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Comparison Assessment of the Intensity of Feeding of Cod of the Southern Barents Sea and Newfoundland

by

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Abstract

A comparative analysis of the results of calculations of daily rations of the Newfoundland cod according to methods and models of the experimental direction developed for the Atlantic cod is presented in this paper.

Data on satiety of the Newfoundland cod according to materials by Popova (1962) and Turuk (1976) with a subsequent recalculation of daily rations by various methods based on the data on stomach contents are used in the calculations. Almost a full identity of the results obtained by the methods of experimental direction, that is a telling argument in their favour, is shown. In the periods of fattening of the Newfoundland cod on capelin and sand eel the daily rations make up 1.0-2.5% on the average, being from time to time as great as 3%. These data are comparable with those for the Arcto-Norwegian cod at its stable feeding on capelin off the Murman coast.

Introduction

Under conditions of intensive fishery the quantitative assessment of food interrelations of fishes occupies one of the leading places in trophological investigations forming the basis for the construction of multi-type models. Inadequate assessments of consumption by predatory fishes of mass fishing species which play an important role in the trophodynamic structure of ecosystems are especially not permissible, since the consequences of their influences of the double pressure on them (fishery and predation) might be almost

unpredictable. As an example we can mention an irrational exploitation of the mass planktophage stocks in the Barents Sea - capelin, with the result that the population of the Arcto-Norwegian cod lost its stable food base. In this connection, in the period of the sharpest decline in capelin abundance (1987-1988) followed by transition of cod to consumption of various food - the young of commercial fishes, small non-fishing objects and crustaceans - changes are noted in some biological indices of cod - a sharp decrease in fatness, disturbances in the seasonal course of growth and in addition to them - change in the terms and directions of its feeding migrations. Only in 1989, when cod was predominantly preying on crustaceans (mainly euphausiids), that were poorly used by planktophages because of a sharp decline in their abundance a certain stabilization in its rate of growth and fat accumulation took place (Orlova *et al.*, 1990).

Preference to some areas where it forms local stocks differing by the rate of growth is characteristic of the Newfoundland cod (Popova, 1962: Postolaky, 1978; Templeman, 1962). The Arcto-Norwegian cod is close to the southern Newfoundland cod by the rate of growth and sexual maturing that is conditioned by similar hydrological conditions of living and close food composition - with the exception of sand eel (*Ammodytes* sp.), that is the main food object of cod in the Newfoundland area all the seasons throughout (Popova, 1962, 1968, Turuk, 1973, 1976; Lilly, 1987). This permits to compare the intensity of feeding of cod of both stocks, and also to use experimental data obtained for the Atlantic cod in various methods and models developed for the assessment of values of daily and yearly rations.

The available information about the Newfoundland cod feeding is mainly restricted by data on satiety of fishes, i.e. by indices of stomach fullness (Popova, 1962; Turuk, 1973), which are not sufficient for the estimation of the press of predation and food requirements of cod. An attempt of calculations of a daily ration of cod (Turuk, 1976) according to the method of Romanova (1958) led to evidently overestimated results. Data by Canadian scientists (Minet and Peredou, 1978) on consumption by Newfoundland cod of capelin accounting for 60-80% of its annual ration on the contrary seem to us to be rather low. Only some prerequisites and methods of calculations

of daily rations of cod based on the data on stomach contents are analyzed in this paper.

Materials and Procedure

Data on quantitative and weight analysis of stomach content, expressed in individual and common indices of fullness (Zenkevich and Brotskaya, 1931) or directly in a weight expression can be used in a number of models of calculations of daily rations of cod. It is method according to Baikov (1935) interpolated for predatory fishes (Zalachowski, 1985; Orlova *et al.*, 1990), 6 models presented by Bogstad and Mehl (MS 1991) and also the equation of linear regression of the following type derived by us: $y = ax + b$, where x and y is index of stomach fullness and daily ration[1] (in %) at a high coefficient of correlation of relationship between them (0.984), with the improved coefficients a and b depending on the food composition (Table 1).

Data on indices of stomach fullness of cod of different size groups fattening on capelin and sand eel in the southern coastal areas of Newfoundland in the summer of 1959 and 1960 (according to Popova, 1962) as well as on sand eel in the Great Newfoundland Bank area in December 1964 (according to Turuk, 1976) are used in our investigation. Subsequent recalculations of daily rations were made using the above methods, with the exception of three models out of six (according to Bogstad and Mehl, MS 1991). They require more exact data on weight of cod itself, and we were forced to use average weights of fishes in the size groups (according to Turuk, 1976).

When calculating daily rations following the method by Baikov (1935) and also according to one of the models in which data on reconstructed weight of food (i.e. consumption index) is used, to obtain it one can use the coefficient of specific agreement CI/IF that is equal to 2. This index was obtained by us (Orlova *et al.*, 1990) for the Arcto-Norwegian cod; it is also given in some models. In some cases however, the doubled index of stomach fullness might not coincide with the consumption index, then the results of calculations of diurnal rations could turn out to be underestimated. Data on duration of food digesting by cod can be taken from the literature

[1] Calculations were made separately following methods by Baikov (1935) and by Fortunatova (1940).

(Karpevich and Bokova, 1936; Tarverdiyeva, 1962; Orlova *et al.*, 1989; Tyler, 1970; Bagge, 1977, etc.), and also determined from the formulas (Jones, 1978; Zalachowski, 1985).

Results and Discussion

Models of calculations of daily rations (R) of cod (by Bogstad and Mehl, MS 1991) whilst still are not widely used, therefore we adduce them for the sake of comparison with other methods.

1. SANMOD (Mod. I). Exponential model based on experiments with different prey species and temperature that were carried out in Northern Norway (Des Santes, personal communication; Mehl, 1989; Bogstad and Tjelmeland, MS 1990). The actual rate of evacuation (E) per hour made up:

   amphipods and capelin $E = 0.0077 + 0.0072\ t$,

   all other prey species $E = 0.0011 + 0.0066\ t$

   $$R = E.\ S.\ 24$$

2. NORMOD (Mod. II). A linear model from the North Sea with a constant time of food digesting for different size groups of predators (Daan, 1973). 2S gives an initial quantity of food and a daily ration is calculated as:

   $$R = 2S/D$$

   where D is digesting time (days). D for different age groups of cod is based on the formula $D = L$, where L is a digestive coefficient, equal to 0.06 (Daan, 1973).

3. BROMOD (Mod. VI). A linear model with a constant quantity of food digested for an hour (according to Bromley, MS 1989):

   $$R = 2S\ (1.76/100)\ .\ 24$$

   where 1.76% is an average rate of evacuation from the initial weight of food per hour (food - sprat).

Since Mod. VI constantly has given overestimated results, we proposed our own data of relative (in % per hour) digesting rates obtained under experimental conditions and accounting for 1.50% for capelin, 1.30% for all other fishes, 1.20% for shrimp. The employment of these data permitted us to obtain results comparable with other models. This way was a sudden success for us. When calculating daily rations of cod preying on capelin according to Mod. VI that were of the following form:

$$R = 2\ (1.5/100)\ .\ 24 \text{ or } 2S\ .\ 0.015\ .\ 24$$

where $R = 2S\ .\ 0.36$, we noticed a complete identity of the results of

these calculations with those obtained according to Mod. 1 (at T = 3°C):

$$R = (0.0077 + 0.0072 \cdot 3) \cdot 24 \text{ or } S \cdot 0.03 \cdot 24$$

where R = S . 0.72. (this coincidence is not incidental) if taking into account that the experiments on determining the rate of food lump breaking or the rate of food evacuation were carried out on Arcto-Norwegian cod approximately within the same temperature range both by the authors of Mod. I and by us. Thus, at cod fattening on capelin calculations can be made only according to one of the models (it is better according to Mod. I, since S is the value that could be determined with a higher accuracy than 2S). Besides, in our case capelin can be identified with sand eel - the prey that is also characterized by a high fat content. It is also evident that Mod. I is close to the formula according to Baikov, their agreement or differences depend only on the index of "digesting time" that should be taken with regard to temperature and prey species.

In the calculations of capelin consumption by cod in the Newfoundland area in the summer of 1959-1960 made by us according to Mod. I and Mod. II, and also by equation of regression (Table 2), the values of daily rations reveal a close relationship with the values of indices of stomach fullness. The closest results were obtained according to Mod. I and following the method by Baikov; Mod. II gives somewhat overestimated results for the smallest cod (where estimated duration of food digesting makes up 2.1 days) and underestimated ones for large specimens, where duration of food digesting makes up 3.9-4.5 days. If we take it to be equal on the average to 3 days (just as it is assumed by Baikov and Fortunatova), the values of daily rations will differ to a lesser extent. The derived values of daily rations of cod in 1959-1960 take account of provision of cod with food in those years to a great extent. In 1959 approaches of capelin to the Newfoundland shores were in more mass (Popova, 1962), therefore fish of modal (50-60 cm) and of adjacent size groups were fattening most intensively . In 1960 at less significant approaches of capelin, cod of modal sizes (40-50 cm), on the contrary, was feeding most weakly (see Table 2).

In 1960, in the period when cod was mainly feeding on sand eel, the indices of stomach fullness were lower than those when feeding on capelin; the daily rations did not exceed 1-2%. In 1964 the indices of stomach fullness were highest (Table 3) that was reflected in the

values of daily rations. Their maximum values of 2.8-3.1% are noted for cod of the average size (51-70 cm). Thus, judging by daily rations, feeding of cod was fairly intensive and stable in the Newfoundland Bank area during the period of investigations.

Indices of cod fatness and average relative fat content are in a good agreement with the dynamics of daily rations (within the size groups of cod and by years) (according to Popova, 1962).

Daily rations of the Newfoundland cod are rather close to the data for Arcto-Norwegian cod in the period of its fattening on capelin off the Murmansk coast in 1986-1987 (Orlova *et al.*, 1990), being however lower than in the 1960s when indices of stomach fullness were as great as 4-7% and daily rations were 5.3-5.5% at cod fattening on capelin (Novikova, 1962; Novikova and Mikhalkovich, 1963). Under the experimental feeding of cod on capelin up to the full satiety in the course of 6-10 days the daily rations account for 4-5% (Orlova *et al.*, 1989) while at a prolonged period of feeding they decline to 2-2.3% in the result of satiety of fishes (Karamushko, 1991).

At the same time, the values of daily rations given by us differ significantly from those obtained following the method by Romanova (1958) in the modification for adult benthophages (Kogan, 1963) and planktophages (Tarverdiyeva, 1982, 1985) both for Arcto-Norwegian and Newfoundland cod (they are overestimated in the last cases). In the calculations of daily rations of the Newfoundland cod (Turuk, 1973, 1976) there is a number of incorrect and at the same time contradictory prerequisites. In the examples given by the author, the role of food objects is estimated from the frequency of their occurrence (nevertheless, they make up 100% in total); as this takes place the importance of capelin prevailing in food of cod throughout the period of observations is significantly underestimated only on the basis that it occurred in a very digested form. Simultaneously, at extremely low vales of indices of stomach fullness (0.38-0.69%) the daily rations turned out to be at a level of 3-10% (their maximum values attained 18-21%) in same samples at indices of stomach fullness of 3-5%. It is evident that the mentioned estimates of the intensity of the Newfoundland cod feeding are considerably overestimated, and the methods themselves cannot be used for calculations of daily rations when cod feeds on food objects with a prolonged digesting periods and does not have a clearly pronounced rhythm of fattening.

In the calculations of daily rations of the Arcto-Norwegian cod for the period when it was mainly feeding on capelin off the Murman coast (March 1990) made by us using all the above methods (6 models by Bogstad and Mehl including), the results turned out to be very close as well. The daily rations did not exceed 2-3%. It is likely that it may be indicative of a rather correct interpretation of the main regularities of consumption and evacuation of food by predatory fishes with a stomach digesting in the models considered and methods of experimental direction, that makes it possible to recommend them for a wide use.

Conclusion

The sharply increased volume of information in the last few years on the quantitative assessment of the intensity of feeding of predatory fishes, Atlantic cod in particular, makes it possible, retaining specific and local peculiarities of feeding, to reveal common regularities of consumption and evacuation of food and to unify approaches and methods of calculation of daily rations. It is reflected to a great extent in modern models having an experimental basis and considering various forms of dependence of the actual content of stomachs and the quantity of food consumed per unit time. Almost complete identity of the results of calculations of daily rations according to the methods of experimental directions enabled one to use them successfully for the Newfoundland cod, that is close by the rate of growth and sexual maturing to the Arcto-Norwegian cod.

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Table 1 Coefficients of linear regression of the interrelation of the value of daily rations by Fortunatova (1940) (in numerator), by Baikov (Baikov, 1935) (in denominator) and the index of stomach fullness (Y = a + bX, where X is index of stomach fullness; Y is daily ration).

Main objects of feeding	a	b	Coefficient of correlation	No. of samples
Total	-0.007583I	0.5784I7	0.9I3254	64
	-0.0025063	0.59I9I2	0.0I532I	
Fish/crustaceans (I:I)	-0.0785I69	0.47III4	0.980578	II
	-0.II37840	0.458430	0.983556	
Fish	-0.0448846	0.456I53	0.959260	I4
	-0.0046064	0.46I294	0.97II34	
Crustaceans	-0.00I2377	0.7I4233	0.965082	I5
	-0.036I85I	0.69I063	0.969684	
Capelin	-0.II82690	0.669726	0.940559	5
	-0.055332I	0.725607	0.9509I4	
Sea redfish	-0.060I060	0.40588I	0.9294I8	8
	-0.022478	0.442544	0.935602	

Table 2 Daily rations of cod of different size groups when fattening on capelin in the Newfoundland area in the summer of 1959-1960.

Size group	Average weight, kg	ISF (S) %	ISF (S) g	Daily rations, % Mod-I	Mod-II	by Fortunatova	by Baikov
			I959				
30-40	0.50	I.I8	5.9	0.85	I.I2	0.68	0.80
41-50	0.88	3.88	34.I	2.79	2.70	2.49	2.76
51-60	I.60	3.58	57.3	2.58	2.I7	2.29	2.54
61-70	2.50	3.2I	80.3	2.3I	I.65	2.03	2.27
71-80	4.60	2.80	I28.8	2.I2	0.79	I.75	2.08
			I960				
30-40	0.50	4.83	24.I	3.47	4.60	3.I2	3.45
41-50	0.88	2.I8	I9.2	I.57	I.6I	I.49	I.53
51-60	I.60	2.96	47.4	2.I3	I.79	I.86	2.09
61-70	2.50	I.04	26.0	0.75	0.60	0.63	0.69

* according to the equation of regression

Table 3 Daily rations of cod of different size groups when fattening on sand eel on the Great Newfoundland Bank in 1960 and 1964.

Size group of cod, cm	Average weight, kg	ISF (S) %	ISF (S) g	Daily rations, % Mod-I	Mod-II	by Baikov* (according to equation of regres.	by Fortunatova*
			I960				
30-40	0.50	I.04	5.2	0.75	I.00	0.70	0.59
41-50	0.88	I.I7	I0.3	0.73	0.86	0.79	0.67
51-60	I.60	I.7I	27.4	I.23	I.04	I.I8	I.03
61-70	2.50	2.64	66.0	I.8I	I.36	I.86	I.65
71-80	4.60	2.7I	I24.7	I.95	I.20	I.9I	I.68
			I964				
36-50 (small)	0.70	2.93	20.5	2.II	I.96**	2.07	I.84
51-70 (average)	I.85	4.28	79.2	3.08	2.85**	3.05	2.75
71-75 (large)	4.60	3.I7	I45.8	2.28	I.39**	2.24	2.00

* according to the equation of regression

** according to Baikov (1935)