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Population structure of *Sebastes mentella* in the North-East Arctic

Fran Saborido-Rey[1] and Kjell H. Nedreaas[2]

[1]Instituto de Investigaciones Marinas
Eduardo Cabello, 6
36208 Vigo, Spain
fran@iim.csic.es

[2]Institute of Marine Research
P.O. Box 1870
N-5024 Bergen, Norway
kjell.nedreaas@imr.no

Abstract

At present time it is considered the existence of only one management unit of *S. mentella* in Northeast Atlantic. In present paper a morphometric analysis is made to compare specimens from different locations and different time of the year. Residuals of the regression between each morphometric variable and standard length are used as input in a Stepwise Discriminant Analysis. Results show a possible different population structure in the area, with three main regions morphometrically different: Svalbard, Barents Sea and Norwegian Sea and Lofoten area being an intermediate area where fish from the other areas are present at different seasons of the year. A previously described spawning migration pattern is also possible to detect from the present analysis and its implication on survey design is discussed.

Introduction

An outline of the geographical distribution of the Northeast Arctic stock of *S. mentella* is shown in Figure 1. The southwestern Barents Sea and the Spitzbergen areas are primarily nursery areas. Although some adult fish may be found in smaller areas within these main areas, the main behavior for the fish is to migrate westwards and southwestwards towards the continental slope as it grows and becomes adult. South of 70°N only few specimens less than 28 cm are observed, and south of this latitude *S. mentella* are only found along the slope from about 450 m down to about 650 m. The southern limit of its distribution is not well defined but is believed to be somewhere on the slope northwest of Shetland. The main larval extrusion grounds are along the slope from north of Shetland to west of Bear Island. The peak in larval extrusion takes place during the first half of April. Low isozyme genetic variation has so far been found in *S. mentella* in the Northeast Arctic (e.g., Nedreaas and Nævdal, 1989), and there are to date therefore no genetic results which may support any further splitting of the present single management unit.

Morphometric studies have provided results useful for identifying marine fish stocks and describing their spatial distribution (Ihssen *et al.*, 1981). It has been previously used in *Sebastes* species and populations in both sides of the North Atlantic (Misra and Ni, 1983; Power and Ni, 1985; Kenchington, 1986 and Saborido-Rey, 1994). Saborido-Rey (1994) studied different populations of *Sebastes* in the North Atlantic, including south of Norwegian Sea and Spitzbergen *S. mentella*. He concluded the existence of two groups of *S. mentella* around Norway and Svalbard; also the individuals *S. mentella, S. marinus* and *S. fasciatus* in Flemish Cap, Grand Bank of Newfoundland and Saint Pierre Bank constituted separated stocks.
Nevertheless the question whether there is a single stock or not in Northeast Arctic stays unresolved since the Norwegian surveys shows a continuous distribution of the resource with a clear pattern of distribution of juveniles and adults, as stated above (Figure 1). The objective of the present paper were to (1) assess and describe the geographic variation in morphological characters of *S. mentella* in the Northeast Arctic, (2) elucidate the distribution pattern of the resource in the area and (3) investigate their implications on survey design

Material and methods

A total of 319 specimens of *S. mentella* were sampled in the area covering Norwegian Sea, Barents Sea and Svalbard. Table 1 gives an account of the sampled data and Figure 2 shows the geographical locations of the samples. In all cases *S. mentella* specimens were identified using the gasbladder musculature to distinguish them from *S. marinus* (Ni, 1981; Power and Ni, 1985).

22 morphometric variables were measured (including preanal length not used in present analysis). Figure 3 shows the landmarks used and the measurements taken with the nicknames for each variable as used below in the results and discussion chapters. Variables were chosen following a truss network method (Humphries *et al.*, 1981) and in addition variables describing the head and fins were incorporated. All the measurements were taken with a digital caliper (MITUTOYO 500-301) at ± 0.01 mm.

In order to remove the size dependence of the morphometric variables and compare the shape of the fish of different sizes, morphometric data were statistically adjusted to permit comparative analysis in terms of shape independently of size (Thorpe, 1983). Outliers were detected by regression analysis of morphometric analysis against standard length and by scatter plots of residuals versus predicted values (Cook and Weinsberg, 1982). When an outlier was found all the morphometric data for that fish were withdrawn. This procedure resulted in the elimination of morphometric data for 3 fish from the Svalbard group.

Residuals of the regression between each variable and standard length were used as input in the subsequent analysis. This regression-related technique has been probed that adequately achieved a separation between size and shape variation (Reist, 1986; Saborido-Rey, 1994). The data was pooled (without group consideration) and the variables regressed with standard length. The residuals thus obtained (adjusted morphometric characters) were used in the Stepwise Discriminant Analysis. This multivariate technique has been widely used in stock discrimination analysis. The discriminant analysis was applied to adjusted morphometric characters with variables entered in a forward manner using $F = 4.0$ for entering, and $F = 3.99$ for removal.

Differences by sexes within groups were tested prior to the final analysis. Differences were tested both with Principal component analysis and stepwise discriminant analysis. Also differences between fish from different hauls within each group were tested using the same methodology. As a result of this analysis a certain pattern in the data was observed for fish collected in the Lofoten area. Therefore it was decided to run the analysis as follows:

Step 1. - Including in the analysis the three more distant groups, i.e. Norwegian Sea, Barents Sea and Spitzbergen (Figure 2).

Step 2. - Bear Island fish, geographically placed between Spitzbergen and Barents Sea is incorporated to the analysis.

Step 3. – Bear Island and Spitzbergen were pooled in the same group (Svalbard) and compared with Norwegian Sea and Barents Sea.

Step 4. – Fish collected from Lofoten in both surveys (autumn and spring) were combined and incorporated to the analysis together with Svalbard, Norwegian Sea and Barents Sea.

Results

There were no differences within each region between sexes except for the spring samples in Lofoten area. The PCA reveal a clear pattern of two groups that can be considered as males and females (Figure 4). In the Stepwise discriminant analysis is shown that the differences between sexes are relatively high, with a final correct classification rate of 92.86 %, although Wilks' λ is not particularly low. For each region, i.e. Spitzbergen, Bear Island, Barents Sea, Norwegian Sea and Lofoten the within variation was tested analyzing differences between stations. Only in the Lofoten area there were variation between the spring and autumn samples. Therefore as explained above it was decided to run the analysis step by step incorporating progressively different groups to the analysis.

Step 1. - More distant groups (Spitzbergen, Barents Sea and Norwegian Sea)

The plot of the two canonical variables shows a complete separation between the three groups (Figure 5). The first canonical variable accounts for the 83 % of the total variation. The total correct classification rate was 94.8 % that can be considered as very good discrimination. 100 % of the specimens from Norwegian Sea are correctly classified. Although there is some overlap of individuals between Spitzbergen and Barents Sea the discrimination between them is high with a correct classification of 89.5 and 94.2 % respectively (Table 2). The analysis was performed with the entrance of 16 morphometric variables and Wilks' λ drop to 0.08 with an approximate F statistic indicating a significant difference among the three groups ($F = 23.58$, df 32, 310, $P < 0.001$).

Step 2.- Including Bear Island

Bear Island samples were collected from two different stations lying between the Spitzbergen and Barents Sea locations. Therefore fish sampled at Bear Island were considered as a different group in this step and analyzed together with the groups described in the previous step. Figure 6 shows the plot of the two first canonical variables, which account for 79 % and 19 % of the total variation. There is a noticeable overlap of individuals of Bear Island and Spitzbergen and less overlap with the Barents Sea. The Norwegian Sea is still 100 % discriminated. The total correct classification rate is only 75.75 %, which is considered as a poor discrimination rate (Table 3). This low rate is due to the low classification rates of Spitzbergen and Bear Island. Note that the Barents Sea specimens are classified mainly within its group (86.2 %) and the rest are mainly classified as belonging to Bear Island (Table 3). However the 55.3 % of Spitzbergen specimens are classified in Bear Island group. The stepwise analysis revealed that 16 of the 20 adjusted morphometric characters contributed significantly to the multivariate discrimination of the four groups of fish (Table 3). The approximate F statistic indicates significant difference among groups (F = 18.25, df 48, 741, P<0.001) and Wilks' λ is low, 0.098. It seems clear that Bear Island are mainly formed by the same fish as Spitzbergen, so it was decided to run a new analysis combining both groups as one Svalbard group.

Step 3. – Spitzbergen and Bear Island combined as Svalbard

The two canonical variates from the discriminant analysis were plotted and are show in Figure 7. As expected there is an overlap between Barents Sea and Svalbard but still the classification rate is high for both groups, 86.2 % and 88 % respectively (Table 4). All the Norwegian Sea specimens are correctly classified. The total classification rate is 89.55 %. 17 morphometric variables were entered in the analysis and the final statistics show a significant multivariate discrimination of the three groups, Wilks' λ was 0.11 and approximate F was 29.54 (df 34, 498, P<0.001). Results can be considered as a good discrimination and the assignation of the Bear Island specimens into a Svalbard group together with the Spitzbergen specimens as a correct step.

Step 4. - Including Lofoten samples

As a final step, the Lofoten samples were included in a new analysis together with the three other groups, Norwegian Sea, Svalbard and Barents Sea. As shown in Figure 8 there are a considerable overlap between the Lofoten individuals and the other three groups, mainly with Svalbard and Barents Sea. The low total correct classification rate, 77.74 % (Table 5) is due to the poor discrimination of the Lofoten specimens that are classified into other groups, 25.49 % into Svalbard, 19.73 % into Barents Sea and 7.84 % into Norwegian Sea. In this analysis it was necessary to enter all the 20 morphometric variables and the Wilks' λ was the highest of the four analysis made in the present paper, 0.16, but still significant (the approximate F was 12.57, df 60, 884, $P<0.001$). These significant values are the result of good discrimination of the Norwegian Sea individuals. It can be said that there is no discrimination between Lofoten and Svalbard at least. As explained above there were significant differences between the sexes in the Lofoten samples, and the samples from Lofoten were collected at two different times of the year (autumn and spring). Therefore a new plot was produced with the same discriminant scores but with different symbols for spring and autumn Lofoten samples and for males and females of the Lofoten spring samples (Figure 9). It can be observed that the Lofoten specimens classified into the Norwegian Sea are those collected in autumn. Females and males of Lofoten spring samples are clearly divided in two groups, the males being more linked with the Svalbard samples, whereas the females show an overlap with both Svalbard and Barents Sea.

Discussion

The results of these analyses of morphometric characters suggest that there are at least three distinct discrete groups of *S. mentella* in the North-East Arctic: Spitzbergen, Barents Sea and the Norwegian Sea. These three groups correspond to the more distant samples collected in this study and the overlapping between them is low. The central part of the studied area is formed by a mix of specimens belong to different groups. Thus Bear Island, placed between the locations where Spitzbergen and Barents Sea samples were collected, shows a high overlap with both groups although are formed mainly by the same specimens of Spitzbergen. Then it can be said that there is a group, we called it Svalbard, formed by those specimens from Spitzbergen and Bear Island and different to Norwegian Sea and Barents Sea, although with some mixture with Barents Sea group.

In the case of Lofoten, previous to further considerations, it should be taken into account that most of the samples were taken in spring, it means spawning time for *S. mentella*. The autumn samples of Lofoten were classified mainly into the Norwegian Sea group suggesting that in autumn there is a clear separated distribution pattern of the three groups. Nevertheless more specimens should be collected in autumn in Lofoten to clarify the distribution range of the Norwegian Sea group. The spring Lofoten samples shows a high mixture of specimens belonging to Svalbard and Barents Sea groups, suggesting that during this time of the year specimens from both areas inhabit Lofoten islands. In that sense it is interesting to observe that Spring Lofoten group was the only one showing differences between sexes. After the four steps analyses strongly suggest that this group be formed for specimens coming from different areas, probably males from Svalbard and females from Svalbard and mainly from Barents Sea.

It means that there are a migration pattern, probably related with spawning, from Svalbard and Barents Sea to Lofoten. *Sebastes* species are known to be viviparous having the copulation in autumn and the parturition in February-July, depending of the species and locations (Saborido-Rey, 1994). *S. mentella* in Northeast Arctic have the parturition peak located between February (authors observations) and April (Sorokin, 1961)

Most of the mature stock of Northeast Arctic *S. mentella* live year around along the continental slope at 450-650 meters from northwest of Shetland and northwards towards Bear Island. It is known that the extrusion of larvae in spring takes place here and most probably the copulation in autumn also. There may well be "spawning" migrations along the slope, but such migrations have so far not been documented. In the present data and analysis no fish from the Norwegian Sea group showed up in the Lofoten spring samples which may, although the data are scarce, point to the fact that they release the larvae elsewhere along the slope.

Smaller aggregations of mature *S. mentella* within the Barents Sea and at Svalbard have been documented to migrate southwestwards to the slope area for extrusion of larvae in April (Sorokin, 1961). This fit well with the observed mixture of Barents Sea and Svalbard *S. mentella* groups outside Lofoten at this time of the year.

A denser grid of sampling stations along the slope during the extrusion time is necessary before any conclusions can be drawn about the structure of the stock(s) in question. It may well be that the different feeding areas recruit to different "spawning" grounds and/or at different times, which may have implications for the subsequent larvae drift routes. It should also be investigated if there are year to year variations. More knowledge about this would be a good basis for optimal survey design and important for correct interpretation of survey results. If we assume the existence of different groups in the whole area we have to consider that these groups are separated during the feeding time (summer) and mainly during copulation time (autumn) but mixed during spawning time (spring).

Thus the morphometric analyses is a useful tool not only for stock discrimination, but also for identified changes in the aggregation of fishes from different areas and migration routes.

References

Cook, R. D. and S. Weisberg (1982) *Residuals and Influence in Regression. Monographs on Statistics and Applied Probability*. Chapman and Hall, NY, 230pp.

Humphries, J. M., F. L. Bookstein, B. Chernoff, G. R. Smith, R. L. Elder and S. G. Poss (1981) Multivariate discrimination by shape in relation to size. *Syst. Zool.*, **30**(3): 291-308.

Ihssen, P. E., H. E. Booke, J. M. Casselman, J. M. McGlade, N. R. Payne and F. M. Utter (1981) Stock identification: Materials and Methods. *Can. J. Fish. Aquat. Sci.*, **38**(12): 1838-1855.

Kenchington, T. J. (1986) Morphological comparison of two Northwest Atlantic redfishes, *Sebastes fasciatus* and *S. mentella*, and techniques for their identification. *Can. J. Fish. Aquat. Sci.*, **43**(4): 781-787.

Misra, R. K. and I-H. Ni (1983) Distinguishing beaked redfishes (Deepwater *S. mentella* and Labrador *S. fasciatus* Redfishes) by discriminant analysis (with covariance) and multivariate analysis of covariance. *Can. J. Fish. Aquat. Sci.*, **40**(9): 1507-1511.

Nedreaas, K. and G. Nævdal (1989) Studies of the Northeast Atlantic species of redfish (Genus *Sebastes*) by protein polymorphism. *J. Cons. int. Explor. Mer*, **46**: 76-93.

Ni, I-H. (1981) Separation of sharp-beaked redfish *Sebastes fasciatus* and *S. mentella* from Northeastern Grand Bank by morphology of extrinsic gassbladder musculature. *J. Northw. Atl. Fish. Sci.*, **2**: 7-12.

Power, D. J. and I-H. Ni (1982) Morphology of the extrinsic gassbladder musculature in the golden redfish, *Sebastes marinus*. *J. Northw. Atl. Fish. Sci.*, **3**: 165-168

Reist, J. D. (1986) An empirical evaluation of coefficients used in residual and allometric adjustment of size covariation. *Can. J. Zool.*, **64**: 1363-1368.

Saborido-Rey, F. (1994) The Genus Sebastes Cuvier, 1829 (Pisces, Scorpaenidae) in the North Atlantic: Species and population identification using morphometric techniques; Growth and reproduction of the Flemish Cap populations. Ph.D. Thesis, Uni. Autónoma, Madrid. 276 pp. In Spanish

Sorokin, V. P. (1961) The redfish, gametogenesis and migrations of the *Sebastes marinus* (L.) and *Sebastes mentella* Travin. *ICNAF Spec. Publ.*, **3**: 245-250.

Thorpe, R. S. (1983) A review of the numerical methods for recognizing and analyzing racial variation. *In* Felsenstein, J. (ed.), Numerical taxonomy, p. 404-423. Springer-Verlag, Berlin.

Table 1.- Description of the sampling location.

Location	Date	n° specimens	Size range (mm)	Source
Norwegian Sea (excluding Lofoten)	October 1990	48	240-390	R/V G. O. Sars
Lofoten	October 1990	8	245-366	R/V G. O. Sars
	March 1993	43		R/V M. Sars
Barents Sea	October 1996	87	201-342	R/V Johan Hjort
Svalbard	August 1992	133	154-379	Spanish cod pair trawler

Table 2. - Summary of stepwise discriminant analysis for Step 1. Variable acronyms are defined in Figure 3.

Step number	Variable entered	Wilks' λ	F value to enter	Approximate F-statistic	Degrees of freedom	
1	AN	0.350489	157.52	157.52	2	170
2	LPO	0.208633	57.45	100.50	4	338
3	D2A	0.179283	13.75	76.26	6	336
4	LM	0.158222	11.11	63.21	8	334
5	DO	0.142430	9.20	54.77	10	332
6	DV	0.128663	8.83	49.17	12	330
7	H2D	0.118660	6.91	44.58	14	328
8	LD	0.110846	5.75	40.82	16	326
9	LA	0.104682	4.77	37.63	18	324
10	LP	0.099219	4.43	35.01	20	322
11	LV	0.095934	2.74	32.42	22	320
12	LMS	0.093424	2.14	30.10	24	318
13	AD	0.090719	2.36	28.20	26	316
14	LC	0.088290	2.16	26.53	28	314
15	VA	0.086740	1.39	24.91	30	312
16	LV	0.084777	1.79	23.58	32	310

Classification matrix

Group	Percent Correct	Number of fish classified into group		
		Norwegian Sea	Spitzbergen	Barents Sea
Norwegian Sea	100.00	48	0	0
Spitzbergen	89.47	0	34	4
Barents Sea	94.25	0	5	82
Total	94.80	48	39	86

Table 3. - Summary of stepwise discriminant analysis for Step 2. Variable acronyms are defined in Figure 3.

Step number	Variable entered	Wilks' λ	F value to enter	Approximate F-statistic	Degrees of freedom	
1	AN	0.463096	102.03	102.03	3	264
2	LPO	0.264574	65.78	82.73	6	526
3	DO	0.214134	20.57	62.62	9	638
4	DV	0.173642	20.29	54.01	12	691
5	LM	0.153065	11.65	46.62	15	718
6	LD	0.138388	9.16	41.22	18	733
7	LMS	0.130901	4.92	36.37	21	741
8	LC	0.124943	4.09	32.59	24	746
9	D2A	0.120420	3.20	29.50	27	748
10	LA	0.115712	3.46	27.09	30	749
11	LV	0.112028	2.78	25.02	33	749
12	LP	0.108062	3.10	23.35	36	748
13	LV	0.104452	2.90	21.92	39	747
14	AD	0.102043	1.98	20.56	42	745
15	H2D	0.099557	2.08	19.40	45	743
16	VA	0.098251	1.10	18.25	48	741

Classification matrix

Group	Percent Correct	Number of fish classified into group			
		Norwegian Sea	Bear Island	Spitzbergen	Barents Sea
Norwegian Sea	100.00	48	0	0	0
Bear Island	69.47	0	66	11	18
Spitzbergen	36.84	0	21	14	3
Barents Sea	86.20	0	10	2	75
Total	75.75	48	97	27	96

Table 4. - Summary of stepwise discriminant analysis for Step 3. Variable acronyms are defined in Figure 3

Step number	Variable entered	Wilks' λ	F value to enter	Approximate F-statistic	Degrees of freedom	
1	AN	0.466454	151.56	151.56	2	265
2	LPO	0.266528	99.01	123.68	4	528
3	DO	0.216088	30.69	100.92	6	526
4	DV	0.176231	29.63	90.53	8	524
5	LM	0.156899	16.08	79.58	10	522
6	LD	0.147214	8.55	69.61	12	520
7	LC	0.140817	5.88	61.60	14	518
8	D2A	0.134979	5.58	55.53	16	516
9	LA	0.130692	4.22	50.43	18	514
10	LP	0.127091	3.63	46.21	20	512
11	LV	0.122221	5.08	43.13	22	510
12	LMS	0.119053	3.38	40.18	24	508
13	H2D	0.116127	3.19	37.65	26	506
14	AD	0.113475	2.94	35.43	28	504
15	LV	0.112021	1.63	33.26	30	502
16	VA	0.110821	1.35	31.31	32	500
17	LMO	0.109861	1.09	29.54	34	498

Classification matrix

Group	Percent Correct	Number of fish classified into group		
		Norwegian Sea	Svalbard	Barents Sea
Norwegian Sea	100.00	48	0	0
Svalbard	87.97	0	117	16
Barents Sea	86.21	0	12	75
Total	89.55	48	129	91

Table 5. - Summary of stepwise discriminant analysis for Step 4. Variable acronyms are defined in Figure 3

Step number	Variable entered	Wilks' λ	F value to enter	Approximate F-statistic	Degrees of freedom	
1	AN	0.534539	91.43	91.43	3	315
2	LPO	0.388847	39.22	63.18	6	628
3	DO	0.307460	27.62	52.79	9	762
4	DV	0.270718	14.11	43.95	12	826
5	AH	0.251413	7.96	37.16	15	859
6	LM	0.235714	6.88	32.50	18	877
7	D2A	0.220017	7.35	29.35	21	888
8	LD	0.209030	5.40	26.65	24	894
9	LB	0.202757	3.17	24.16	27	897
10	LP	0.196173	3.42	22.22	30	899
11	LV	0.189043	3.83	20.72	33	899
12	LMS	0.184049	2.75	19.31	36	899
13	LC	0.179729	2.43	18.08	39	898
14	H2D	0.176080	2.09	16.99	42	897
15	LMO	0.173086	1.74	16.00	45	895
16	LV	0.170183	1.71	15.14	48	893
17	LA	0.167768	1.43	14.35	51	891
18	VA	0.165463	1.38	13.64	54	889
19	D2D	0.162155	2.02	13.07	57	886
20	AD	0.158706	2.14	12.57	60	884

Classification matrix

Group	Percent Correct	Number of fish classified into group			
		Norwegian Sea	Lofoten	Svalbard	Barents Sea
Norwegian Sea	95.84	46	0	2	0
Lofoten	52.94	4	27	13	7
Svalbard	83.46	0	10	111	12
Barents Sea	73.56	0	7	16	64
Total	77.74	50	44	142	83

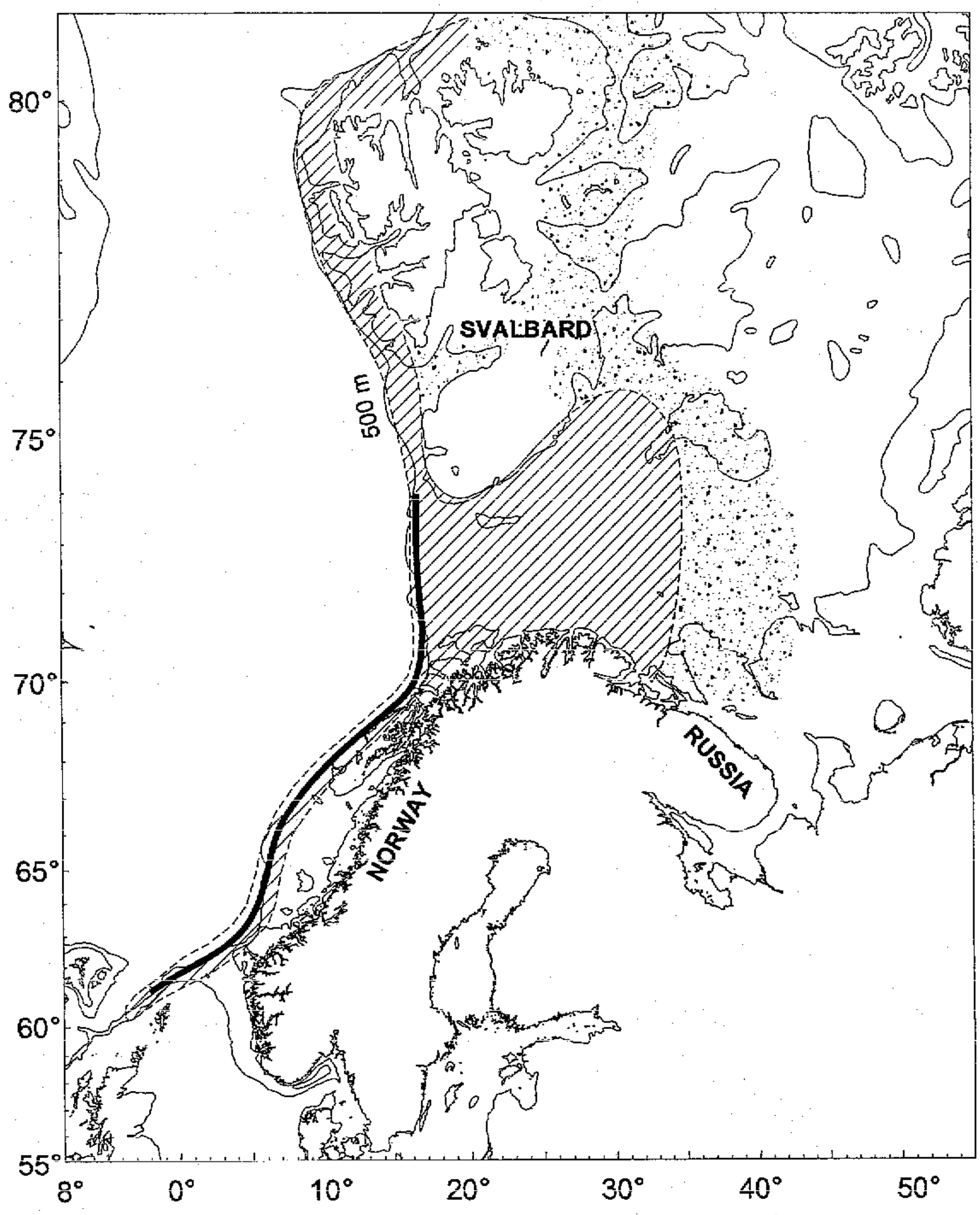

Figure 1 Main distribution area of *Sebastes mentella* in the North-East Arctic. The hatched area shows the center of abundance. The black area along the slope shows the main area of larvae release.

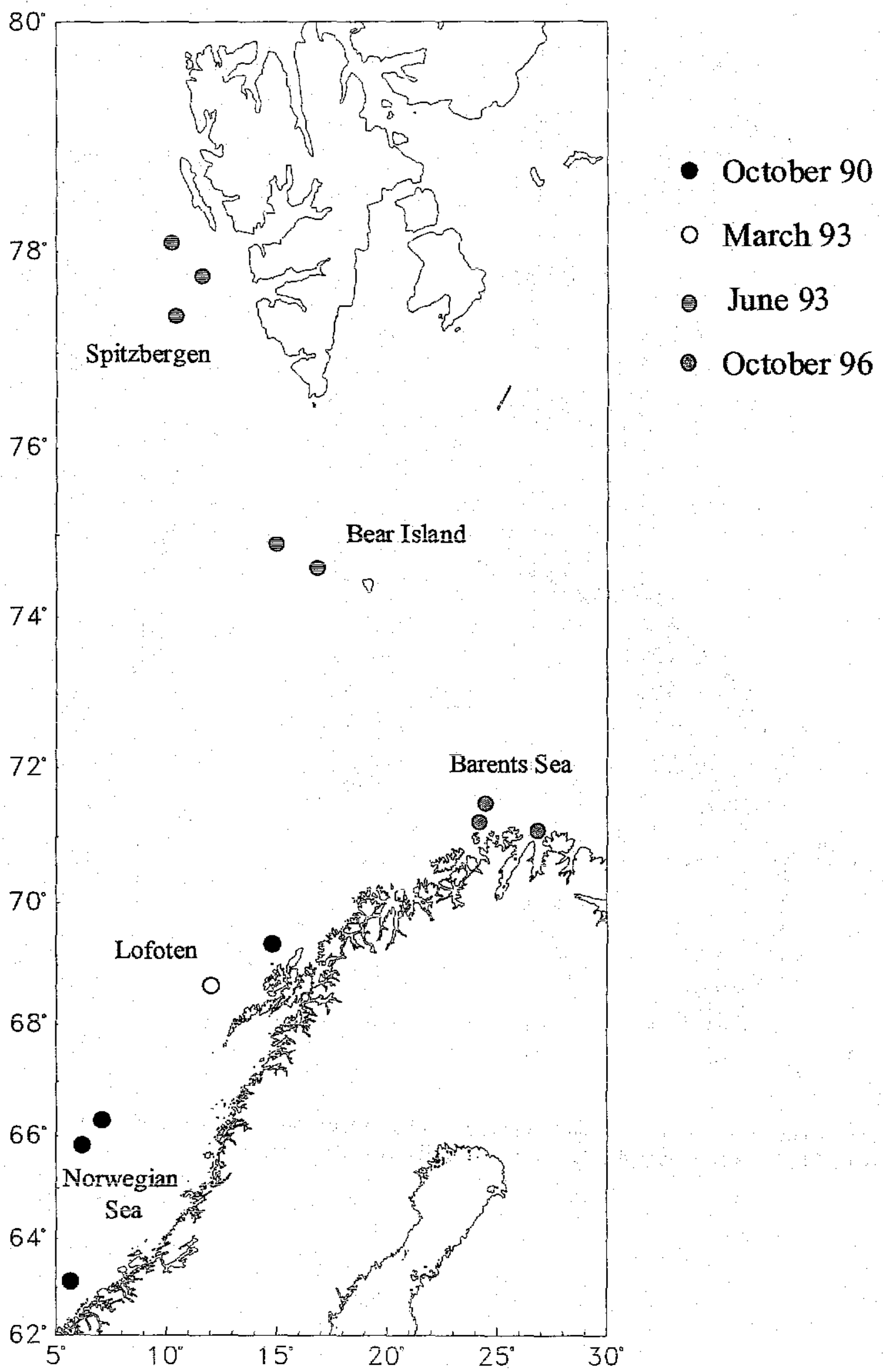

Figure 2. - Sampling locations and dates or the five groups of *S. mentella* collected in the Northeast Arctic.

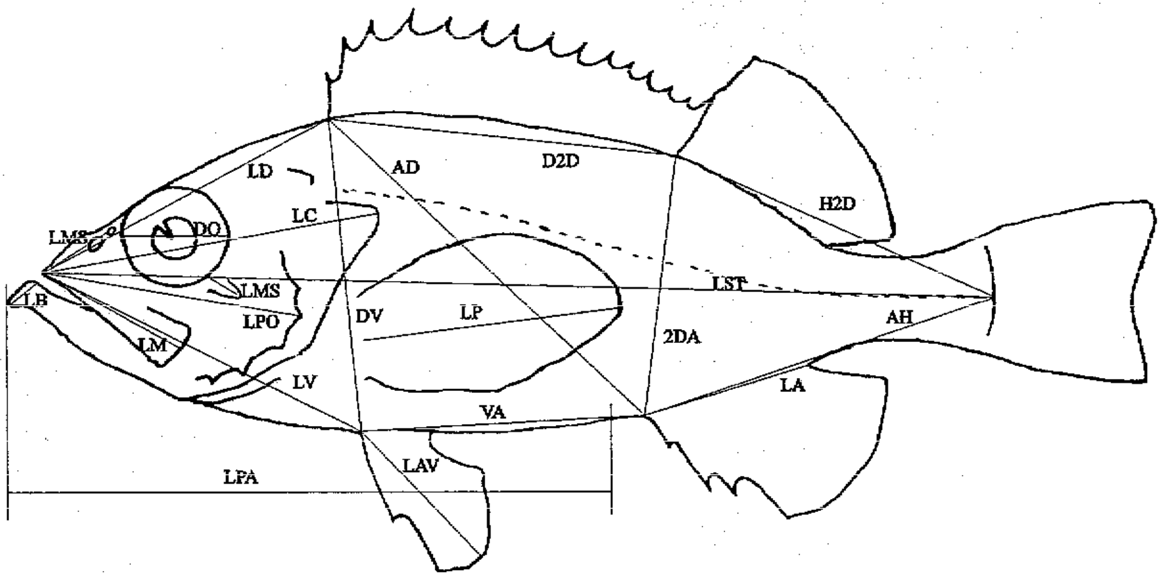

Figure 3. - Morphometric variables measured and acronyms used for analysis ofpopulations structure of Northeast arctic *S. mentella.*

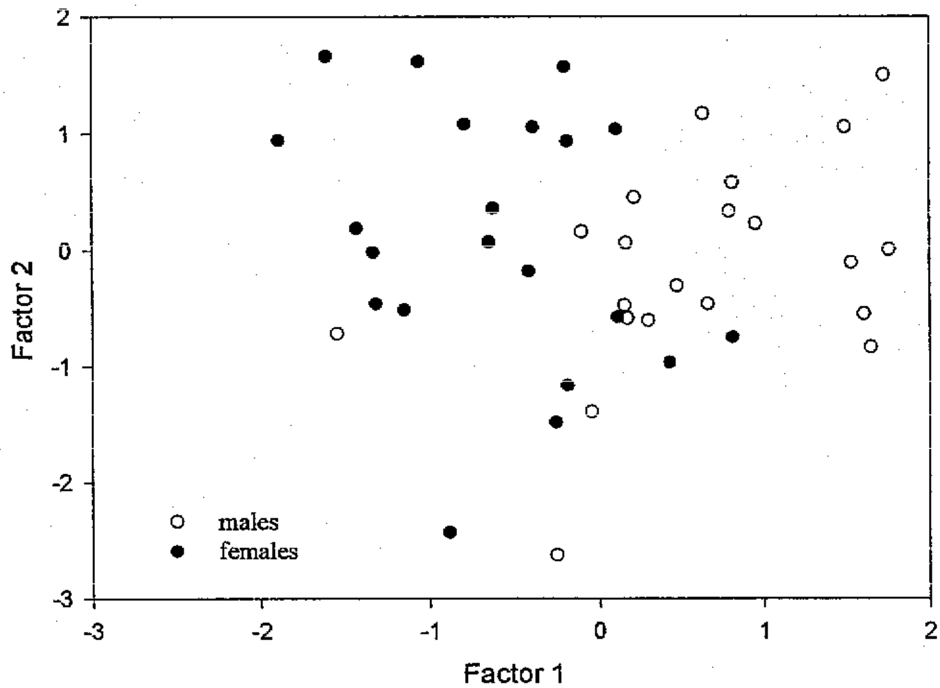

Figure 4. - Factorial scores of Principal component analysis made with Spring Lofoten morphometric characters

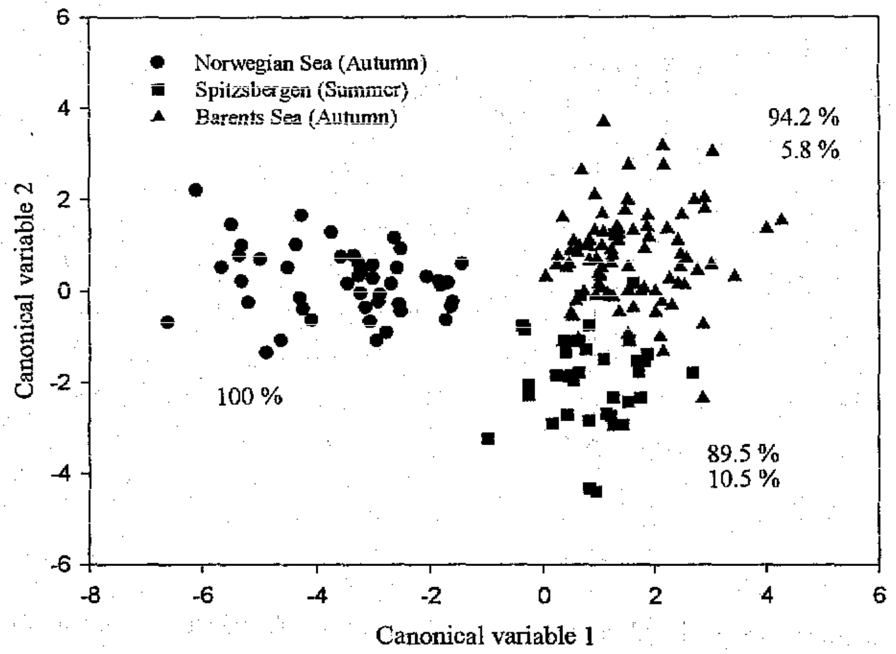

Figure 5. - Plot of canonical scores for the three groups considered in step 1 (Norwegian Sea, Spitzbergen and Barents Sea)

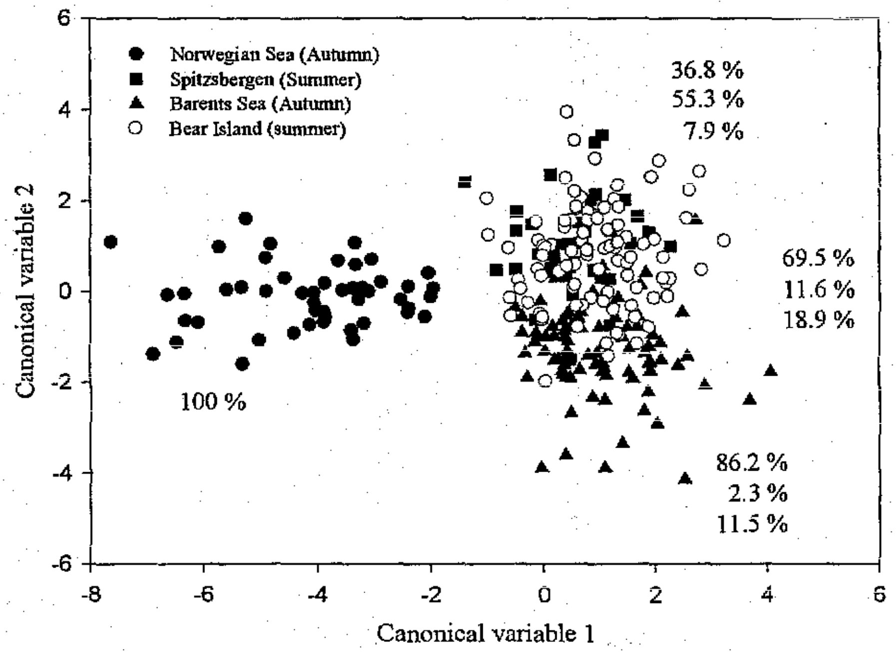

Figure 6. - Plot of canonical scores for the four groups considered in step 2 (Norwegian Sea, Spitzbergen, Barents Sea and Bear Island)

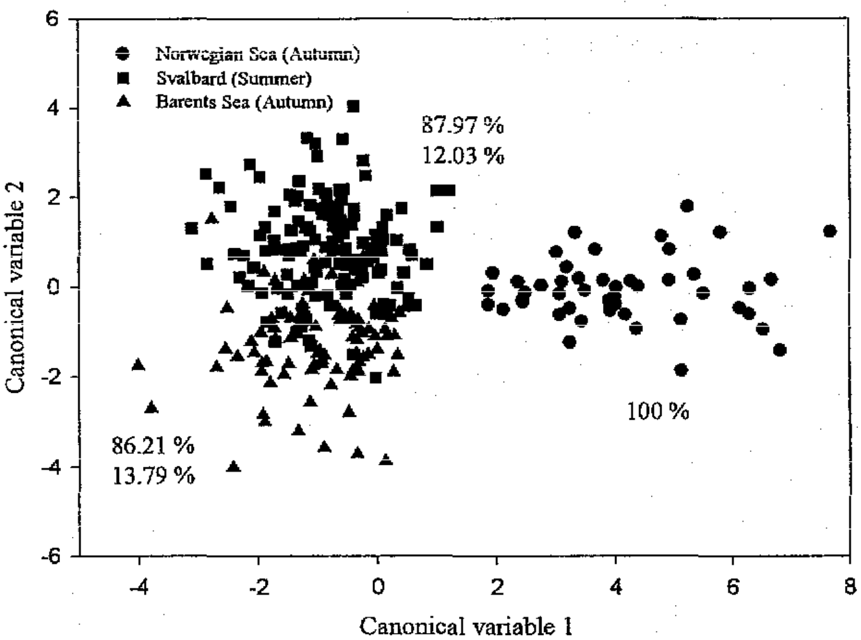

Figure 7. - Plot of canonical scores for the three groups considered in step 3 (Norwegian Sea, Svalbard and Barents Sea)

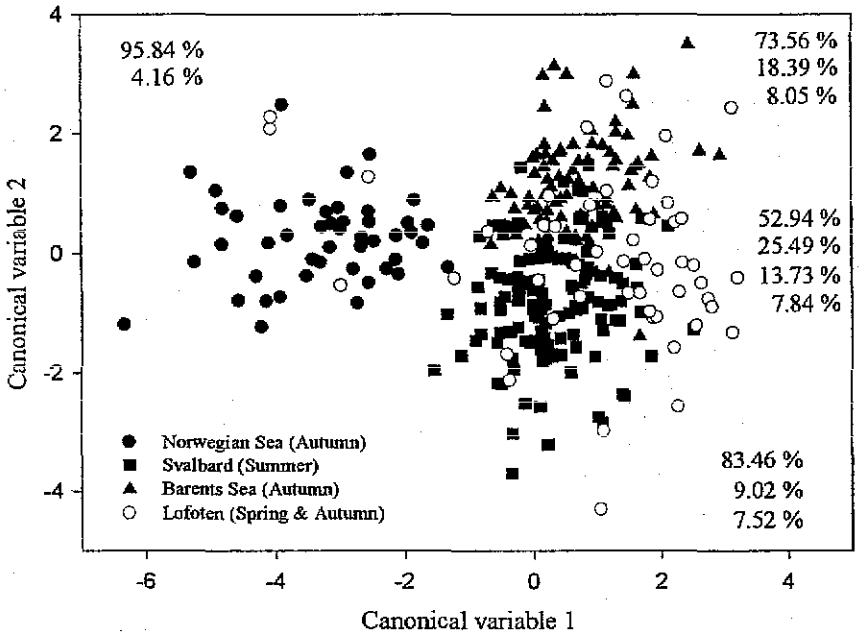

Figure 8. - Plot of canonical scores for the four groups considered in step 4 (Norwegian Sea, Svalbard, Barents Sea and Lofoten)

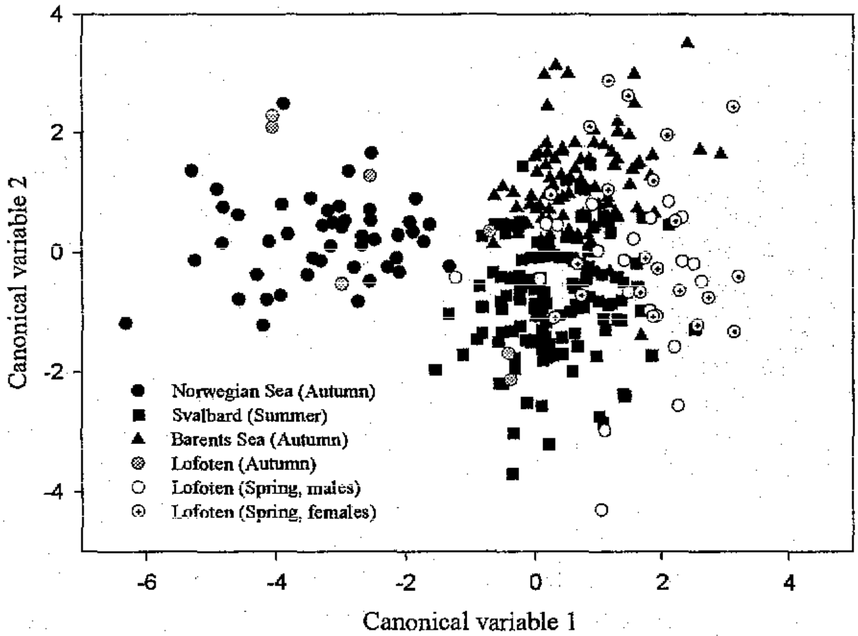

Figure 9. - Plot of canonical scores as in step 4 but with different symbols for the samples fromAutumn and spring (males and females separated).