Age and growth, dietary habits, and parasitism of the fourbeard rockling, *Enchelyopus cimbrius,* from the Gulf of Maine

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Abstract.–The fourbeard rockling, *Enchelyopus cimbrius*, is a small gadid fish found primarily over mud bottoms along the continental margins of the North Atlantic. This study defines the age classes of the fourbeard rockling from the Gulf of Maine, analyzes stomach contents, and characterizes the fish's metazoan parasite fauna. Age was determined from sectioned sagittal otoliths. Nine age classes were identified and compared with the Fraser-Lee back-calculation method. The rate of linear growth was constant throughout age classes. The diet of fourbeard rockling consisted primarily of bivalves, copepods, and decapods, in both number and frequency of occurrence indices. Prey composition in the diet changed with age. One-year-old fish preyed primarily upon copepods; bivalves were second in importance. The reverse was seen in 2–7 year old fish. Data on food habits suggest that the fourbeard rockling is a "grazer." Parasites of this species were one larval nematode, from the family Raphidascaridinae, one larval cestode, *Grillotia erinaceus*, and the two species of adult digenetic trematodes, *Genolinea laticauda* and *Gonocerca phycidis*. Prevalence and abundance data indicate that the parasitic fauna was dominated by Raphidascaridinae sp. and *G. erinaceus*.

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The fourbeard rockling, *Enchelyopus cimbrius* L., is a small gadid fish found primarily over soft mud or sand bottoms along the continental margins of the North Atlantic Ocean (Bigelow and Schroeder, 1953). This fish lives in burrows during daylight hours and forage at night (Keats and Steele, 1990). Although larval stages of *E. cimbrius* are well documented throughout its range (Battle, 1929; Demir et al., 1985), limited information exists about the age and growth of this species. This study estimates growth rates of *E. cimbrius* from the Gulf of Maine, analyses stomach contents, and characterizes the metazoan parasitic fauna.

Dietary studies for this species have been made at various localities in the eastern North Atlantic (Nagabhushanam, 1965; Wheeler, 1969; Mattson, 1981; Moller-Buchner et al., 1984; Tully and O Ceidigh, 1989), but little is known of the food habits for the western Atlantic, and there have been no dietary reports for *E. cimbrius* from the Gulf of Maine. Diets of *E. cimbrius* vary with location but have been found to consist primarily of polychaetes or crustaceans (Tyler, 1972; Langton and Bowman, 1980; Keats and Steele, 1990).

Records of parasitism of *E. cimbrius* are all apparently coincidental with parasite surveys. Reported parasites include a protozoan (Lom and Laird, 1969), a coccidian (Odense and Logan, 1976), an acanthocephalan (Linton, 1899), digenetic trematodes (Linton, 1899; Gibson and Bray, 1984; Brinkmann, 1988), and a nematode (Nagabhushanam, 1965). No survey of parasites to date has been specifically devoted to this host species.

Materials and methods

A collection of 727 fourbeard rocklings was obtained during the Gulf of Maine Northern Shrimp Survey GM 93-20, 2–13 August 1993. Collections were made during daylight hours at 41 randomly generated stations at depths ranging from 79 to 254 m aboard the NOAA RV *Gloria Michelle* equipped with a 4-seam modified commercial shrimp trawl with a 35-mm stretched mesh. In case of large hauls, a 1-kg random subsample was taken. An additional 36 fish, for stomach analyses, were collected from 6 stations at depths of 170–227 m during the GM 94-12 survey between 2 August and 3 August 1994 by using identical gear and methods.

Specimens collected during the GM 93-20 survey were frozen immediately at sea. To assess the effects of freezing on shrinkage, 218 fresh specimens were individually tagged, measured to the nearest mm for total length (TL), frozen, then remeasured after being thawed for 24 h. Fish were then weighed to the nearest g on a top loading balance and sexed. In addition, both sagittal otoliths were extracted for ageing purposes and stored dry in coin envelopes.

Fish age classes were determined by counting presumed annual growth increments in otolith sections. For temperate-water fish, which generally exhibit seasonal growth patterns, one year of growth is defined by one opaque and one hyaline zone termed the "annulus" (Pentilla et al., 1988). Sagittal otoliths have been used for age determination in the majority of commercially important gadids (Andrade and Smith, 1988; Dery 1988; Pentilla, 1988) including *E. cimbrius* (Cohen et al, 1990). The assumption that increments were annual in *E. cimbrius* was based on the following: prolonged spawning in the Gulf of Maine (May–October) (Cohen et al, 1990), a pelagic stage (40.0–45.0 mm TL) spanning several months (Bigelow and Schroeder, 1953), time of year sample was taken (August), and presence of a prominent hyaline zone. The otolith of the smallest fish (95 mm TL) in the present study exhibits a prominent hyaline zone and this fish is assumed to have hatched in the previous year.

One otolith from each pair was embedded in a mixture of 1 part carbon powder and 4 parts paraffin wax, then sectioned dorsoventrally through the nucleus on an Isomet saw producing a section 203 µm thick. Sections were mounted on glass slides with Crystal Bond 509, polished with 3.0-µ and 0.5-µ metallurgic lapping film, etched for 6 minutes with 5% EDTA, and stained for 3 minutes with 0.1% toluidine blue. Otolith sections were viewed under a compound microscope at 40× by using transmitted light (Fig. 1). Etching with EDTA provided three-dimensional relief to the polished otolith surface, affording the greatest resolution and definition of the hyaline zones (Secor et al., 1992).

To reduce sample size for age determinations, the length-frequency distribution of *E. cimbrius* at station 40 was used to generate a rarefaction curve. Fifty-seven fish were aged by using both left and right sagittal otoliths during one trial under the following treatment effects: low-power dissecting microscope (LD); high-power zoom stereomicroscope (HS); and high-power zoom stereomicroscope after otoliths were etched with EDTA and stained with toluidine blue (EDTA). Nine fish were omitted from the analysis because of the inability to obtain either the left or the right otolith.

Individual variances of the six trials were plotted in groups of five to generate a rarefaction curve. The

Figure 1

Transverse section of a sagittal otolith etched with 5% EDTA and stained with 0.01% toluidine blue photographed under a compound microscope at 40× by using transmitted light.

magnitude of the variance was stabilized at 30 fish per age class, yielding approximately 270 specimens to be aged. A length-based stratification was developed to avoid underrepresentation of the least abundant fish located at the extremes (Fournier, 1983). After removing the 77 lower (95–129 mm TL) and 54 upper (250–328 mm TL) extremes, 150 rocklings between 130 and 249 mm TL were randomly selected, then added to the extremes, yielding a total subsample size of 281 fish.

Otoliths from 281 fourbeard rocklings were etched and stained, then aged with a compound microscope at a magnification of 40 by using transmitted light. After three complete trials, an ANOVA was run on the assigned age classes.

Assigned age classes were compared by using the Fraser-Lee back-calculation formula which assumes that the relationship between individual fish length and otolith length is maintained proportionally throughout the back-calculation (Carlander, 1981)

It is defined as

$$L_i = a + OD_i (L_c - a/OR),$$

Where L_i = estimated total length (TL) when otolith has formed annulus i;
a = intercept of the (TL):otolith length (OL) regression determined from the sample;
OD_i = otolith distance from the nucleus to annulus i;
OR = otolith radius measured form the nucleus to the edge of the anterior rostrum; and
L_c = *TL* at capture.

Lengths at assigned ages were compared to back-calculated lengths at ages by means of correlation analysis. Total length back-calculation measurements were used to construct a length-frequency distribution to further corroborate ages assigned to length classes by otolith analysis. A Kolmogorov-Smirnoff test was used to test for differences between the observed and back-calculated length-frequency distributions.

Specimens from the GM 94-12 survey were labeled according to station, cut lengthwise along the abdomen, and preserved in 10% formalin. Stomachs were removed and their contents, after identification, summarized by using both numerical and frequency of occurrence indices. These analyses were further divided into two length categories: 1-year-old (105–121 mm TL) and 2–7 year old (119–271 mm TL) fish, on the basis of assigned age-class information. The size range of the first year class was calculated by using ±1 standard deviation from the mean. The second category, 2–7 year old fish, was calculated by using the –1 deviation of the mean size of the age-2 year class and the +1 deviation of the age-7 year class. Fish (n=1) that fitted within the size limits of these two age groups were placed in the category with the smallest difference between mean age-class length and length of the fish.

In addition to the 36 stomach samples from the GM 94-12 survey, a sample of 112 frozen fish from the GM 93-20 survey was obtained to inspect for occurrence of parasitism. Each gastrointestinal tract was removed and cut into its component parts, then sliced lengthwise to allow for inspection with a dissecting microscope. Nematodes were labeled according to the location of infection, preserved in 70% ethanol, then transferred to 70% ethanol and 5% glycerine.

Trypanorhynch blastocysts and digenetic trematodes were preserved and stored in 10% buffered formalin. Trypanorhynchs were removed from their blastocysts, transferred to 70% ethanol, and stained overnight in Mayer's paracarmine diluted 1:9 in 70% ethanol. Specimens were destained in 0.1 HCl in 70% ethanol until internal organs were visible, neutralized with 70% sodium bicarbonate for 20 minutes, then dehydrated in a graded ethanol series prior to clearing in methyl salicylate. Digenetic trematodes were similarly prepared. Each specimen was mounted on a glass slide in Canada balsam with slides stored flat until the mounting medium had hardened, when they were viewed under a dissecting scope for identification.

Helminth data were summarized by using prevalence, abundance, and intensity indicies. Prevalence (%P) is defined as the number of infected individuals divided by the number of individuals examined multiplied by 100, abundance (A) as the mean number of parasite species per host examined, and intensity range (I range) as the number of parasite species in each infected host (Margolis et al., 1982). Helminth data were further divided into nine length-class categories with ±1 standard deviation from the mean of each age class. Again, fish (n=3) that fitted within the limits of two age classes were treated in the same manner as in the food habits analysis. Splitting the data into length-class categories provided a better indication of the representative parasites in a respective year class than did dividing the data arbitrarily.

Results

Age and growth

The length-frequency distribution of *E. cimbrius* (n=727) sampled during the GM 93-20 survey ranged

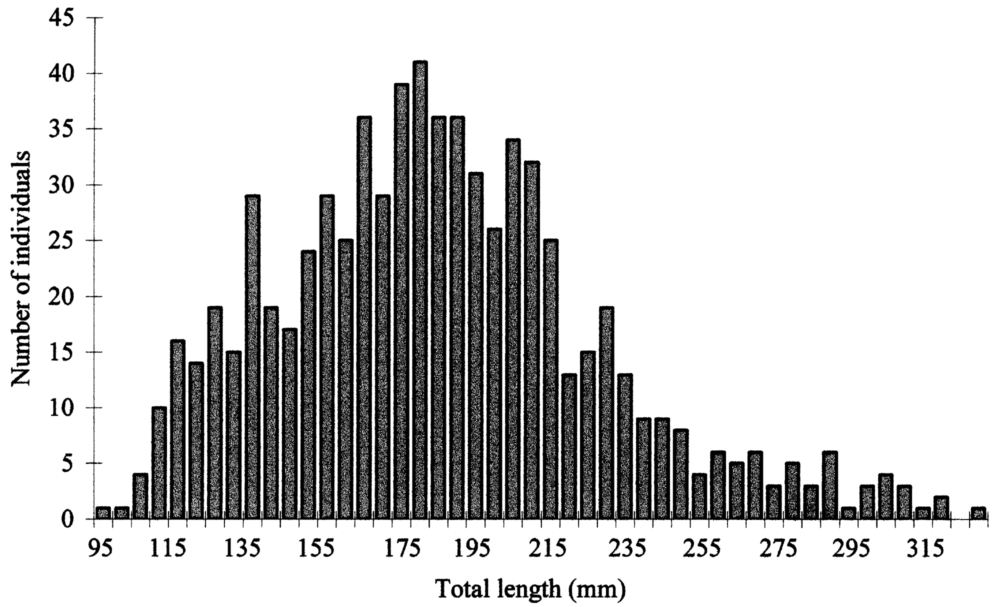

Figure 2

Length-frequency distribution of *E. cimbrius* collected during the GM 93-20 survey between 2 August and 13 August 1993 plotted in groups of 5 (e.g. 95=91–95). (n=727).

from 95 to 328 mm TL (Fig. 2). Shrinkage was not significant (P=0.2465), therefore, all total lengths reported in this study are from previously frozen fish.

None of the treatment effects (LD, HS, EDTA) employed on both otoliths from fish collected at station 40 was found to be significantly different (P=0.9488). The EDTA method was selected because it produced the highest r^2 value (r^2=0.9961) in a regression analysis. There was no significant difference between left and right otoliths (P=0.8934).

Nine age classes were identified (Table 1). An ANOVA was run on the assigned ages of the 281 rocklings. The three independent trials were not significantly different from one another (P=0.8028). There was a high correlation (P=0.984) between total length and age (Fig. 3). Because of the difficulty in interpreting annular growth or disagreement about age over the three independent readings, 28 out of 281 otoliths were discarded.

Linear growth was significantly different in males and females (P=0.0001) (Table 2). Nine male and eight female age classes were observed. To account for the sex differences in growth, the length frequency has been subdivided to show the distribution of male, female, and undetermined sexes (Fig. 4). Undetermined sexes were either immature or badly preserved.

There was a significant difference between the weights of males and females (P=0.0001). The average weight of all sexed specimens regardless of age showed that males weighed more than females (mean 26.5 ±19.3 and 24.5 ±24.2 g, respectively). Females were heavier at age than males for the first three year classes (Fig. 5). A scattergram of age versus total length (mm) and weight (g) is presented in Figure 6.

Table 1

Age-class statistics based on observed otolith readings of *E. cimbrius* collected during the GM 93-20 survey between 2 August and 13 August 1993. (n=253).

		Total length (mm)		
Age class	n	Mean	Range	SD
1	37	112.6	95.0–127.0	8.1
2	52	127.4	115.0–149.0	8.5
3	24	157.3	142.0–178.0	8.8
4	38	180.5	155.0–207.0	12.4
5	35	204.3	189.0–226.0	9.2
6	16	240.7	223.0–268.0	13.8
7	26	258.5	228.0–282.0	12.8
8	13	283.6	272.0–297.0	6.8
9	12	307.7	293.0–328.0	9.9

Regression analysis of TL vs. OL is defined by $y = 0.014x + 0.838$ where 0.838 is the intercept used to standardize the Fraser-Lee back-calculation equation. Back-calculated lengths at age (Table 3) and

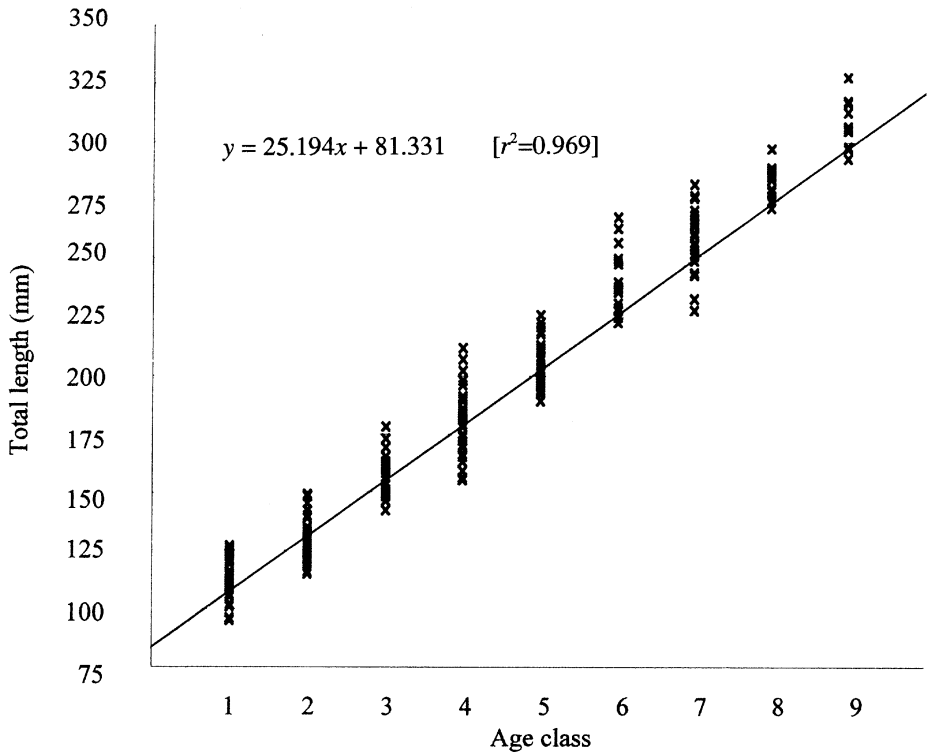

Figure 3

Regression of observed age-class data vs. total length (mm) of *E. cimbrius* collected during the GM 93-20 survey between 2 August and 13 August 1993. (n=253).

observed lengths at age were not significantly different (P=0.9608). The Kolmogorov-Smirnoff test revealed there was no significant difference between the back-calculated and observed length-frequency distributions (P=0.3124) (Fig. 7). In addition, back-calculated and observed lengths at ages were highly correlated (P=0.996).

Dietary habits

Stomach contents consisted primarily of mollusks and arthropods. Three specimens contained no food and were not included in the determination of numerical and frequency of occurrence indices. *Yoldia* sp. and calanoid copepods composed the majority of prey items in both number and frequency (Table 4). *Yoldia* sp. and calanoid copepods, combined with *Diastylis quadrispinosa*, *Crangon septemspinosa*, unidentified cumaceans and decapods, composed 91.6% of the prey items ingested. Frequency indices showed that the latter four prey items had similar frequencies.

Numerical indices show that copepods composed 71.2% of the diet of 1-year-old fish (Table 5). Bivalves were second in importance (19.2%), followed by cumaceans (5.4%), amphipods (2.7%), and decapods (1.4%). The importance of copepods decreased to

Table 2

Mean lengths of males, females, and immature or undetermined sexes per age class based on observed otolith readings. (n=253).

		Mean total length (mm)		
Age class	n	Male	Female	Immature or undetermined
1	37	116.7	113.3	110.7
2	52	130.6	125.7	125.8
3	24	158.0	155.8	160.3
4	38	180.0	181.2	—
5	35	204.0	204.5	—
6	16	239.4	242.8	—
7	26	257.9	257.5	277.0
8	13	281.8	287.0	286.0
9	12	307.7	—	—

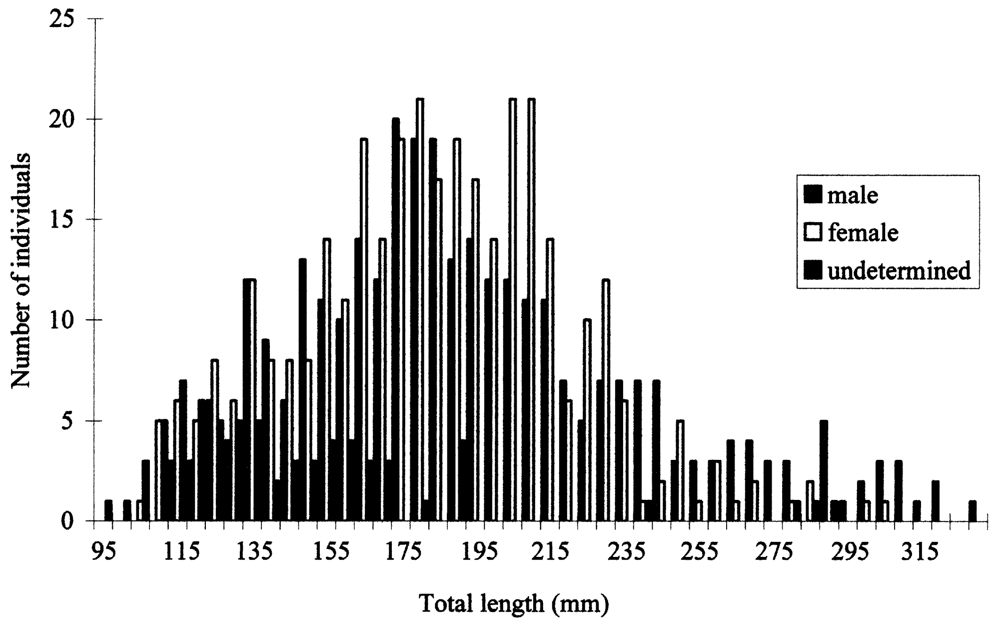

Figure 4

Length-frequency distribution of males, females, and undetermined sexes collected during the GM 93-20 survey between 2 August and 13 August 1993 plotted in groups of 5. (*n*=727).

28.7% and was replaced by bivalves (56.3%) in fish ranging from 2 to 7 years old (Table 5). Polychaetes (2.0%) and decapods (3.7%) were found only in the stomachs of older fish. Cumaceans made up a small percentage of the diet in both size ranges.

Bivalves (80.0%) and copepods (80.0%) were the most frequent items encountered in 1-year-olds, with cumaceans (40.0%) third in importance (Table 5). The frequency of bivalves (71.0%) in the diet of older fish was similar to that of 1-year-olds. Decapods and polychaetes were consumed in higher frequency in larger fish. Copepods were eaten in large numbers in both size categories but were taken less frequently by larger fish (12.9%).

Table 3

Age-class statistics based on back-calculated lengths at age of *E. cimbrius* collected during the GM 93-20 survey between 2 August and 13 August 1993. (*n*=40).

	Total length (mm)		
Age class	Mean	Range	SD
1	102.3	86.0–118.0	8.1
2	127.7	116.0–140.0	6.8
3	153.8	140.0–174.0	8.0
4	183.1	167.0–202.0	9.5
5	212.9	191.0–231.0	10.0
6	235.5	223.0–260.0	9.6
7	257.1	244.0–270.0	8.2
8	280.0	272.0–287.0	6.2

Parasitism

Four parasite species were identified for the first time for this host. The nematodes were identified as all second- or third-stage and third- or fourth-stage larvae of the family Raphidascarinidae, probably *Hysterothylacium* sp. These identifications were based on the presence of a boring tooth, globular ventriculus, ventricular appendage, intestinal caecum, and excretory pore near the nerve ring. Raphidascarinidae sp., located mainly in the body cavity, were found to have the highest prevalence (23.0%) of all parasites surveyed (Table 6).

Encysted plerocerci larvae were identified as *Grillotia erinaceus* Van Beneden, 1858 and were found in the body cavity, stomach, and intestine of 20.9% of the fish examined.

The two species of digenetic trematodes, found in the stomachs of *E. cimbrius* collected during the GM 94-12 survey, were identified as *Genolinea laticauda* Manter, 1925 and *Gonocerca phycidis* Manter, 1925. Body length dimensions of two specimens of *G.*

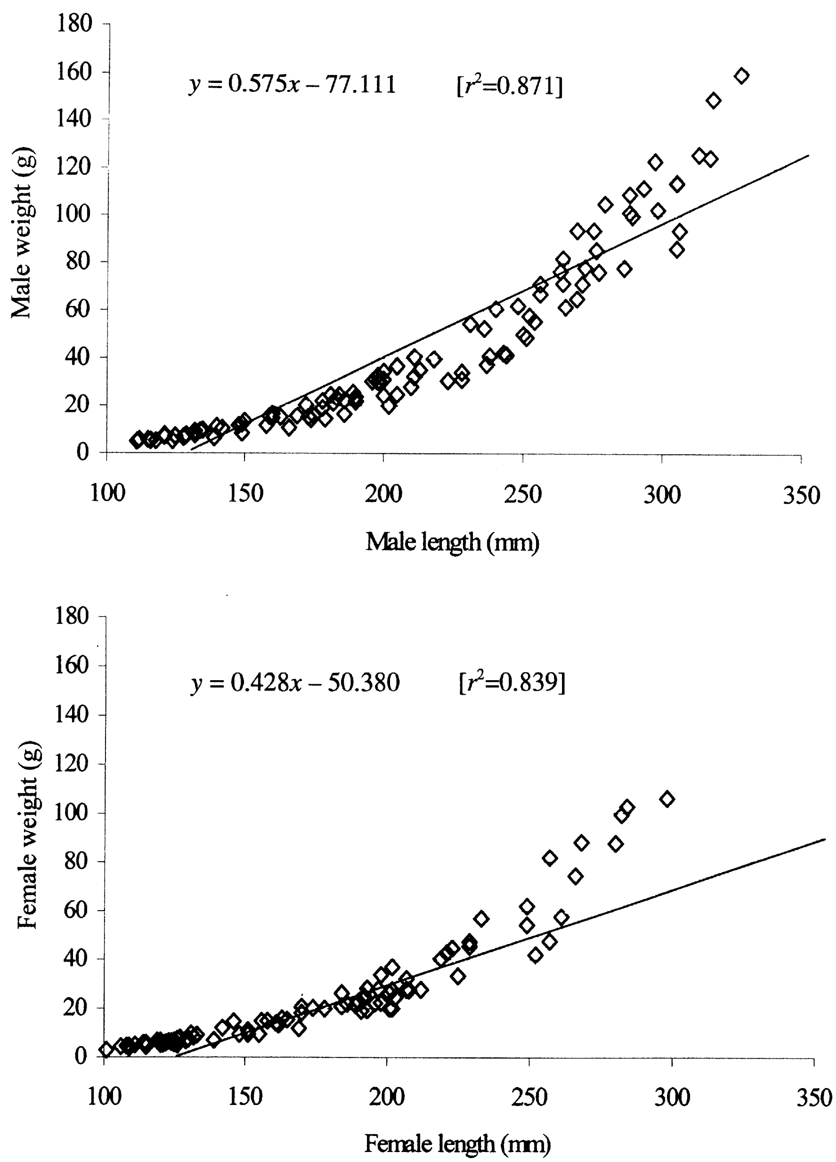

Figure 5

Regression of male length (mm) vs. male weight (g) (n=119) and female length (mm) vs. female weight (g) (n=96) for *E. cimbrius* collected during the GM 93-20 survey.

laticauda and *G. phycidis* ranged from 1.26 to 1.34 mm and from 1.38 to 1.76 mm, respectively. Both digenetic trematodes were found in low prevalence (4.7% and 1.4%, respectively) (Table 6).

The prevalence of infection of Raphidascarinidae sp. steadily increased from 8.3% in 1-year-olds to 100.0% in 9-year-olds (Table 7). The prevalence of *G. erinaceus* fluctuated but generally increased with fish age. There was an increase in infection from 9.1% to 20.0% and 25.0%, respectively by Raphidascarinidae sp. and *G. erinaceus* in 2- and 3-year-old fish. Infection by *G. laticauda* and *G. phycidis* was minimal in all size classes. All helminths in all year classes were found in low abundance.

Discussion

Age and growth

The age distribution of the sample comprised primarily of 3-, 4-, and 5-year-old *E. cimbrius*, with a maximum age of 9. The maximum age attained by this species in the Gulf of Maine is similar to that

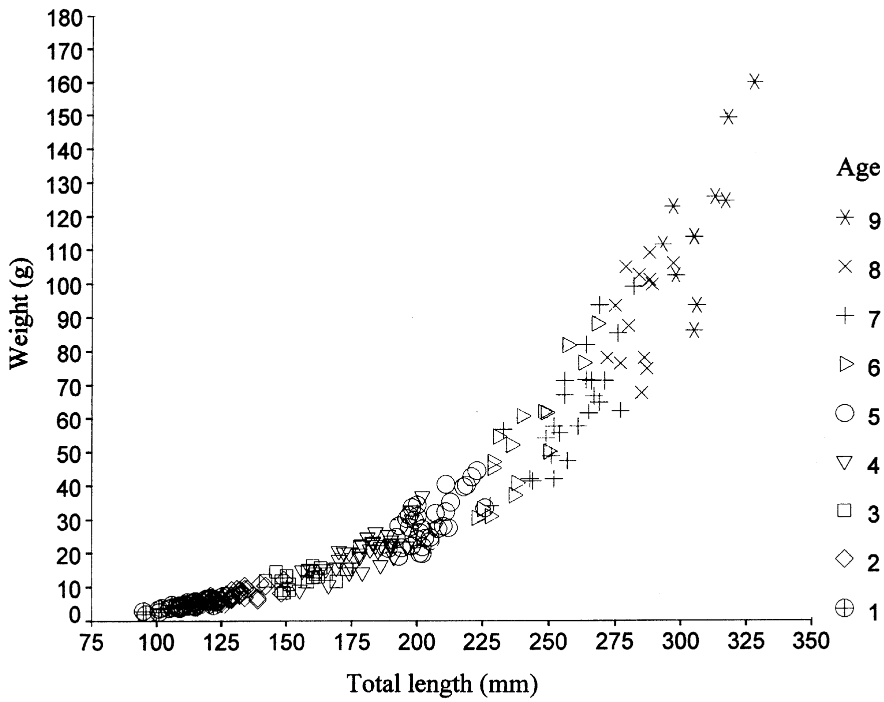

Figure 6

Scattergram of age vs. total length (mm) and weight (g) for *E. cimbrius* collected during the GM 93-20 survey. (n=241).

reported from the western and eastern Atlantic (Cohen et al., 1990). Age classes discerned in this study also agree well with those documented by Cohen et al. (1990) for the eastern Atlantic. Age classes for the eastern Atlantic are defined as follows: 3 years at 150 mm total length (TL), 5 years at 200 mm TL, 7 years at 250 mm TL, and 9 years at 290 mm TL (Cohen et al., 1990). The maximum length of *E. cimbrius* from this study (328 mm TL) again is similar to the maximum length recorded in the western Atlantic (305 mm TL) by Cohen et al. (1990).

The Kolmogorov-Smirnoff test showed no significant difference between length-frequency distributions of observed total lengths and back-calculated lengths derived from otolith increment data. This finding further corroborates that presumed annuli in sagittal otoliths were formed at regular time intervals and can be used to assign ages to length classes.

In aging studies, it is a common technique to compare assigned ages to length-frequency modes to confirm age classes (Campana and Jones, 1992). This was not attempted because of substantial overlap in the length-frequency modes of *E. cimbrius*. Length-frequency modes with substantial overlap have proven to be unreliable as predictors of component age groups because of several factors: the number of modes may be less than the number of components, modes may be obscured or indistinct, or false modes may be generated (Beamish and McFarlane, 1987). Fourbeard rocklings spawn from May to October (Battle, 1930; Cohen et al., 1990) and overlap in the length-frequency modes is likely due to this prolonged spawning season.

After the first year, the age-length relationship of fourbeard rocklings was linear. The young grew to an average of 113 mm during the first year, and, on average, grew 24 mm per year to age 9. The relative large size and narrow size range of one-year-old fish may be attributed to the under-representation of smaller fish in the sample size. Fast early growth, like that of *E. cimbrius*, is exhibited by most gadids, and is particularly evident in red hake, *Urophycis chuss*, and white hake, *U. tenuis*. This type of growth is probably advantageous to *U. chuss* and *U. tenuis* and to other small demersal marine fishes that enter habitats dominated by larger individuals (Markle et al., 1982). Arctic cod, *Boreogadus saida*, from Labrador also exhibits growth rates similar to that of *E. cimbrius*. After reaching approximately 90 mm in their first year, *B. saida* average roughly 40 mm per year until age 5; they rarely live beyond age 6 (Lear, 1983).

Table 4

Relative importance of prey items of *E. cimbrius* according to numerical and frequency of occurrence indices. (*n*=36).

Prey taxon	No.	%No.	Frequency	%Frequency
Phylum Mollusca				
Class Bivalvia	183	49.1	26	72.2
Order Protobranchia	183	49.1	26	72.2
Family Nuculanidae				
Yoldia sp.	183	49.1	26	72.2
Phylum Annelida				
Class Polychaeta	6	1.6	6	16.7
Family Phyllodocidae				
Unidentified Phyllodocidae	1	0.3	1	2.8
Paranaitis sp.	2	0.5	2	5.6
Family Nereidae				
Nereis sp.	1	0.3	1	2.8
Unidentified Polychaeta	2	0.5	2	5.6
Phylum Arthropoda				
Subphylum Mandibulata				
Class Crustacea	172	46.1	36	100.0
Order Copepoda	138	36.9	8	22.2
Suborder Calanoida	138	36.9	8	22.2
Subclass Malacostraca				
Series Eumalacostraca				
Superorder Peracarida				
Order Cumacea	13	3.5	9	25.0
Eudorella truncata	1	0.3	1	2.8
Diastylis quadrispinosa	7	1.9	4	11.1
Unidentified Cumacea	5	1.3	4	11.1
Order Isopoda	2	0.5	2	5.6
Unidentified Isopoda	2	0.5	2	14.0
Order Amphipoda	5	1.6	5	13.9
Family Hyperiidea				
Unidentified Hyperiidea	3	0.8	2	5.6
Family Calliopidae				
Calliopius laeviusculus	1	0.3	1	2.8
Family Gammaridae				
Unidentified Gammaridae	2	0.5	2	5.6
Order Mysidacea	1	0.3	1	2.8
Mysidopsis bigelowi	1	0.3	1	2.8
Order Decapoda	12	3.2	11	30.6
Infraorder Caridea				
Family Crangonidae				
Crangon septemspinosa	5	1.3	4	11.1
Family Pandalidae				
Unidentified Pandalidae	1	0.3	1	2.8
Unidentified Decapoda	4	1.1	4	11.1
Infraorder Brachyura				
Unidentified Brachyura	2	0.5	2	5.6
Animal remains	11	2.9	10	27.8
Unidentified vertebrates	1	0.3	1	2.8
Number examined	36			
Number empty	3			

Total length is the most appropriate parameter to set limits around an age class for *E. cimbrius*. For example, a fish with a total length of 165 mm would be approximately 3 or 4 years old. If the weight of this same fish, approximately 15 g, was used to estimate age, the range of this estimated age would increase from 2 to 5 years. Conversely, weight appears to be a better measure of absolute growth than total

Table 5

Relative importance of prey items of 1-year-old (105–121 mm TL) (*n*=5) and 2–7 year old (119–271 mm TL) (*n*=31) *E. cimbrius* based on numerical and frequency of occurrence indices.

	105–121 mm TL				119–271 mm TL			
Prey taxon	No.	%No.	Freq.	%Freq.	No.	%No.	Freq.	%Freq.
Phylum Mollusca								
Class Bivalvia	14	19.2	4	80.0	169	56.3	22	71.0
Order Protobranchia	14	19.2	4	80.0	169	56.3	22	71.0
Family Nuculanidae								
Yoldia sp.	14	19.2	4	80.0	169	56.3	22	71.0
Phylum Annelida								
Class Polychaeta	0	0.0	0	0.0	6	2.0	6	19.4
Family Phyllodocidae								
Unidentified Phyllodocidae	0		0		1	0.3	1	3.2
Paranaitis sp.	0		0		2	0.7	2	6.5
Family Nereidae								
Nereis sp.	0		0		1	0.3	1	3.2
Unidentified Polychaeta	0		0		2	0.7	2	6.5
Phylum Arthropoda								
Subphylum Mandibulata								
Class Crustacea	59	80.7	8	160.0	113	37.7	28	90.3
Order Copepoda	52	71.2	4	80.0	86	28.7	4	12.9
Suborder Calanoida	52	71.2	4	80.0	86	28.7	4	12.9
Subclass Malacostraca								
Series Eumalacostraca								
Superorder Peracarida								
Order Cumacea	4	5.4	2	40.0	9	3.0	7	22.6
Eudorella truncata	0		0		1	0.3	1	3.2
Diastylis quadrispinosa	2	2.7	1	20.0	5	1.7	3	9.7
Unidentified Cumacea	2	2.7	1	20.0	3	1.0	3	9.7
Order Isopoda	0	0.0	0	0.0	2	0.7	2	6.5
Unidentified Isopoda	0		0		2	0.7	2	6.5
Order Amphipoda	2	2.7	1	20.0	4	1.3	4	12.9
Family Hyperiidea								
Unidentified Hyperiidea	2	2.7	1	20.0	1	0.3	1	3.2
Family Calliopidae								
Calliopius laeviusculus	0		0		1	0.3	1	3.2
Family Gammaridae								
Unidentified Gammaridae	0		0		2	0.7	2	6.5
Order Mysidacea	0	0.0	0	0.0	1	0.3	1	3.2
Mysidopsis bigelowi	0		0		1	0.3	1	3.2
Order Decapoda	1	1.4	1	20.0	11	3.7	10	32.3
Infraorder Caridea								
Family Crangonidae								
Crangon septemspinosa	0		0		5	1.7	4	12.9
Family Pandalidae								
Unidentified Pandalidae	0		0		1	0.3	1	3.2
Unidentified Decapoda	1	1.4	1	20.0	3	1.0	3	9.7
Infraorder Brachyura								
Unidentified Brachyura	0		0		2	0.7	2	6.5
Animal remains	0	0.0	0	0.0	11	3.7	10	32.5
Unidentified vertebrate	0	0.0	0	0.0	1	0.3	1	3.2
Number examined	5				31			
Number empty	0				3			

length. The weight of fish between 300 mm and 325 mm TL ranged widely from 80 g to 160 g. After linear growth has slowed, fish still continue to gain weight.

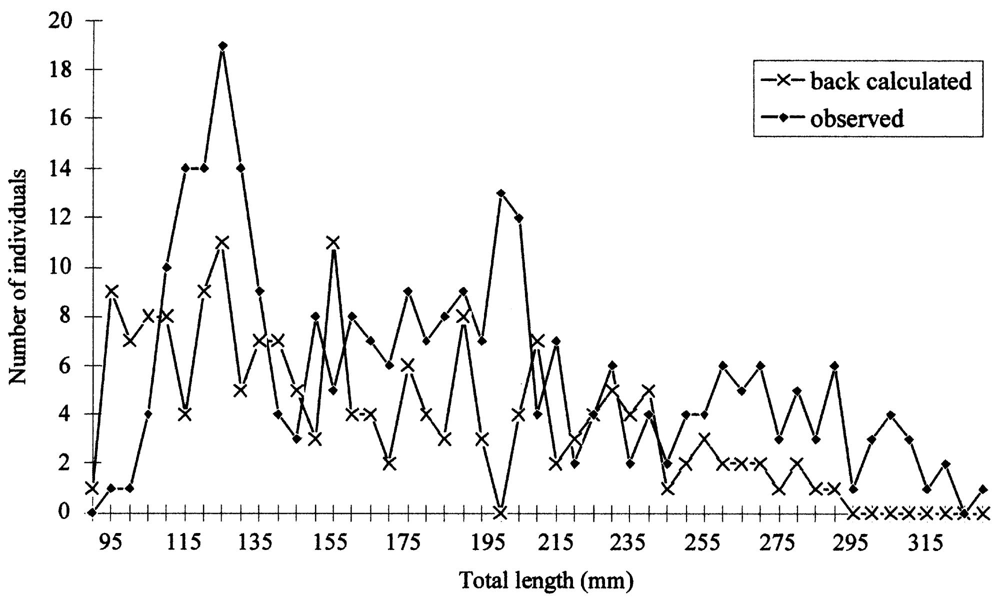

Figure 7

Length-frequency distribution of back-calculated lengths at age vs. observed lengths at age of *E. cimbrius* collected during the GM 93-20 survey between 2 August and 13 August 1993 plotted in groups of 5.

The dietary habits of *E. cimbrius* may contribute to its constant absolute growth. Fourbeard rocklings generally forage on small animals in large numbers instead of large animals in small numbers. Fishes that swim actively and forage for small organisms (i.e. "grazers") generally have a higher unit of energy expenditure per unit of energy input than do fishes that are lie-and-wait predators on large organisms. In addition, preference for cold temperatures may explain further why *E. cimbrius* exhibits constant linear growth. I speculate that *E. cimbrius* uses its energy to forage; energy that would otherwise have contributed to absolute growth.

Table 6

Prevalence (P), abundance (A), standard error (SE), and intensity (I) of Raphidascaridinae sp., *Grillotia erinaceus*, *Genolinea laticauda*, and *Gonocerca phycidis* in *E. cimbrius* collected during the GM 93-20 and GM 94-12 surveys.

Parasite	*n*	P (%)	A ± SE	I range
Raphidascaridinae sp.	34	23.0	1.69 ± 1.24	1–32
Grillotia erinaceus	31	20.9	1.65 ± 0.25	1–8
Genolinea laticauda	7	4.7	4.33 ± 0.96	1–7
Gonocerca phycidis	1	1.4	2.00 ± 0.00	2

Dietary habits

Prey items of *E. cimbrius* surveyed in this study were predominately bivalves, particularly *Yoldia* sp., in both number and frequency. Calanoid copepods, although present in great numbers, were consumed by few individuals. The importance of copepods is replaced by bivalves, *Yoldia* sp., and polychaetes in the diet of larger fish (>119 mm TL). After their first year, fish shift from a diet dominated by planktonic copepods to a diet comprising infauna (bivalves and polychaetes).

Calanoid copepods composed the majority (71.2%) of the prey taken, with bivalves (although consumed in relatively high frequency (80.0%)) second in importance by number (19.2%) in 1-year-old fish. Juveniles in the present study exhibited feeding preferences for various calanoid copepods similar to those of pelagic larval gadids off the Isle of Man (Nagabhushanam, 1965.) This preference for planktonic organisms suggests that juveniles lead a less sedentary existence and feed more frequently in the water column than do adults. In addition, the selection for smaller prey is directly related to mouth size (Moyle and Cech, 1988).

On Georges Bank, fourbeard rocklings >100 mm TL consumed motile epifauna, particularly *Crangon septemspinosa* (46.3%), in the highest percentage by

Table 7

Prevalence of infection (P%) and abundance (A) of four species of helminths in age-class ranges from *E. cimbrius* collected during the GM 93-20 and GM 94-12 surveys. (n=148).

		Raphidascaridinae sp.		*G. erinaceus*		*G. laticauda*		*G. phycidis*	
Age class	*n*	P(%)	A	P(%)	A	P(%)	A	P(%)	A
1	12	8.3	0.1	16.7	0.2	0.0	0.0	0.0	0.0
2	11	9.1	0.5	9.1	0.2	9.1	0.2	9.1	0.2
3	20	20.0	0.3	25.0	0.3	0.0	0.0	0.0	0.0
4	51	21.6	1.3	17.6	0.2	5.9	0.2	0.0	0.0
5	27	26.0	2.3	14.8	0.4	3.7	0.2	0.0	0.0
6	15	26.7	1.9	20.0	0.4	6.7	0.5	0.0	0.0
7	8	37.5	1.5	37.5	0.4	0.0	0.0	0.0	0.0
8	2	50.0	1.0	100.0	1.5	0.0	0.0	0.0	0.0
9	2	100.0	2.5	100.0	2.5	0.0	0.0	0.0	0.0

weight followed by animal remains (30.1%) and infauna, primarily polychaetes (13.6%) (Langton and Bowman, 1980). Decapod crustaceans were not as important as these other groups to juvenile fish in the present study. Decapods appeared in number for the first time in 2- to 7-year-old fish. This can be explained by the preference for larger prey by older, larger fish.

In a Norwegian fjord, *E. cimbrius* between 70 and 300 mm TL preyed primarily on crustaceans, polychaetes, fish, bivalves and rarely on copepods (Mattson, 1981). In adult rocklings, high percentages of infauna, particularly polychaetes, have been reported from the North Sea (Moller-Buchner et al., 1984) and Passamaquoddy Bay, where the frequency was found to be correlated with an increase in fish size (Keats and Steel, 1990). The high frequency of infaunal organisms, predominantly bivalves, in the diet of 2- to 7-year-old fish in the present study exhibits a similar trend. This finding may be correlated with adults having a sedentary existence and remaining in close contact with the substrate (Bigelow and Schroeder, 1953; Cohen et al., 1990). This lifestyle, compounded with the fact that this species has well-developed stout barbels equipped with taste buds (Nagabhushanam, 1965), would enable larger fish to feed more effectively on epifauna and infauna.

E. cimbrius is best characterized as a euryphagous bottom-rover or "grazer." (Moyle and Cech, 1988). The size of the prey appears to be directly correlated with the size of the predator as seen in the change in diet from 1-year-old fish to those 2 to 7 years of age.

Parasitism

The parasite fauna of *E. cimbrius* consisted of three taxa and four species: Nematoda (1), Cestoda (1), and Trematoda (2). The prevalence (P%) and abundance (A) of a nematode from the subfamily Raphidascaridinae (probably *Hysterothylacium*) and a trypanorhynch cestode, *G. erinaceus*, appear to increase with fish age. The P% and A of both digenetic trematodes were low in all age classes.

The few helminths found were in low abundance. This is uncommon because other gadids are known to have abundant and diverse parasite faunas (Margolis and Arthur, 1979). The very low parasite diversity of *E. cimbrius* supports evidence of limited movements and benthic feeding preferences in its habitat.

All nematode specimens of the subfamily Raphidascaridinae were second- or third-stage and third- or fourth-stage larvae (Measures[1]). The presence of parasites in the same stage of development are indicative of a "grazer" (Dogiel, 1966) and provides additional support to characterize *E. cimbrius* as such. A similar trend is seen in *G. morhua*, where its mode of life, generalist feeding habits, and association with the bottom facilitate the infestation by *Raphidascaridinae* spp. (Dogiel et al., 1970).

The increase in prevalence of *Grillotia erinaceus* from 9.1% at 2 years to 25.0% at 3 years appears to be correlated with the an increase of arthropods in the diet. In the life cycle of *G. erinaceus*, the plerocercus larvae can be acquired by an intermediate teleost host through consumption of arthropods, mainly copepods, which have previously ingested the tapeworm eggs (Sakanari and Moser, 1985). It is not possible to draw any firm conclusions on this relationship because food habit data in this study did

[1] Measures, L. 1995. Maurice Lamontagne Institute, Fisheries and Oceans, Mont-Joli (Quebec), Canada G5H 3Z4. Personal commun.

not account for seasonal variation and because the sample size of 8- and 9-year-old fish was low.

The definitive hosts of adult trypanorhynchs are elasmobranchs, suggesting that fourbeard rocklings are consumed by elasmobranchs or act as paratenic hosts. It is likely that barndoor skate, *Raja laevis*, and thorny skate, *Raja radiata*, prey upon *E. cimbrius*. *Raja laevis* and *R. radiata* >700 mm TL forage primarily on fish that include hake, *Urophycis* spp., and whiting, *Merluccius* spp., and may also feed on cod and haddock (Bigelow and Schroeder, 1953; McEachran et al., 1976). Because both *Raja* spp. consume fishes with similar habits and are definitive hosts for *G. erinaceus* (Margolis and Arthur, 1979), it is probable that *R. laevis* and *R. radiata* prey upon *E. cimbrius*.

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