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FECUNDITY AND MATURITY OF COD (*Gadus morhua* L.) FROM NORTHERN NORWAY.

by

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ABSTRACT

The fecundity was determined for cod caught during March 1986 and 1987 in the region Lofoten - Malangsgrunnen, northern Norway. No significant difference in fecundity appeared between the two years. Fecundity was closely related to length:

Northeast Arctic cod: $F=1.25\cdot10^{-2}\cdot L^{4.27}$ ($r^2=0.931$, $P < 0.001$, n=100)
Coastal cod : $F=1.38\cdot10^{-5}\cdot L^{6.01}$ ($r^2=0.759$, $P < 0.001$, n= 40)

The formulae apply to the length range 50-135 cm and 54-95 cm, respectively. The fecundity in the Coastal cod is significantly higher than in the Northeast Arctic cod.

A comparison of the present estimate for Northeast Arctic cod with that made during 1971 and 1972 shows no significant difference.

The number of oocytes per g ovary was used as an indicator of maturity phase prior to spawning. The results suggest that peak spawning in the Coastal cod takes place 3 - 4 weeks later than in the Northeast Arctic cod but that the duration of the season appears to be longer.

RÉSUMÉ

On a déterminé la fécondité de la morue capturée pendant Mars 1986 et 1987 dans les eaux de Lofoten-Malangsgrunnen dans le nord de la Norvège. Aucune différence significative n´a été observée entre les observations des deux années. La fécondite était fortement reliée à la taille de la morue:

La morue nord-est-arctique: $F=1.25\cdot10^{-2}\cdot L^{4.27}$ ($r^2=0.931$, $P<0.001$, n=100)
La morue côtière : $F=1.38\cdot10^{-5}\cdot L^{6.01}$ ($r^2=0.759$, $P<0.001$, n= 40)

Les formules sont applicables aux longeurs 50-135 cm et 54-95 cm, respectivement. La fécondité de la morue côtière est significativement plus grande que celle de la morue nord-est-arctique.

Pour la morue nord-est-arctique l´éstimation présente n´indique aucune différence de l´éstimation qui a été faite pendant les années 1971 et 1972.

On a employé le nombre d´oozytes pour indiquer la phase de maturité avant le frai. Les resultats indiquent, que chez la morue côtière, le frai maximal a lieu environ 3-4 semaines plus tard que celui de la morue nord-est-arctique, mais qu´il a une durée plus longue.

I. INTRODUCTION

In the period 1983-1985 the population fecundity of the Northeast Arctic cod was calculated from egg surveys combined with spawning intensity curves (Sundby & Solemdal, 1984; Sundby & Bratland, 1987). In order to estimate spawning biomass it is necessary to estimate individual fecundities. So far, there are two studies on this subject; Sorokin (1957) and Aldonov et al. (1982). The former author examined the fecundity in 8 specimens collected between 1949 and 1951. The fecundities ranged from $1.4 \cdot 10^6$ to $10.7 \cdot 10^6$ within the fish length 80-108 cm. Aldonov et al. (op.cit.) sampled 110 specimens, 6-18 years old, in 1971 and 1972. The fecundities ranged from $1.2 \cdot 10^6$ to $19.2 \cdot 10^6$. However, it is possible that the fecundity may have changed since then (Bagenal, 1978a). Further examples of cod fecundity are given by Oosthuizen & Daan (1974) and by Buzeta & Waiwood (1982).

The purpose of the present work was primarily to study the fecundity of the Northeast Arctic cod. However, because Norwegian Coastal cod appeared in the catches and because its fecundity has not been estimated since 1959 (Botros, 1962), it was decided to include this population in the estimate. The Coastal cod grow faster and reach maturity earlier than the Northeast Arctic cod, phenomena explained by the different environmental conditions experienced by the two populations (Godø & Moksness, 1987). The oocyte size of the Coastal cod was more varied and the number of oocytes per g ovary (West, 1970) was used to indicate the time of start of spawning.

II. MATERIALS AND METHODS

The specimens were caught during March 1986 and 1987 in the region Lofoten - Moskenesgrunnen - Malangsgrunnen by commercial vessels using Danish seine or gill nets and by research vessels using a bottom trawl. A total of 140 specimens were collected and the total length was recorded to the nearest cm, few fish exceeded 100 cm. In 1986 all specimens were weighed (whole-body weight) on landing to the nearest 0.1 kg. The same procedure was applied in 1987 on the specimens caught in Lofoten. Age was determined from the otoliths and the specimens classified as Norwegian Coastal cod (CC) or Northeast Arctic cod (NAC) (Rollefsen, 1933; 1934). About 40% out of the specimens in both the CC and the NAC group were placed with lesser certainty.

The ovaries were frozen whole. Before freezing, the ovaries from the 1986 material were weighed to the nearest 10 g. All ovaries showed vitellogenic oocytes clearly visible to the naked eye indicating a maturity stage suitable for fecundity estimates (West, 1970). It was confirmed that no hyaline oocytes were present in the ovaries as this would indicate the commencement of spawning.

At the laboratory, the ovaries were thawed and then weighed to the nearest g. For comparison of fresh with thawed ovarian weight, ovaries heavier than 500 g fresh weight (weight with an error < 1%) were used. Thawed ovaries showed 5.0% (S.D.= 2.5, n = 14) lower weight. Subsamples of about 200 mg were taken and weighed to the nearest mg (Sartorius electronic balance) and subsequently preserved in a fluid containing 165 g of sucrose per l of water and 2% formaldehyde. The purpose of including sucrose was to protect the oocytes during shaking and to increase the refractive index thus making the oocytes easily visible under the binocular microscope. The subsamples were shaken, stored for at least 24 h, shaken again and then the vitellogenic oocytes were counted. The fecundities were obtained using a wet gravimetric method (oocytes/g of ovary) (Bagenal, 1978b).

To ascertain the degree of homogeneity in the ovary, 10 randomly selected ovaries were used, and sampling was carried out from the anterior, middle and posterior region of the right ovary lobe and from the middle region of the left ovary lobe. Bagenal (1978b) has indicated that 4 samples are needed to estimate the fecundity with confidence, consequently 4 samples were taken from each site. The Kruskal-Wallis test (4 groups a 40 observations) showed that the fecundity was independent of the position of sampling; $0.975 < P < 0.995$. In a further test sampling from the middle region of the right ovary lobe showed that it was not necessary to examine all 4 samples to get a reliable final mean estimate. The following procedure was therefore adopted. At first two samples were compared. If their estimates deviated < 5%, the final mean was calculated. If the deviation > 5%, the third sample was examined. This estimate was then compared with the mean of the two estimates. If it was still > 5%, a fourth sample was examined. For 80% of the ovaries (n=130), the final mean estimate was based on 2 samples, for 17% on 3 samples and for 3% on 4 samples. In the latter two cases, the minimal and maximal individual estimate deviated by no more than 15%.

Two types of condition factors were estimated:

Fulton´s condition factor: $(W/L^3)\cdot 100$ (Bagenal & Tesch, 1978)

Somatic condition factor : $(S/L^3)\cdot 100$ (Scott, 1979)
W: whole body weight; S: somatic weight = whole body weight - ovarian fresh weight (all weights in g). L: total fish length.

Relative fecundity was defined as: F/S, F: fecundity. The ovarian thawed weight was used in the calculation of the number of oocytes per g ovary (NG).

The statistical tests were carried out using the program package BIOM (Sokal & Rohlf, 1981). Rejection of the null hypothesis was made at a significance level of 5% using two-tailed tests. The graphs were produced with the aid of the package Graphicus (Graphic User System, Inc.). All equations given in the present work are of the form : $\hat{Y} = aX^b$,i.e the log-log transformation giving the best fit. For comparison of regression lines (log-log), an analysis of covariance (ANCOVA) was used. In this test a common x-axis range was chosen corresponding to a region where each group was well represented. The Kolmogorov-Smirnov test was used when data were checked for normal distribution.

III. RESULTS

Fecundity

The relation between fecundity and fish length is shown in Fig.1 for 1986 and in Fig.2 for 1987. For the NAC, the specimens caught in 1986 belonged to the the year classes 1971 - 1982 (Fig.3 and 4) while the 1987-sample included mostly two year classes; 1981 and 1982. No atresia was observed.

Several correlations were performed on the 1986 NAC data (Table I). Further, the Somatic condition factor was correlated to the relative fecundity. The correlation was not significant; $r^2 = 0.07$, $P > 0.05$. The Fulton´s condition factor (CF) ranged 0.67 - 1.29 and was significantly positively ($r^2 = 0.380$, $P < 0.001$) correlated with total length: $CF = 4.60\cdot 10^{-3}\cdot L + 0.51$. No such relation was found for the CC; $P > 0.05$ in both 1986 and 1987. The mean Fulton´s condition factors were here 1.01 (S.D = 0.15) and 1.13 (S.D = 0.11), respectively, means which proved to be significantly ($P \approx 0.01$) different in a Student t-test with equal variances ($F = 2.10$, df = 17,19).

ANCOVA revealed that there was no significant difference in the fecundity-length relations in 1986 and 1987 for the NAC (Fig.5); intercept: $F = 3.75$, df = 1,60 ($0.10 < P < 0.20$) and slope: $F = 4.17$, df = 1,59 ($0.05 < P < 0.10$). Consequently, the data were combined.

This test was also applied to the CC (fish length below 78 cm) and the same conclusion was reached; intercept: $F = 0.45$, $df = 1,29$ ($P > 0.50$) and slope: $F = 3.74$, $df = 1,28$ ($0.10 < P < 0.20$). The pooled fecundity-length curves obtained are shown in Fig.6. The formulae were:

<u>NAC</u>

$$F = 1.25 \cdot 10^{-2} \cdot L^{4.27} \quad (r^2 = 0.931,\ P < 0.001)$$

<u>CC</u>

$$F = 1.38 \cdot 10^{-5} \cdot L^{6.01} \quad (r^2 = 0.759,\ P < 0.001)$$

The latter formula is not valid for fish lengths beyond 95 cm due to few data there.

Comparing the fecundity-length data (length range: 54 - 95 cm) of the CC with those of the NAC, the ANCOVA-test showed that the fecundity in the CC was significantly higher; intercept: $F = 107.20$, $df = 1,110$ ($P << 0.001$) and slope: $F = 8.20$, $df = 1,109$ ($P < 0.001$). At the fish lengths 55, 75 and 95 cm, the fecundity of the CC exceeded that of the NAC by a factor of 1.2, 2.0 and 3.0, respectively.

The fecundity estimates of Aldonov <u>et</u> <u>al</u>. (1982) on NAC for 1971 and 1972 and those by Botros (1962) on CC for 1959 were compared where possible with the present data. Aldonov <u>et</u> <u>al</u>. (op.cit.) collected the specimens within the same geographic region as those used in the present study. Botros (op.cit.), on the other hand, used specimens caught off Bergen; about 1000 km further south. In both studies data for individual specimens are not given, however the mean fecundity and mean length within each age group or 10 cm length group are tabled. To improve comparisons, the present data were pooled in the same manner. The curves obtained are shown in Fig.7. ANCOVA revealed no significant inter-year variation in fecundity for either NAC or CC; NAC (age group 7-11), intercept: $F = 7.54$, $df = 1,7$ ($0.05 < P < 0.10$) and slope: $F = 0.15$, $df = 1,6$ ($P > 0.50$), CC (length 60 - 100 cm), intercept: $F = 0.38$, $df = 1,5$ ($P > 0.50$) and slope: $F = 5.12$, $df = 1,4$ ($0.10 < P < 0.20$).

The age-length data recorded by Aldonov <u>et</u> <u>al</u>. (op.cit.) were further compared to those of the present study. The length at age was not significantly different; intercept: $F = 0.63$, $df = 1,7$ ($P > 0.50$) and slope: $F = 0.94$, $df = 1,6$ ($P > 0.50$). Finally, Fulton´s condition factor was calculated. The comparisons did not differ significantly ($P > 0.20$, Wilcoxon test).

Number of oocytes per g ovary

In 1986 all specimens were collected within the first week of March. The NG, plotted in Fig.8, decreased significantly (r^2 = 0.342, P < 0.001) with increasing fish length for the NAC, while this trend was not observed for the CC (r^2 = 0.008, P >> 0.05). The result for the NAC was due to the larger specimens in the sample and selecting the same length interval (54 - 95 cm) as for the CC no trend was found (r^2 = 0.001, P >> 0.05). Within this length interval, the variance in the NG for the CC was significantly larger; F = 5.98, df = 17,26 (P < 0.001). Consequently, for comparison of the two NG-means, a Student t-test with unequal variances was used. It appeared that the mean for the CC was significantly larger (0.001 < P < 0.01) than the mean for the NAC (9050 and 5800 g^{-1}, respectively).

In 1987 most of the NAC were sampled at the same time as in 1986. The inter-year variation in the NG for NAC (fish length < 90 cm) was investigated using a Student t-test with equal variances; F = 1.25, df = 21,38 (P > 0.50). No significant difference was found; 0.10 < P < 0.20.

Nearly all CC specimens from 1987 were taken on 31 March which was about 3 weeks later in the year than in 1986. Using a Student t-test with equal variances, F = 1.41, df = 17,19 (0.20 < P < 0.50), a significant difference in the 1986 and 1987 NG-mean for CC was noted; 0.01 < P < 0.02. The mean in 1986 was, as stated above, 9050 g^{-1} while it was 6350 g^{-1} in 1987; a reduction of about 30 %.

IV. DISCUSSION

The correlation coefficients given for the NAC, based upon the 1986 data, were all highly significant (Table 1). When fecundity is correlated, it seems uncommon in literature to get that close relations. This indicates that the method for estimation of the fecundity was suitable.

The fecundity-length curve of CC from southern (Botros, 1962) and northern Norway did not depart significantly (Fig.7). On the other hand, the fecundity in CC exceeded that in NAC significantly (Fig.6). It is the first time this difference in fecundity between the CC and the NAC is documented, the result suggests additionally that the specimens have been classified correctly from reading otoliths. A comprehensive account of the fecundities in cod from different geographical areas was given by Oosthuizen & Daan (1974). It appears that the CC and the Baltic cod have very similar fecundities. Including the present fecundity data of the NAC, no significant difference is observed between the NAC, the Islandic cod and the North Sea cod, the Newfoundland cod, however, show significantly lower fecundities.

Both for the NAC and the CC, the fecundity data were pooled due to an insignificant variation in fecundity between 1986 and 1987. The fecundity of cod in the North Sea was also very similar among subsequent years (Oosthuizen & Daan, 1974). However, substantial inter-year variation was found in Newfoundland cod (Pinhorn, 1984). This area is characterized by showing changing and often extreme cold water temperatures. Accordingly, Pinhorn (op.cit.) attributed the observed variation to less feeding, slower digestion rate and increased atresia at low temperatures. Unfortunately, neither condition factors nor histological slides of the ovaries were studied. Considering fecundity estimates more widely spaced in time, the present one of the NAC was not significantly different to that in 1971 and 1972 (Fig.7). The observed lack of variation among the length-age relations and condition factors were consequently not surprisingly. Buzeta & Waiwood (1982) compared the fecundity in the cod from Gulf of St. Lawrence with data published about 25 years earlier. They too were unable to detect any significant change. Thus apart from the study on Newfoundland cod there is no evidence for significant inter-year differences in fecundity.

Scott (1962) has shown experimentally, using rainbow trout (Salmo gairdneri), that the degree of atresia (resorption of vitellogenic oocytes) is correlated with the degree of starvation. Capelin (Mallotus villosus) is regarded as one of the principal food items for the cod (Burgos & Mehl, 1987; Mehl, 1987). It seems unlikely, however, that the collapse of the Barents Sea capelin stock, which happened in the period 1983-86 (Tjelmeland, 1987), has affected the fecundity of the NAC under study negatively: no atresia was observed and both the fecundity and the condition factor were assumingly at a normal level. This normal values explain why there was not found any significant correlation between the relative fecundity and the Somatic condition factor. The conclusion to be drawn is that the mature specimens seem to have got enough food so far, probably due to increased feeding on other fish species and increased cannibalism (Mehl, 1987; Burgos & Mehl, 1987). It is known, however, that the condition factors of the immature specimens (mostly 2-4 years old specimens) have dropped pronounced (10-15%) from 1986 to 1987, 1988 showing the same values as 1987 (Jakobsen, pers.comm.). For that reason, the present fecundity data will be important as a reference in further fecundity studies, and when recruiting the slim specimens will give a very good chance to study the effect of starvation on the fecundity. There are two aspects more which should be considered in the coming years: 1) the quality of the oocytes: a reduction in the energy content may occur (Wootton, 1979), 2) the time of recruitment to the spawning stock: postponed recruitment is expected (Bagenal, 1969).

In a laboratory experiment using reared CC, Kjesbu (1988) showed that the growth of the vitellogenic oocytes is arrested at a mean fresh diameter of about 800 µm irrespective of the fish length. This phenomenon is the basis for the present use of the number of oocytes per g of ovary. Because egg size seems to be independent of the fecundity (Kjesbu, op.cit.) and because CC and NAC appear to be genetically similar (Mork et al., 1985; Godø & Moksness, 1987), it is suggested that the NG-value can be used directly for a comparison of the phase of maturity in CC and NAC.

Larger specimens (> 100 cm) of the NAC showed a more advanced phase of maturity than the smaller ones (Fig.8) indicating that they will begin to spawn first. This is corroborated by the fact that specimens > 80 cm appear first in Lofoten in the spawning season (Sund, 1938). The CC showed significantly higher NG-values than the NAC; its day of peak spawning is assumed to be later, results suggest 3-4 weeks. Spawning peaks on 1 April for the NAC (Solemdal, 1982; Pedersen, 1984). The variance in the NG of the CC was also higher pointing to a longer spawning season. Photoperiod and/or temperature are assumed to be the most important environmental factors in timing of gametogenesis (Lam, 1983). The light regime experienced by the specimens was probably very similar; the differences observed in the maturity phases between the CC and the NAC may be correlated with the water temperature, eg. the CC which showed a high NG have most likely stayed in the cold fjords of Finnmark (Loeng, pers.comm.) during most of the year.

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References

Aldonov, V.K., Borisov, V.M. & Serebriakov, V.P. (1982). Fecundity of Arcto-Norwegian cod spawning populations. Coun. Meet. int. Coun. Explor. Sea, 1982 (G:19), 5 pp. (mimeo.)

Bagenal, T.B. (1969). The relationship between food supply and fecundity in brown trout *Salmo trutta* L. J. Fish Biol. 1, 167-182.

Bagenal, T.B. (1978a). Aspects of fish fecundity. In Ecology of Freshwater Fish Production (S.D. Gerking, ed.), pp.75-101. London: Blackwell Scientific Publications.

Bagenal, T.B. (1978b). Fecundity. In Methods for assessment of fish production in fresh waters (T.B. Bagenal, ed.). IBP Handbook No.3. Third edition, pp. 166-178. London: Blackwell Scientific Publications.

Bagenal, T.B. & Tesch, F.W. (1978). Age and growth. In Methods for assessment of fish production in fresh waters (T.B. Bagenal, ed.). IBP Handbook No.3. Third edition, pp. 101-130. London: Blackwell Scientific Publications.

Botros, G.A. (1962). Die Fruchtbarkeit des Dorches (*Gadus morhua* L.) in der westlichen Ostsee und den westnorwegischen Gewässern. Kieler Meeresforsch. 18, 67-80.

Burgos, G. & Mehl, S. (1987). Diet overlap between North-East Arctic cod and haddock in the southern part of the Barents Sea in 1984-1986. Coun. Meet. int. Coun. Explor. Sea, 1987 (G:50), 7 pp. (mimeo.)

Buzeta, M.-I & Waiwood, K.G. (1982). Fecundity of Atlantic cod (*Gadus morhua*) in the southwestern Gulf of St. Lawrence. Can. Tech. Rep. Fish. Aquat. Sci. 1110, 6 pp.

Godø, O.R. & Moksness, E. (1987). Growth and maturation of Norwegian Coastal Cod and Northeast Arctic cod under different conditions. Fish. Res. 5, 235-242.

Kjesbu, O.S. (1988). Aspects of the reproduction in cod (Gadus morhua L.): oogenesis, fecundity, spawning in captivity and stage of spawning. Dr.Scient.Thesis, University of Bergen, Norway. Submitted 15 August.

Lam, T.J. (1983). Environmental influences on gonadal activity in fish. In Fish physiology (W.S. Hoar, D.J. Randall & E.M. Donaldson, eds.) Vol. 9B, pp. 65-116. London: Academic Press.

Mehl, S. (1987). The North-East Arctic cod stock´s consumption of commercially exploited prey species in 1984 - 1986. Coun. Meet. int. Coun. Explor. Sea, 1987 (Symp/No.9), 11 pp. (mimeo.)

Mork, J., Ryman, N., Ståhl, G., Utter, F. & Sundnes, G. (1985). Genetic variation in Atlantic cod (Gadus morhua) throughout its range. Can. J. Fish. Aquat. Sci. 42, 1580-1587.

Oosthuizen, E. & Daan, N. (1974). Egg fecundity and maturity of North Sea cod, Gadus morhua. Neth. J. Sea Res. 8, 378-397.

Pedersen, T. (1984). Variation of peak spawning of Arcto-Norwegian cod (Gadus morhua L.) during the time period 1929-1982 based on indices estimated from fishery statistics. In The propagation of cod Gadus morhua L. An international symposium. Arendal. 1983. (E. Dahl, D.S. Danielssen, E. Moksness & P. Solemdal, eds.), pp. 301-316.

Pinhorn, A.T. (1984). Temporal and spatial variation in fecundity of Atlantic cod (Gadus morhua) in Newfoundland waters. J. Northw. Atl. Fish. Sci. 5, 161-170.

Rollefsen, G. (1933). The otoliths of the cod. FiskDir. Skr. Ser. HavUnders. 4, 14 pp.

Rollefsen, G. (1934). The cod otolith as a guide to race, sexual development and mortality. Rapp. P.-v. Réun. Cons. perm. int. Explor. Mer. 88, 5 pp.

Scott, D.B.C. (1979). Environmental timing and the control of reproduction in teleost fish. Symp. zool. Soc. Lond. No. 44, 105-132.

Scott, D.P. (1962). Effect of food quantity on fecundity of rainbow trout, Salmo gairdneri. J. Fish. Res. Bd. Canada. 19, 715-731.

Sokal, R.R. & Rohlf, F.J. (1981). Biom. A package of statistical programs to accompany the text Biometry. 76 pp. San Francisco: W.H. Freeman and Company.

Solemdal, P. (1982). The spawning period of Arcto-Norwegian cod during the years 1976-1981. Report on the working group on larval fish ecology, Lowestoft, England, 1981. Coun. Meet. int. Coun. Explor. Sea, 1982 (L:3), 21 pp. (mimeo.)

Sorokin, V.P. (1957). The oogenesis and reproductive cycle of the cod (Gadus morhua Linn.). Trudy Pinro. 10, 125-144. (In Russian). English trans. No. 72F49 Ministry Agric. Fish. Food, U.K. 1961.

Sund, O. (1938). Torskebestanden i 1937 (The stock of cod 1937). FiskDir. Skr. Ser. HavUnders. 5, 11-22. (In Norwegian)

Sundby, S. & Solemdal, P. (1984). The egg production of Arcto-Norwegian cod (Gadus morhua L.) in the Lofoten area estimated by egg surveys. In The proceedings of the Soviet-Norwegian symposium on reproduction and recruitment of Arctic cod. Leningrad 1983. (O.R. Godø & S. Tilseth, eds.), pp. 113-135.

Sundby, S. & Bratland, P. (1987). Kartlegging av gytefeltene for norsk-arktisk torsk i Nord-Norge og beregning av eggproduksjonen i årene 1983-1985 [Spatial distribution and production of eggs from Northeast-arctic cod at the coast of Northern Norway 1983-1985]. Fisken Hav. 1, 58 pp. (In Norwegian)

Tjelmeland, S. (1987). Mortality on Barents Sea capelin calculated by the IMR multispecies model for the Barents Sea. Coun. Meet. int. Coun. Explor. Sea, 1987 (H:55), 15 pp. (mimeo.)

West, W.Q.-B. (1970). The spawning biology and fecundity of cod in Scottish waters. Ph. D. Thesis. 257 pp. Aberdeen, U.K: University of Aberdeen.

Wootton, R.J. (1979). Energy costs of egg production and environmental determinants of fecundity in teleost fishes. Symp. zool. Soc. Lond. No.44, 133-159.

1986

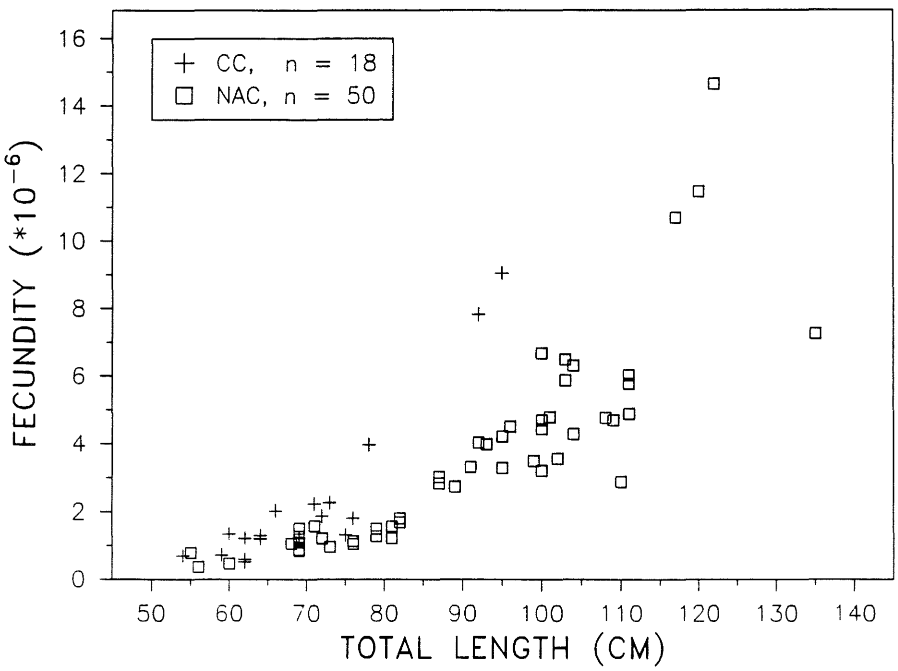

Fig.1. Individual fecundity estimates for 1986 versus fish length.

1987

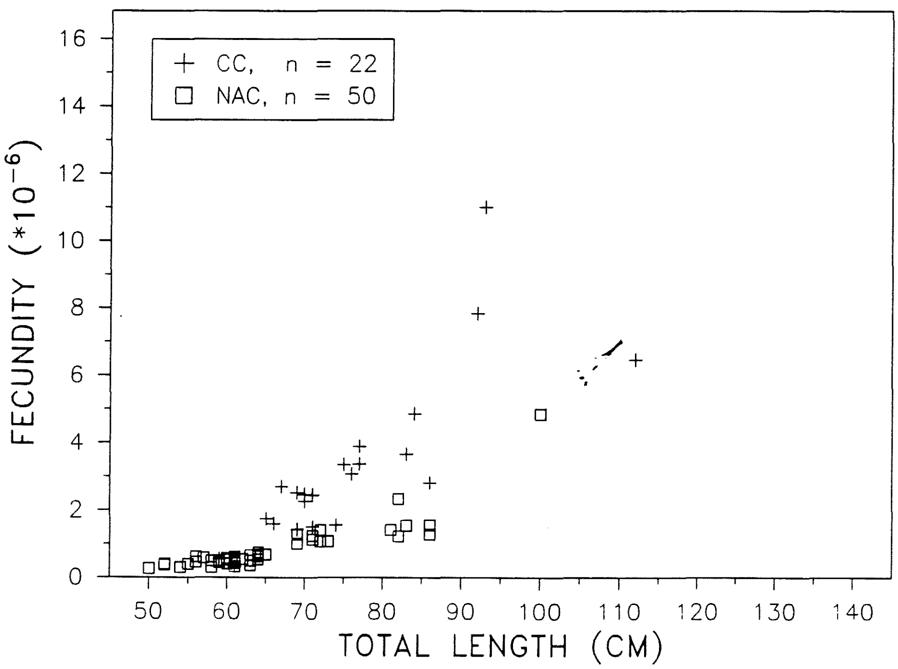

Fig.2. Individual fecundity estimates for 1987 versus fish length.

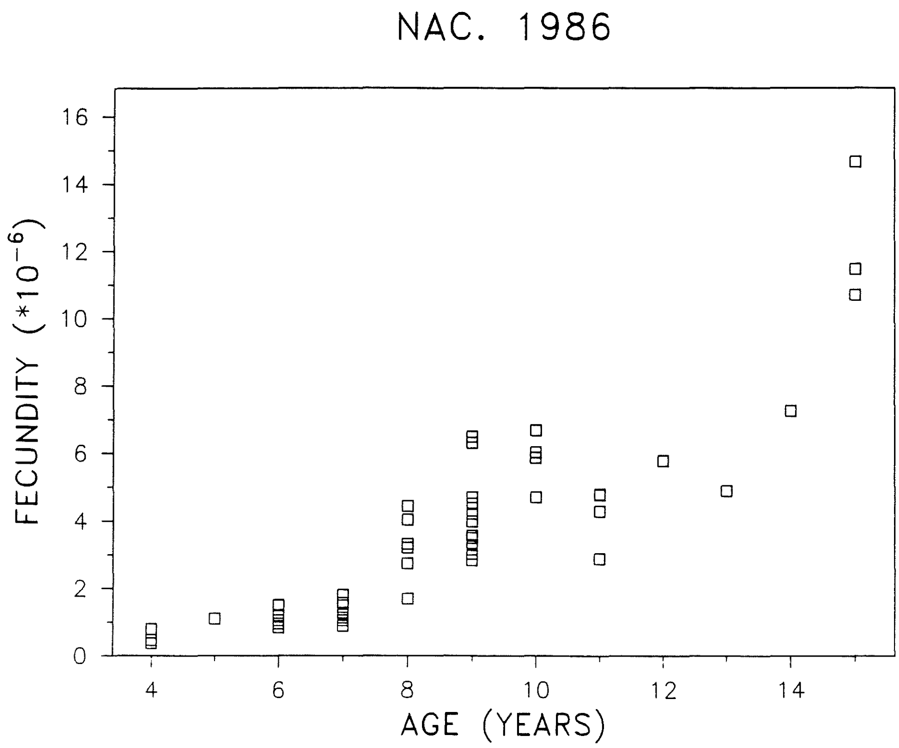

Fig.3. Fecundity at age for NAC caught in 1986.

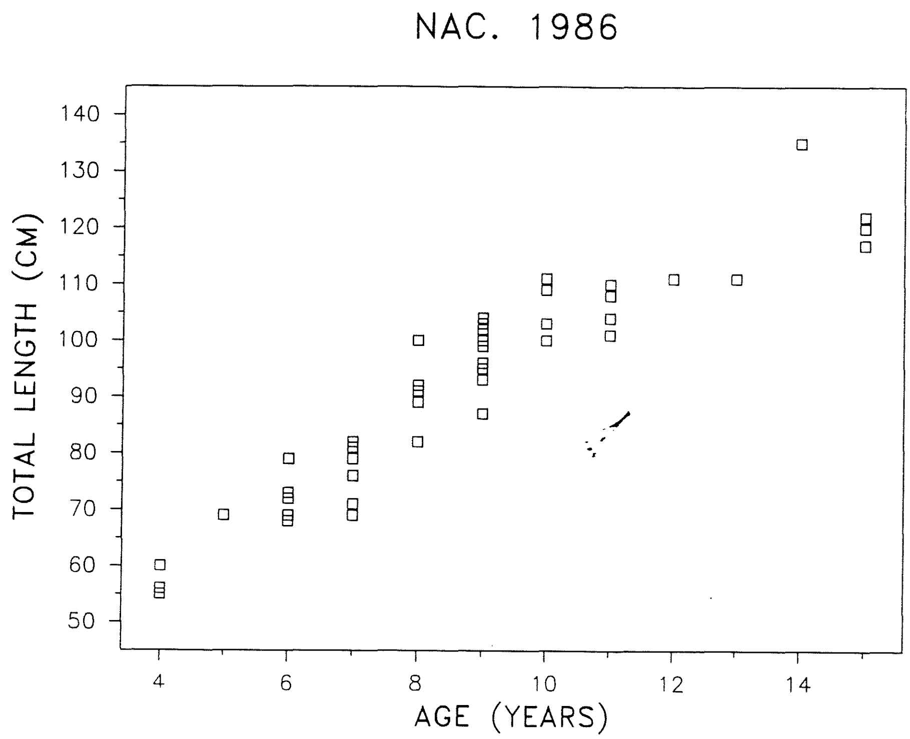

Fig.4. Length at age for NAC caught in 1986.

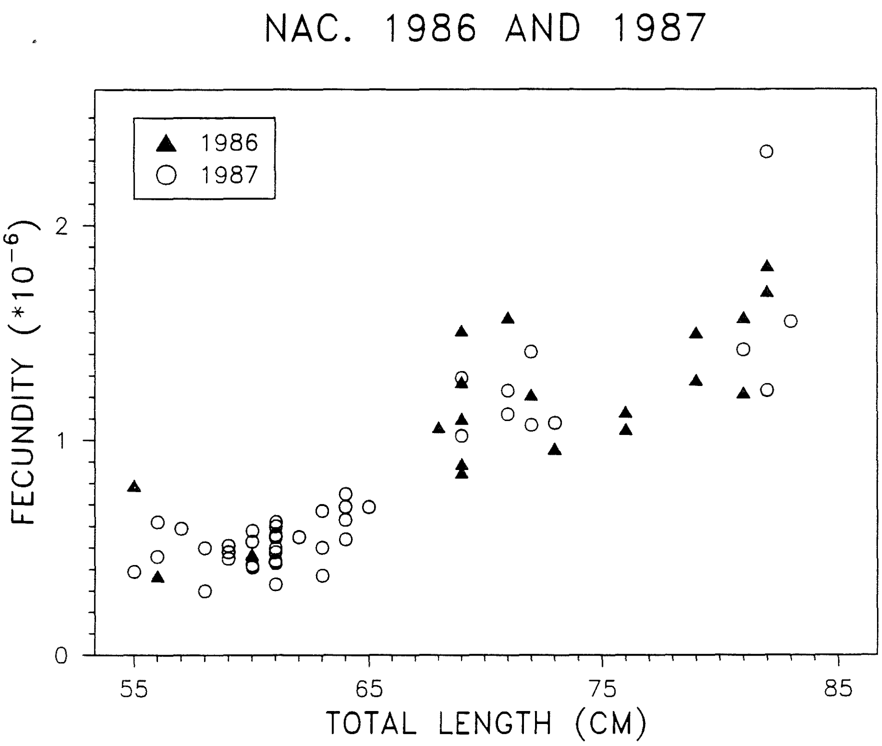

Fig.5. Comparison of the fecundity of NAC caught in 1986 and 1987 for specimens 55 to 85 cm in length.

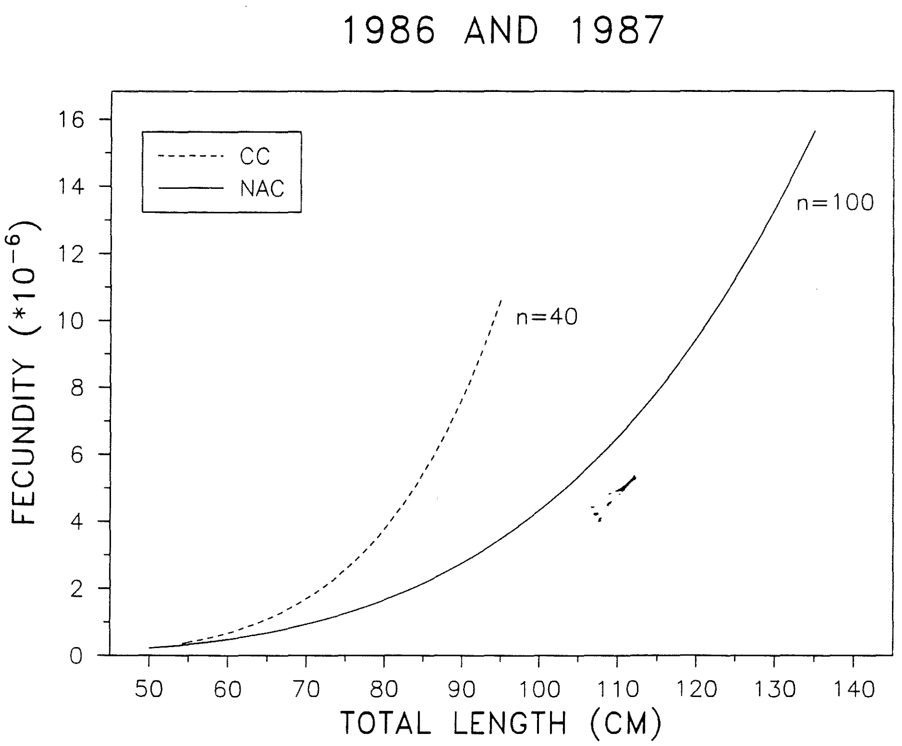

Fig.6. The pooled fecundity-length curves obtained for the CC and the NAC caught in 1986 and 1987.

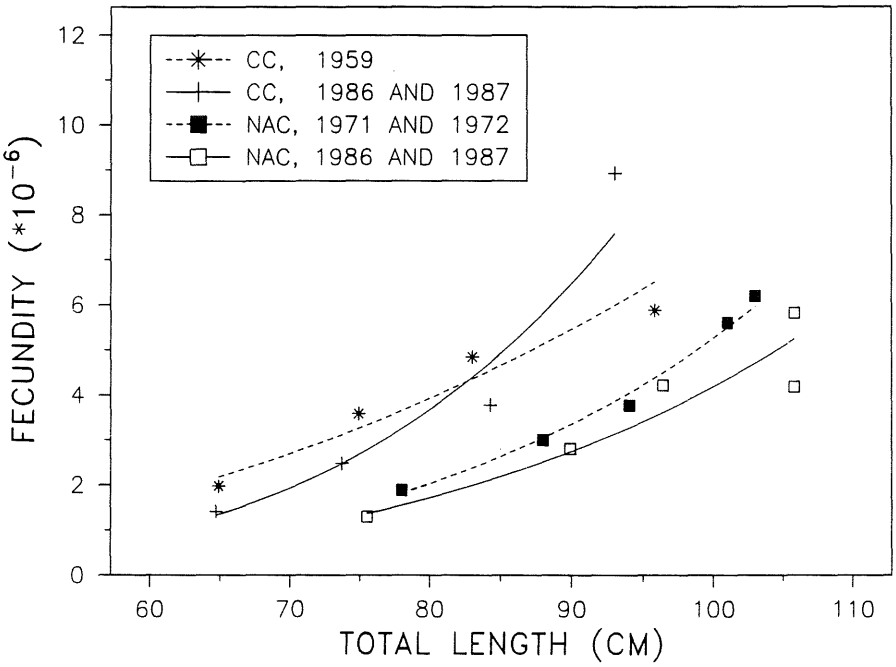

Fig.7. The fecundity-length relation for CC and NAC caught between 1959 and 1987. Data from Botros (1962): curve 1959, Aldonov et al. (1982): curve 1971 and 1972 and this study: curves 1986 and 1987.

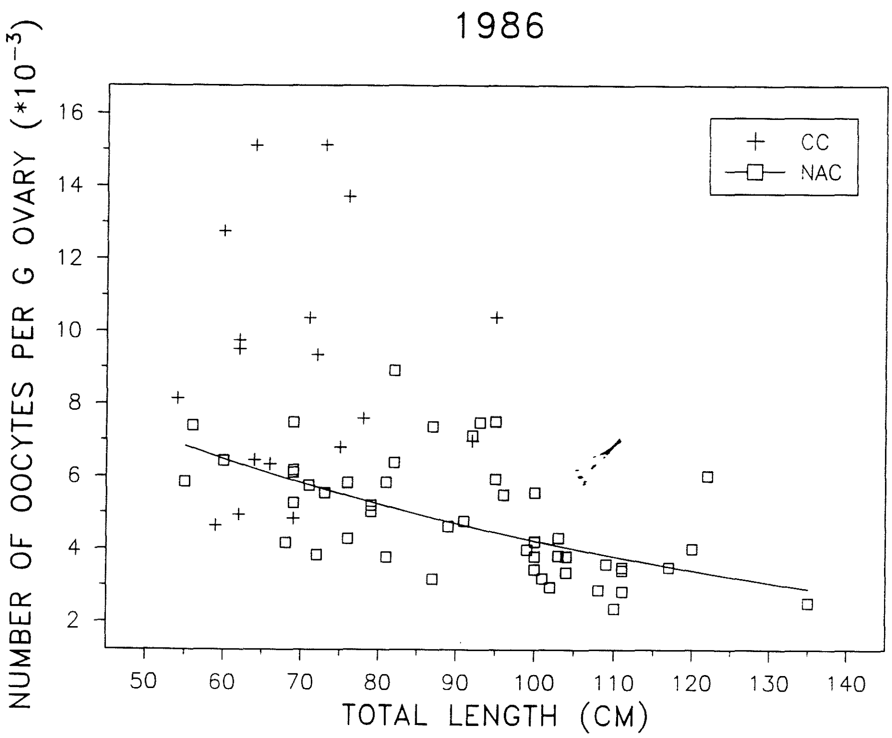

Fig.8. Number of oocytes per gram of ovary for CC and NAC in the first week of March 1986 in relation to the fish length.

Table I. Formulae found for the Northeast Arctic cod (n=50) collected in 1986.

Correlation		Equation	r^2
Whole body weight (W)	vs. total length (L)	$W = 1.11 \cdot 10^{-6} \cdot L^{3.47}$	0.974
Somatic weight (S)	vs. total length	$S = 1.80 \cdot 10^{-6} \cdot L^{3.34}$	0.970
Total length	vs. age (A)	$L = 2.28 \cdot 10^{1} \cdot A^{0.65}$	0.890
Ovarian fresh weight (OW)	vs. total length	$OW = 5.06 \cdot 10^{-8} \cdot L^{5.17}$	0.923
Fecundity (F)	vs. whole body weight	$F = 3.01 \cdot 10^{5} \cdot W^{1.17}$	0.925
Fecundity	vs. somatic weight	$F = 3.11 \cdot 10^{5} \cdot S^{1.22}$	0.917
Fecundity	vs. total length	$F = 1.59 \cdot 10^{-2} \cdot L^{4.22}$	0.888
Fecundity	vs. age	$F = 6.84 \cdot 10^{3} \cdot A^{2.83}$	0.839

W and S in kg, OW in g.

Tests of significance for the correlation coefficients gave $P < 0.001$