THE DAILY FEEDING DYNAMICS IN VARIOUS LENGTH GROUPS OF THE BARENTS SEA CAPELIN

by

A. M. Ajiad [1] and T. Ya. Pushchaeva [2]

[1]Institute of Marine Research
P.O.Box 1870 Nordnes
N-5024 Bergen, Norway

[2] Polar Research Institute of Marine
Fisheries and Oceanography (PINRO)
6 Knipovich Street, 183763
Murmansk, Russia

ABSTRACT

A total of 692 capelin stomachs collected in the Goose Bank area in August 1989 by 24 hour fishery were analyzed by 3 cm capelin length groups. The number of prey categories consumed by the Barents Sea capelin showed a tendency to increase with increasing fish length up to 12 cm. Calanus finmarchicus was the major contributor in the diet (66.4 % of total stomach weight) of length group 6–8.9 cm. Capelin in length group 9–11.9 cm had mainly fed on Calanus finmarchicus (33.5 %), Parathemisto abyssorum (14.5 %) and Thysanoessa raschii (28.0 %) while the two species Thysanoessa inermis and Thysanoessa raschii occupied 95.2% of the stomach content weight in length group 12–14.9 cm. The feeding seemed to have a peak in the evening and a minimum during the midday for all length groups. The daily ration during this period is estimated to between 1.3 and 2.2 % of fish body weight. Accordingly, these data gives between 3640 and 6160 tonnes as the daily consumption of zooplankton by the capelin stock in the Goose Bank area.

INTRODUCTION.

Capelin Mallotus villosus is one of the most important predators on zooplankton organisms in the Barents Sea and it has been shown to play a major role in the ecosystem during their feeding migration to the northern part of the Barents Sea (Panasenko and Soboleva, 1980; Panasenko and Nesterova, 1983, Hassel, 1984, 1986; Panasenko, 1989; Skjoldal and Rey, 1989). Furthermore, Hassel et al. (1991) reported that if capelin consumes 10% of its body weight per day, the zooplankton will be depleted in only 3–4 days where the capelin is heavily concentrated.

The heat content of the water masses exerts a significant influence on the feeding migration routes. During the warm years the immature part of the population is distributed in the northeastern area while in cold years the capelin stock mainly found at the western and the northwestern parts of the Barents Sea (Panasenko and Soboleva, 1980).

The development of the capelin stock during 1972–1989 was dramatic and the driving forces were stock interactions (Bogstad and Tjelmeland, 1990), operating under strong influence of physical environmental variability, particularly on the climatic scale (Skjoldal and Rey, 1989). The capelin stock development can only be understood in a multispecies context (Bogstad and Tjelmeland, 1990), and hence the consumption rate have to be estimated for a larger number of species in the ecosystem.

The objective of the present study is to determine the diel feeding pattern of various length groups, to estimate gastric evacuation rate based on field data from the observed decline in stomach fullness during part of the diel cycle and to estimate the consumption by the capelin stock in the area during the first half of August.

MATERIAL AND METHODS

The data on capelin stomach contents was obtained from the joint PINRO — IMR fish stomach content data base. Capelin stomachs were collected during the 9–11 August 1989 by bottom trawl on board a Russian vessel with one hour tows made every 4 hour at the same geographical position (70° 51′ N and 44°56′ E) at a depth of 106–110 m. Capelin of length 6–15 cm were selected for further analysis. Table 1 summarizes the number of stomachs by 3 cm length groups collected during the 24h fishery. Figure 1 shows the geographical position of the 24h station from which the capelin stomachs were collected.

Table 1 Number of the stomachs in each length group by time from 9/8–11/8 1989.

Time / Date / length group	9 Aug 7:00	12:20	16:00	20:00	23:20	10 Aug 4:00	8:00	11:45	16:40	20:00	24:00	11 Aug 4:00	7:20	total
6-8.9cm	15	15	16	15	1	6	12	15	13	17	3	8	9	145
9-11.9cm	19	22	24	23	12	5	22	32	41	37	18	21	11	287
12-14.9cm	1	22	21	24	17	22	6	15	28	22	22	19	-	219
15-17.9cm	-	1	1	-	3	2	-	-	3	11	7	3	-	31
total	35	60	62	62	33	35	40	62	85	87	50	51	20	682

RESULTS AND DISCUSSION

Species composition of prey

The number of prey categories varied between the different capelin size groups. 18 different prey categories have been recorded in length group 6–8.9 cm and 22 in 9–11.9 cm while only 13 prey categories are found in the larger size group 12–14.9 cm. Three preys were considered as important component of the capelin diet, Calanus spp., Parathemisto and Thysanoessa. Calanus finmarchicus was the major contributor in the diet (66.4 % of total stomach content weight) of length group 6–8.9 cm. Capelin in size group 9–11.9 cm had mainly fed on Calanus finmarchicus (33.5 %), Parathemisto abyssorum (14.5 %) and Thysanoessa raschii (28.0 %) while the two species Thysanoessa inermis and Thysannoessa raschii occupied 95.2 % of the stomach weight in length group 12–14.9 cm. (Tables 5, 6 and 7 in Appendix).

Prey size

Prey size distribution based on stomach contents analysis of three length groups seems to change with length of the fish. Prey in size less than one cm consist of 100% of prey size distribution in the stomachs of fish less than 9 cm, while in length groups 9–11.9 cm and 12–14.9 cm, the same prey size contributed 82% and 58%, respectively. The possible explanation of consuming smaller prey items in length groups 6–8.9 cm: 1) fish in this size group are unable to capture the larger size of the same prey due to their swimming speed. 2) the larger size of the same prey are scarce. 3) prey size is a function of the predator mouth size. When capelin in total length reached 9–11.9 cm, food preference shifted only slightly to the larger preys (Table 6). This shift did not appear to be a response to changes in prey availability since the abundance of the same prey taxa and size in stomachs increases in the larger size group (12–14.9 cm). Other studies on diet compositions of the Barents Sea capelin have indicated that selection of prey species and prey size seems to change with the length of the fish (Lund, 1981; Hassel, 1984; Panasenko, 1984).

Diet analysis shows a critical length group between 12–14.9 cm within which a slight reduction in the number of preys consumed was recorded while prey size increased. The switch in feeding strategy of capelin in this length group was most likely related to the transition stage between mature and immature fish since maturation of individual fish is known to be length dependent, rather than age dependent in the Barents Sea capelin (Forberg and Tjelmeland, 1984) and maturity starts when capelin reaches 12 cm, especially for females (Gjøsæter pers. comm.).

Diet overlap between capelin and polar cod

Polar cod and capelin have a similar annual rhythm of feeding and in the period of maximum feeding (July, August) they are feeding in the same area (Panasenko and Soboleva, 1980). There was a high similarity of the diet (much Euphausiids) and possibly intensive competition between polar cod and capelin in this area (Goose Bank) (Panasenko and Soboleva, 1980). Our data on diet compositions of polar cod sampled from the same area (Ajiad and Gjøsæter, 1990) revealed that in the length group 8–10.9

cm, Copepoda and Euphausiidae were the major dietary components (36.7 % and 47.8 % of the total stomach content weight). This data clearly demonstrated that the polar cod in this length interval are sharing the same prey taxa (Copepoda) with capelin 6–8.9 cm, while with capelin in length 9–11.9 cm and 12–14.9 cm (Tables 5, 6 and 7 in Appendix), the two species are preying upon Copepoda and Euphausiidae. Another possible interaction between capelin and polar cod is predation on polar cod larvae by capelin, especially the young year classes (Skjoldal and Rey, 1989). No single incidence confirms this interaction during the present investigation. The only fish species recorded in capelin stomachs (length group 12–14.9 cm) was from the genus Lumpenus. A key question in trophic interrelation between capelin and polar cod is to what extent the food competition is more important between the two species than a competition between different length groups of the same species.

Length-weight relationship

Log-transformation of length —weight relationship of the Barents Sea capelin showed increase in the slope of the regression line for fish below 12 cm (Fig. 2). This relationship has the following form for fish between 6–11.9 cm and 12–17.9 cm, respectively:

$$W = 0.00092L^{3.6928}$$

$F_{1,277}$ = 4650, P > F = .0001; S.E slope = .0541

$$W = 0.00371L^{3.1604}$$

$F_{1,250}$=853.61, P > F= .0001: S.E.slope = .1081

Commonly the growth stanzas in fish are separated by a change in a body form which shows up in the length-weight relationship (Ricker,1975). The two growth stanzas may reflect an increase in a gross conversion efficiency in a capelin smaller size compared to the larger fish and indicate that the proportion of the total food energy available for growth is slightly higher in smaller fish. Niimi (1981) found that the gross conversion efficiency decrease with increasing fish weight because the body surface area of the fish increases as the body weight raised to 0.6–0.7.

Biphasic growth patterns can also arise, if the sample were biased towards the number of females within the length interval since the capelin growth is higher in males than in females (Gjøsæter, 1984). The length —weight relationship was analyzed for each sex for capelin above and below 12 cm. Table 2 summarizes the relationship for females which indicate that the slope of the relationship in the smaller fish is substantially higher than in the larger fish (Fig. 3):

Table 2 Length — weight relationship for female capelin.

length groups	n	slope	S.E slope	intercept	P>F
6-11.9 cm	232	3.6708	0.05869	0.000963	.0001
12-17.9 cm	188	3.15867	0.12429	0.00370	.0001

Diel feeding pattern

Maximum stomach filling occurred between 16:00 and 23:20 approximately for all length groups (Table 4, Fig. 5A and 5B). The daily level of the food intake during that period was higher than that observed during the first half of the day, and the feeding was at minimum during the midday (12:00). The evening peak in feeding during August has also been reported by Panasenko (1984, 1989), and the reason is thought to be due to the prey behavior. According to Panasenko (1984), Copepoda, Euphausiacea and Hyperiidae in that period of the year formed dense concentration at the deeper layer and their vertical migration were poorly pronounced. Two daily peaks of feeding activity from May to August was reported for capelin in the estuary and Western Gulf of St. Lawrence (Vesin et. al., 1981). In the southern part of the Bering Sea capelin has a single peak of feeding activity during the afternoon hours during winter (Naumenko, 1986).

Gastric evacuation rate

The amount of food in the stomach at any time (t) of a nonfeeding period follows an exponential decay function (Elliot and Persson, 1978):

$$S_t = S_0 e^{-rt}$$

The equation for S_t can be used to estimate r if it assumed that capelin has a nonfeeding period. The period chosen was from 9 August 23:20 to 10 August 11:45. The best exponential curve was fitted with a non linear regression (Fig. 4), all regression lines were forced through t=0, $S_t = S_o$. Estimated regression parameters were run by SAS using non linear least square regression of the type $y = B_o e^{-B_1 x}$. Table 3 summarizes the regression for capelin length group 6–17.9 cm.

Table 3 Gastric evacuation rate parameters for capelin

Source	DF	Sum of Squares	Mean Square
Regression	2	2.4930	1.2465
Residual	2	.0072	.0036
Uncorrected total	4	2.5002	
Parameter	Estimate	Std.error	95% Conf.interval
Bo	1.2395	.05749	.9921-1.4869
B1	0.1037	.01037	.05907-.1483

Daily food consumption

Two methods were applied to the capelin stomach content data to estimate the daily ration:

1.The calculation of daily consumption follows the formula (Elliot and Persson,1978):

$$C_t = \frac{(S_t - S_o e^{-rt})rt}{1 - e^{-rt}}$$

where C_t= the consumption of food by fish over the time interval T_o to T_t, S_t and S_o= the amount of food in the stomach at time T_t and T_o, r = exponential gastric evacuation rate. C_t is calculated for each time interval and then summed to give the total daily ration (Durbin et. al., 1983). For the time periods used in estimating the evacuation rate, the consumption is set to 0.0. This is also done for other periods where this model gives a negative consumption.

2.The total daily ration calculated as:

$$C_t = 24rS$$

where S equals the mean stomach contents weight over 24h (Elliot and Persson, 1978). This model assumes that during a 24h period the food ingested is equal to the amount of food passed through the stomach (Doble and Eggers, 1978). In our calculations, the average is taken over all individual fish sampled during the 24 hour period.

Table 4 Stomach fullness and estimates of daily food consumption for capelin. All length groups combined.

n	day, time	mean length- cm	mean weight gram	mean stomach fullness % of BW	consum- ption method 1 %BW	consum- ption method 2 %BW
	9 Aug 1989					
35	07:00	9.19	3.72	0.553		
60	12:20	10.95	7.97	0.556	0.303	
62	16:00	11.09	7.89	1.052	0.808	
62	20:00	10.97	8.10	0.985	0.355	
33	23:20	12.68	12.60	1.262	0.667	
	10 Aug 1989				total 07:00-23:20 : 2.232	2.009
35	04:00	12.51	11.88	0.711	set to 0.0	
40	08:00	10.31	6.28	0.491	set to 0.0	
62	11:45	10.36	5.92	0.402	set to 0.0	
85	16:40	11.04	7.28	1.062	1.048	
87	20:00	11.47	9.22	0.589	set to 0.0	
50	24:00	12.75	12.47	0.581	0.234	
	11 Aug 1989				total 23:20 Aug 9 -24:00 Aug 10: 1.282	1.699
51	04:00	11.62	9.12	0.318	set to 0.0	
20	07:20	9.47	4.32	0.278	0.083	

The capelin daily ration based on the present investigation provided an evidence of low predation pressure on the zooplankton community at the Goose Bank area. The above data questions whether the Goose Bank is an ideal feeding ground compared to the northern area. Hassel (1986) reported that the index of stomach fullness increased markedly towards the northern limit of capelin distribution. However, a high index of stomach fullness reflects the feeding activity of the fish population (Lilly, 1991) and do not necessarily indicate a high consumption rate, since gastric evacuation rate is a function of temperature. Digestion, being a physiological process, accelerates with rising temperature (Ney, 1990). One would assume a low daily ration in fish distributed in the area dominated by Arctic water.

The estimated total capelin biomass based on the acoustic survey during September — October in the same area (Gjøsæter, pers. comm.) was about 280 000 tonnes of capelin of length 8–16.9 cm. When combining these data with our estimates of capelin daily ration (1.3 — 2.2 % of body weight), the daily consumption by capelin becomes between 3640 tonnes and 6160 tonnes.

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Appendix A Capelin stomach content data

Table 5 Diet compositions of length group 6–8.9 cm of capelin during 9/8–11/8–1989.

TAXA	SIZE-CM	MGRAMS/ PREDATOR	WEIGHT %
Gastropoda	.02-.029 .03-.039 .04-.049 .1-.14	.00 .00 .00 .00	.00 .00 .00 .00
Bivalvia	.02-.029 .03-.039	.02 .04	1.86 .35
Calanus glacialis	.06-.069 .4-.49 .5-.69	.04 .09 .06	.35 .81 .58
Calanus finmarchicus	.15-.19 .2-.24 .25-.29 .3-.39 .4-.49 indet	.06 1.71 1.78 3.68 .37 .04	.58 15.58 16.28 33.60 3.37 .35
Microcalanus pygmaeus	.06-.069 .07-.079 .08-.089	.09 .01 .00	.81 .12 .00
Pseudocalanus elongatus	.08-.089 .1-.14 .15-.19 .2-.24	.09 .08 .27 .01	.81 .70 2.44 .12
Metridia longa	.1-.14 .15-.19 .2-.24 .25-.29 .3-.39	.00 .00 .51 .00 .01	.00 .00 4.65 .00 .12
Acartia	.1-.14	.00	.00
Microsetella norvegicus	.06-.069	.00	.00
Oncaea borealis	.05-.059	.00	.00
Oithona similis	.06-.069 .07-.079 .08-.089	.03 .01 .00	.23 .12 .00
Oithona atlantica	.06-.069 .07-.079 .1-.14	.00 .00 .01	.00 .00 .12
Parathemisto abyssorum	.25-.29 .5-.69 .7-.99	.01 .09 .09	.12 .81 .81
Euphausiidae	.06-.069 .08-.089 .09-.099 .1-.14 .15-.19	.00 .00 .00 .18 .00	.00 .00 .00 1.63 .00
Decapoda	.3-.39	.03	.23
Oikopleura	.3-.39	.02	.14
Oikopleura labradoriensis	.1-.14 .2-.24	.00 1.34	.00 12.18
Indeterminatus	egg	.01	.13

Table 6 Diet compositions of length group 9–11.9 cm of capelin during 9/8–11/8–1989.

TAXA	SIZE - CM	MGRAMS/ PREDATOR	WEIGHT %
Gastropoda	.03-.039 .06-.069 .1-.14	.04 .00 .00	.15 .00 .00
Clione limacina	indet	1.47	5.25
Bivalvia	.02-.029 .03-.039 .06-.069	.03 .03 .00	.11 .11 .00
Copepoda	.03-.039	.00	.00
Calanus glacialis	.4-.49 .5-.69	.48 .34	1.70 1.20
Calanus finmarchicus	.02-.029 .1-.14 .15-.19 .2-.24 .25-.29 .3-.39 .4-.49 .5-.69 indet	.04 .00 .01 1.62 2.20 4.63 .79 .10 .01	.13 .00 .02 5.78 7.85 16.55 2.81 .37 .02
Microcalanus pygmaeus	.06-.069 .07-.079	.00 .01	.00 .02
Pseudocalanus elongatus	.08-.089 .1-.14 .15-.19	.00 .06 .14	.00 .22 .50
Metridia longa	.15-.19 .2-.24 .25-.29 .3-.39	.01 .62 .07 .04	.02 2.22 .24 .15
Microsetella norvegica	.03-.039	.00	.00
Oncaea borealis	.1-.14	.00	.00
Oithona similis	.06-.069 .07-.079	.01 .00	.02 .00
Oithona atlantica	.07-.079 .1-.14	.00 .01	.00 .02
Parathemisto abyssorum	.06-.069 .2-.24 .25-.29 .3-.39 .5-.69 .7-.99 1.-1.4 1.5-1.9	.06 .01 .01 .07 .44 .85 2.01 .78	.23 .03 .05 .25 1.59 3.05 7.17 2.17
Euphausiidae	.02-.029 .06-.069 .08-.089 .1-.14 .15-.19 .2-.24	.00 .01 .00 .00 .00 .00	.00 .04 .00 .00 .00 .00
Thysanoessa inermis	indet	1.04	3.71
Thysanoessa raschii	.3-.39 1.-1.4 1.5-1.9 2.-2.4 2.5-2.9 3.-3.9	1.46 .53 1.39 .62 2.08 1.77	5.21 1.90 4.96 2.20 7.43 6.32
Echinodermata	.03-.039	.00	.00

Table 6 (Continued) Diet compositions of length group 9–11.9 cm of capelin during 9/8–11/8–1989.

Asteriidae	.04-.049	.00	.00
Oikopleura	.2-.24 .3-.39 .5-.69	.34 .46 .12	1.21 1.65 .43
Oikopleura labradoriensis	.05-.059 .4-.49	.02 1.15	.07 4.12
Indeterminatus	-	.04	.15

Table 7 Diet compositions of length group 12–14.9 cm during 9/8–11/8–1989.

TAXA	SIZE-CM	MGRAMS/ PREDATOR	WEIGHT %
Calanus glacialis	.4-.49	.07	.04
Calanus finmarchicus	.2-.24 .25-.29 .3-.39 .4-.49 .5-.69 indet	.11 .32 1.11 .08 .03 .03	.07 .19 .68 .05 .02 .02
Microcalanus pygmaeus	.06-.069	.00	.00
Pseudocalanus elongatus	.1-.14	.00	.00
Metridia longa	.2-.24 .3-.39	.03 .01	.02 .00
Oithona similis	.06-.069 .07-.079	.00 .00	.00 .00
Parathemisto abyssorum	.4-.49 .5-.69 .7-.99 1.-1.4 1.5-1.9 2.5-2.9	.08 .54 1.01 .25 1.91 .49	.05 .33 .62 .15 1.16 .30
Thysanoessa inermis	.25-.29 .5-.69 1.5-1.9 2.-2.4 2.5-2.9 3.-3.9	.55 3.87 1.18 8.44 63.43 37.15	.33 2.36 .72 5.14 38.64 22.63
Thysanoessa raschii	.2-.24 1.-1.4 1.5-1.9 2.-2.4 2.5-2.9 3.-3.9	.37 .14 .81 5.51 24.34 10.58	.22 .08 .50 3.35 14.82 6.44
Ophiurida	.01-.019	.00	.00
Oikopleura	.2-.24 .4-.49	.03 .35	.02 .22
Oikopleura labradoriensis	.15-.19	.03	.02
Lumpenus	3.-3.9	1.31	.80