AN APPROACH TO ESTIMATE THE DAILY RATION OF COD DURING INTENSIVE FEEDING BASED ON 24 HOUR FISHERY

by

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ABSTRACT

A model describing gastric evacuation developed by dos Santos (1990) using a modified version of the power exponential model for stomach evacuation is applied to the Northeast Arctic cod stomachs collected during 24 hour fishery. An approach to estimate the individual daily ration that takes into account the effects of initial meal size and fish weight on gastric evacuation rate in the course of 24 hour period is presented. The results indicate that the Northeast Arctic cod (length groups 40–44 cm and 45–49 cm) during intensive feeding on deep sea shrimp Pandalus borealis consumed between 0.50 % and 0.58 % of the body weight.

INTRODUCTION

Trophic supply and demand relationship (Ney, 1990) is one of the central issues in the multispecies management approach. In an ecosystem such as the Barents Sea, it is a well pronounced phenomenon that increased predation pressure from a top predator cause dramatic collapse in a prey stock. The Barents Sea capelin stock collapsed during 1983–1986 and one of the main factors causing the collapse was a rapid increase in consumption of capelin by cod (Bogstad and Tjelmeland, 1990). Mehl (1989) reported that about 675000 tonnes of deep sea shrimp were consumed in 1984 compared to 574000 tonnes of capelin while in 1985 the cod stock's consumption of capelin exceeded 1.8 million tonnes and the consumption of shrimp was reduced to 320000 tonnes.

All published information concerning the cod stock's consumption (Ponomarenko and Ponomarenko, 1975; Yaragina, 1985; Orlova et al., 1988; Mehl, 1989; Orlova et al., 1989; Bogstad and Mehl, 1990) of various prey species in the Barents Sea in general and the consumption of deep sea shrimp by cod in particular, shows that there is an inconsistency between the shrimp stock estimate and the consumption calculations by a factor 2–3. And no comparison of the consumption estimation with requirements based on energetic consideration as a test of validity has been done so far.

In this paper Santos' evacuation model was used to estimate gastric evacuation based on field measurements of the stomach contents and the daily ration of the Northeast Arctic cod during intensive feeding on *Pandalus borealis* was estimated .

MATERIALS AND METHODS

The data used in the current paper are obtained from the joint PINRO-IMR fish stomachs content data base. Cod stomachs were collected during the 14–15 April, 1987 by bottom trawl on board a Soviet research vessel with one hour tow made every 4 hour at the same position (73° 44′ N 30° 30′ E). The method of sampling and stomach contents analysis are described in detail in Mehl (1986). Cod of length 40 – 49 cm were selected for further analysis of stomach contents. Table 1 summarizes shrimp distribution by length groups in the cod stomachs.

RESULTS

The power exponential model was modified by Santos(1990) to:

$$W_{it} = W_{io} 2^{-\left(t/\left(H_i e^{-Tc}\left(\frac{W_o}{BW}\right)^b\right)\right)^{S_i}} \tag{1}$$

This function state that the time (t) dependent trajectory of the gastric remains (W) is a function of initial meal size (W_o), temperature (T), fish size (BW) and a prey—specific evacuation pattern (S_i). The parameters b and c are constant across prey types, and the rate constant (H_i) is a theoretical value expressing (for a given prey i) the half—life (in hours) of a meal of the same size as the fish body weight at 0 °C. We will assume that the evacuation pattern is exponential (S_i=1).

Consider a fish whose stomach contents weight of prey (i) are known at t_1, t_2, $t_n$during a 24 h period . The evacuation rate (h^{-1}) of prey (i) at t_1 can be estimated as

$$\frac{ln2}{H_i e^{-Tc}\left(\frac{Wo_{it1}}{BW_{t1}}\right)^b} \tag{2}$$

where :

b=0.54

c=0.11

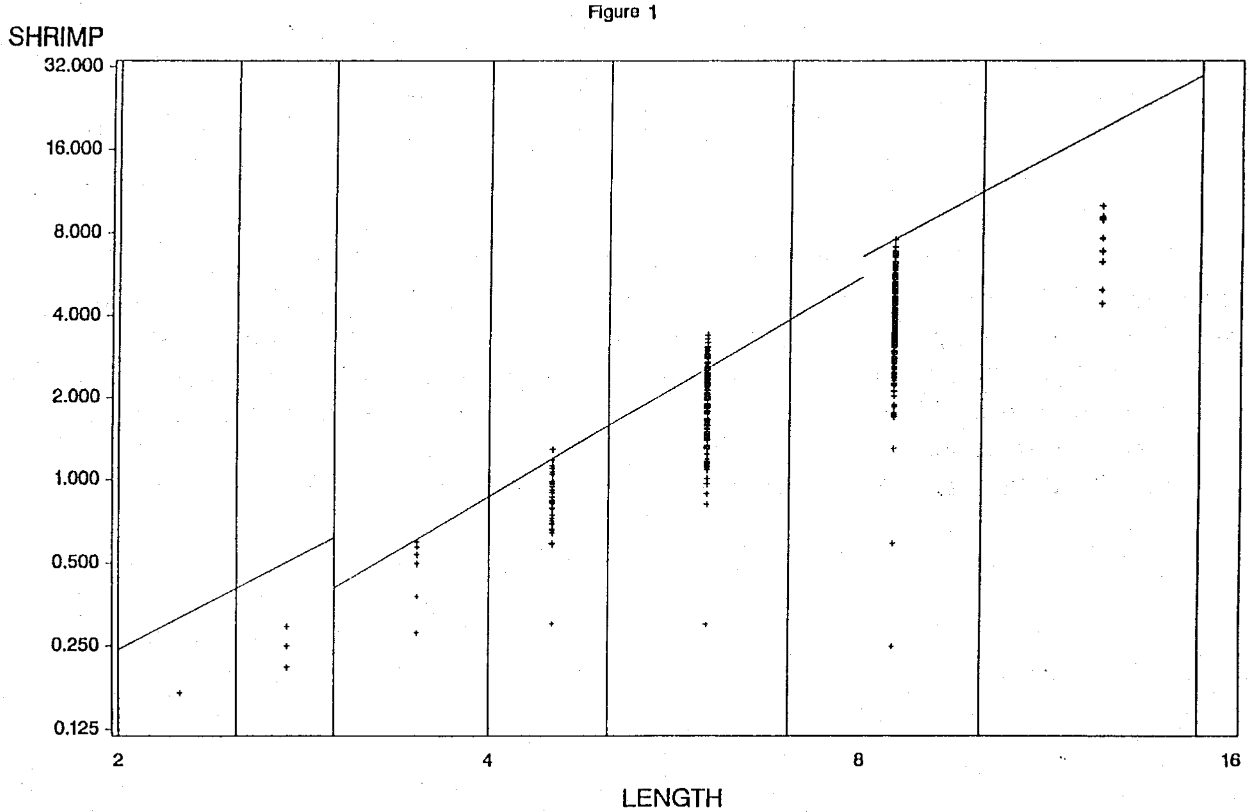
H=533 (shrimp)

T=2.66 °C (temperature during time of sampling)

W_{oit1} = reconstructed initial meal size of prey (i) at (t_1).

Weight of prey (i) was corrected for digestion by using length —weight relationship (Fig.1) of prey (i) in the Barents Sea (Berestovsky, et al., 1989).

Figure 1



The parameters of the length —weight relationship $W = a \times l^b$ of various length groups of Pandalus borealis is shown in the text table below:

Pandalus length-cm	a	b
< 3	0.0481	2.33
3-8	0.0220	2.658
>8	0.04475	2.400

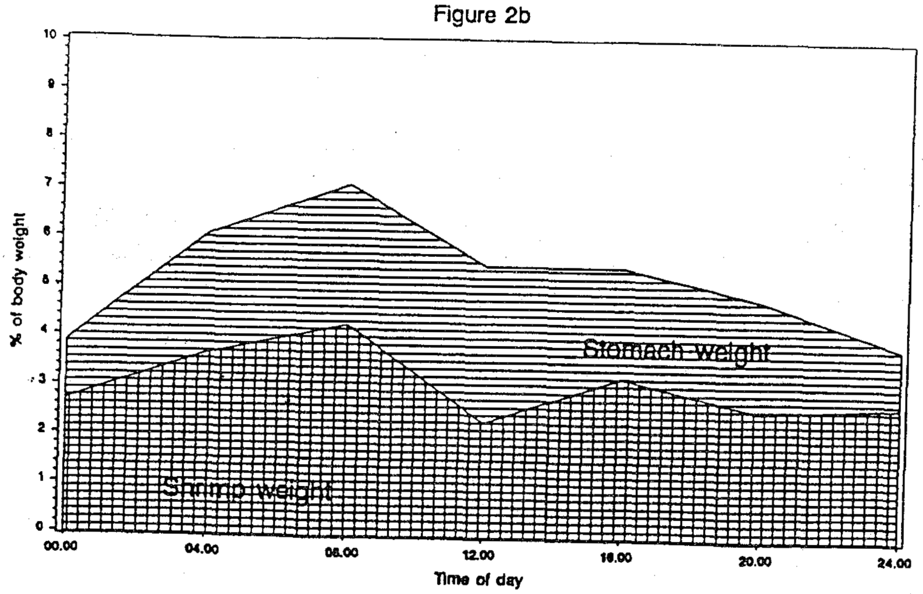
The corrected weight of various size groups of the prey (i) can then be summed to provide the initial meal size of prey (i) at time (t_1).

Equation (2) is applied to the stomach content data collected at the various times of the day, and the average daily ration of prey (i) is equal to :

$$C_i = \frac{1}{n} \sum_{t=1}^{n} \frac{ln2 * W_i * 24}{H_i e^{-Tc} \left(\frac{Wo_{it}}{BW_i} \right)^b} \qquad (3)$$

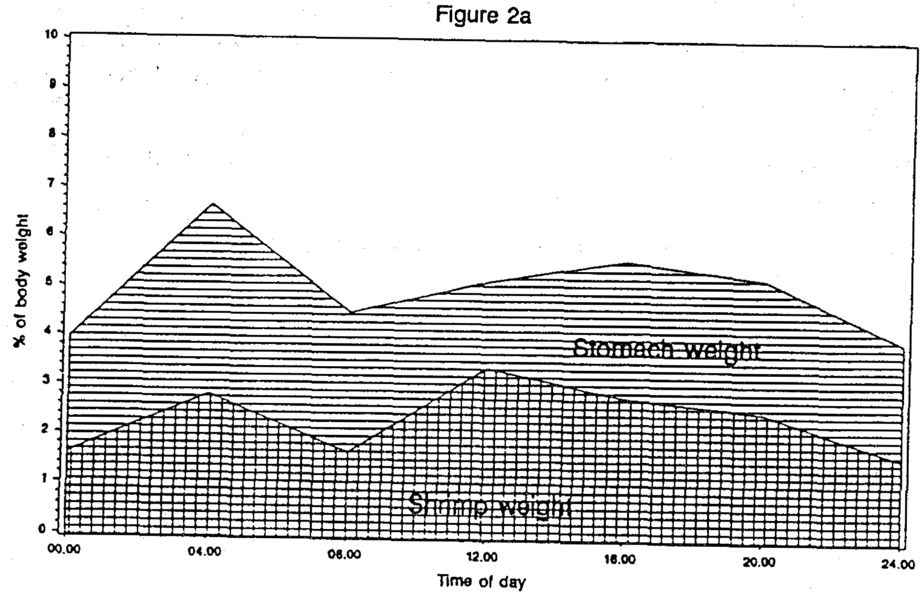
Application of equation (3) to individual cod stomachs collected at 4 hour intervals provides a daily consumption by cod of shrimp estimate of 0.52 % and 0.58 % of the body weight for cod in length group 40–44 cm and 45–49 cm, respectively, when we assumed that the initial meal size equal to individual total stomach content weight (method 1). The overall mean of the daily ration calculated using the length-weight relationship to find the initial meal size (method 2) amounted to 0.53 % and 0.62 % for the same length groups. The data and results are shown in Table 2 and Figures 2a, 2b and 3.

Figure 2b



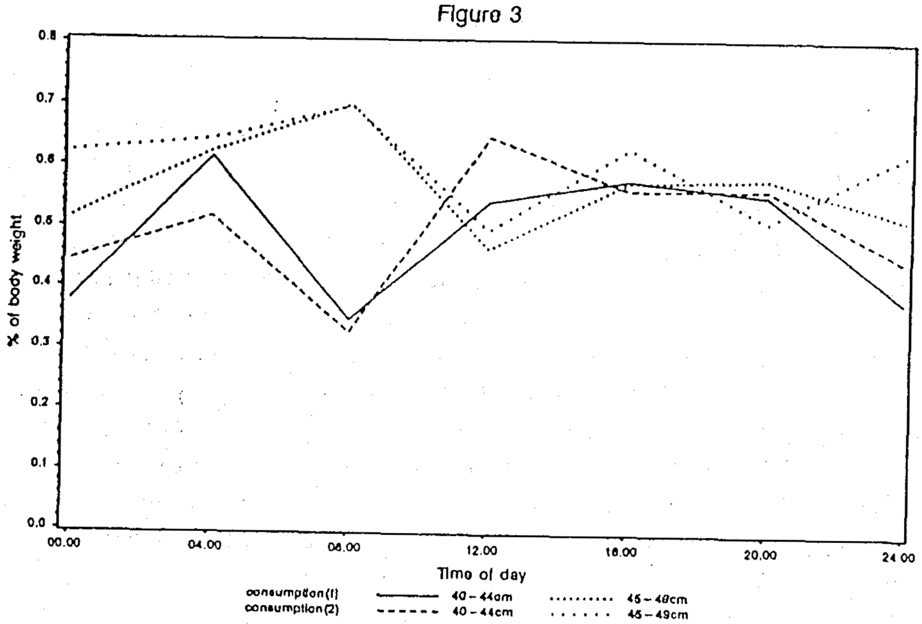
Length interval: 45–49 cm

Figure 2a



Length interval: 40–44 cm

Figure 3



Converting consumption in weight to consumption in numbers

If the consumption of a prey is calculated it is possible to calculate the numbers consumed if one has the following information. The length distribution of preys in the stomachs and the length-weight relationship. This is best illustrated through an example:

Let C denote the total consumption for one day of this prey for a given area/population. The weighted length distribution of the prey is calculated:

$$F_j = \frac{\sum_{i=1}^{s} w_i n_{ij}}{\sum_{j=1}^{k} \sum_{i=1}^{s} w_i n_{ij}} \tag{4}$$

where F_j is the fraction of preys in length interval j. (j=1..k), n_{ij} is the number of preys in length interval j in haul number i (i=1..s) and w_i is the weight given to haul number i. The weight could be calculated as: total catch weight/sample weight and would very often be equal 1.

Using the length-weight relationship, we can calculate the mean prey weight (in grams) for each length interval $W_1..W_k$.

Total numbers consumed can then be calculated as:

$$N = \frac{C}{\sum_{j=1}^{k} F_j W_j} \tag{5}$$

or for each length interval:

$$N_j = N * F_j \tag{6}$$

DISCUSSION

The basic assumption of Santos' model is that every prey item evacuated independently of other food items which has already been consumed but not completely evacuated. This was the assumption of several food consumption models, such as Elliot and Persson (1978), Eggers (1979), Pennington (1985), Olsen and Mullen (1986) and Sainsbury (1986). However, the "dependent" form of the same model above predicted increased clearance of the first prey and a low evacuation rate of the second prey while the "independent" form model tended to overestimate the contents of the first prey remaining in the stomach and faster evacuation of the second prey than observed (dos Santos, 1990). Tyler (1970) reported that single meal evacuation model led to underestimate of the total food remaining in the stomach after consumption of multiple meal and suggested that this was caused by a starvation period. Ruggerone (1989) show that single meal evacuation rate models can accurately describe the evacuation of multiple meals and may therefore be used to estimate the daily ration.

The accuracy of any method of estimating daily ration in wild fish rests ultimately upon an assumption that laboratory results are representative of field conditions (Swensen and Smith, 1973). The estimated values of the equation parameters appear to be satisfactory for use in field study since Northeast Arctic cod are very seldom found outside the experimental temperature and stomach contents higher than 9% of body weight, which is the highest value used in the experiments (dos Santos,1990), do not normally occur.

The model proposed in this paper for estimating the consumption of various prey items based on 24 h fishery, removes the possible bias associated with:

1) Violation of the assumption that feeding occurs only during a discrete feeding period (Sainsbury,1986; Krasnoper, 1988) during feeding cycle.

2) The assumption that the rate of food consumption is constant over an interval between samples (Elliot and Persson,1978).

3) "guesstimate" this was the approach followed by Bogstad and Mehl (1990) by changing initial meal size in dos Santos' evacuation model to set equal to double stomach contents weight for yearly average and to average stomach content during intensive feeding.

Several authors have been estimating the daily ration of Northeast Arctic cod based on field observation (Yaragina, 1985; Tarverdieva and Yaragina, 1989; Dolgov and Yaragina, 1990). Their model assumed a constant gastric evacuation rate, basically cod stomach was collected during many days station every 4 hour and the hourly evacuation rate is estimated as (maximum stomach content weight - minimum stomach contents weight)/4. However, it has been shown that the exponential model explains reasonably well the trends observed in gastric emptying in cod (dos Santos, 1990) and the linear model is appropriate for determining the daily ration for larvae and stomachless fish species (Krasnoper, 1988). Using the linear model is impossible in conditions of food resource instability as observed recently in the Barents Sea (Orlova, 1989).

The curve fitting to the diel changes in stomach fullness of the Barents Sea cod reported by Tarverdieva and Yaragina (1989), explains only 26% of the variability in the stomach fullness during three days of observation. This results led the mentioned authors to conclude that the feeding rhythm was poorly expressed. The daily ration during intensive feeding on shrimp reported by the same authors amounted from 6.2% to 6.5% of the body weight.

One of the advantages of this approach is that the effect of the initial meal size and fish weight on gastric evacuation rate in the course of 24 hour period have been taken into account. In addition, equation (3) can be used to calculate the daily ration regardless of whether the stomach samples were taken between time interval or at the end of each interval.

Table 1 Shrimp size distribution in cod stomachs by time.

time/ shrimp size cm	04:00	08:00	12:00	16:00	20:00	24:00	Total
2.0-2.4	0	0	0	0	1	0	1
2.5-2.9	0	1	0	2	1	4	4
3.0-3.9	6	1	0	2	1	0	10
4.0-4.9	10	14	10	10	2	7	53
5.0-6.9	124	90	81	203	39	91	628
7.0-9.9	93	109	106	144	81	98	631
10.0-14.9	6	1	1	1	3	0	12
Total	239	216	198	362	128	196	1337

Table 2 Consumption, mean stomach weight and shrimp weight as a percent of the cod body weight during 24 hour.

time of day	Consumption method (1)		Consumption method (2)		Stomach weight		Weight of shrimp	
	40-44	45-49	40-44	45-49	40-44	45-49	40-44	45-49
00.00	0.38	0.52	0.44	0.62	3.96	3.86	1.60	2.68
04.00	0.61	0.62	0.52	0.64	6.67	6.08	2.81	3.64
08.00	0.35	0.70	0.32	0.70	4.50	7.09	1.66	4.23
12.00	0.54	0.47	0.65	0.50	5.17	5.47	3.39	2.29
16.00	0.58	0.57	0.56	0.63	5.60	5.47	2.81	3.23
20.00	0.55	0.58	0.56	0.51	5.24	4.81	2.52	2.56

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