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Some Aspects of the Biology and Distribution of Glacier Lanternfish (*Benthosema glaciale*) Over the Slopes of Flemish Cap and Eastern Grand Bank

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Abstract

Midwater-trawl catches of glacier lanternfish (*Benthosema glaciale*) over the slopes of Flemish Cap and eastern Grand Bank in the Northwest Atlantic consisted mainly of age-groups 3 and 4, most of which were in the 45–60 mm SL range. The smallest and largest specimens were 27 and 72 mm SL, and males were somewhat more numerous than females. The pattern of gonad development in females indicated that spawning probably occurs intermittently in early autumn and winter, with the subsequent occurrence of larvae being coincident with the period of high zooplankton abundance (April–May). Growth is evidently rapid during the first 2–3 years of life and decelerates markedly thereafter, with the lifetime being at least 5 years. Bertalanffy growth parameters were L_∞= 73.7 mm, K = 0.419 and t_o = 0.006 yr. Copepods were the most significant food organisms in the stomachs, but the number of empty stomachs was quite high and the intensity of feeding was very low in all months. Hydrological observations in July, together with acoustic and catch information, indicated a highly-stratified thermal structure with a cold intermediate layer (<0° C) at 30–200 m. The sonic-scattering layer (mainly *B. glaciale* and other myctophids) remained at 300–400 m (3.5° C) with little daily vertical movement, due presumably to the overlying very sharp temperature gradient.

Introduction

The glacier lanternfish (*Benthosema glaciale*) is probably the most common myctophid north of 40° N in the North Atlantic. Its range extends from Cape Hatteras to Davis Strait in the Northwest Atlantic and from Cape Verde Islands to Spitzbergen in the Northeast Atlantic (Leim and Scott, 1966). Growth and reproduction of the species was studied by Halliday (1970) from research vessel catches on the Scotian Shelf and by Gjøsaeter (MS 1970, 1981) from sampling in Norwegian waters. The study by Halliday (1970) showed that *B. glaciale* spawn off Nova Scotia in early spring because maturing fish were caught in January and February and postlarvae were found in July. He observed that the maximum age was at least 4.5 years with Bertalanffy growth parameters of L_∞ = 68 cm and K = 0.36. Gjøsaeter (1981) reported that *B. glaciale* in the Northeast Atlantic spawn mainly in summer and that there is considerable variation in growth parameters (L_∞ = 70–87 cm, and K = 0.19–0.46).

The purpose of this paper is to present data on length and age compositions, reproduction, growth and feeding of *B. glaciale* from the Flemish Cap and eastern Grand Bank areas of the Northwest Atlantic. Some patterns of vertical distribution of the species are considered.

Materials and Methods

The materials for this study were collected from midwater-trawl (codend of double 12-mm mesh netting) catches during research vessel surveys which were aimed at investigating the biology and distribution of mesopelagic fishes in the Flemish Cap and eastern Grand Bank areas (Fig. 1). Most of the *B. glaciale* samples were obtained during April–August 1984, but some samples were collected in different months of 1982, 1983, 1985 and 1986 (Table 1). Standard length (SL) measurements (tip of snout to base of median rays of caudal fin) were recorded in millimeters and body

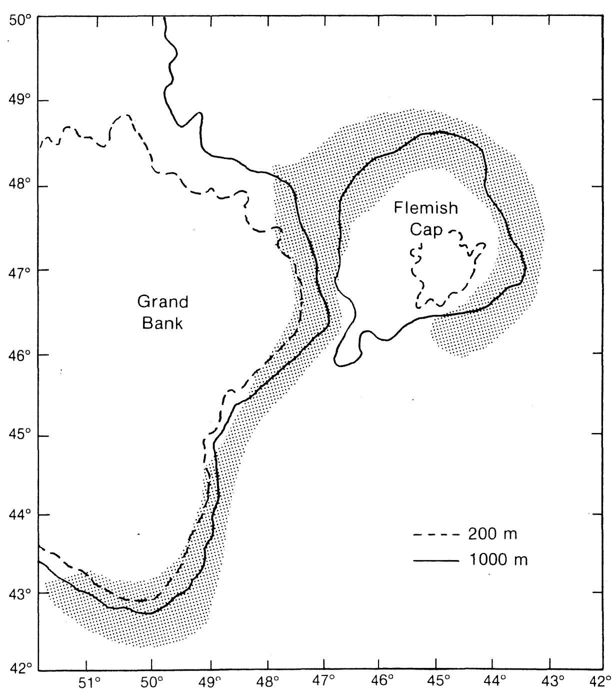


Fig. 1. Area covered by midwater trawl surveys for mesopelagic fishes in the Flemish Cap-eastern Grand Bank region, 1982–86.

TABLE 1. Numbers of male (M) and female (F) *B. glaciale* sampled from midwater trawl catches in the Flemish Cap and eastern Grand Bank areas, 1982-86.

Year	Month	No. measured M	No. measured F	No. aged M	No. aged F	Feeding study
1982	Feb	292	677	10	40	125
	Oct	682	689	50	50	340
1983	Nov	321	285	24	24	385
	Dec	789	186	24	26	500
1984	Apr	359	244	35	15	170
	May	4,077	3,354	48	52	1,230
	Jun	2,389	1,711	53	46	521
	Jul	4,800	3,611	95	55	1,051
	Aug	1,384	1,142	85	65	500
1985	Jan	1,013	893	108	91	275
1986	Sep	—	—	—	—	146

weights were taken to the nearest 0.1 g. Maturity stages were determined visually according to the scheme which was developed for *Notoscopelus kroeyeri* and described by Mazhirina and Filin (1987).

To characterize the feeding intensity of *B. glaciale* at different times of the year, field analysis of about 5,200 specimens involved estimating the degree of stomach fullness by the 5-point scale (0 = empty, 1 = one-quarter full, 2 = half full, 3 = three-quarters full, and 4 = full or nearly full). The role of different prey in the feeding regime of *B. glaciale* was studied in the laboratory by examination of the stomach contents of a small number of fish which had been preserved in 4% formalin. The samples for use in the feeding studies were collected and analyzed according to guidelines for the study of feeding of fishes (Anon., 1974).

Ages of *B. glaciale* were determined from otoliths (initially stored in glycerine) which were examined under a binocular microscope with reflected light. Age compositions of the monthly samples were derived from the application of age-length keys to the length compositions.

Some ichthyoplankton sampling with conical plankton nets (50 and 80 cm diameter, 99 μm mesh) in 1981–84 (April–June) yielded *B. glaciale* larvae and juveniles (5–19 mm) which were measured as total length (TL).

The daily distribution of *B. glaciale* by depth was studied by conducting 20 midwater trawl tows at various times of the day during 15–20 July 1984 in the sonic-scattering layer, the distribution of which was continuously monitored by acoustic instrumentation.

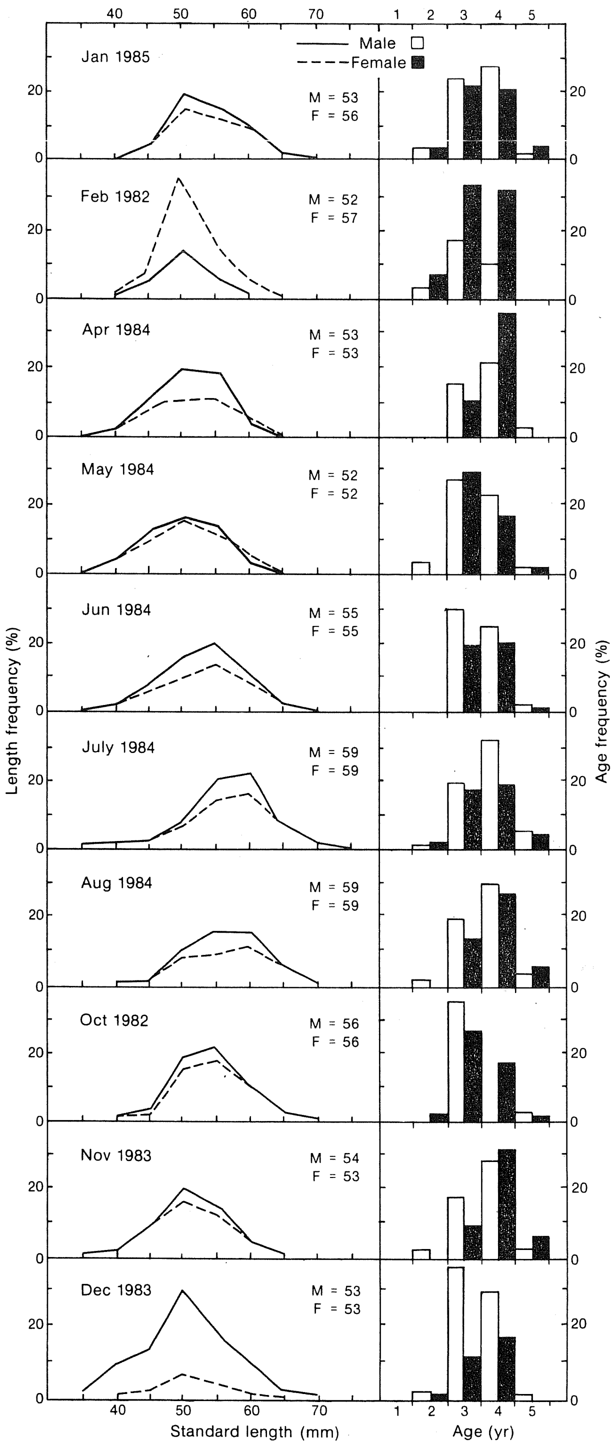


Fig. 2. Monthly length and age distributions of *B. glaciale* in trawl samples from the Flemish Cap-eastern Grand Bank region, 1982-85. (Mean lengths of males and females are given in millimeters for each sample.)

Results and Discussion

Length and age compositions

The monthly length compositions of *B. glaciale* in samples of midwater trawl catches during 1982-85 (Fig. 2) indicated very little difference in the size of males and females, with the average lengths for each sex ranging from 52 to 59 mm SL in different months. The smallest and largest individuals were 27 and 72 mm SL respectively. Males were more numerous than females in most months, with percentages generally in the 53-60% range, although the December 1983 sample contained 81% males. Females (70%) were more abundant than males only in February 1982.

The samples consisted mainly of age-groups 3 and 4 which together constituted more than 85% of the specimens in each month (Fig. 2). A few 2- and 5-year-old specimens were present in most months. The absence of age 1 and the small number of age 2 fish in the samples were due to trawl selectivity and the tendency for many of the small fish to be damaged, with consequent arbitrary selection of larger less-damaged specimens.

Reproduction

Analysis of data on maturity stages of females in various months of 1984-86 gives a general view of gonad maturation and possible time of spawning of *B. glaciale* (Table 2). The samples in April and May 1984 consisted entirely of immature females with gonads at maturity stage II. From June to December, there was a progressive increase in the number of females with gonads at stage III (maturing). In November 1984, 30% of the females had gonads in prespawning condition (stage IV), although none had progressed to that stage in November 1985. In January, 68% of the females were at maturity stage IV and 13% were at stage VI (spent or partially spent condition). In November 1985 and September 1986, a few females with gonads at stage VI-III (recovering from an earlier spawning) were observed.

Ichthyoplankton samples in the spring usually contained some *B. glaciale* larvae. The April sample of 23 specimens (2 in 1982 and 21 in 1984) had a length range of 5-10 mm TL and mean length of 6.6 mm (Fig. 3). In May 1981, a sample of 57 specimens had a length range of 7-12 mm TL with mean length of 9.3 mm. In June 1981, a sample of 136 specimens ranged from 5 to 19 mm TL with modes at 6 and 13 mm. Seemingly, these modal groups represented successive cohorts of larvae from spawning earlier in the spring. Serebryakov *et al.* (1987) noted the capture of *B. glaciale* larvae and postlarvae on Flemish Cap from March to July. The specimens larger than 12 mm TL in June (Fig. 3) had undergone metamorphosis and acquired the features of adults. According to information in the literature, metamorphosis has been observed in 11-15 mm specimens (Halliday, 1970; Shiganova, 1977; Fahay, 1983). Konstantinov *et al.* (1985) noted that there is a synchronous occurrence of fish larvae and high abundance of zooplankton (particularly copepod eggs and nauplii) as food for the larvae in the Flemish Cap area during April and May.

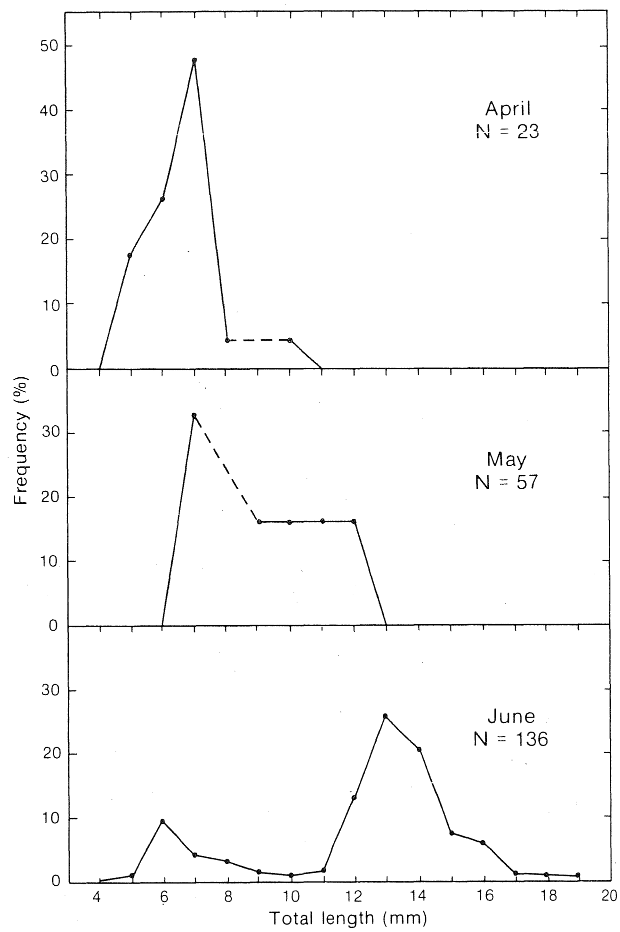


Fig. 3. Length distributions of *B. glaciale* larvae and postlarvae from ichthyoplankton sampling in spring (April-June).

TABLE 2. Percentage distribution of female *B. glaciale* at different maturity stages in samples from the Grand Bank-Flemish Cap region, 1984-86. (Samples contained no stage V females.)

Month/year	No. of fish	Maturity stage (%)[a] II	III	IV	VI-III(IV)	VI
Apr 1984	46	100.0	—	—	—	—
May 1984	472	100.0	—	—	—	—
Jun 1984	111	91.9	8.1	—	—	—
Jul 1984	547	96.0	4.0	—	—	—
Aug 1984	245	95.1	4.9	—	—	—
Sep 1986	370	71.7	25.1	—	3.2	—
Oct 1985	181	63.5	34.8	1.7	—	—
Nov 1985	167	50.9	40.2	—	8.9	—
Nov 1984[b]	165	4.0	66.0	30.0	—	—
Dec 1985	124	26.6	71.8	1.6	—	—
Jan 1985[b]	191	7.0	12.0	68.0	10.0	3.0

[a] Maturity stages from Mazhirina and Filin (1987).
[b] Data from Gorchinsky and Mazhirina (1985).

Growth

The weight-length relationship for *B. glaciale* was determined from the summarized data for 1982–85. Least-squares log-log regression lines were calculated for each year but there was very little variation in the parameters (e.g. $W = 0.000280\ L^{2.29}$ for 1984, and $W = 0.000251\ L^{2.32}$ for 1985). Utilization of the data for all

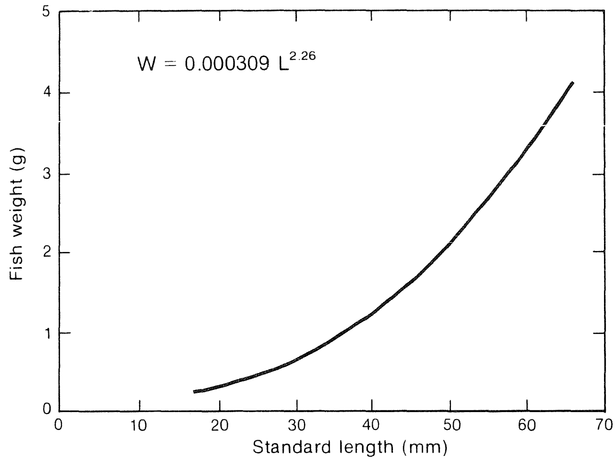


Fig. 4. Weight-length relationship for *B. glaciale* in the Flemish Cap eastern Grand Bank region, based on 1982-85 data.

years resulted in derivation of the following equation of allometric growth for *B. glaciale* in the Flemish Cap and eastern Grand Bank slopes:

$$W = 0.000309\ L^{2.26}$$

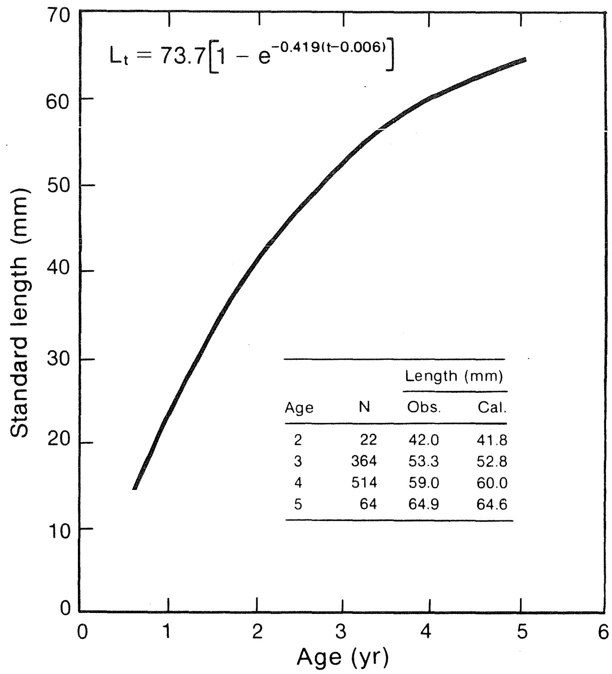
where W is weight of fish (g) and L is standard length (mm) (Fig. 4).

The method of Hohendorf (1976) was used to estimate the parameters of the Bertalanffy growth equation from the mean values for age-groups 2 to 5, resulting in values of $L_\infty = 73.7$ mm, $K = 0.419$ and $t_o = 0.006$ yr. Thus, the growth of *B. glaciale* may be represented by the following equation:

$$L_t = 73.7(1 - \exp(-0.419(t - 0.006)))$$

where L_t (mm) is length at age t (yr). From the weight-length relationship, $W_\infty = 5.14$ g. The values of L_∞ and K are slightly higher than those (68 cm and 0.36) reported by Halliday (1970) for fish from the Scotian Shelf but within the ranges of values (70–78 cm and 0.19–0.46) given by Gjøsaeter (1981) for fish from Norwegian waters.

It is evident from the growth curve for *B. glaciale* (Fig. 5) that growth is rapid during the first 2–3 years of life and decreases markedly thereafter. Evidently, the decrease in growth is due to maturation of the gonads. The growth of other mesopelagic fishes has been reported to be rapid prior to maturation for spawning and then decelerates sharply (Go *et al.*, 1977). Studies of *B. glaciale* from widely different areas of the North Atlantic (waters off Nova Scotia and Norway) indicated that the age of first spawners was similar, with about 50% of females maturing to spawn for the first time at age 2 (Halliday, 1970; Gjøsaeter, 1981). All of the mature fish in samples from the Flemish Cap-eastern Grand Bank region were greater than 50 mm long. Gjøsaeter (1981) suggested that maturation of *B. glaciale* was more related to length than age, with 45-50 mm being the lower limit of size at which first spawning occurs. Thus, in diverse areas of the North Atlantic, maturation for first spawning seems to begin in the larger fish of age-group 2, and all age 3 fish are likely to be mature.



Age	N	Length (mm) Obs.	Cal.
2	22	42.0	41.8
3	364	53.3	52.8
4	514	59.0	60.0
5	64	64.9	64.6

Fig. 5. Bertalanffy growth curve, with observed and calculated mean length-at-age values, for *B. glaciale* in the Flemish Cap-eastern Grand Bank region, based on 1982-85 data.

Feeding

On the basis of some ecological and morphological features, *B. glaciale* may be referred to as a "non-active" myctophid (Bekker, 1983). Moving passively with the water currents, their livelihood depends on the dynamics of the water masses. They do not undertake feeding and spawning migrations but tend to be immobile (Gjøsaeter and Kawaguchi, 1980). Consequently, *B. glaciale* requires little food, and this is indicated by the very low intensity of feeding. The average degree of stomach fullness did not exceed 1.0 in any month except September when it was 1.41 (Fig. 6). The number of empty stomachs was usually quite high.

Biochemical analysis of *B. glaciale* muscle tissue indicates a high lipid content. It is likely that, after maturation when more energy is expended on growth, there is an intensive accumulaton of lipids (with low specific gravity) which plays a role in providing near-neutral buoyancy of *B. glaciale*, with little expenditure of energy for swimming. The low values of the exponents (less than 3.0) in the weight-length relationships may be related to the rather inactive behavior of this species.

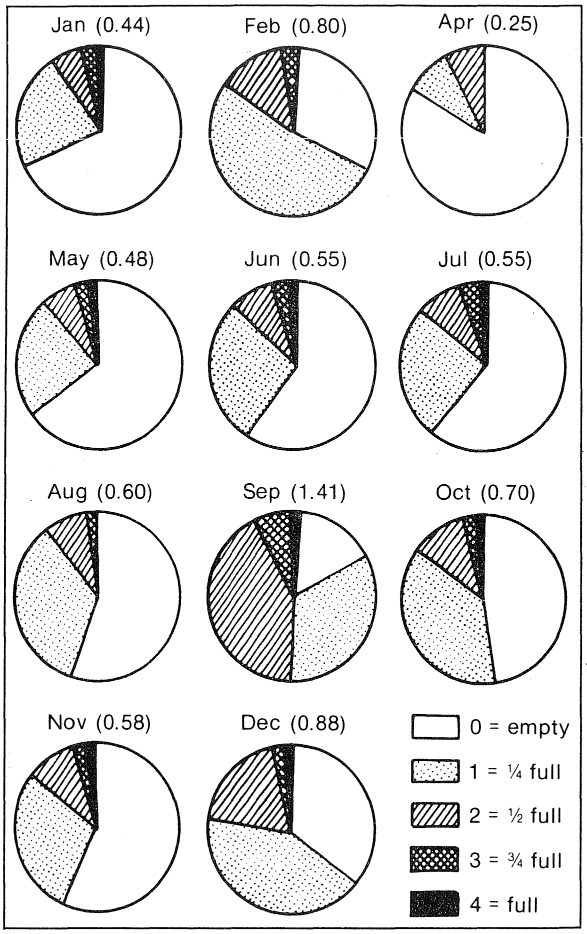


Fig. 6. Monthly patterns of stomach fullness in *B. glaciale* from the Flemish Cap-eastern Grand Bank region, 1982-86. (The value in parentheses for each month is the mean degree of stomach fullness.)

The composition and occurrence of various food organisms in *B. glaciale* stomachs were determined from rather small samples at different times of the year (Table 3). Many of the stomachs were empty, and the identification of organisms in stomachs with food was complicated by the high degree of digestion. Nevertheless, the results indicate the important role of different copepods in the feeding regime, but euphausiids, amphipods, ostracods, appendicularians and chaetognaths were also observed.

Vertical distribution

Studies of the influence of abiotic factors on daily movements of aquatic organisms have indicated that light is a major regulator of vertical migrations. Detection of sonic-scattering layers in the ocean and attempts to elucidate the role of different organisms (particularly Myctophidae) in their formation has often led to assumptions about the great importance of light in the vertical displacement of the scattering layers (Bekker, 1967; Backus, 1968; Halliday, 1970; Zhitkovsky and Mozgovoy, 1980). Thus, authors have pointed to daily vertical migrations as a peculiar feature of myctophid biology, with the fish moving quite rapidly over several hundred meters through water layers of very different temperature (Bekker and Borodulina, 1968; Bekker, 1983). Active daily migrations of *B. glaciale* species have been observed in different regions. In the Northwest Atlantic, the depth of occurrence during the day was about 500 m and the major part of the population moved to 185-300 m at night (Zahuranec and Pudh, 1971). In the Northeast Atlantic, the species occurred at 250-450 m during the day and migrated to the near-surface layers at night (Roe and

TABLE 3. Composition and occurrence of various food components in stomachs of *B. glaciale* from the Flemish Cap-eastern Grand Bank region.

	Percent occurrence			
Food organisms	Feb 1982	Apr 1984	Aug 1985	Oct 1984
Copepoda (total)	10.5	25.0	13.9	24.0
Calanus finmarchicus	—	25.0	2.3	4.0
Calanus hyperboreus	—	12.5	—	—
Calanus sp.	—	12.5	—	8.0
Metridia sp.	5.3	—	—	—
Pareuchaeta norvegica	—	—	—	16.0
Pareuchaeta sp.	5.3	—	4.6	4.0
Pleuromamma sp.	—	—	—	4.0
Pseudocalanus elongatus	—	—	—	4.0
Undeuchaeta sp.	—	12.5	—	4.0
Unidentified	—	—	9.3	8.0
Amphipoda	—	12.5	7.0	—
Euphausiacea	5.3	12.5	2.3	—
Mysodacea	—	—	—	4.0
Ostracoda (*Conchoecia* sp.)	5.3	—	—	—
Chaetognatha	—	—	2.3	—
Urochordata (*Oikopleura* sp.)	—	—	2.3	—
Digested food	21.0	12.5	48.8	28.8
No. of stomachs examined	19	8	43	25
Percent empty stomachs	58	63	37	52

Badcock, 1984). Near the Azores, the population inhabited 500-600 m depths during daylight and moved to 0-100 m at night (Badcock and Merrett, 1977). Gjøsaeter (1981) mentioned *B. glaciale* migrations in Norwegian deepwater fjords.

Hydrological conditions in the Flemish Cap and Grand Bank areas are influenced by the cold Labrador Current, the vertical thermal structure of which is characterized in spring and summer by an intermediate cold layer at 50-200 m. From the survey in July 1984, as a result of radiant heat, temperatures of the near-surface layer (0-20 m) were 5° to 7° C. Temperatures were negative in 30-200 m and were as low as -1.5° C in the cold core of the Labrador Current. Hydroacoustic observations during 15-20 July 1984 showed that the sonic-scattering layer was located at about 300-400 m where the temperature was about 3.5° C. There was no indication of daily vertical movements of the layer. The results from 20 midwater trawl tows indicated that *B. glaciale* constituted the greater part of the aggregations which were detected acoustically at 300-400 m. The average density of concentrations did not vary much at different times of the day and night (0.02-0.05 g/m^3). Maximum density (0.08 g/m^3) was recorded for a tow at 300-320 m during daylight.

From the behavior of *B. glaciale* and characteristics of water stratification in the Flemish Cap and Grand Bank areas, this species appears to be one of those whose extent and intensity of migration, as well as the character of vertical distribution, are dependent on the vertical thermal structure of the water masses. The vertical migrations of *B. glaciale* could be limited by sharp gradients in water temperature.

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