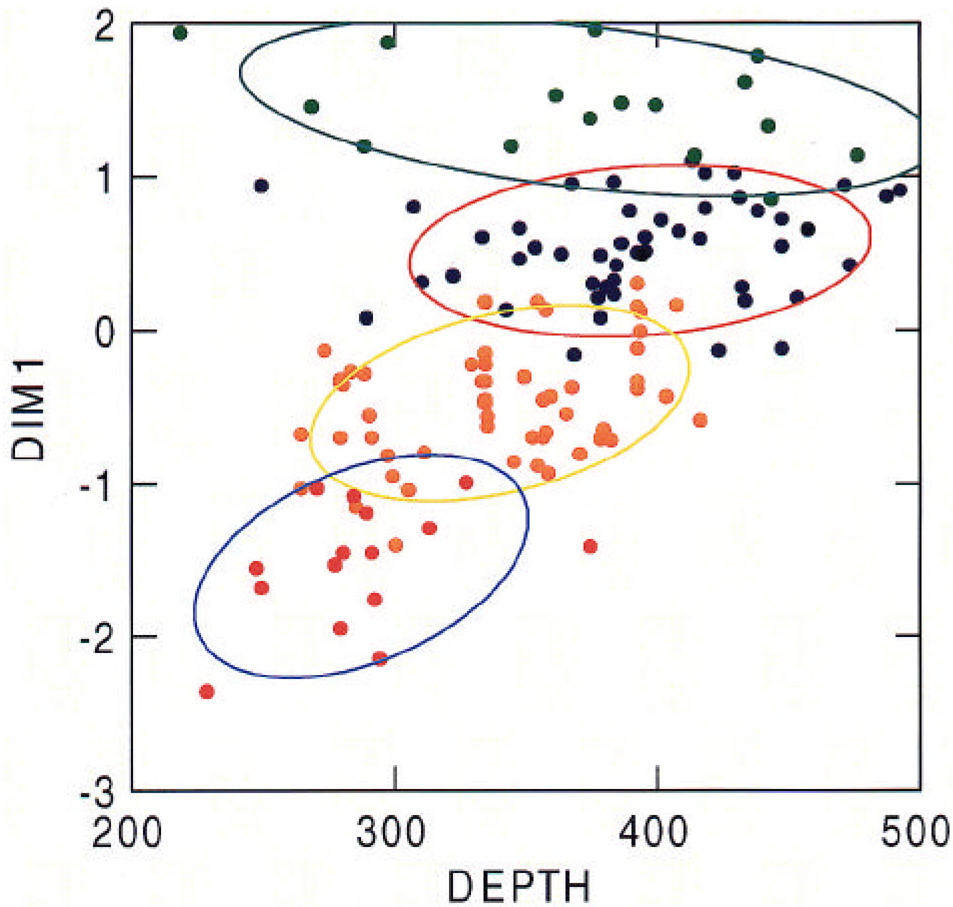


Fig. 6. Depth against value for dimension 1 from the Monotonic Multidimensional Scaling plotted for each station in the Barents Sea in 1996.

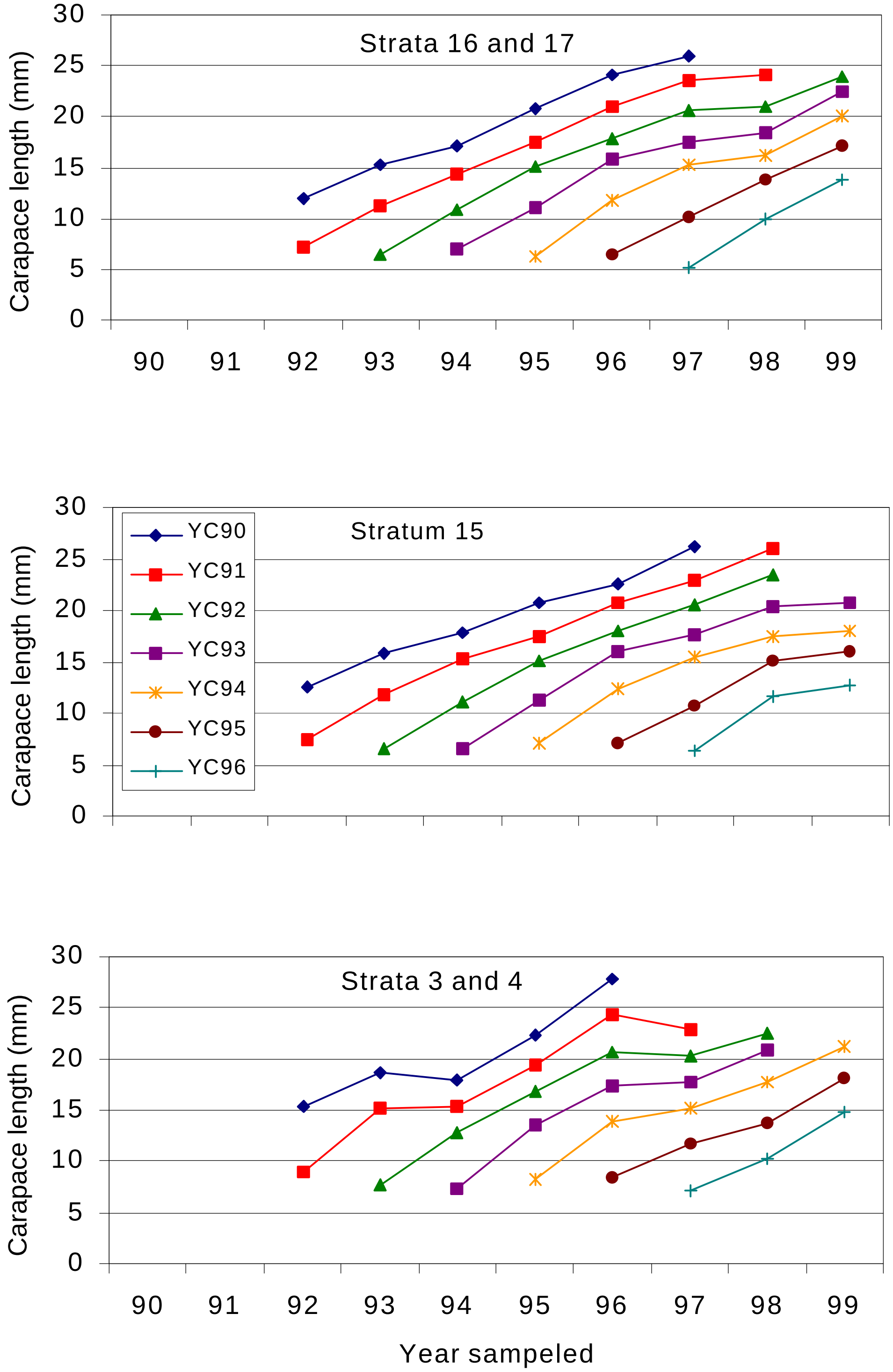


Fig. 7. Growth curves for 90-96 year classes of shrimp in the northern Barents Sea (strata 16 & 17 and stratum 15) and southern Barents Sea (strata 3 & 4) in 1996.

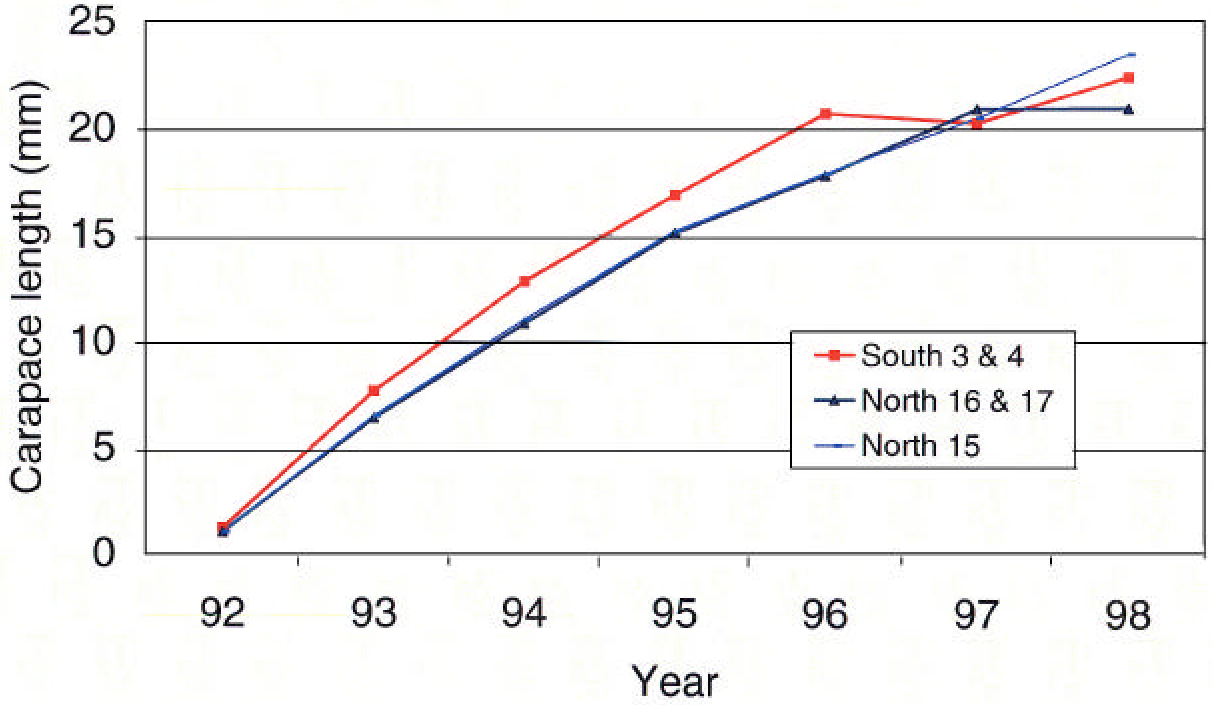


Fig. 8. Growth curves of the 92 year class shrimp in the northern Barents Sea (strata 16 & 17 and stratum 15) and in the southern Barents Sea (strata 3 & 4). Based on data from surveys conducted in 1993-1997.