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SPATIAL DISTRIBUTION OF VARIABLES IN MARINE ENVIRONMENTAL AND FISHERIES RESEARCH
PART II: DISTRIBUTION AND LENGTH OF 0-GROUP FISH IN RELATION TO ENVIRONMENTAL FACTORS

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Abstract

Each year in August-September joint Norwegian-Russian 0-group surveys are carried out in the Barents Sea and adjacent waters. Based on data from these surveys, the ambient temperature and salinity for several species were calculated for the Barents Sea and the Svalbard waters as well as the total area. Estimates of mean length were made for each interval in the environmental variables in order to study the variation in 0-group length with temperature and salinity. Differences within and between years in mean lengths were discussed in relation to spatial distribution and overall abundance.

Keywords
Spatial statistics, ambient temperatures, salinity, 0-group fish, abundance, length distribution, the Barents Sea.

Introduction

Sea temperature influences both abundance and size of larvae and 0-group fish in the Barents Sea area (Nakken 1994, Ottersen et al. 1994, Loeng et al. 1995, Ottersen et al. 1998). Loeng et al. (1995) found that the length of 0-group cod, haddock and herring to a large extent had shown the same fluctuation patterns since the time series were established in the late 1960s and that the mean lengths of all three species tended to be longer in warm years than in cold years. They also found that 0-group capelin increased in size with increasing temperature but with a somewhat different pattern than for the other species. The difference was explained with the different environment inhabited by the capelin larvae as compared with the other three species.

The present paper is an attempt to describe and characterize the hydrographic environment of 0-group fish in the area in more detail than has been done hitherto in order to analyse possible effects of temperature and salinity on 0-group size, density and abundance.

Ambient temperatures and salinities for 0-group fish of 8 species in the Barents Sea and in adjacent waters are calculated separately, and comparisons with 0-group length and abundance within and between years, areas, and species are discussed. The species are cod, haddock, saithe, redfish, herring, capelin, polar cod, and Greenland halibut.

Material and method

The survey data

The data include densities (catch in number per nautical mile trawling) and length distribution of 0-group fish from trawl hauls and CTD profiles of temperature and salinity (5m depth intervals) at predesigned positions observed during the annual 0-group surveys 1989-1996. Sampling methodology and procedures are given in the annual reports (Anon 1989-1996). Those reports include maps showing the spatial distributions of fish density, temperature and salinity as well as tables with length distribution for each species and average temperature in various depth intervals for given hydrographic transects.

Ambient temperature and ambient salinity

The ambient temperature (Ottersen et al. 1998) for a fish population is the average over that population of the sea temperature each member is exposed to. It has been used as an index in investigations of how temperature influences fish growth and distributions.
Temperature is a 3D (3-dimensional) variable, depending on surface coordinates *(x,y)* and depth. Let the fish population in the study area have density function $\rho(x,y)$ and let $T(x,y)$ be the average temperature for the depth interval within which $\rho(x,y)$ is estimated. The ambient temperature for this population, within the study area, may then be expressed by means of double integrals over the area as

$$\frac{\iint \rho(x,y)\cdot T(x,y)\cdot dx\cdot dy}{\iint \rho(x,y)\cdot dx\cdot dy}.$$

This expression generalizes the first notion of a population average of actually experienced temperature. Ambient salinity is defined and computed in the same manner by replacing temperature with a salinity function S(x,y).

Grid, interpolation system and calculations.
The location of the Barents Sea makes the polar stereographic projection a suitable method to project the latitude and longitude location on to a plane. The plane is chosen to pass through the 80 degree latitude.

The variables are spatially located data. We apply the geostatistical method (kriging) in the study of these data. It is an interpolation method for additive regionalized variables, and the interpolation value, y, is expressed as a linear combination of the neighboring values x_i, $y = \sum_{i=1}^{n} a_i \cdot x_i$. Kriging takes into account the data values, their location, and the degree of dependence or correlation between the data points. It also allows us to quantify the uncertainty associated with each interpolated value. (Cressie 1991, Journel 1989, Journel and Huijbregts 1978). In order to study the relationship between different spatially distributed variables we must have values of each variable at the same location, and these must be distributed uniformly all over the study area. We obtain this by interpolating the data onto the same grid system. Calculations were done using ISATIS software (ISATIS 1997).

Stensholt and Sunnanå (1996) focussed on the geostatistical methods and their application to spatially correlated environment and fishery data. They presented the spatial distribution of 0-group cod in relation to the temperature, salinity, polar front area and bottom topography. The methods and the grid point values obtained there for temperature, salinity and fish densities are used throughout the present paper.

The 2D variables (fish density and bottom depth) are interpolated from the observed values at each station onto a 20km X 20km 2D grid.
The 3D variables, temperature and salinity, are interpolated on to a 3D grid which extends the 2D grid above with a depth extension of 5m intervals. We use a 3D grid with 50 meters depth.
In order to calculate ambient values it is necessary to have temperature or salinity in a 2D format to match the fish data. This is done by averaging the temperature (salinity) over the depth interval 0-50m. The 0-group is mainly found here, above or at the thermocline (usually 35-50m).

For each species calculation were carried out for two separate areas (fig.1) as well as for the whole survey area. Corresponding values of mean and median length were computed from the length distributions of fish density. In order to study the variation in fish length with temperature within each particular year mean lengths were estimated from the length distributions aggregated from stations within each 0.5^{0}C temperature (mean 0-50 m) interval. General statistical calculation and graphic presentation were done using SAS software (SAS 1990).

The partition into two areas (Fig.1) was based on inspection of distribution maps of density, temperature, and salinity in the annual survey reports as well as on maps showing the horizontal distribution of different length groups within each 0-group; Fig.1 shows the example of cod.

Here the "Svalbard area" (area S) means the surveyed area west and south of Spitzbergen, above the 1300 mark on the y-axis in Figure 1, while the rest, inside the Barents Sea proper, is area B.

Results

Ambient temperature and salinity

Estimates of ambient temperature and salinity as well as mean and median lengths are given in Tables 1-8 and Figs. 2 and 3. The numerical values of each year's estimates are in line with the expectations one gets when comparing the horizontal distribution of 0-group density with the corresponding distributions of temperature and salinity in the annual survey reports. The year to year variations in ambient temperature and salinity (Tables 1-8) are merely caused by changes in the 0-group density distributions within the horizontal fields of the hydrographic variables. For instance the relatively low ambient temperature (and salinity) for capelin in 1994 is because the higher concentrations of 0-group capelin that year were located in the easternmost part of the survey area in waters of low temperature and salinity.

The plots in Figs. 2 and 3 show the "position" of the various species in the temperature-salinity fields; as a rule cod, haddock, herring, and redfish are situated in the warmer and more saline waters (Atlantic water masses) while Greenland halibut and polarcod are in the colder and less saline water. Most years the values of ambient temperature and salinity for capelin are in between the two mentioned groups with exception of 1994 as mentioned above.

Regarding saithe it should be pointed out that the most of the 0-group saithe are found along the Norwegian coast in shallow waters and outside the survey area. The estimates of ambient temperatures and salinity thus represent only a small fraction of the total abundance of saithe; a fraction which in addition is located in the extreme low temperature part of the total distribution area of the 0-group.

In Fig.4 are the estimates of ambient temperature compared with the corresponding values observed during the survey at the standard section along the Kola meridian. It is seen that the year to year variations at Kola, i.e. in the temperature field itself, are less than in the ambient temperatures, because of the year to year variations in the 0-group density fields as mentioned above.

0-group length at different temperatures

A year by year comparison of mean lengths for the total area and the corresponding ambient temperatures (Tables 1-8) did not reveal any systematic trend in the length-ambient temperature relationship for any of the species. For cod, haddock, saithe, herring and redfish there is a tendency that lengths, median as well as mean lengths, are less in the Svalbard area than in the Barents Sea. It is also noted that the estimates of ambient temperature in the Svalbard region are consistently less than those for the Barents Sea. These observations thus indicate that the smaller sized fish are found in the colder waters.

In order to investigate this in more detail Fig.5 was made where mean length is presented as a function of temperature for each year of observation. The main trends in the length-temperature relationships as appearing from visual inspections of Fig.5 are summarised in table 9. 0-group herring tend to increase in mean length with increasing temperature in most years while the mean length of 0-group capelin seem to decrease. For cod and redfish no apparent systematic variation occurred. The length of haddock showed an increase with temperature in the years 1991, 1992 and 1993 but no systematic pattern when all years are compared.

It should also be noticed that in 1990 and 1992 there was a reduced survey east of 42°E.

Discussion

Several factors may contribute to errors in the estimates of ambient temperature and salinity. We have used the average values between surface and 50 meters as representative for the 0-group density of all species. As shown by Beltestad et al. (1975) the 0-group in the area had pronounced diel vertical migrations; 0-group redfish were found at the surface at dark and spread in the upper 50 m during the day while the unpigmented capelin stayed in small schools close to the surface by daylight and dispersed into a scattering layer at the depth of the thermocline at dark. Hylen et al. (1995 Fig.3) reported 0-group cod concentrations with relatively small (10-20 m) depth extension but varying in depth between 0 and 70 m. In future investigations echo sounder/echo integration observations should thus be used to determine the appropriate depth and depth extensions of the 0-group at each particular trawl haul in order to determine the depth interval for which mean values are to be established.

The estimates of ambient temperature and salinity for polar cod (Table 7) are too high. Every year the distribution of polar cod had an extension to the north and northeast beyond the area surveyed and thus into colder and less saline waters. For saithe the limited area coverage, see above, probably generated too low estimates of ambient temperature. Moreover, the salinity in the near shore shallow waters along the Norwegian coast where the bulk of 0-group saithe reside in August - September is far below the estimates in table 6. For Greenland halibut the samples were small and scattered most years so that the confidence which can be put in the estimated values is limited.

Concerning cod, haddock, herring, redfish and capelin for which the entire 0-group distributions were covered satisfactorily all years, we believe that the estimated values of ambient temperature and salinity reflect the yearly variations in the water-masses these species inhabitated as 0-group during the period studied. These variations are generally larger than the corresponding variations at Kola (Fig.4) due to the differences in the density distributions from year to year; a result similar to that of Ottersen et al. (1997) for juvenile cod.

The comparison of estimates from the two areas, the Barents Sea and the Svalbard area, clearly indicatefff that for several species the smaller fish were found in the colder water. Hylen et al. (1995) showed that the small sized 0-group cod and haddock (4-6 cm in length) were largely under sampled by the trawl used as compared with larger fish (9-12 cm in length). Hence the estimated mean lengths are systematically biased upward with larger bias for stations and areas were small sized fish were predominant. Therefore, the differences in

length between the two areas are probably larger than estimated from Tables 1 and 2. The selectivity pattern also complicate the comparison of mean lengths at given temperature.
We cannot from the present study conclude that this shows a temperature effect on growth of the 0-group since we do not know the age (in days or weeks) of the specimens and the spawning ground at which the various patches were hatched. Neither do comparisons of length and ambient temperature between years show any clear relationship between length and temperature as indicated by Loeng et al. (1994). A possible reason for the lack of such a relationship in our data is the relatively small year to year variations in temperature in the Barents Sea during the period studied as compared with previous periods (Loeng et al. 1994).

The results indicated that the mean length of 0-group herring is as a rule bigger in warm waters than in colder, while the opposite is true for capelin. For herring this is possibly an effect of the large north-south extension of the spawning grounds. Larvae from the southern spawning sites will inhabit waters of higher temperatures throughout the entire northward drift during spring and summer than larvae from the northern spawning sites. For capelin which do not have such a latitudinal extension of the spawning grounds the observation of larger 0-group fish in colder waters may simply reflect the age; the older the fish the further it has drifted towards north and northeast.

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References

Anon. ICES Preliminary Report of the International 0-group Fish Survey in the Barents Sea and Adjacent Waters in August-September 1989, Demersal Fish Committee, C.M. 1989/G:40 Ref.H.

Anon. ICES Preliminary Report of the International 0-group Fish Survey in the Barents Sea and Adjacent Waters in August-September 1990, Demersal Fish Committee, C.M. 1990/G:46 Ref.H.

Anon. ICES Preliminary Report of the International 0-group Fish Survey in the Barents Sea and Adjacent Waters in August-September 1991, Demersal Fish Committee, C.M. 1991/G:50 Ref.H.

Anon. ICES Preliminary Report of the International 0-group Fish Survey in the Barents Sea and Adjacent Waters in August-September 1992, Demersal Fish Committee, C.M. 1992/G:82 Ref.H.

Anon. ICES Preliminary Report of the International 0-group Fish Survey in the Barents Sea and Adjacent Waters in August-September 1993, Demersal Fish Committee, C.M. 1994/G:3 Ref.H.

Anon. ICES Preliminary Report of the International 0-group Fish Survey in the Barents Sea and Adjacent Waters in August-September 1994, Demersal Fish Committee, C.M. 1995/G: Ref.H.

Anon. ICES Preliminary Report of the International 0-group Fish Survey in the Barents Sea and Adjacent Waters in August-September 1995, Demersal Fish Committee, C.M. 1996/G:30 Ref.H.

Anon. ICES Preliminary Report of the International 0-group Fish Survey in the Barents Sea and Adjacent Waters in August-September 1996, Demersal Fish Committee, C.M. 1996/G:31 Ref.H.

Beltestad, A., Nakken, O, and Smedstad, O.M. 1975 Investigtions on diel vertical migration of 0-group fish in the Barents Sea, FiskDir. Skr. Ser. HavUnders., 16; 229-244.

Cressie, N.AC. 1991 Statistics for Spatial Data, John Wiley & Sons.

Hylen, A., Korsbrekke, K., Nakken, O., and Ona, E. 1995 Comparison of the capture efficiency of 0-group fish in pelagic trawls. Hylen, A (ed.): Proceedings of the sixth IMR-PINRO symposium, Bergen 14-17 June 1994. Institute of Marine Research, Bergen, Norway. ISBN 82-7461-039-3.

ISATIS Transvalor and Geovariance Avon France (1997)

John, P.W.M. (1971), Statistical Design and Analysis of Experiments, New York: Macmillan.

Journel, A. G. 1989, Fundamentals of Geostatistics in Five Lessons, Amer. Geoph. Union, 40p.

Journel, A. G. and Huijbregts Ch. J. 1978, Mining geostatistics Academic Press London, 600p.

Loeng, H., Bjørke, H. and Ottersen G. 1994 Larval fish growth in the Barents Sea. R.J. Beamish (ed.) Climate change and northern fish populations. Can. Spec. Publ. Fish. Aquat. Sci. 121. P691-698.

Myers, Raymond H. (1976), Response Surface Methodology, Blackburg, Virginia: Virginia Polytechnic Institute and State University.

Ottersen, G, Michalsen, K., and Nakken, O. 1998, Ambient temperature and distribution of north-east Arctic cod, ICES Journal of Marine Science, 55: 67-85.

Ottersen, G, Loeng, H., and Raknes, A. 1994 Influence of temperature variability on recruitment of cod in the Barents Sea ICES Marine Science Symposia, 198:471-481.

Nakken, O. et al. Acoustic estimates of 0-group fish abundance in the Barents Sea and adjacent waters in 1992 and 1993, Proceedings of the sixth IMR-PINRO Symposium Bergen, 14-17 June 1994, p. 187-197.

Nakken, O, 1994 Causes of trends and fluctuations in the Northeast arctic cod stock. ICES marine science Symposia, 198:212-228.

Sakshaug, et al., 1992, Økosystem Barentshavet, Pro Mare, 304p.

SAS Institute Inc. 1990, SAS procedures Guide Version 6, third edition, 705p.

Stensholt, B.K. and Sunnanå, K. 1996 Spatial distributions of variables in marine environmental and fisheries research; Part I: Geostatistics and autocorrelated environmental and fisheries data. ICES Annual Science Conference, Reykjavik, Iceland 27.Sept-1.Oct 1996

Table 1-8. Estimates of ambient temperature (a.temp) and salinity (a.sal), mean length and median length (med. length) for 8 species of 0-group fish in the Barents Sea and adjacent waters 1989-1996.
all: total survey area, B: Barents Sea area, S: Svalbard area.

Table 1: Cod

	a.temp	a.temp	a.temp	a.sal	a.sal	a.sal	mean length	med. length	mean length	med. length	mean length	med. length	percentage of sample in area
year	all	B	S	all	B	S	all	all	B	B	S	S	S
89	6.9	7.0	4.7	34.6	34.57	34.43	7.8	7.6	7.9	7.7	6.6	6.4	2.25
90	8.4	8.4	6.1	34.8	34.80	34.75	8.3	8.0	8.3	8.1	7.2	6.9	1.10
91	6.3	6.9	5.7	34.8	34.86	34.78	8.0	7.6	8.4	8.0	7.2	6.9	26.23
92	6.3	6.7	5.7	34.8	34.91	34.66	8.0	7.8	7.9	8.0	8.2	7.4	33.19
93	6.1	6.5	5.3	34.7	34.78	34.46	8.2	7.7	8.3	8.0	8.0	7.1	25.65
94	7.3	7.4	6.0	34.8	34.84	34.84	8.7	7.9	8.8	8.2	6.8	6.6	0.93
95	6.6	6.6	5.9	34.9	34.90	34.71	8.9	8.7	8.9	8.9	8.6	7.7	8.12
96	7.0	7.0	6.0	34.7	34.74	34.78	7.7	7.6	7.7	7.7	8.7	6.7	0.51

Table 2: Haddock

	a.temp	a.temp	a.temp	a.sal	a.sal	a.sal	mean length	med. length	mean length	med. length	mean length	med. length	percentage of sample in area
year	all	B	S	all	B	S	all	all	B	B	S	S	S
89	7.1	7.2	5.9	34.8	34.77	34.64	8.1	8.0	8.3	8.5	6.1	6.0	4.98
90	8.1	8.3	6.5	34.9	34.87	34.83	9.8	9.7	9.9	10.1	8.1	7.8	7.43
91	6.7	7.8	5.7	34.8	34.88	34.78	8.3	8.1	8.8	8.9	7.5	7.5	37.96
92	7.4	7.5	6.5	34.9	34.90	34.78	9.5	9.8	9.5	9.9	9.1	8.3	10.87
93	7.1	7.2	5.9	34.8	34.84	34.62	10.0	10.0	10.1	10.0	8.3	8.3	3.27
94	7.6	7.7	5.6	34.8	34.78	34.76	9.6	9.3	9.7	9.4	7.3	6.8	1.07
95	6.4	6.5	5.7	34.9	34.91	34.67	10.1	10.3	10.3	10.5	7.3	6.4	4.84
96	8.0	8.4	6.6	34.8	34.79	34.84	10.3	10.1	10.4	10.2	10.2	9.9	9.90

Table 3: Capelin

	a.temp	a.temp	a.temp	a.sal	a.sal	a.sal	mean length	med. length	mean length	med. length	mean length	med. length	percentage of sample in area
year	all	B	S	all	B	S	all	all	B	B	S	S	S
89	6.4	6.6	4.4	34.6	34.64	34.40	4.7	4.8	4.7	4.8	5.0	4.8	4.32
90	6.1	6.1	4.0	34.8	34.79	34.22	4.9	4.8	4.8	4.7	5.7	5.5	8.32
91	5.5	5.5	4.5	34.7	34.74	34.55	5.3	5.0	5.3	5.0	5.4	5.0	14.75
92	5.6	5.6	4.2	34.7	34.72	34.36	4.5	4.1	4.5	4.2	3.8	3.8	7.52
93	5.6	6.2	2.4	34.3	34.39	34.04	6.4	5.4	6.5	5.5	4.9	4.9	4.70
94	3.5	3.5	2.8	34.0	33.96	34.32	5.3	5.4	5.3	5.4	4.8	4.8	0.01
95	5.2	5.5	.	34.7	34.74	.	4.5	4.4	4.5	4.4	.	.	0
96	5.2	5.3	3.0	34.6	34.58	34.25	5.0	4.7	5.0	4.7	4.7	4.4	0.75

Table 4: Herring

	a.temp	a.temp	a.temp	a.sal	a.sal	a.sal	mean length	med. length	mean length	med. length	mean length	med. length	percentage of sample in area
year	all	B	S	all	B	S	all	all	B	B	S	S	S
89	7.9	8.5	6.3	34.6	34.53	34.73	7.6	7.1	7.9	7.3	7.2	7.0	27.52
90	9.2	9.2	7.1	34.7	34.72	34.80	9.2	8.5	9.2	8.7	7.2	7.0	0.32
91	7.9	8.1	7.2	34.9	34.88	34.97	8.0	8.3	8.1	8.5	7.1	7.2	8.05
92	7.5	7.6	6.8	34.7	34.65	34.84	8.9	8.7	8.9	8.7	9.1	8.5	25.62
93	6.8	7.3	6.5	34.7	34.69	34.76	7.4	7.9	7.9	8.2	7.0	6.9	54.95
94	7.8	7.8	5.4	34.8	34.85	34.76	6.6	6.3	6.6	6.4	5.5	5.4	0.10
95	6.9	7.2	6.1	34.8	34.84	34.77	6.3	6.2	6.5	6.4	5.9	5.7	27.05
96	7.7	7.7	4.5	34.8	34.78	34.52	6.2	6.3	6.2	6.5	5.2	5.0	0.54

Table 5: Redfish

	a.temp	a.temp	a.temp	a.sal	a.sal	a.sal	mean length	med. length	mean length	med. length	mean length	med. length	percentage of sample in area
year	all	B	S	all	B	S	all	all	B	B	S	S	S
89	6.9	8.4	5.7	34.7	34.76	34.70	3.9	3.3	3.5	3.1	4.1	3.4	66.21
90	7.3	8.7	6.9	34.9	34.88	34.88	4.4	4.3	4.6	4.5	4.3	4.0	67.24
91	7.3	8.5	7.2	35.0	34.89	35.04	3.5	3.8	4.1	3.9	3.5	3.7	86.61
92	6.0	6.6	6.0	34.9	34.89	34.86	4.3	3.9	5.0	4.9	4.3	3.8	99.65
93	5.6	6.4	5.6	34.5	34.71	34.46	3.2	3.2	4.3	4.1	3.2	3.1	99.72
94	6.2	7.7	5.5	34.9	34.83	34.91	4.3	4.0	4.8	5.0	4.1	3.2	65.75
95	6.8	8.0	6.5	34.9	34.81	34.95	4.1	3.9	4.3	4.6	4.0	3.6	70.63
96	6.8	7.7	5.2	34.7	34.82	34.63	4.1	3.2	4.6	4.5	2.8	2.8	17.94

Table 6: Saithe

	a.temp	a.temp	a.temp	a.sal	a.sal	a.sal	mean length	med. length	mean length	med. length	mean length	med. length	percentage of sample in area
year	all	B	S	all	B	S	all	all	B	B	S	S	S
89	8.5	8.5	.	34.5	34.52	.	5.6	4.8	5.6	4.8	.	.	0
90	8.3	8.4	3.4	34.9	34.89	34.01	9.9	10.6	9.9	10.6	8.7	8.7	1.20
91	6.1	6.1	.	34.8	34.81	.	10.1	10.5	10.1	10.5	.	.	0
92	6.7	7.0	6.2	34.8	34.86	34.68	11.7	11.6	11.7	11.7	11.6	11.5	33.09
93	5.0	6.2	4.4	34.2	34.72	33.93	7.4	9.1	9.8	9.5	6.5	8.0	65.09
94	7.4	7.4	.	34.8	34.85	.	9.7	10.0	9.7	10.0	.	.	0
95	6.7	6.7	6.6	34.9	34.89	34.86	9.5	9.5	9.8	9.7	9.0	9.0	29.06
96	5.6	5.7	2.6	34.7	34.70	34.19	8.8	8.5	8.9	8.6	6.1	5.9	0.45

Table 7: Polarcod

	a.temp	a.temp	a.temp	a.sal	a.sal	a.sal	mean length	med. length	mean length	med. length	mean length	med. length	percentage of sample in area
year	all	B	S	all	B	S	all	all	B	B	S	S	S
89	3.9	3.2	4.2	34.2	34.28	34.25	3.3	3.4	3.2	3.5	3.3	3.4	92.10
90	3.3	2.2	3.4	34.2	33.92	34.24	4.1	4.1	4.0	4.0	4.1	4.2	97.36
91	2.9	4.1	3.6	34.3	34.49	34.40	3.6	4.0	3.1	3.5	4.4	4.1	44.72
92	4.3	4.4	4.4	34.3	34.32	34.28	3.9	4.1	4.2	4.3	3.9	4.1	95.51
93	5.3	6.6	4.1	34.1	34.18	34.12	4.0	3.9	4.3	4.5	3.6	3.8	40.09
94	3.7	3.7	4.2	34.3	34.27	34.51	3.7	3.8	3.7	4.0	3.3	3.6	3.17
95	4.7	4.2	4.7	34.4	34.56	34.43	4.2	4.3	3.8	4.1	4.2	4.3	97.22
96	4.4	4.9	1.6	34.5	34.53	34.07	3.7	3.6	3.8	4.1	2.9	3.0	8.29

Table 8: Greenland halibut

	a.temp	a.temp	a.temp	a.sal	a.sal	a.sal	mean length	med. length	mean length	med. length	mean length	med. length	percentage of sample in area
year	all	B	S	all	B	S	all	all	B	B	S	S	S
89	4.7	10.0	2.9	34.2	34.42	34.11	6.1	7.0	3.3	3.3	6.9	7.2	87.91
90	6.5	8.5	4.2	34.4	34.66	34.09	7.2	7.5	7.6	7.5	6.1	6.1	22.47
91	5.0	.	4.9	34.7	.	34.73	7.2	7.5	.	.	7.2	7.5	100.00
92	5.0	.	5.1	34.4	.	34.42	6.7	7.1	.	.	6.7	7.1	100.00
93	3.9	.	3.9	34.0	.	34.19	5.4	5.4	.	.	5.4	5.4	100.00
94	4.3	3.0	4.3	34.6	34.44	34.56	6.2	5.6	7.7	7.7	6.2	5.6	99.33
95	4.5	4.2	4.7	34.5	34.76	34.43	6.3	6.4	7.7	7.5	6.2	6.0	86.64
96	4.9	5.7	4.7	34.6	34.72	34.56	5.5	5.6	5.5	7.0	5.5	5.5	58.88

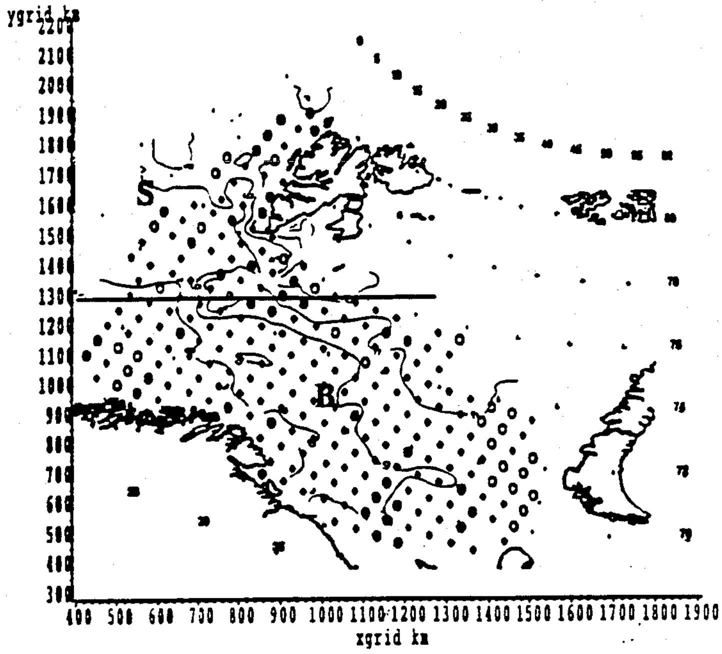
Table 9. Trends in 0-group mean length as a function of temperature in the Barents Sea area (area B):

N - No trend, I - Increasing, D - Decreasing

Brackets are for year which total catch number below 2000.

Table 9: Trends in 0-group mean length as a function of temperature

year	1989	1990	1991	1992	1993	1994	1995	1996
species								
cod	N/D	N/I	N/D	N	N	N	N	N/I
haddock	[*D*]	N	I	I	I	N/I	N/D	N
Herring	I	I	I	I	N	I	N	I
Redfish	D	N	N	[*N*]	[*N*]	N/I	N	[*N*]
capelin	D	D	D	[*N*]	[*I*]	D	N	D



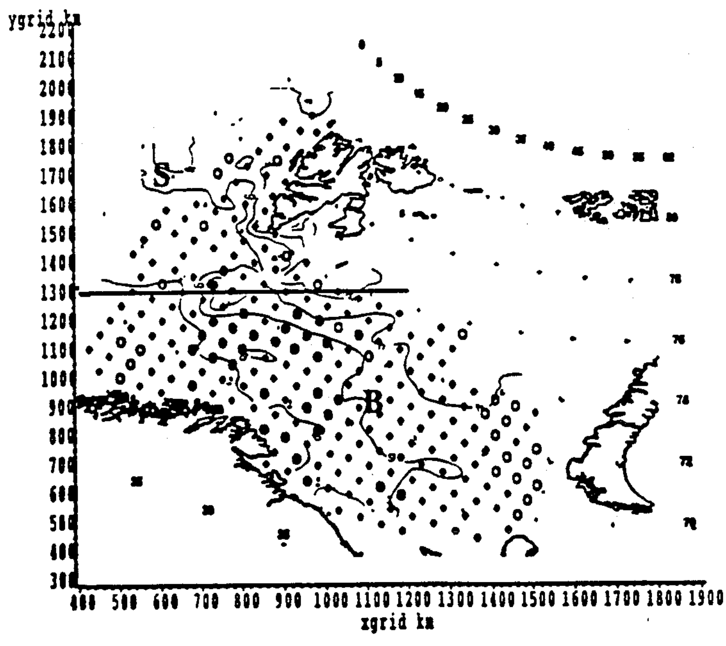


Fig. 1 Trawl stations and catch rate of 0-group cod in 1996.
Upper: Cod length 3 - 5 cm.
Lower: Cod length ≥ 11 cm.

O - no cod, ♦ -catch of cod, ● -catch of cod at indicated length

S - Svalbard area B - Barents Sea area

Isotherms 2, 4, 6 and 8 °C are indicated.

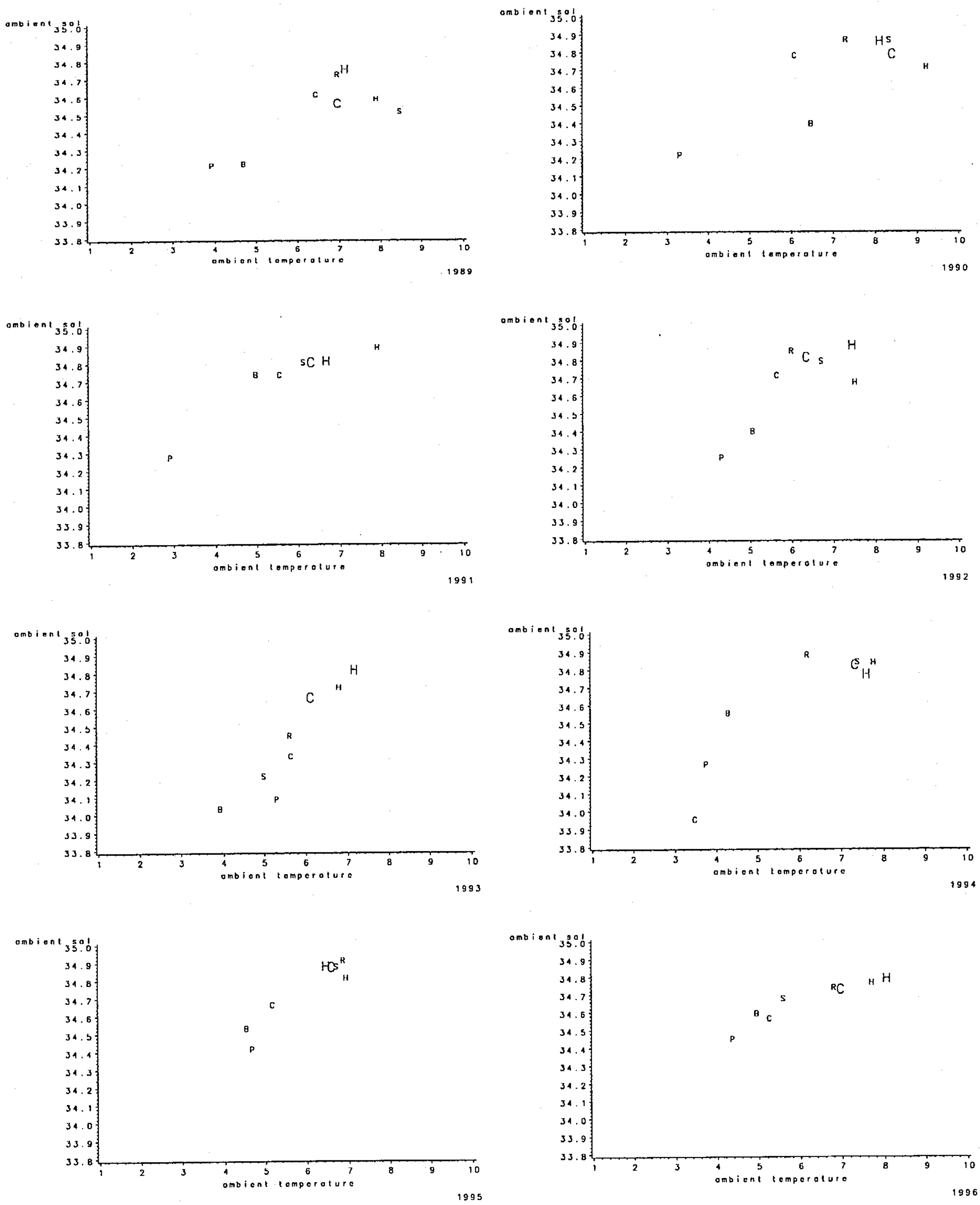


Fig. 2 Ambient temperature $°C$ and ambient salinity $\%_0$ (0-50 m depth) for 0-group fish in the Barents Sea and adjacent waters 1989 - 1996.
C - cod, C - capelin, H - haddock, H - herring, R - redfish, p - polarcod, s - saithe, B - Greenland halibut

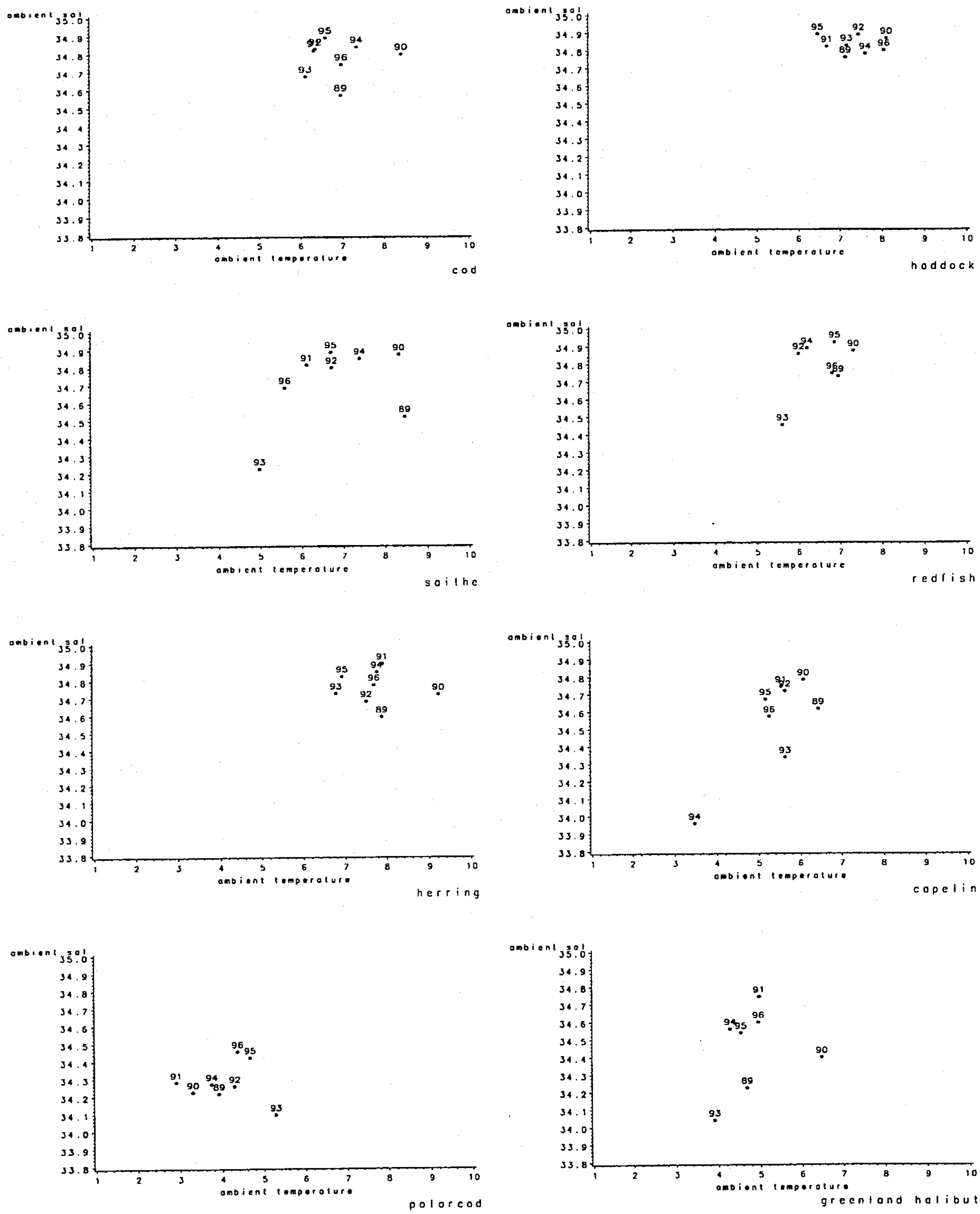


Fig.3 Ambient temperature °C and ambient salinity (0-50m depth) for 0-group fish in the Barents Sea and adjacent waters 1989-1996.

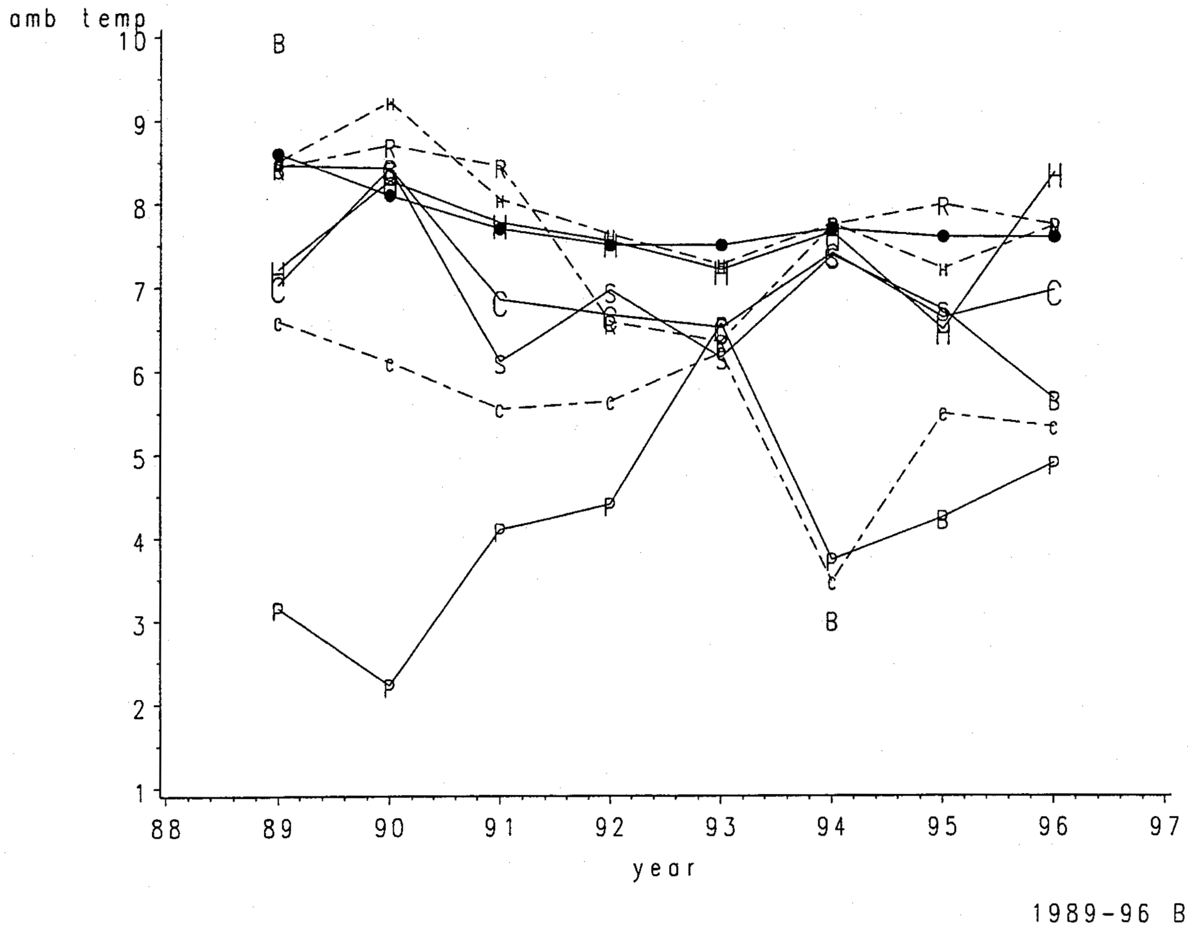
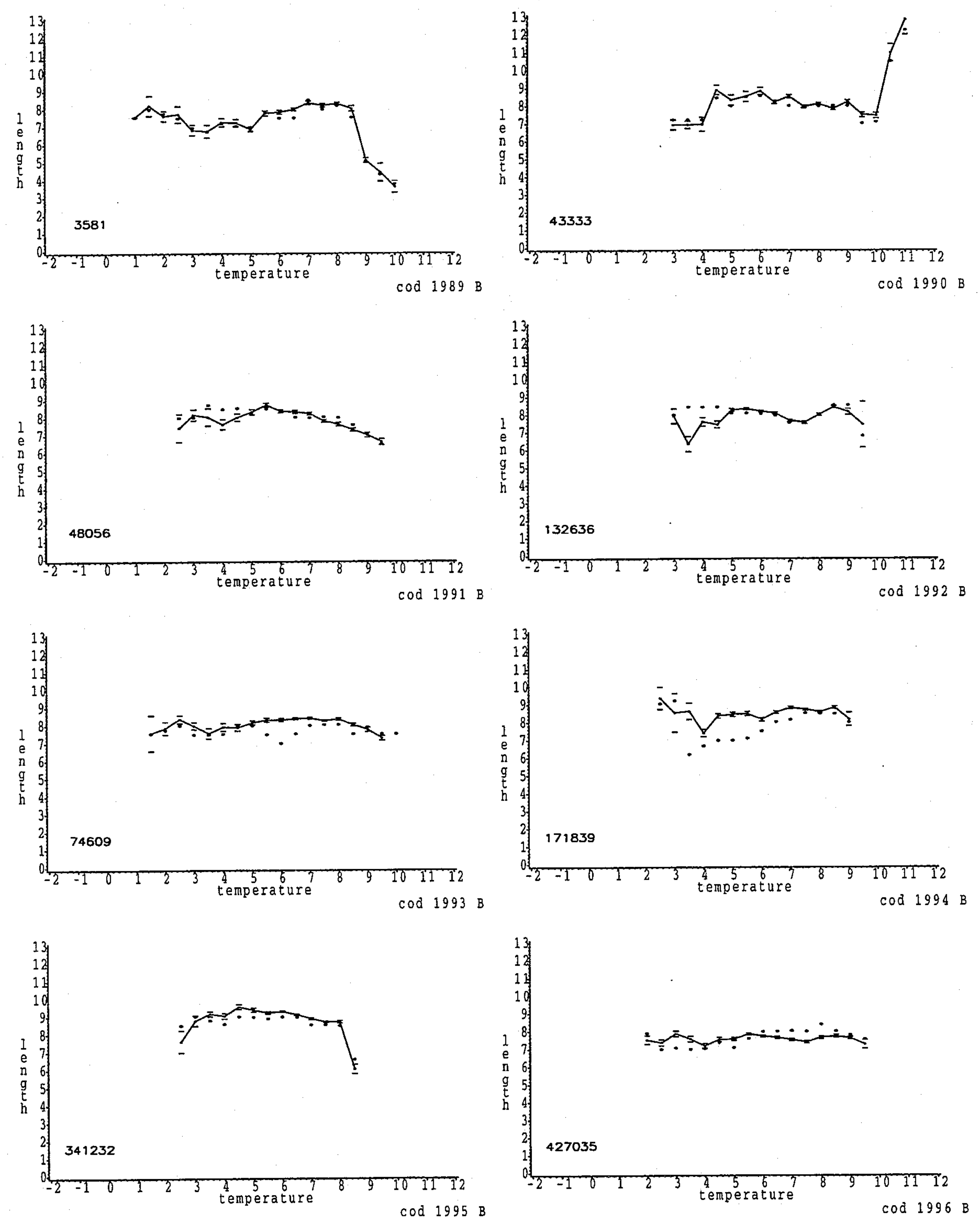
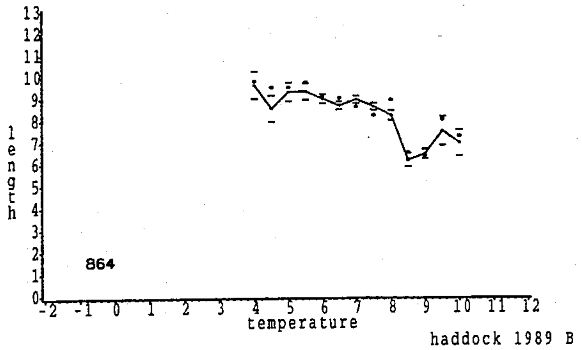


Fig.4. Ambient temperature *t°C* (0-50m depth) of 0-group fish in the Barents Sea (area B) 1989-1996 and corresponding temperature at the Kola subdivision.

C - cod, c - capelin, H - haddock, H - herring, S - saithe, R - redfish, P - polarcod, B - Greenland halibut

Fig.5 Solid line shows mean length of 0-group cod within each 0.5°C temperature interval (average over 0 to 50m depth), 1989-1996 in the Barents Sea area (B). The bars mark 2 standard deviations of the mean. Dots mark the median length within that interval. Total number caught are indicated on the left hand side of the graph. Species, year, and location are indicated on the right hand side of the graph.

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864
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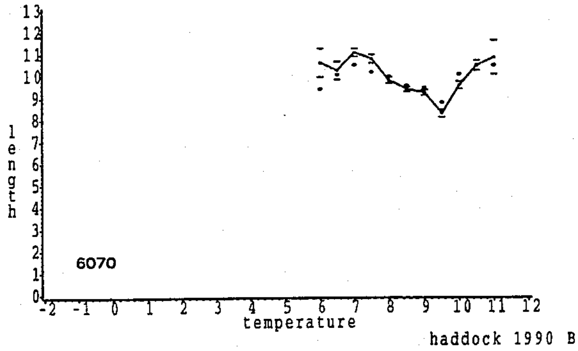
haddock 1989 B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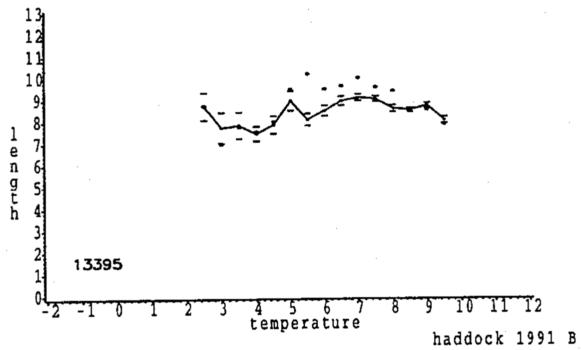
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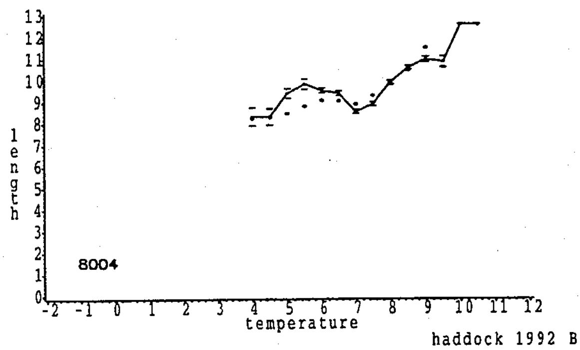
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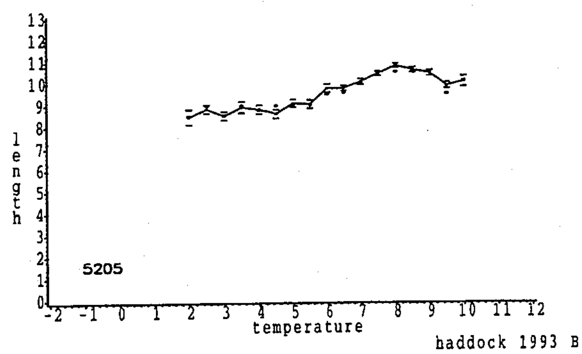
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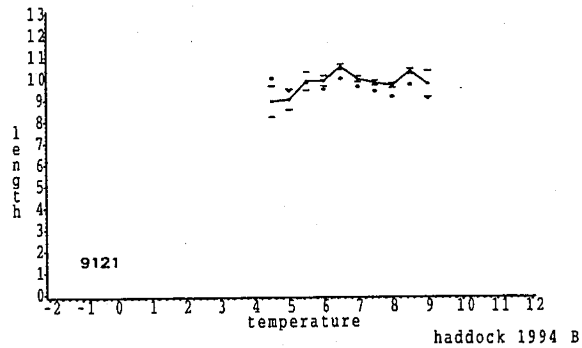
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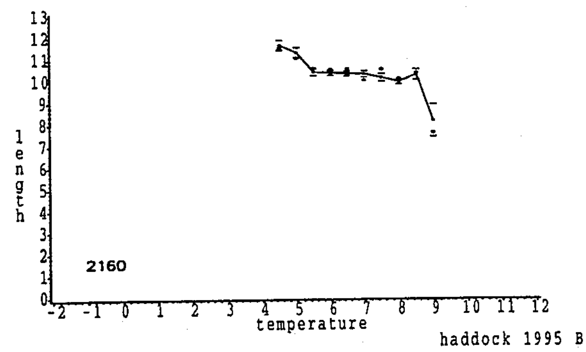
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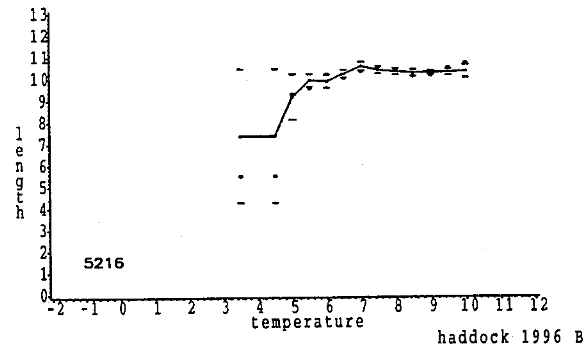
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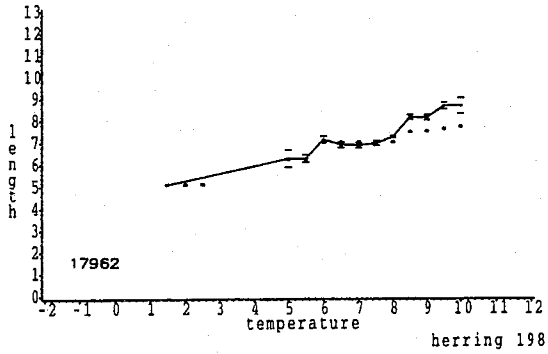
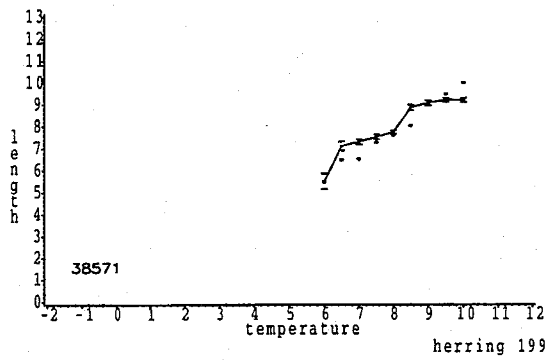


herring 1989 B



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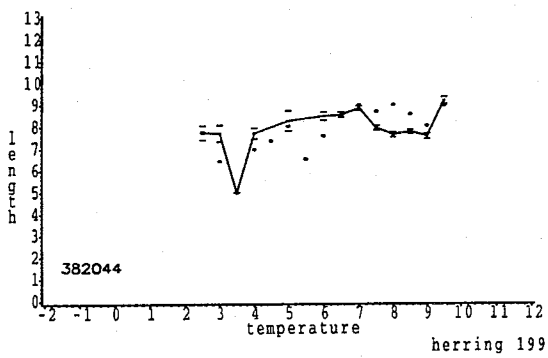

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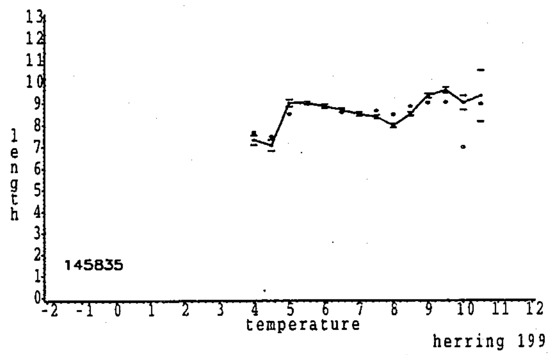

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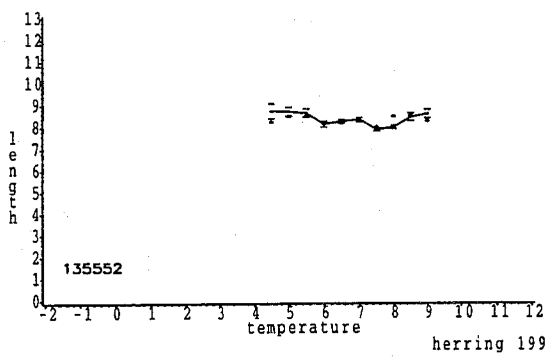

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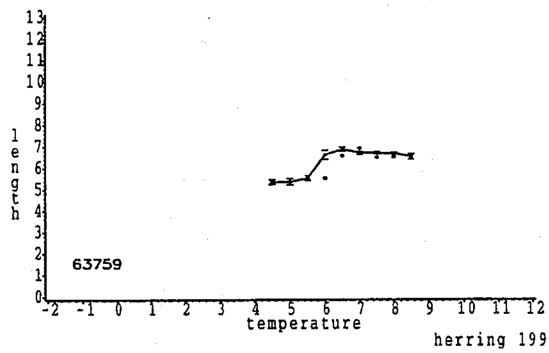

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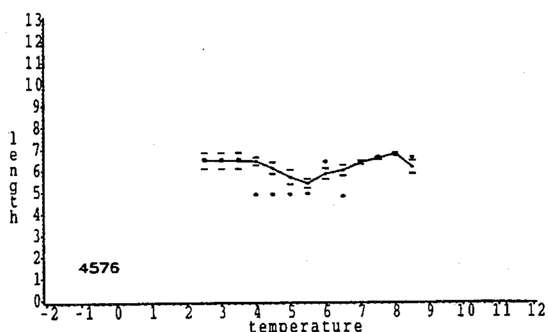

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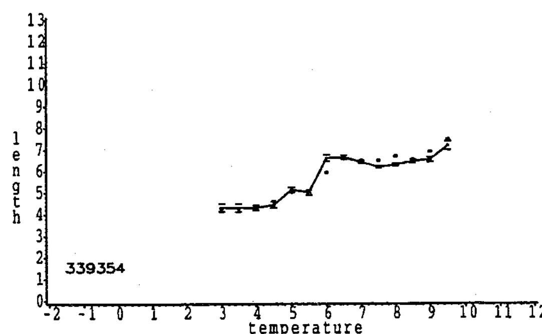

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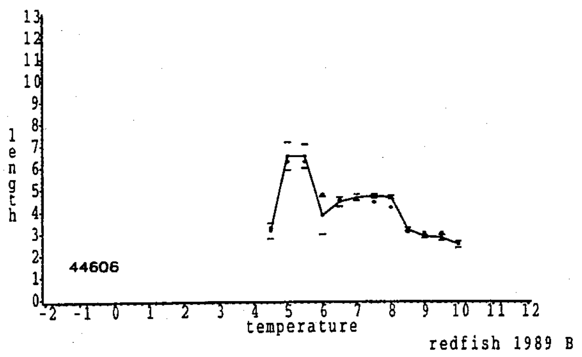
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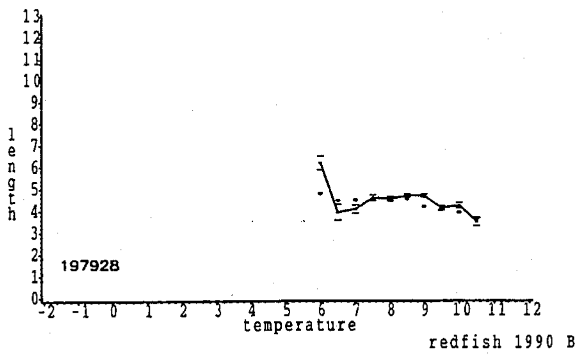
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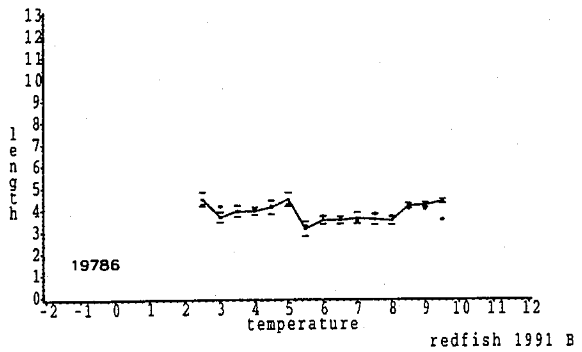
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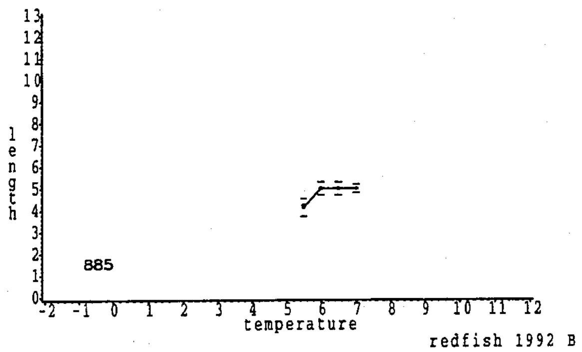
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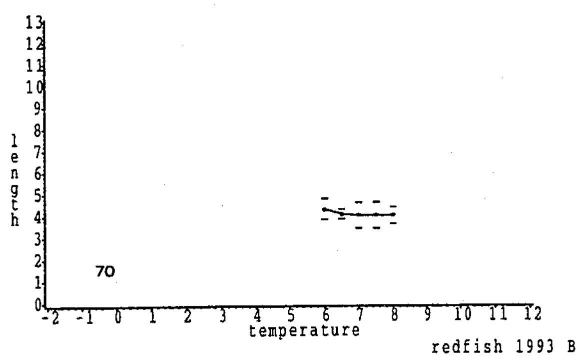
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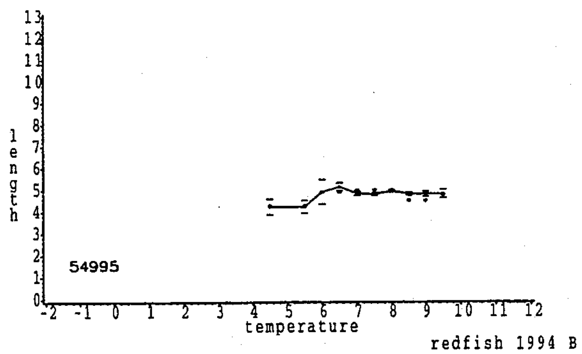
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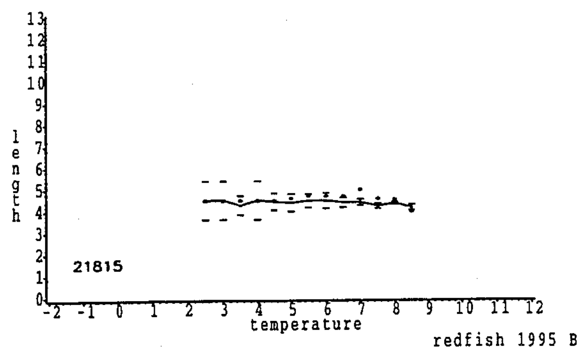
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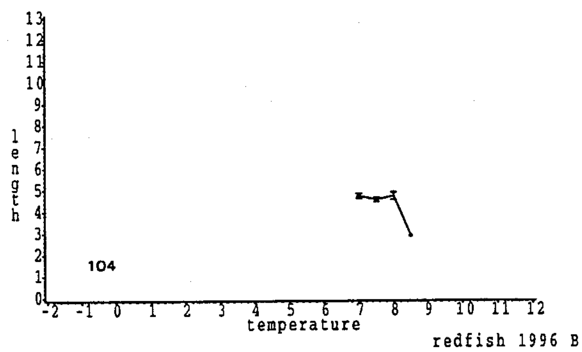
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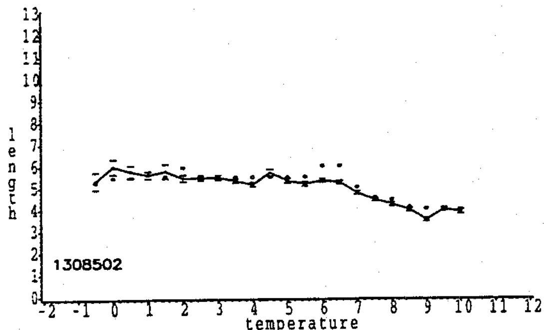
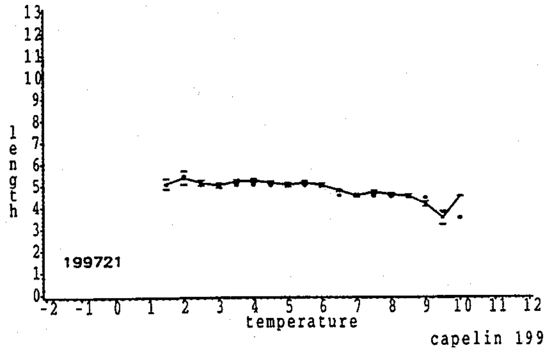


capelin 1989 B



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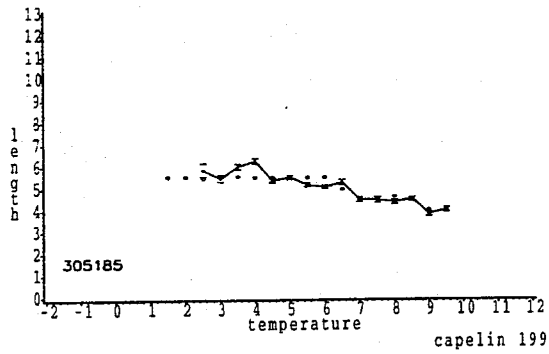

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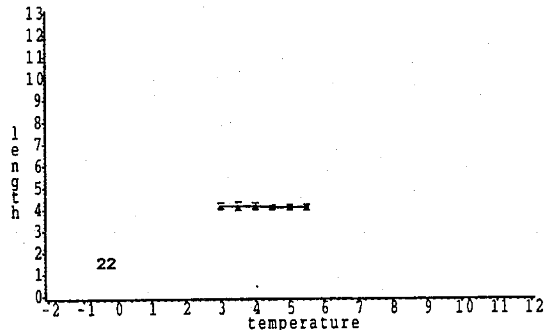

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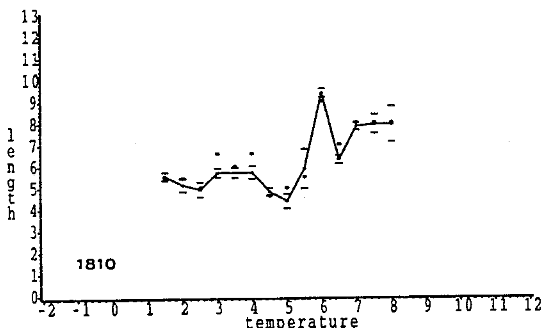

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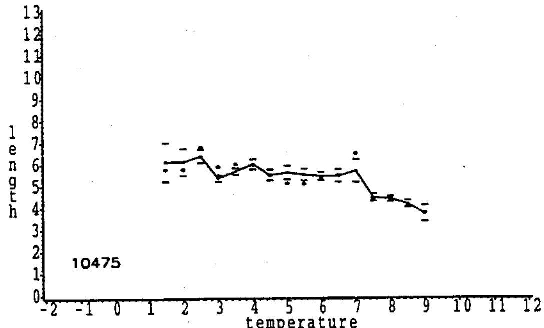

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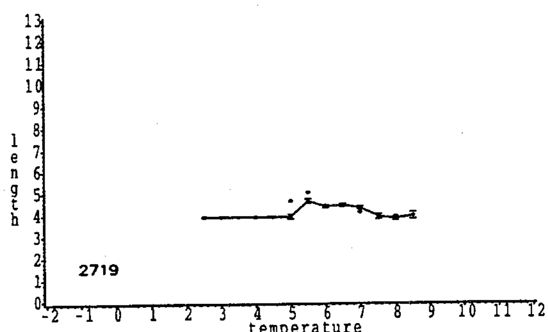

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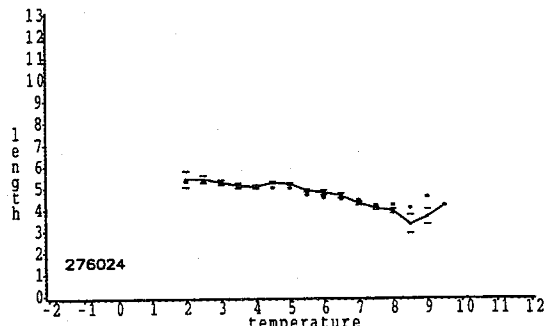

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