The diet of North-East Arctic cod 1984-1994.

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by

Bjarte Bogstad and Sigbjørn Mehl, IMR, Bergen, Norway

Introduction

In this document, we provide data on the yearly consumption of various prey species by North-East Arctic cod in the period 1984-1994. Such data can be used to assess the impact of predation by cod on various prey species, and also to study the relationship between food consumption and individual growth of cod.

Material and methods

The cod stomach content data are taken from the joint PINRO-IMR stomach content data base (Mehl and Yaragina 1992). The consumption is calculated mainly in the same way as in Bogstad and Mehl (1992), but the stomach evacuation rate model is revised.

The Barents Sea is divided into three areas (west, east and north, see Figure 1), and the consumption by cod is calculated from the average stomach content of each prey group by area, half-year and cod age group (ages 1-6 separately and 7-11 as one group). For some half-years and areas the calculations are made for ages 1-7 separately, with 8-11 as one group.

The number at age and weight at age of cod is based on the assessment made by the Arctic Fisheries Working Group in 1995 (Anon., 1996a). In this assessment, cod cannibalism was included for the first time, and this gave a higher number of age 1-3 cod than used in previous assessments, where a constant M of 0.2 was assumed for these age groups. The number of cod and weight of cod at age for the first and second half of the year is represented by the number and weight at April 1 and October 1, respectively. The number at age at these dates is calculated assuming that the natural mortality and fishing mortality is constant through the year, and the weight at age is calculated assuming that the growth (in g/day) is constant throughout the year. It is assumed that the mature part of the cod stock is found outside the Barents Sea for three months during the first half of the year. We have very few samples of the stomach content of cod in the spawning areas, and thus the consumption by cod in the spawning period is omitted from the calculations. It is believed that the cod generally eats very little during spawning time, but some predation by cod on herring has been observed close to the spawning areas. The geographical distribution of the cod stock by season is based on Norwegian survey data.

The following consumption rate model (the 'restricted form' model used by dos Santos and Jobling (1995)) is used:

$$S_{it} = S_0 \exp -((t \ln 2 \exp(\gamma T) B^{\delta})/(\alpha_i S_0^{\beta}))$$

where

t = time (hours)

S_i = cod stomach content of prey species i (g)

S_0 = initial meal size (g)

B = cod body weight (g)

T = temperature (° C)

The temperature used in the equation above is calculated from a standard climatological data base, adjusted for year-to-year variation using data from the Kola section. The following representative positions were used : West 7230N, 2200E, East 7130N, 3500E, North 7500N, 2200E. The average depth at which stomach samples are taken, was calculated for the stomach samples taken in the period 1984-1992, for each of the three areas. Based on information about vertical distribution of the cod from Norwegian surveys, a depth of 50 m less than the average bottom depth was taken to be representative, giving the following values for the three areas: West 250m, East 180m, North 150m. The temperature for April was used for the first half of the year and the temperature for October was used for the second half of the year.

$\beta = 0.26$, $\gamma = 0.13$, $\delta = 0.52$

α_i = prey-specific constant, the values are given in the table below. The value for cod is set equal to the value for haddock, the value of other food is set equal to that for capelin, and the value obtained for krill is used for amphipods.

Amphi-pods	Krill	Shrimp	Capelin	Herring	Cod	Haddock	Redfish	Polar cod	Other
41	41	103	58	88	84	84	68	59	58

If one assumes that over a period of days or weeks the fish reaches a steady-state, i.e. the amount ingested equals the amount evacuated, then the expected consumption of species i per hour, C_i , is given by

$$C_i = \ln 2 \exp(\gamma T) B^{\delta} S_i / (\alpha_i S_0^{\beta})$$

Another problem arises here since the initial meal size S_0 is normally not known in field work.

As a further simplification, S_0 may be approximated by a constant factor k times the observed total stomach content, ΣS_i. dos Santos and Jobling (1995) also tested the consumption model (equation 2 using $S_0 = \Sigma S_i$, i.e. k=1) by feeding cod for a period of 14 days (with a preceding adaption period), and comparing the consumption calculated in this way and the measured consumption. When multiple prey types were used in the experiment, and the average stomach content was used in the calculations (as is done in our calculations), it was found that the consumption was overestimated by 35 % using this method, which implies that k should be set to 1.78. This value is close to the (arbitrarily set) value of 2.0 used by Bogstad and Mehl (1992) where the evacuation rate model from dos Santos and Jobling (1992) was applied. Whether this value of k found from experiments can be applied when calculating the consumption from field data, is open to question, but at present this seems to be the best assumption we can make. A discussion of the problems related to the use of evacuation rate models when calculating the consumption from field samples can be found in (Anon., 1996b).

The equation used for calculating the consumption thus becomes:

$$C_i = \ln 2 \exp(\gamma T) B^{\delta} S_i / (\alpha_i (k \Sigma S_i)^{\beta}))$$

where k =1.78 and S_i now denotes the average stomach content of prey species i.

Results

Table 1. Consumption by cod of various prey species 1984-1994, in thousand tonnes.

Year	Amphi-pods	Krill	Shrimp	Cape-lin	Herr-ing	Cod	Hadd-ock	Redfish	Polar cod	Others	Total
1984	28	120	442	735	77	23	53	369	15	520	2381
1985	156	49	155	1630	187	32	47	226	3	1138	3623
1986	1232		140	833	136	82	109	315		888	3735
1987	1107		191	221	32	24	4	313		948	2840
1988	1299		137	325	8	9	3	235		805	2821
1989	895		141	640	3	9	11	250		1151	3101
1990	155		214	1788	8	21	18	277		2150	4631
1991	80		207	3250	9	31	23	360		1922	5883
1992	155		429	3107	389	127	165	242		2012	6628
1993	280	499	365	3690	198	361	91	122	341	1250	7197
1994	809	819	629	1094	175	311	51	118	803	1007	5817

Krill and polar cod has not yet been separated from the 'other' category for the years 1986-1992, , but this will be done in the near future so that the WG report will contain a table with the consumption of these species listed for all years.

Table 1 shows that the cod's consumption of capelin decreased strongly from 1993 to 1994, but that the consumption in 1994 is high compared to the acoustic abundance estimate in the autumn 1993 and 1994 (796 and 199 thousand tonnes, respectively). The same phenomenon was also observed in 1986, when the capelin stock also was low. We also see that the annual consumption of shrimp by cod almost doubled from 1992 to 1994. The consumption of cod by cod (cannibalism) was more than doubled from 1992 to 1993-1994. The fraction of cod in the diet is, however, not higher than the few stomach content data from the 1950s (Bogstad *et al.* 1994) indicate. The amount of redfish consumed dropped from a previously rather stable level of 250 000 - 350 000 tonnes in 1984-1992 to about 120 000 tonnes in 1993 and 1994. The amount of amphipods consumed increased in 1994, but has not yet reached the level observed during the previous capelin stock collapse in 1986-1989, when the cod switched from capelin to amphipods as prey. The fraction of herring in the diet is relatively low, and decreased from 1992 to 1994. Very few of the stomach samples are from pelagic trawl hauls, and thus the consumption of prey like herring, which are distributed in the upper layers of the sea, may be underestimated.

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Fig 1.

Areas used for consumption calculations.