Northwest Atlantic Fisheries Organization

Serial No. N1873

NAFO SCR Doc. 91/3

SCIENTIFIC COUNCIL MEETING - JUNE 1991

Feeding Habits of Mesopelagic Species of Fish and Quantitative Estimation of Plankton Grazed in the Northwest Atlantic

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The feeding habits, trophic webs, diurnal rhythms and diets of mesopelagic species of fish from the North Atlantic have not yet been adequately studied. No special-purpose investigations of the feeding habits of lanternfishes from the family Myctophidae from this region have been made. The present investigation was conducted on board R/V "Akademik Knipovich" (Cruise XXI) in the open waters of the Northwest Atlantic off the Canadian Zone at the depths of 60-400 m in July-October 1983 (Fig.1). A mid-water trawl was used. A total of 344 stomachs from 11 species of adult myctophids (Table 1) 30-135 mm in size were collected and examined. Most fish were at maturity stages II and III. Stomachs were collected and examined according to "Manual". 1961.

The most representative material was collected on four species of myctophids: Bentosema glaciale, Myctophum punctatum, Ceratoscopelus maderensis and Notoscopelus elongatus. B.glaciale is an arcto-boreal species endemic for the North Atlantic. Protomyctophum arcticum is also endemic for the area. The rest three species are immigrants brought with warm currents, they do not spawn in the North Atlantic (M.punctatum and C.maderensis are warm-requiring species and N. elongatus occupies an intermediate position).

The average volume of food in the stomachs examined was not high and ranged from 0.2 (B.glaciale) to 1.9 points (Notoscopelus bolini) in a 5-point scale. There were many empty stomachs (up to 82.5% in B.glaciale). The mean-value of the feeding index was

also not so high, from 28.6‰ in B.glaciale to 173.3‰ in Protomyctophum arcticum. The one exception to many species is Symbolophorus veranyi, its mean value of the feeding index was equal to 422.3‰ and fish were predominant in the stomach contents.

The food spectra of the myctophids are wide including practically all groups of zooplankton. The food of myctophids consists mainly of copepods, euphausids and hyperids. Of less importance are decapods and Chaetognatha. All zooplankton specimens found in the stomach content fall in the group of interzonal species (Vinogradov, 1968) making regular migrations between various vertical layers (Table 2). Most myctophids investigated belong also to interzonal species (Bekker, 1967). Mesopelagic myctophids are migrants eating migrating zooplankton and forming a single mesopelagic trophical complex (Parin, 1971). The proportion of food species in the myctophids examined is, however, different. Copepods are the main food item found in the stomachs of B.glaciale, Hygophum benoiti, Lobianchia dolfeni, Electrona risso and P.arcticum (Table 3) whereas M.punctatum, N.elongatus, Diaphus rafinesque and N.bolini feed mainly on euphausids. Hyperiids dominate in the food of C.maderensis and substitute euphausids in B.glaciale.

Fish, mainly lanternfishes, occur in the stomachs of several species of myctophids, but they dominate only in the food of S.veranyi. Representatives of other zooplankton groups were found in some species of myctophids, e.g. Foraminifera occurred only in the stomachs of B.glaciale as well as Algae. Sagitta occurred only in E.risso and pelagic Polychaeta (Tomopterus) were found in the stomachs of N.elongatus.

The area investigated is one of the most productive regions in the Northwest Atlantic. Its oceanographic regime and character of bioproductive processes are formed under the influence of the Labrador, North Atlantic and Gulf Stream Currents. It is noted that it is not only the spatial distribution of the main water masses, but their vertical structure that plays an important role. The North Atlantic (NAC) and Subarctic (SubA) water masses - the vertical structures of the Labrador Current (LC) were encountered in the area investigated at the depths of up to 1000 m (Fig.1). There

is rather a wide zone of transformed waters between the Labrador and North Atlantic Currents. And finally, the southwesternmost part of the area investigated is influenced by the Gulf Stream waters and their hydrological characteristics did nor differ from those of the North Atlantic Current in the summer of 1983 (Zozulya et al., 1986).

The food composition of most mass species of myctophids from the Northwest Atlantic caught from different water masses is shown in Fig.2. The most representative material was collected from the North Atlantic and Labrador water masses.The analysis of the material shows that the most favourable feeding conditions for myctophids are focused in the North Atlantic water mass.The evidence is supported not only by high values of the feeding index (from 78.8‰ in N.elongatus to 138.8‰ in C.maderensis), but also by a narrow spectrum of food species,e.g. M.punctatum and N.elongatus feed mainly on euphausids and C.maderensis prefers hyperids.

Food species from the Labrador Current water mass are widely represented in the stomachs of myctophids,almost all groups of zooplankton are available. Values of the feeding index range from 40.1‰ in B.glaciale to 129.4‰ in N.elongatus. The zooplankton species composition found in the stomachs of myctophids inhabiting the Labrador water mass is represented by boreal fauna. The mass species are Calanus finmarchicus, Parathemisto norvegica,Parathemisto compressa, Metridia lucens and some species of the genera Conchoecia and Pleuromamma. The Arcto-boreal species Calanus hyperboreus and Metridia longa occur fairly frequently.

The examination of the stomach contents of myctophids caught in the North Atlantic water mass shows that Arcto-boreal species are absent and the boreal fauna is substituted with subtropical Eucalanus and Pleuromamma,which is supported by our data on food resources available in the area investigated (Podrazhanskaya,Khromov, 1986).

The examination of the stomach contents of myctophids collected from the Gulf Stream water mass revealed a variety of zooplankton groups though neither groups nor species seemed to be predominant. Zooplankters were represented by boreal and subtropical forms: Cala-

nus borealis, Undinula, Paratemisto abyssorum, Pleuromamma robusta, Vibilia sp.

An attempt to estimate at the first approximation the quantity of zooplankton grazed by mass species of mesopelagic species of fish in the Northwest Atlantic in the summer-autumn period,i.e. in the period when the feeding rate is not so intensive, requires knowledge of the diurnal diets of fish (A), biomass of fish (B) and biomass of food plankton (C).

The diurnal feeding rhythms of myctophids is still unknown. The North Atlantic myctophids are reported to belong to the so-called mesopelagic group of myctophids making diurnal vertical migrations , and at night they ascend to the surface layer.

The diurnal rhythm of feeding in Pacific myctophids is known to be characterized with a peak at night when they migrate to the surface layer. In the daytime they do not consume food in lower layers. (Gorelova,1978). This is specific,in part, to Ceratoctopelus warmingi and Bolinichthys longipes. So it may be arbitrarily assumed that food found in the stomachs of myctophids examined will be the minimum diurnal diet guaranteeing the life activity of fish. The values of daily diets of the North Atlantic myctophids are not high (Table 4) or beyond the scope of diurnal diets of various myctophids from other areas of the ocean (Gorelova,1985; Albikovskaya,1989). The value ranges from 0.3 to 1.5% (Table 4). The only exclusion is the diurnal diet of S.veranyi equal to 4.5% . The reason of lower values of diets of myctophids is likely to be a high percentage of the lipid content in tissues and the fact that in the daytime myctophids staying in lower layers "hover" almost without moving (Backus et al.,1968),therefore their metabolic rate seems to be lower than that of more active species of fish.

The investigation of myctophids from the Northwest Atlantic in the summer-autumn season shows that concentrations are formed by migrating anchovy to be aggregated in wave structures of the Labrador Current. This seems to be a most economical way of migrations since it takes place on the account of water dynamics.This mode of migrations makes assessments of resources very difficult. It is suggested that two indices should be used for this purpose -

the biomass of anchovy assessed once and the biomass of fish migrating through this particular fishing area in the fishing period.

The echometric survey of fish schools made in the XXI cruise of R/V "Akademik Knipovich" yielded the estimate of the biomass of anchovy but once equal to 4,000 -25,000 tons or I7.9-III.8 mg/m^3 to the north of $47^{\circ}N$ in the area equal to 660 sq.miles in the 200-300 m layer in the first I0 days of October. The biomass of fish migrating through the area in the same period was estimated to be I00,000 - 400,000 tons or 447.I- I788.3 mg/m^3 depending upon the velocity of currents.

The biomass of food plankton in the 200-500 m layer of the area investigated in the same period was equal to 75 mg/m^3 (Podrazhanskaya,Khromov,I986).

The amount of zooplankton grazed ($\mathcal{E}$) by the biomass of fish is calculated by the formula (Manual ,I96I):

$$\mathcal{E} = \frac{A \cdot B}{I00} \qquad (mg/m^3),$$

where A is a diurnal value of the fish diet (%) and B is the biomass of food plankton (mg/m^3).

The grazing rate is calculated as a ratio of the amount of plankton eaten (mg/m^3) and the zooplankton biomass (%) (Table 5). Thus, the biomass of myctophids assessed but once graze 0.I-22.6 mg/m^3 of zooplankton in the area of 660 sq.miles, which makes up 0.I-30.I% of zooplankton available.

T.V.Gorelova (I983) made an attempt to estimate in the first approximation the biomass of zooplankton grazed by myctophids in the pre-surface layer of tropical waters. The grazing rate was estimated to range from I to 9 mg/m^3 a day or,on the avarage, roughly I0% of the zooplankton biomass available. The biomass of fish migrating through the same area,which ranged from I00,000 to 400,000 tons, graze I.3- 80.4 mg/m^3 of zooplankton or I.7-I07.2% of the plankton biomass available.

The life cycle of mesopelagic species of fish from the Northwest Atlantic is closely associated and depends on the current system in the area.

Concentrations of myctophids in the North Atlantic are regularly associated with frontal zones and with the system of Gulf Stream flows -the North Atlantic Current. The heaviest concentrations of

fish are related to convergence and divergence zones of some flows of the currents where meandering and eddy-making are very intensive. (Zozulya,Polonsky,Popkov,1986).

The summer-autumn period in the area investigated in the North-west Atlantic is characterized with the highest intensity of both the Labrador and North Atlantic Currents,their velocities reaching 30-50 cm/sec, which handicaps formation of stable dense concentrations of both fish and food zooplankton. It is likely that feeding concentrations of myctophids are formed in the open ocean north of 50°N in summer where there are dynamical structures favourable for concentration of mesopelagic fish. Myctophids seem to spawn southward and eastward over lower depths.

Thus, the area investigated is a transit region for mesopelagic myctophids in the summer-autumn period. Heavier localization of concentrations is impeded both by hydrographical characteristics of the area and by availability of food for myctophids. Feeding concentrations of myctophids are not unlikely to be formed in late autumn and winter when fish may feed on the wintering stock of zooplankton.

Conclusions

I.The food spectra of myctophids examined are very wide including representatives of all groups of zooplankton,e.g. copepods, hyperids,euphausids, decapods and chaetognaths. All plankton species found in the stomachs of myctophids belong to the group of interzonal species.

2. The most favourable conditions for feeding are focused in the North Atlantic water mass,the evidence of that is supported by high values of the feeding index and a narrow spectrum of food organisms in the stomachs of myctophids.

3. The diurnal diet of North Atlantic myctophids is rather moderate ranging from 0.3 to I.5% .

4. The grazing rate of the known biomass of myctophids ranges widely : from 0.I to 30.I% in the biomass of fish estimated but once and up to I07.2% in the biomass of migrating fish. This means that the availability of food in the area in the summer-autumn period may be a limited factor. This reason together with some characteri-

stics of the hydrographical regime seems to responsible for the absence of fishable concentrations of myctophids in July-October I983.

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Table I

Material examined

Species of fish	No.of hauls	Size of specimens,mm	No.of stomachs		Mean extent of filling in stomachs (points)	Mean value of feeding index,‰
			total:	including : empty,%		
I	2	3	4	5	6	7
Bentosema glaciale	7	35- 65	86	82.5	0.2	28.6
Myctophum punctatum	4	55- 90	44	38.6	0.9	66.9
Ceratoscopelus maderensis	6	45- 80	65	50.7	0.5	86.3
Notoscopelus elongatus	4	75- I35	4I	3I.7	I.4	88.0
N. bolini	I	45- I05	II	I8.I	I.9	I43.3
Lobianchia dolfeni	3	30- II0	20	25.0	I.5	95 6
Diaphus rafinesque	2	30- 70	24	I6.6	0.3	I3I.0
Hygophum benoiti	2	40- 60	28	25.0	0.8	97.8
Protomyctophum arcticum	I	35- 40	7	57.I	0.4	I73.2
Symbolophorus veranyi	I	85- I20	3	0.0	-	422.3
Electrona risso	I	60- 90	I5	20.0	0.7	48.4

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Table 2

Food species of myctophids and their association with various water masses in the Northwest Atlantic

Food species \ Water masses	Subarctic (Sub A)	Labrador (L)	North Atlantic (NA)	Transformed (Tr)
1	2	3	4	5
Foraminifera	–	+	–	–
Tomopterus	–	+	–	–
Limacina sp.	–	+	–	–
Microcalanus sp.	–	+	–	–
Pleuromamma robusta	–	–	+	–
P. abdominalis	–	+	–	–
Metridia lucens	–	+	–	–
M. longa	–	+	–	–
Euchaeta acuta	–	+	+	–
Parauchaeta norvegica	+	–	–	–
Undinula sp.	–	–	+	–
Calanus hyperboreus	–	+	–	–
C. finmarchicus	+	+	–	–
Calanus sp.	–	+	+	–
Gaidius tenispinus	–	+	–	–
Neomysis	–	+	–	–
Parathemisto abyssorum	–	–	+	–
P. libellula	+	+	–	+
P. compressa	–	–	–	+
Vibilia sp.	–	–	+	–
Nematoscelis megalops	–	+	+	+
N. microps	+	–	–	–
Thysanoessa longicaudata	–	+	+	–
T. raschii	–	–	+	–
Meganyctiphanes norvegica	–	+	–	–
Copepodida	+	–	–	–
Coechoecia borealis	–	–	+	–
Sagitta	+	+	+	–
Eukrohnia hamata	–	+	–	–
Myctophidae	+	–	–	–

Table 3

The composition of food in myctophids from the Northwest Atlantic (% by weight)

July-September 1983

Composition of food	B.glaciale	M.punctatum	C.maderensis	N.elongatus	N. bolini	L.dolfeni	D.rafinesque	H.benoiti	P.arcticum	S.veranyi	E.risso
Foraminifera	2.0	-	-	-	-	-	-	-	-	-	-
Polychaeta	-	-	-	0,4	-	-	-	-	-	-	-
Copepoda	38.6	24.2	19.4	23.1	35,2	45.4	24,6	44.7	61.9	1.2	67.6
Mysidacea	-	0,6	-	-	-	9,5	-	-	-	-	-
Parathemisto	28.9	17.4	30,6	0.2	-	13.2	-	20.2	-	19,7	-
Euphausiacea	11.3	36.0	27,1	70,6	57,7	17.7	48.0	14.8	-	3,3	8.6
Decapoda	-	-	-	-	-	-	14.5	12.8	-	10.1	1,3
Sagitta	-	-	-	-	-	-	-	-	-	-	7,0
Pisces	2,6	-	-	-	7,1	0,8	-	4,7	-	65,7	5,0
Algae	2,0	-	-	-	-	-	-	-	-	-	-
Digested food	14.6	21,9	22,9	5.7	-	13.4	12.9	9.2	38.1	-	11.1

Table 4

Diurnal diets of myctophids from the Northwest Atlantic

July–October 1983

Species of fish	No. of specimens	Mean weight of fish, g	Diurnal diet	
			mg	%
Bentosema glaciale	86	I.4	4.2	o.3
Myctophum punctatum	44	3.8	30.4	0.8
Ceratoscopelus maderensis	65	3.6	32.4	0.9
Notoscopelus elongatus	4I	II.0	66.0	0.6
N.bolini	II	5.3	54.0	I.0
Lobianchia dolfeni	20	3.8	34.2	0.9
Diaphus rafinesque	24	I.8	27.0	I.5
Hygophum benoiti	28	I.9	I3.3	0.7
Protomyctophum arcticum	7	3.7	II.I	0.3
Symbolophorus veranyi	3	I0.6	5I4.6	4.5
Electrona ross·	I5	5.2	20.8	0.4

Table 5

Feeding habits of mesopelagic myctophids and utilization of their food resources in the Northwest Atlantic

Diurnal diet of fish, % (A)	Biomass of fish mg/m^3 (B) estimated once	Biomass of fish mg/m^3 (B) migrating	Biomass of food zooplankton (mg/m^3) (C)	Amount of grazed zooplankton, mg/m^3 $\mathcal{E} = \frac{A \cdot B}{100}$ biomass estimated once	Amount of grazed zooplankton, mg/m^3 $\mathcal{E} = \frac{A \cdot B}{100}$ migrating biomass	Rate of grazing zooplankton, % ($\frac{\mathcal{E}}{C} \cdot 100$) Biomass estimated once	Rate of grazing zooplankton, % ($\frac{\mathcal{E}}{C} \cdot 100$) migrating biomass
0.3–4.5	I7.9–III.8	447.I–I788.3	75.0	0.I–0.3 0.8–22.6	I.3–5.4 20.I–80.4	0.I–0.4 I.I–30.I	I.7–7.2 26.8–I07.2

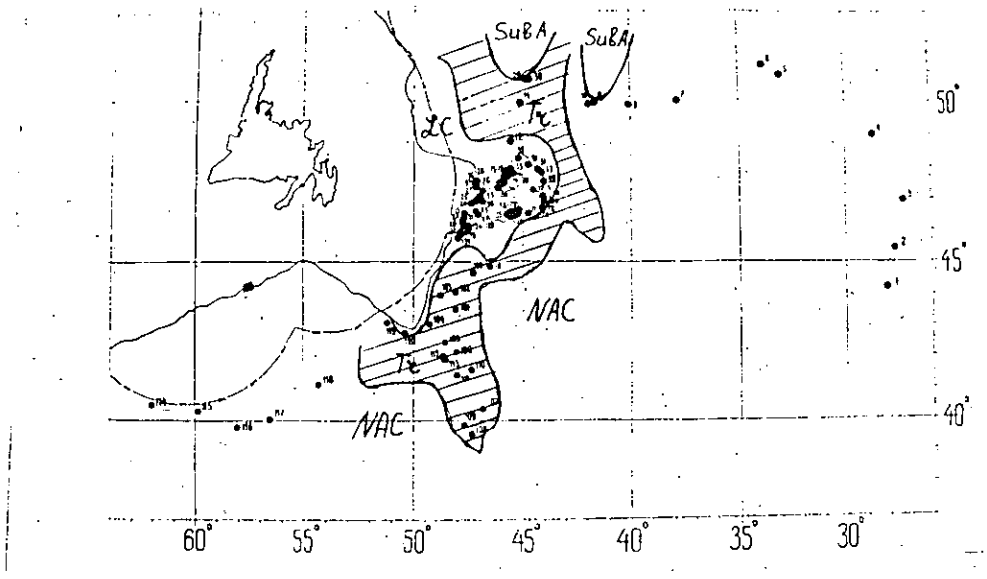

Fig.I. Schematic map of hauls made on board R/V "Akademik Knipovich" and distibution of water masses in the Northwest Atlantic July-October 1983

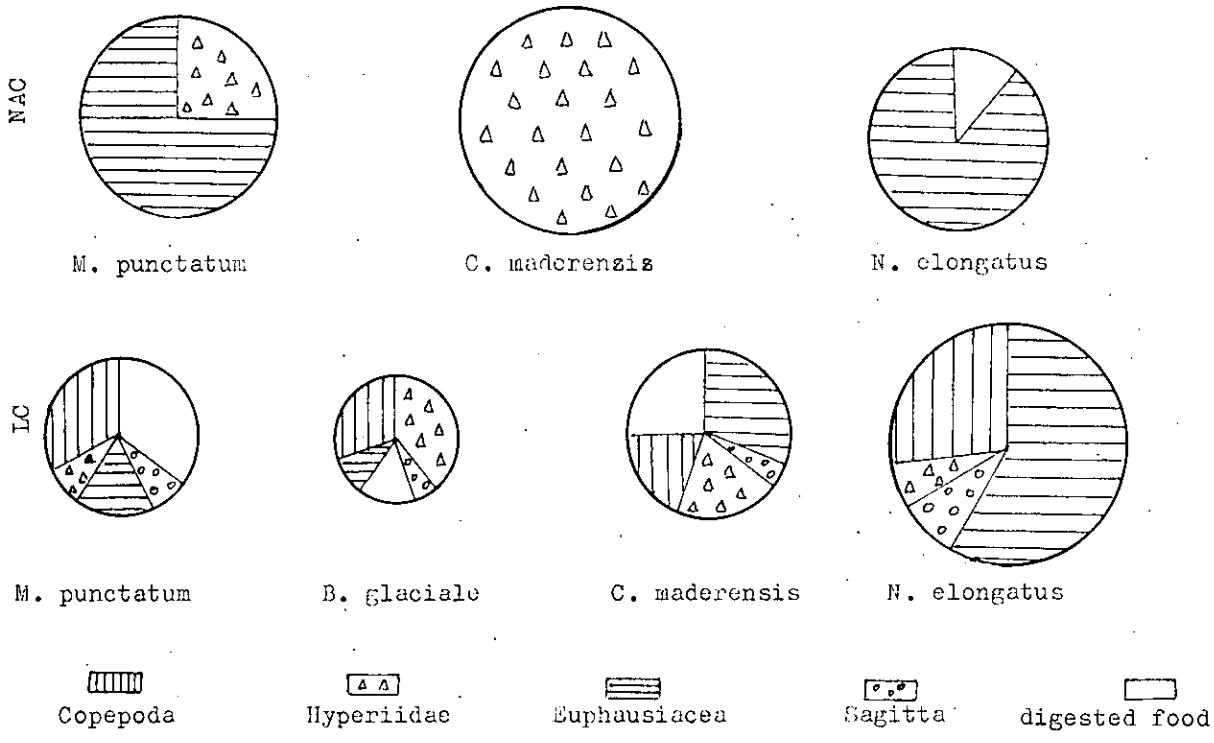

Fig. 2. Feeding habits of myctophids in various water masses of the Northwest Atlantic