

SPATIAL AND TROPHIC ECOLOGY OF THE SAWTOOTH EEL, *SERRIVOMER*
BEANII, A BIOMASS-DOMINANT BATHYPELAGIC FISH OVER THE
NORTHERN MID-ATLANTIC RIDGE

by

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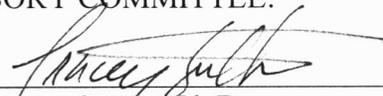
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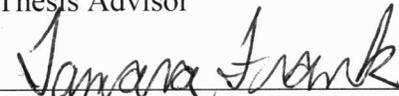
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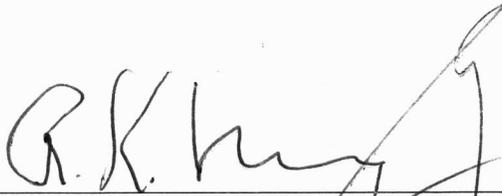
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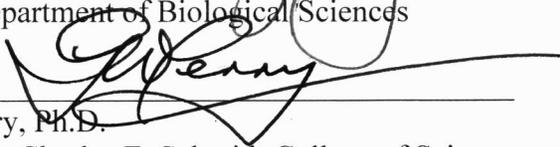
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ABSTRACT

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The role of *Serrivomer beanii* in bathypelagic food webs is poorly known, but abundance and biomass estimates from the 2004 *G.O. Sars* MAR-ECO Expedition suggest it to have a high level of importance. MAR-ECO, a Census of Marine Life field project, has allowed us to increase our knowledge of *S. beanii* through spatial analysis, including the congeneric species *Serrivomer lanceolatooides*, and trophic analysis. *Serrivomer beanii* abundance and biomass exhibited a decreasing trend along the northern Mid-Atlantic Ridge from north to south. In terms of size, *S. beanii* was found to increase as distance from the ridge decreased, suggesting a topographic aggregation strategy. The diet of *S. beanii* consisted of crustaceans, cephalopods, and teleosts. The trophic results of this study reveal a likely “alternative” trophic pathway in the deep mid-North Atlantic, and perhaps other, bathypelagic ecosystems: higher trophic-level predators are supported by micronektonic invertebrates as primary prey.

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1. INTRODUCTION

The majority of the area World Ocean seafloor (88%) lies in waters deeper than 1 km, while depths ranging from 3 to 6 km constitute 76%. Covering approximately 62% of the Earth's total surface area, deepwater habitats (> 1 km) are therefore the planet's largest ecosystems. The pelagic oceanic ecosystem is divided into four main depth zones: epipelagic (< 200 m), mesopelagic (200-1000 m), bathypelagic (1000-4000 m), and abyssopelagic (> 4000 m) (Herring, 2002). The latter three zones, or 'deep-pelagic' zone (Sutton et al., 2008) represents 92% of the Earth's volume (Haedrich, 1997).

The mid-ocean ridge (MOR) system is a conspicuous component of the deep-sea environment. A MOR is the point at which the deep-sea floor forms through volcanic activity, and spreads outward (Marshall, 1979). In 1954, it was discovered that the MOR system extends throughout the Earth's oceans (Spencer, 1977), stretching across the ocean floor for 50,000 km. The width of the ridge ranges from 100 to 4000 km, which makes up one-third of the ocean floor (Marshall, 1979). One particular area of interest, the Mid-Atlantic Ridge, is becoming increasingly studied through the Census of Marine Life (www.coml.org) field project, MAR-ECO (www.mar-eco.no). The Mid-Atlantic Ridge is a portion of the MOR that runs along the center of the North and South Atlantic Ocean extending into the Arctic Ocean. It constitutes 32.3% of the Atlantic Ocean's sea floor, demonstrating its importance as a deep-sea habitat (Heirtzler, 1982).

The purpose of the MAR-ECO project is to investigate the occurrence, distribution and ecology of animal populations along the northern Mid-Atlantic Ridge

(MAR) between Iceland and the Azores (Bergstad and Godø, 2003). One fish species that inhabits the deep-sea waters of the northern MAR is the sawtooth eel (Figure 1), *Serrivomer beanii* Gill and Ryder 1883 (Anguilliformes: Serrivomeridae). *Serrivomer beanii* was selected for this study because preliminary studies have shown that it is a dominant species with regard to abundance and biomass over the northern MAR (Sutton et al., 2008), and thus of high potential importance in bathypelagic food webs.

Currently, the genus *Serrivomer* includes nine species. *Serrivomer beanii* is found in the Atlantic, Pacific, and Indian Oceans (Nelson, 2006), inhabiting both meso- and bathypelagic depths, mainly between 500 to 1000 m (Smith, 2002). There are three major characteristics that separate *S. beanii* from other North Atlantic serrivomerids: mode of branchiostegal attachment to the hyoid arches, enlarged vomerine teeth, and ray counts of the dorsal and anal fins. Coloration is dark brown to black, with the presence of an iridescent silvery epidermal layer (Tighe, 1989). The body of *S. beanii* is slender, tapering gradually to the tail. The dorsal and anal fins originate posterior to the anus, while the anus originates anterior to midlength. The maximum recorded length is 780 mm total length (TL) (Castle, 1986). *Serrivomer beanii* has maxillary (two to four rows), mandibular (three to five rows), and vomerine teeth (two alternating rows, laterally compressed) (Gill and Ryder, 1883). *Serrivomer beanii* experiences a pre-reproductive metamorphosis between the juvenile and adult stages, during which vomerine teeth become grouped in sections of four to six teeth, while maxillary and mandibular teeth are both reduced to a single row. The eyes of *S. beanii* also become enlarged. Sexual dimorphism occurs as well, in which the male premaxillary projection reduces from its

original length, resulting in a foreshortened snout. Also, a longer, more laterally compressed caudal region is found in males (Gill and Ryder, 1883).

1.1. Distribution Studies

In the Atlantic Ocean, *Serrivomer beanii* is found between 60°N and 20°S (Saldanha and Karmovskaya, 1990), and ranges further north and south in the eastern Atlantic (Castle, 1986; Jonsson, 1992). The current distributional study also included *Serrivomer lanceolatooides*, which is found in the North Atlantic and the Gulf of Mexico between approximately 40°N and 0° (Tighe, 1975). Both species inhabit the waters along the MAR. In the current study, the geographic and vertical distributions of *S. beanii* and *S. lanceolatooides* along the northern MAR were examined to better clarify distributions in this region as well as understand the influences of both the MAR and the hydrography of the North Atlantic on these populations.

The Mid-Atlantic Ridge is a major topographic feature and the species inhabiting the water column above this feature remain understudied (Hosia et al., 2008). This highly heterogeneous environment varies in depth, due to numerous seamounts and deep valleys along the MAR. This could have an important influence on the distribution of species (Gaard et al., 2008). Another feature of the MAR that could affect animal distribution is the Sub-Polar Front (SPF). The North Atlantic Current (NAC) crosses the MAR (45°N to 52°N; Sy et al., 1992), forming the SPF. The SPF is the boundary, north of the Azores, between the cool, less-saline waters of the Subpolar Gyre and the warm, saline waters of the Subtropical Gyre (Rossby, 1999). It has been suggested that the topographic features of the MAR improve biological productivity compared to the

adjacent ocean basins. This could be due to local upwelling, caused by the topographic features affecting the currents (Fossen et al., 2008).

1.2. Feeding Studies

A key aspect of feeding is variability in prey selection. Variability can be categorized as: generalist, specialist, or opportunist. Specialized predators feed on a narrow range of prey, while opportunists feed on food sources outside of their normal diet, taking advantage of infrequently encountered but occasionally abundant prey (Gage and Tyler, 1991). *Serrivomer beanii* consumes prawns, euphausiids, amphipods, and fishes, including *Cyclothone* and myctophids (Beebe and Crane, 1936; Bauchot, 1986) and would therefore be categorized as a generalist. In the study of Beebe and Crane (1936), *Serrivomer lanceolatooides* was suggested to consume primarily shrimp and euphausiids.

Many large predators that feed on large prey items have a decreased feeding rate, because larger prey items take a longer period to digest (Gartner et al., 1997). *Serrivomer beanii* may consume prey items large enough that the digestion period may be longer than 24 hours. A digestion period of longer than 24 hours would mask diel patterns in feeding. In the current study we utilized a large sample set collected using large, commercial-sized trawling gear during two international studies to understand the distribution and ecology of this key bathypelagic predator, *S. beanii*, as well as the distribution of the congeneric species *S. lanceolatooides*.

2. OBJECTIVES

The overall aim of this study was to increase our knowledge of the spatial and trophic ecology of *Serrivomer beanii* (Serrivomeridae), a dominant deep-pelagic fish over the northern MAR. The spatial ecology of the congeneric species *S. lanceolatoides* was also examined throughout this study. Abundance and biomass estimates were analyzed to determine distribution, and gut contents were examined in order to quantify feeding. Study questions included: 1) Do variations in abundance and biomass of *S. beanii* or *S. lanceolatoides* occur along the MAR from Iceland to the Azores, with respect to ridge region, depth, and height above the ridge? 2) Does *S. beanii* or *S. lanceolatoides* exhibit size differences with respect to ridge region, depth, and height above the ridge? 3) What is the prey spectrum of *S. beanii*? and 4) How much does *S. beanii* eat in terms of abundance and biomass?

3. MATERIALS AND METHODS

Serrivomer beanii samples were collected during the 2003 Icelandic REDFISH/MAR-ECO Cruise (R/V *Árni Fridriksson*; 04-30 June, Sutton and Sigurðsson, 2008) and the 2004 *G.O. Sars* MAR-ECO Expedition (05 June – 03 July, Wenneck et al., 2008). *Serrivomer lanceolatooides* samples were collected only during the 2004 *G.O. Sars* MAR-ECO Expedition. The 2003 Icelandic cruise covered the Reykjanes Ridge region of the northern MAR (Figure 2) as part of a biannual survey of the deepwater redfish, *Sebastes mentella*, which supports an important fishery (Sigurðsson et al., 2006). The 2004 *G.O. Sars* MAR-ECO Expedition began in Norway and sampled the area between Iceland and the Azores, at depth ranges from 0-4000 m (Wenneck et al., 2008; Figure 3).

Fish collection data from the 2003 Icelandic cruise will be presented here for the first time. The 2004 expedition found *S. beanii* to be a numerical and biomass dominant fish over the MAR, particularly within the benthic boundary layer (bottom 200 m) near the ridge itself (Sutton et al., 2008).

3.1. Trawl Sampling

During the 2003 cruise a Gloria-type midwater trawl was used to sample pelagic cephalopods, large zooplankton, and fishes, including *S. beanii* (Sigurðsson and Gislason, 2003). The trawl opening was 46 × 46 m, with a 9-mm mesh cod-end. The trawl was not equipped with an opening-closing device, so vertical distributions could not be

determined accurately using these data. Samples from this expedition were used primarily for trophic studies.

The 2004 expedition collected 114 discrete-depth samples from the northern MAR (Table 1). Throughout the 2004 expedition two different midwater trawls were used, an “Åkra” trawl and a krill trawl. The larger “Åkra” trawl, a commercial-sized net with a 20-35-m vertical opening, a 110-m door spread and a cod-end of 22-mm mesh, was used to sample deep-pelagic fishes, including *S. beanii* and *S. lanceolatooides* (Sutton et al., 2008). The smaller krill trawl had a $6 \times 6 \text{ m}^2$ mouth opening, with a $3 \times 3 \text{ mm}$ (6 mm stretched) diamond-shaped mesh from the front of the net to the codend and a total trawl length of 45 m (Wenneck et al., 2008). A modified version of each trawl was used for this expedition, equipped with a multisampler (Norwegian opening/closing device), which allowed each tow to collect samples consecutively from three (Åkra trawl) to five (krill trawl) discrete depth strata with the use of remotely operated multiple collection bucket codends (Wenneck et al., 2008). Sampling with either trawl was conducted within five depth ranges: 0-200 m, 200-750 m, 750-1500 m, 1500-2300 m, and >2300 m. Samples were further categorized by the time of day at which they were collected: daytime (D), dusk (DN), night (N), and dawn (ND) (Sutton et al., 2008).

3.2. Sample Handling

All fishes from trawl samples from the 2003 cruise were identified to species onboard, and a subset weighed and measured. Samples were then either frozen in seawater or preserved in formalin. Trawl samples of the 2004 expedition were first sorted by depth, then by major taxonomic group. Sorting continued until species was

determined. Samples were then either frozen in seawater or preserved in formalin. (Sutton et al., 2008)

3.3. Spatial Analysis

The abundance and distribution of *S. beanii* and *S. lanceolatooides* throughout the 2004 *G.O. Sars* MAR-ECO Expedition were determined with respect to ridge region, depth, and height above the ridge. Geographically the MAR was divided into four ridge regions: Reykjanes Ridge (RR), Charlie-Gibbs Fracture Zone (CGFZ), Faraday Seamount Zone (FSZ), and Azorean Zone (AZ) (Sutton et al., 2008). The RR was the shallowest region with an average bottom depth, at trawl locations, of 1880 m. The CGFZ and Sub-Polar Front, which overlap, are of interest geographically due to the convergence of cool, less-saline waters with warm, saline waters. The FSZ, containing various seamounts, was the deepest region with an average bottom depth, where trawls took place, of 3341 m. The final region containing the Azorean islands, AZ, was the southernmost region with an average bottom depth, at trawl locations, of 2527 m. Hydrological details of the 2004 expedition can be found in Søiland et al. (2008).

Abundance and biomass of *S. beanii* and *S. lanceolatooides* were first examined with respect to the four ridge regions, with each trawl's fish catch plotted by depth. Most sampling during the 2004 *G.O. Sars* Expedition was conducted during the day. Only day trawls were used when comparing abundance and biomass by depth zone throughout the four ridge regions. By using strictly day trawls, it was possible to determine variations in depth distributions throughout the four ridge regions. The abundance and biomass of both species were then plotted vs. height (m) above the ridge. Spatial ranges were further

examined to determine distribution trends with respect to time of day and size. Abundance data were provided from “Åkra” and krill trawls and biomass data were provided from the krill trawl. Due to the variation in mesh size of the “Åkra” trawl’s net, the volume of water filtered per trawl was difficult to determine. Biomass data are based on volume of water filtered; and therefore, samples collected with the “Åkra” trawl could not be used. In order to integrate abundance data from the two trawl types, the “Åkra” trawl catches were standardized according to catchability and unit effort (trawl distance), using the krill trawl as the reference trawl (Sutton et al., 2008). The catchability coefficient was defined as the ratio of “Åkra” trawl catch numbers to those of the krill trawl. Separate catchability coefficients were calculated for each fish taxon (Heino et al., submitted). Then “Åkra” trawl results were divided by the appropriate catchability coefficient, forming an integrated station×species matrix for both trawls (Sutton et al., 2008).

Length and weight measurements of dissected *S. beanii* specimens were plotted to determine size distribution for the species. Trawl stations were numbered evenly between 2 to 36 (Figure 3), and pre-anal lengths (AL) and wet weights (WW) for *S. beanii* were plotted vs. ridge region by station number. AL and WW were also plotted vs. depth. *Serrivomer lanceolatooides* specimens were not dissected; therefore, they were not included in this analysis.

Statistical tests included analysis of variance (ANOVA) and Student-Newman-Keuls. ANOVA tests were used to determine if there was a significant difference in abundance, biomass, or size across the four ridge regions, the five depth zones, and the time of day. The four ridge regions were further analyzed by the Student-Newman-Keuls

test to determine if each ridge region was significantly different from the other three, in terms of abundance, biomass, and size. The Student-Newman-Keuls test was also used to determine if each depth zone was significantly different from the other four, in terms of size.

3.4. Trophic Analysis: Dissection Process

A total of 300 *Serrivomer beanii* specimens were dissected for gut content analysis (Table 2). Each eel was measured for total length (TL) and pre-anal length (AL) to the nearest mm. TL was defined as the distance from the tip of the lower jaw to the end of the caudal filament. AL was defined as the distance from the posterior orbit of the eye to the anus; this measurement was used primarily due to its higher level of accuracy, as trawl damage often resulted in broken jaws and/or tails. After measurements were taken the specimen was weighed to the nearest 0.01 g.

An incision was made at the isthmus, the boundary between the mouth cavity and the pharynx, with 10-mm effective cutting edge scissors. The incision was continued along the ventral surface of the body until the entire body cavity, including gonads, was exposed. The esophagus was then severed and the rectum disconnected using forceps. Internal organs were placed in a large Petri dish, separated, and stomachs and gonads were placed in individual vials containing 70% ethanol.

Stomachs were dissected by gently tearing apart the posterior end using micro-dissection forceps. Food items were removed and either placed in individual vials of 70% ethanol or on a slide containing a drop of glycerol:water mixture. Vial or slide placement was chosen based on size and level of digestion. The same process was

undertaken with intestinal contents. The majority of intestine food items were placed on slides due to the higher degree of digestion. All vials and slides were labeled with the station, specimen number, and organ. Identifier labels were placed in the jaws of dissected specimens. Dissected eels were then placed into jars of 70% ethanol by station.

3.5. Trophic Analysis: Gut Contents

Each stomach was ranked based on stomach fullness. The following scale was used: zero = empty, one = stomach 1/4 full, two = stomach 1/2 full, three = stomach 3/4 full, four = stomach full, five = stomach full and stretched. Once stomach contents of each specimen were removed, prey were identified through detailed microscopic analysis. Well-digested prey were identified using an anatomical reference collection for diagnostic “hard parts” (e.g., bones, ommatidia, mandibles, and uropods) of potential prey species. Prey items were also ranked based on degree of digestion. The following scale was used: one = no digestion (fresh), two = partially digested, three = well digested, four = digestion nearly complete. Prey items located in the mouth cavity were not included in the trophic analysis.

In order to calculate feeding ration, length/weight regressions were computed to estimate biomass for crustacean (euphausiids, carideans, sergestids, and mysidaceans) prey items (Table 3). Uropod (UL), mandible (ML), and carapace lengths (CL) were plotted against total length (TL) and wet weight (WW) of the specimen. Measurements and weights were recorded in millimeters and grams, respectively. Measurements were made using the computer image analysis software NIS-Elements BR 3.00. Caridean and mysidacean TLs were measured manually, due to their larger size. The lack of reliable

hard part measurements for cephalopod and teleost prey prevented regression analyses for these dietary items.

Wet weights of whole crustacean and cephalopod prey items were determined using an OHAUS Adventurer Pro digital microbalance. Items were blotted dry with a paper towel and weighed every five minutes until constant weight was observed (cephalopods, euphausiids and sergestids ± 0.01 g; carideans and mysidaceans ± 0.02 g). In cases where prey items could not be weighed, the smallest WW determined for that prey taxon was substituted. By substituting the lowest WW for a prey item, the possibility of overestimating total biomass intake of *S. beanii* was reduced. For crustaceans, if a prey item was partially identified (e.g. caridean or sergestid) the smaller biomass value of the two, determined from the prey items collected in the gut content of *S. beanii*, (e.g. sergestid) was used for analysis involving regressions. Prey items identified as cephalopods or teleosts, but unidentifiable beyond major prey taxon, were unaccounted for in biomass totals. Leaving out the unidentifiable prey items also underestimated total biomass intake of *S. beanii*. Total prey item biomass was divided by the biomass of *S. beanii* specimens containing prey items to estimate the minimum average meal size, expressed as % predator weight.

4. RESULTS

4.1. Spatial Analysis

Abundance distribution of *Serrivomer beanii* and *S. lanceolatooides* with respect to ridge region, i.e. Reykjanes Ridge (RR), Charlie-Gibbs Fracture Zone (CGFZ), Faraday Seamount Zone (FSZ), and Azorean Zone (AZ), is shown in Figure 4. *Serrivomer beanii* was present in each region, but exhibited a six-fold decrease in total abundance from the northernmost zone (RR: 24.98 ind. 10^{-6} m^{-3}) to the southernmost zone (AZ: 3.95 ind. 10^{-6} m^{-3}) (ANOVA, $P < 0.01$). The Student-Newman-Keuls test determined that the RR, CGFZ, and FSZ were not significantly different from each other, and the FSZ and AZ were not significantly different from each other (Student-Newman-Keuls, $P > 0.05$). However, *Serrivomer beanii* abundance in the RR and CGFZ were found to be significantly higher than in the AZ (Student-Newman-Keuls, $P < 0.05$). *Serrivomer lanceolatooides* was only collected in the AZ, at low abundances (2.66 ind. 10^{-6} m^{-3}).

Biomass distributions of *S. beanii* and *S. lanceolatooides* were then examined along the northern MAR. Biomass was plotted similar to abundance distribution to determine variations in size. The biomass of *S. beanii* represented 18.2% of the total biomass of all fishes collected during the 2004 *G.O. Sars* Expedition, from the surface to 3000+ m. Biomass distributions of *S. beanii* and *S. lanceolatooides* were determined for the four ridge regions (Figure 5). The biomass of *S. beanii* from northern to southern regions decreased by half from each ridge region to the next, however an ANOVA test

determined that this decrease was not statistically significant ($P = 0.195$). *Serrivomer lanceolatooides* had a slightly lower biomass than *S. beanii* in the AZ.

Abundance and biomass distribution of *Serrivomer beanii* and *S. lanceolatooides* with respect to ridge region by depth zone, i.e. Depth Zone 1 (0-200 m), Depth Zone 2 (200-750 m), Depth Zone 3 (750-1500 m), Depth Zone 4 (1500-2300 m), and Depth Zone 5 (>2300 m), was examined (Figure 6). Abundances were highest in the RR between 750-1500 m. Due to a small sample size, it was not possible to determine if the abundance was significantly higher in this depth zone compared to the other depth zones. *Serrivomer beanii* abundances in the CGFZ shifted upward, becoming evenly distributed from 0-1500 m. Following the upward shift, abundances gradually shifted downward through the FSZ, and the AZ. *Serrivomer lanceolatooides* abundance in the AZ (Figure 7) was maximal from 200-1500 m, overlapping with *S. beanii* from 750-2300 m.

Biomass analysis for *S. beanii* by depth zone (Figure 8) revealed similar patterns to the abundance analysis, with one exception. In the CGFZ, abundance was distributed through depths from 0-1500 m, but the majority of biomass was distributed from 0-200 m and 750-1500 m. The majority of *S. lanceolatooides* biomass, in the AZ, was distributed from 200-750 m (Figure 9). The only overlap with *S. beanii* occurred between 750-2300 m. *Serrivomer beanii* and *S. lanceolatooides* were the dominant (> 50%) contributors to total fish biomass in several samples taken during the 2004 *G.O. Sars* Expedition (Table 4). Bauchot (1986) suggested that *S. beanii* vertically migrates on a diel basis. The high percentage biomass of *S. beanii* in the CGFZ from 0-200 m during the day suggested that downward diurnal vertical migration may not occur on a diel basis. Due to sample size, it was not possible to determine if the biomass in the CGFZ was significantly shallower

compared to the RR, FSZ, and AZ. In the AZ from 200-750 m, the high percentage biomass of *Serrivomer lanceolatooides* was from a single specimen.

Abundances of *S. beanii* and *S. lanceolatooides* did not vary directly as a function of height above the ridge, as high catches were taken at various levels throughout the water column (Figure 10). With respect to biomass, however, the highest values of *S. beanii* were within ~350 m of the ridge, though not all samples within ~350 m exhibited high biomass (Figure 11). *Serrivomer lanceolatooides* biomass distribution did not exhibit the same relationship (Figure 12).

Length and weight measurements of dissected *S. beanii* specimens were used to further evaluate size distribution by ridge region and depth. First, individual *S. beanii* pre-anal length (AL) and weight were examined as a function of ridge region (Figures 13, 14). Individual AL of fishes taken over the RR, CGFZ, and AZ were not significantly different from each other (Student-Newman-Keuls, $P > 0.05$), but the AL of specimens collected over the FSZ was significantly less than that of the other three ridge regions ($P < 0.05$). Individual weights of fish collected over the FSZ were not significantly different from those collected over the RR (Student-Newman-Keuls, $P > 0.05$), but were significantly less than those collected over the CGFZ and AZ ($P < 0.05$). When AL was plotted against depth (Figure 15) the length of *S. beanii* specimens increased with depth (ANOVA: $P < 0.01$), with fish collected between 200-750 m being significantly shorter than fish collected below 750 m (Student-Newman-Keuls, $P < 0.05$). Individual weights of *S. beanii* exhibited a similar increase as depth increased (Figure 16).

4.2. Trophic Analysis

Of the 300 *S. beanii* specimens dissected for trophic analysis, two had stomachs that were split open inside the body cavity, and were therefore not included. Of the remaining 298 specimens analyzed, 82 (27.5%) contained prey items in the stomach. Of the stomachs containing prey, 67 contained a single prey item, 14 contained two prey items, and one contained three items. Stomach fullness, on the scale 0 = empty to 5 = full and stretched, of the 298 specimens is shown in Figure 17. The majority of specimens containing prey items had a stomach fullness ranking between 1 and 3. Prey items found in the stomach were also ranked by degree of digestion (Figure 18). The majority of prey items were either well or nearly completely digested (stages 3 and 4, respectively).

A wide range of prey selection was apparent from gut (stomachs and intestines) content analysis (Table 5). Major prey taxa included crustaceans, cephalopods, and teleosts (Figure 19). Crustaceans made up approximately half of the prey numbers of *S. beanii*, followed by cephalopods, and then teleosts. The category “trace” was used for unidentifiable prey items. The majority of crustacean prey items were placed within the “trace euphausiid/decapod/mysid” category (Figure 20A). Decapods contributed 30% of the crustacean diet, followed by euphausiids (25%). Based on comparisons of euphausiid, caridean, sergestid, and mysid mandibles collected from the NOAA ship *Delaware II* in mid-May 2004 (Figure 21), the “benthic decapods” (Table 5) are likely to be benthic or benthopelagic carideans (Figure 22). The majority of cephalopods were digested beyond species recognition (Figure 20B), but less-digested cephalopods were determined to be of the genus *Gonatus* or *Mastigoteuthis* (Michael Vecchione, pers. examination). All of the cephalopod prey that could be determined to species (9.8%) were identified as *Gonatus steenstrupii*. Identified teleost prey (Figure 20C) included

Chiasmodon sp., *Cyclothone* sp., and an unidentified melamphaid. The remaining 78.6% of fish prey were unidentifiable.

Biomass estimates of crustacean, cephalopod, and teleost prey are presented in Table 5. Length/weight regressions were used to determine total length (TL) and biomass (wet weight, WW) of the 13 crustacean prey items (Table 6) that contained hard parts (uropod, mandible, or carapace) that could be measured accurately. No entire crustacean specimen was found among gut contents. Total biomass of crustaceans should be considered minimum estimates, as specimens that could not be measured were assigned the smallest WW value calculated for that prey taxon. Likewise, all prey items in the “trace euphausiid/decapod/mysid” category were given the smallest calculated WW of euphausiids, given that euphausiids have the smallest biomass within this group. Total biomass for crustacean prey was 18.73 g WW, representing 59.9% of the diet of *S. beanii*. Cephalopods represented 41 of the 123 total prey items. Of this 41, an entire *Gonatus steenstrupii* specimen was found three times. Total biomass of cephalopods in the diet of *S. beanii* was determined from the three *Gonatus steenstrupii* specimens, also likely underestimating total cephalopod biomass. These three specimens contributed 10.66 g WW of total cephalopod prey biomass, or 34.3% of the diet of *S. beanii*. Teleosts contributed 14 of the 123 total prey items. Three prey items were identified at least to family: Melamphaidae, *Cyclothone* sp., and *Chiasmodon* sp. The smallest measured WW for these three taxa from specimens obtained during the 2004 *G.O. Sars* Expedition was substituted for each prey taxon (*Scopelogadus beanii* for the Melamphaidae, *Cyclothone microdon* for *Cyclothone* sp., and *Chiasmodon niger* for *Chiasmodon* sp.; MAR-ECO biotic database, unpubl.), representing the total biomass of

teleost prey. The total teleost biomass of 1.8 g WW was surely underestimated, as the remaining 11 unidentified teleost prey items were not included. Teleosts contributed 5.8% of the prey biomass of *S. beanii*. Total prey biomass from the diet of the 298 dissected *S. beanii* was 31.23 g WW. The total biomass of *S. beanii* specimens containing prey items was 3134.14 g WW. Thus, the minimum average meal size of *S. beanii* was approximately 1% of the predator weight.

5. DISCUSSION

5.1. Spatial Distribution

Serrivomer beanii occurred throughout each of the four subregions of the northern Mid-Atlantic Ridge. Abundance exhibited a decreasing trend from north to south, evidenced by statistical analysis indicating significantly fewer *S. beanii* in the Azorean Zone compared to the Reykjanes Ridge region. Although a similar trend in biomass was apparent, the differences were not statistically significant. This may be due to a smaller sample size used in biomass determination, as biomass estimates were based on krill trawls samples only, while abundance came from both “Åkra” and krill trawl samples. *Serrivomer lanceolatooides* was only sampled in the AZ, with slightly lower abundance and biomass than *S. beanii* in that region. The decline exhibited by *S. beanii* along the northern MAR, followed by the appearance of *S. lanceolatooides* in the southernmost region may suggest a shift from a northern species to a southern species. Further sampling of the MAR, south of the Azorean Zone, must be completed to accurately determine a species shift.

Depth vertical distribution of both species varied as a function of ridge region. The majority of the numbers and biomass of *S. beanii* in the RR was distributed between 750-1500 m, throughout dawn, day, dusk and night trawls. In the CGFZ abundance and biomass were shifted upwards during daylight, with even distribution between the 0-200, 200-750 and 750-1500 m depth zones. Biomass, however, was minimal between 750-1500 m. This was apparently related to size; larger individuals were sampled above and

below the 200-750 m layer, while smaller individuals were sampled within this layer. It should be noted that the abundance and biomass of *S. beanii* in the CGFZ were based on daylight trawls only, as these stations were not occupied during nighttime. This temporal variation in sampling across the ridge regions precludes accurate determination of geographic differences in vertical distribution; more sampling is needed to verify the patterns reported here. That said, the shift in size and vertical distribution in the CGFZ relative to the other MAR subregions could, in part, be influenced by the subsurface chlorophyll-*a* concentrations reaching a maximum in this zone (Opdal et al., 2008), which could potentially affect the vertical distributions of zooplankton and higher trophic levels upon which *S. beanii* feeds. *Serrivomer lanceolatooides* abundance and biomass was distributed evenly throughout 750-2300 m the AZ. However, *S. beanii* was still the dominant species in the AZ, both in terms of abundance and biomass.

Abundances of *S. beanii* were not significantly higher within the benthic boundary layer (BBL: within 350 m of the bottom), as high and low fish catches were patchily distributed relative to the ridge surface. However, biomass values were highest within ~350 m of the ridge. This finding suggests an overall increase in *S. beanii* size within the BBL. Porteiro (2005) found that specimens of the family Stomiidae exhibit a similar increase in size within the BBL. Other primarily pelagic fish families that exhibit this adult benthopelagic life strategy include the Gonostomatidae, Myctophidae, Paralepididae and Melamphaidae (Novikov et al., 1981; Vinnichenko, 1997). Sutton et al. (2008) posited two ecological drivers for this strategy, one being short-term and the other long-term. The short-term advantage would be an increase in trophic efficiency by adopting a sit and wait approach, capturing prey traveling horizontally in tidal currents or

prey swimming downward being trapped by the ridge surface. The long-term advantage would be an increase in the ‘best’ genetic opportunity for offspring by assembling the largest, ‘fittest’ males and females. Due to the magnitude of the mid-ocean ridge system, an increase in spawning at these sites could have an important impact on the oceanic genetic structure and evolution of bathypelagic fishes (Sutton et al., 2008). Small *S. beanii* specimens may be excluded from the BBL due to predation from benthic species, such as rattail, *Coryphaenoides armatus* (Haedrich and Henderson, 1974), and Atlantic cod, *Gadus morhua* (Casas and Paz, 1996). *Serrivomer lanceolatooides* did not exhibit a correlation between size and height above the ridge, but this pattern may have been obfuscated by low overall numbers.

Length and weight measurements of dissected *S. beanii* specimens further suggest an increase in size with depth. The challenge when dealing with distributions along ridge systems is the presence of two variables at the same time: distance from the surface (depth), and distance from the ridge. This study has not only indicated an increase in size of *S. beanii* as depth increases, but also an increase in size as the height above the ridge decreases.

5.2. Trophic Ecology

Unlike the primarily piscivorous mesopelagic top predators (e.g. dragonfishes, family Stomiidae; Sutton and Hopkins, 1996), feeding data suggest *Serrivomer beanii* to be more generalistic, feeding on crustaceans, cephalopods, and teleosts. As a generalist, *S. beanii* may spend less time and energy searching for prey in the food-limited deep-sea environment, compared to other piscivorous top predators. The diet of *S. beanii*

consisted of 48.8% crustaceans, 33.3% cephalopods, and 11.4% teleosts, with the remaining 6.5% unidentifiable (“trace”). The top predators of the mesopelagic zone (e.g. dragonfishes) use passive luring to capture fish, based on fishes with lures containing mostly fish in their gut content and fish without lures containing mostly crustaceans, suggesting that crustaceans are not attracted to these lures. (Sutton and Hopkins, 1996). The majority of prey items found were luminescent, suggesting that the visual system of *S. beanii* may play an important role in the active hunting of prey. The majority of top predators in the mesopelagic realm feed on fishes (Hopkins et al., 1996), which feed on copepods and other zooplankton; however, *S. beanii* feeds on mostly invertebrates, which feed on zooplankton. This “alternative” trophic pathway suggests micronektonic crustaceans play a key role in supporting higher trophic level predators in bathypelagic ecosystems, in contrast to the piscivory-dominated mesopelagic.

Prey biomass from the *S. beanii* specimens examined in this study was estimated to be 31.23 g WW. Compared to the total predator biomass, the minimum average meal size of *S. beanii* was estimated to be 1% predator weight. Most coastal and epipelagic fishes consume approximately 1 - 5% of their weight daily, while in deep-sea fishes this value is thought to be much lower, around 0.01 - 2% predator weight (Brett and Groves, 1979). The average meal size determined for *S. beanii* would be considered minimal given the methodology used here, but comparisons with other deep-sea fishes suggest that *S. beanii* may exert a high predation impact in the deep-pelagic food webs in which they occur. Estimation of the relative abundance of all prey taxa is currently underway. Therefore, the degree of selectivity of the feeding of *S. beanii* within each taxon, and the

overall predation impact of *S. beanii* on its prey, could not be estimated with the available data.

Sampling during the 2004 *G.O. Sars* Expedition was not conducted throughout the diel cycle at each station, preventing the possibility of accurately determining diel vertical migration and feeding chronologies. As mentioned in Sutton et al. (2008), the cruise track was designed to sample the most stations in the allotted time (30 d); therefore extended occupation at any given station was sacrificed for larger-scale sampling. The majority of stomach fullness rankings were between 1 (stomach 1/4 full) and 3 (stomach 3/4 full). The rankings for degree of digestion suggest that feeding had not recently occurred, since the majority was ranked as either 3 (well digested) or 4 (digestion nearly complete). These data suggest that either *S. beanii* feeds at all times during the day, feeds on prey that take several days to digest, feeds less than once a day, or some combination of the three.

Previous studies suggest that *S. beanii* vertically migrates on a diel basis (Bauchot, 1986), ostensibly to feed. However, three specimens dissected for this study contained whole, fairly undigested soft-bodied prey (the cephalopod *Gonatus steenstrupii*), indicative of a recent feed. These specimens were collected at depths of 744-1774 m, suggesting feeding at depth. Further analysis of *S. beanii* must be completed to accurately determine the occurrence of vertical migrations, but the data at hand suggest distributions that do not appear tied to the diel cycle, as exhibited by myctophids, for instance (Kinzer and Schulz, 1985).

Our understanding of oceanic food webs is limited by our knowledge of the role occupied by large pelagic predators, such as eels, which are generally undersampled with

traditional gear (e.g., rectangular midwater trawls). Broadening our understanding of the trophic ecology of *S. beanii* increases our knowledge about this species and the role of a high level predator in bathypelagic ecosystems. The role of such predators in bathypelagic ecosystems is likely an important, but missing, component of oceanic food web models, and thus, our understanding of carbon flow and community structure in the deep ocean interior. Previous studies suggest *Serrivomer beanii* is a generalist predator (Beebe and Crane, 1936; Bauchot, 1986), but detailed dietary analysis was limited in those studies. The current study utilizes the largest and most comprehensive sample set available for this species, and further establishes *S. beanii* as a high trophic level predator that consumes a high percentage of large invertebrate prey (micronektonic shrimp and squid). Based on the potential importance of this species in bathypelagic food webs as demonstrated by its high relative abundance and biomass (Sutton et al., 2008), results of this study suggest an alternative pathway in deep North Atlantic food webs, in which a dominant, fourth(+)-level bathypelagic predator focuses on invertebrate micronektonic prey, rather than fishes.

Table 1. Trawl samples used for distributional analysis from the 2004 MAR-ECO expedition (after Sutton et al., 2008). RR = Reykjanes Ridge, CGFZ = Charlie-Gibbs Fracture Zone, FSZ = Faraday Seamount Zone, and AZ = Azorean Zone. Trawl: AK = Åkra trawl sample; KT = krill trawl sample. Depth zones: 1 = 0-200 m; 2 = 200-750 m; 3 = 750-1500 m; 4 = 1500-2300 m; 5 = >2300 m. Solar cycle: D = day; N = night; DN = dusk; ND = dawn

Ridge Region	Stations	Trawl	Sample Code	Max Trawl Depth	Bottom Depth	Depth Zone	Solar Cycle
RR	2	AK 1-3	1	180	2260	1	D
RR	2	AK 1-2	2	750	2314	2	D
RR	2	KT 1-4	3	850	2150	2	ND
RR	2	KT 1-3	4	1550	2187	3	ND
RR	2	AK 1-1	5	2070	2264	4	D
RR	2	KT 1-2	6	1900	2219	4	N
RR	2	KT 1-1	7	2100	2222	3	N
RR	2	KT 1-5	8	200	2127	1	ND
RR	4	AK 2-3	9	200	1467	1	D
RR	4	KT 2-5	10	175	1393	1	D
RR	4	AK 2-2	11	850	1397	2	ND
RR	4	KT 2-3	12	740	1353	2	D
RR	4	KT 2-4	13	475	1393	2	D
RR	4	AK 2-1	14	1260	1419	3	ND
RR	4	KT 2-2	15	1300	1664	3	D
RR	4	KT 2-1	16	1330	1501	3	D
RR	6	KT 3-5	17	200	2315	1	N
RR	6	KT 3-4	18	700	2321	2	N
RR	6	KT 3-3	19	1500	2357	3	N
RR	6	KT 3-2	20	2140	2344	4	N
RR	6	KT 3-1	21	2170	2309	4	N
RR	8	AK 3-3	22	300	1344	1	D
RR	8	KT 4-5	23	200	2031	1	N
RR	8	AK 3-2	24	800	1315	2	ND
RR	8	KT 4-4	25	760	1847	2	N
RR	8	KT 4-3	26	1280	1680	3	N
RR	8	AK 3-1	27	1050	1219	3	ND
RR	8	KT 4-1	28	1335	1651	3	DN
RR	8	KT 4-2	29	1330	1552	3	DN
RR	10	KT 5-5	30	202	2026	1	D
RR	10	KT 5-4	31	751	2104	2	D
RR	10	KT 5-2	32	1920	2144	4	D

Table 1 (*continued*)

Ridge region	Stations	Trawl	Sample Code	Max Trawl Depth	Bottom Depth	Depth Zone	Solar Cycle
RR	10	KT 5-1	33	1985	2147	4	D
CGFZ	12	AK 4-3	34	293	3239	1	D
CGFZ	12	KT 6-5	35	200	1912	1	D
CGFZ	12	AK 4-2	36	800	2744	2	D
CGFZ	12	KT 6-4	37	700	1808	2	D
CGFZ	12	AK 4-1	38	1750	2112	3	D
CGFZ	12	KT 6-3	39	1186	1514	3	D
CGFZ	12	KT 6-2	40	1460	1636	3	D
CGFZ	14	AK 5-3	41	340	3102	1	D
CGFZ	14	KT 7-5	42	200	3103	1	D
CGFZ	14	AK 5-2	43	900	3127	2	D
CGFZ	14	KT 7-4	44	665	3055	2	D
CGFZ	14	KT 7-3	45	1480	3172	3	D
CGFZ	14	KT 7-2	46	2300	3130	4	D
CGFZ	14	KT 7-1	47	2530	3153	5	D
CGFZ	16	KT 8-5	48	238	3794	1	D
CGFZ	16	KT 8-4	49	678	3793	2	D
CGFZ	16	KT 8-3	50	1488	3764	3	D
CGFZ	16	KT 8-2	51	2248	3710	4	D
CGFZ	16	KT 8-1	52	3008	3688	5	D
CGFZ	18	KT 9-5	53	202	3131	1	D
CGFZ	18	KT 9-4	54	676	3100	2	D
CGFZ	18	KT 9-3	55	1502	3106	3	D
CGFZ	18	AK 6-2	56	1774	3935	4	D
CGFZ	18	KT 9-2	57	2256	3095	4	D
CGFZ	18	KT 9-1	58	2527	3070	5	D
CGFZ	20	KT 10-5	59	202	3131	1	D
CGFZ	20	KT 10-4	60	676	3100	2	D
CGFZ	20	AK 7-2	61	1837	3167	3	D
CGFZ	20	KT 10-3	62	1502	3106	3	D
CGFZ	20	KT 10-2	63	2256	3095	4	D
CGFZ	20	KT 10-1	64	2527	3070	5	D
FSZ	22	KT 11-5	65	210	3177	1	D
FSZ	22	KT 11-4	66	656	3179	2	D
FSZ	22	AK 8-2	67	1800	3650	3	D
FSZ	22	KT 11-3	68	1487	3420	3	D

Table 1 (*continued*)

Ridge region	Stations	Trawl	Sample Code	Max Trawl Depth	Bottom Depth	Depth Zone	Solar Cycle
FSZ	22	AK 8-1	69	2370	3604	4	D
FSZ	22	KT 11-2	70	2301	3520	4	D
FSZ	22	KT 11-1	71	2731	3705	5	D
FSZ	24	KT 12-5	72	211	3077	1	N
FSZ	24	KT 12-4	73	665	3366	2	N
FSZ	24	AK 9-2	74	1800	2706	3	D
FSZ	24	KT 12-3	75	1776	3530	3	ND
FSZ	24	AK 9-1	76	2230	2672	4	D
FSZ	24	KT 12-2	77	2338	3494	4	ND
FSZ	24	KT 12-1	78	2768	3589	5	ND
FSZ	26	AK 11-3	79	250	3495	1	D
FSZ	26	AK 11-2	80	603	3095	2	D
FSZ	26	AK 10-2	81	1746	3517	3	D
AZ	28	KT 13-5	83	138	2996	1	D
AZ	28	KT 13-4	84	691	2989	2	D
AZ	28	AK 12-2	85	1770	2657	3	D
AZ	28	AK 12-1	86	2400	3010	4	D
AZ	28	KT 13-2	87	2308	2822	4	D
AZ	28	KT 13-1	88	2202	2890	5	D
AZ	30	KT 14-5	89	186	1949	1	D
AZ	30	KT 14-4	90	598	2443	2	D
AZ	30	AK 13-2	91	1800	2407	3	D
AZ	30	KT 14-3	92	1500	2718	3	D
AZ	30	AK 13-1	93	2390	2492	4	D
AZ	30	KT 14-2	94	2283	2828	4	D
AZ	30	KT 14-1	95	2383	2839	5	D
AZ	32	KT 15-4	96	675	2364	2	DN
AZ	32	AK 14-2	97	1800	2532	3	D
AZ	32	KT 15-3	98	1523	2289	3	DN
AZ	32	AK 14-1	99	2300	2542	4	D
AZ	32	KT 15-2	100	2005	2411	4	D
AZ	32	KT 15-1	101	1828	2287	4	D
AZ	34	KT 16-5	102	203	1927	1	N
AZ	34	KT 16-4	103	684	2317	2	N
AZ	34	AK 15-2	104	1800	2230	3	D
AZ	34	KT 16-3	105	1494	2177	3	N

Table 1 (*continued*)

Ridge region	Stations	Trawl	Sample Code	Max Trawl Depth	Bottom Depth	Depth Zone	Solar Cycle
AZ	34	AK 15-1	106	2000	2335	4	D
AZ	34	KT 16-1	107	1981	2524	4	N
AZ	34	KT 16-2	108	1887	2154	4	N
AZ	36	KT 17-5	109	180	2698	1	N
AZ	36	KT 17-4	110	729	2524	2	N
AZ	36	AK 16-2	111	1800	2616	3	D
AZ	36	KT 17-3	112	1493	2602	3	N
AZ	36	AK 16-1	113	2400	2722	4	D
AZ	36	KT 17-1	114	1980	2654	4	N
AZ	36	KT 17-2	115	2036	2441	4	N

Table 2. *Serrivomer* trophic analysis sample set. RR = Reykjanes Ridge, CGFZ = Charlie-Gibbs Fracture Zone, FSZ = Faraday Seamount Zone, and AZ = Azorean Zone. N = number of specimens used for trophic analysis

Ridge Region	Cruise	Station	Depth (min)	Depth (max)	N
RR	<i>Árni Friðrikkson</i> 2003	387	N/D	N/D	14
RR	<i>Árni Friðrikkson</i> 2003	388	N/D	N/D	5
RR	<i>Árni Friðrikkson</i> 2003	391	N/D	N/D	19
RR	<i>Árni Friðrikkson</i> 2003	398	N/D	N/D	19
RR	<i>Árni Friðrikkson</i> 2003	399	N/D	N/D	5
RR	<i>Árni Friðrikkson</i> 2003	403	N/D	N/D	10
RR	<i>Árni Friðrikkson</i> 2003	404	N/D	N/D	26
RR	<i>Árni Friðrikkson</i> 2003	499	N/D	N/D	1
RR	<i>G.O. Sars</i> 2004	2	0	2070	11
RR	<i>G.O. Sars</i> 2004	4	200	850	10
RR	<i>G.O. Sars</i> 2004	4	744	1302	7
RR	<i>G.O. Sars</i> 2004	4	850	1260	31
RR	<i>G.O. Sars</i> 2004	10	N/D	N/D	17
CGFZ	<i>G.O. Sars</i> 2004	12	815	1750	26
CGFZ	<i>G.O. Sars</i> 2004	18	0	743	9
CGFZ	<i>G.O. Sars</i> 2004	18	805	1774	24
FSZ	<i>G.O. Sars</i> 2004	24	0	800	7
FSZ	<i>G.O. Sars</i> 2004	26	600	825	16
FSZ	<i>G.O. Sars</i> 2004	26	800	1746	5
FSZ	<i>G.O. Sars</i> 2004	26	N/D	N/D	22
AZ	<i>G.O. Sars</i> 2004	28	1474	2308	2
AZ	<i>G.O. Sars</i> 2004	30	0	795	2
AZ	<i>G.O. Sars</i> 2004	36	800	1800	2
N/D	N/D	N/D	N/D	N/D	10
Total					300

Table 3. Crustacean length/length (mm/mm) and length/weight (mm/g) regressions of uropod length (UL), mandible length (ML), and carapace length (CL) to total length (TL) and wet weight (WW). N = number of specimens used to generate regression

Taxon (N)	Regression Type	Regression Equation	R ² Value
Euphausiid (8)	UL-TL	$y = 5.5549x^{1.0343}$	0.9615
	ML-TL	$y = 38.766x^{0.629}$	0.8717
	CL-TL	$y = 3.1334x^{1.0687}$	0.7069
	TL-WW	$y = 2E-06x^{3.2059}$	0.9239
	UL-WW	$y = 0.0005x^{3.4114}$	0.9404
	ML-WW	$y = 0.3003x^{2.2202}$	0.9762
	CL-WW	$y = 3E-05x^{3.9235}$	0.8565
Caridea (7)	UL-TL	$y = 14.37x^{0.6936}$	0.9029
	ML-TL	$y = 67.172x^{0.6294}$	0.9395
	CL-TL	$y = 12.957x^{0.6533}$	0.9066
	TL-WW	$y = 1E-06x^{3.2989}$	0.9461
	UL-WW	$y = 0.006x^{2.3417}$	0.8946
	ML-WW	$y = 1.0897x^{2.1422}$	0.9461
	CL-WW	$y = 0.0037x^{2.2497}$	0.9348
Sergestid (8)	UL-TL	$y = 4.125x^{1.1438}$	0.9384
	ML-TL	$y = 35.447x^{1.271}$	0.6607
	CL-TL	$y = 6.2425x^{0.7879}$	0.8623
	TL-WW	$y = 5E-06x^{2.8782}$	0.8974
	UL-WW	$y = 0.0003x^{3.2672}$	0.8294
	ML-WW	$y = 0.1338x^{4.0222}$	0.7168
	CL-WW	$y = 0.0005x^{2.5135}$	0.9506
Mysidacea (7)	UL-TL	$y = 7.329x^{1.0209}$	0.7974
	ML-TL	$y = 78.591x^{0.966}$	0.5670
	CL-TL	$y = 2.4677x^{1.0991}$	0.8379
	TL-WW	$y = 6E-05x^{2.3206}$	0.9551
	UL-WW	$y = 0.0037x^{2.5679}$	0.8948
	ML-WW	$y = 1.4432x^{2.4794}$	0.6624
	CL-WW	$y = 0.0002x^{2.7903}$	0.9578

Table 4. Areas of high relative biomass (% of total fish biomass in sample) along the Mid-Atlantic Ridge, for *Serrivomer beanii* and *Serrivomer lanceolatoides*. RR = Reykjanes Ridge, CGFZ = Charlie-Gibbs Fracture Zone, FSZ = Faraday Seamount Zone, and AZ = Azorean Zone. Depth zones: 1 = 0-200 m; 2 = 200-750 m; 3 = 750-1500 m; 4 = 1500-2300 m; 5 = >2300 m

Ridge Region	Station	Depth (m)	Species	% of total biomass
RR	4	750-1500	<i>Serrivomer beanii</i>	78
RR	4	1500-2300	<i>Serrivomer beanii</i>	77
CGFZ	12	0-200	<i>Serrivomer beanii</i>	83
CGFZ	18	1500-2300	<i>Serrivomer beanii</i>	57
AZ	28	200-750	<i>Serrivomer lanceolatoides</i>	>50*
AZ	36	750-1500	<i>Serrivomer lanceolatoides</i>	36

*from single *Serrivomer lanceolatoides*

Table 5. Occurrence and biomass (g WW) of prey taxa collected from *Serrivomer beanii* gut content analysis. N = number of prey items

Prey Taxon (N = 123)	Occurrence (%)	Biomass (%)
Crustacean	60 (48.8)	18.7328 (60.0)
Trace Euphausiid/Decapod/Mysid	60 (100.0)	18.7328 (100.0)
Euphausiid/Decapod	34 (56.7)	18.7120 (99.9)
Euphausiid	15 (44.1)	0.0312 (0.002)
<i>Meganyctiphanes norvegica</i>	1 (6.7)	0.0008 (0.03)
Decapod	18 (52.9)	18.68 (99.8)
Benthic Decapod	6 (33.3)	6.81 (34.5)
Caridean/Sergestid	10 (55.6)	11.59 (62.0)
Caridean	3 (30.0)	6.46 (55.7)
Sergestid	4 (40.0)	1.30 (0.11)
Cephalopod	41 (33.3)	10.7 (34.3)
Trace Squid	16 (39.0)	N/D
Squid	25 (61.0)	10.7 (100.0)
<i>Gonatus steenstrupii</i>	4 (16.0)	10.7 (100.0)
Teleost	14 (11.4)	1.8 (5.7)
Trace Teleost	11 (78.6)	N/D
Teleost	3 (21.4)	1.8 (100.0)
Melamphaid	1 (33.3)	0.6 (33.3)
<i>Cyclothone</i> sp.	1 (33.3)	0.2 (11.1)
<i>Chiasmodon</i> sp.	1 (33.3)	1.0 (55.6)
Trace	8 (6.5)	N/D

Table 6. Total length (TL) and biomass calculations of 16 crustacean specimens from length/length and length/weight regressions

Specimen	Prey Item	Part (x)	Length (mm)	Formula (TL)	TL (mm)	Formula (WW)	Biomass (g WW)
6-391	Euphausid	Uropod	3.03	$y = 5.5549x^{1.0343}$	17.48	$y = 0.0005x^{3.4114}$	0.02
16-391	Caridean	Mandible	1.70	$y = 67.172x^{0.6294}$	93.81	$y = 1.0897x^{2.1422}$	3.40
103-28	Sergestid	Uropod	11.87	$y = 4.125x^{1.1438}$	69.88	$y = 0.0003x^{3.2672}$	0.97
134-4	Sergestid	Uropod	14.63	$y = 4.125x^{1.1438}$	88.76	$y = 0.0003x^{3.2672}$	1.92
142-26	Euphausid	Uropod	1.18	$y = 5.5549x^{1.0343}$	6.59	$y = 0.0005x^{3.4114}$	0.0008
159-4	Caridean	Mandible	1.17	$y = 67.172x^{0.6294}$	74.15	$y = 1.0897x^{2.1422}$	1.53
197-26	Sergestid	Uropod	6.53	$y = 4.125x^{1.1438}$	35.28	$y = 0.0003x^{3.2672}$	0.14
202-26	Sergestid	Uropod	15.03	$y = 4.125x^{1.1438}$	91.54	$y = 0.0003x^{3.2672}$	2.10
207-4	Sergestid	Uropod	13.81	$y = 4.125x^{1.1438}$	83.10	$y = 0.0003x^{3.2672}$	1.59
213-4	Sergestid	Uropod	11.51	$y = 4.125x^{1.1438}$	67.47	$y = 0.0003x^{3.2672}$	0.88
253-12	Sergestid	Uropod	14.65	$y = 4.125x^{1.1438}$	88.90	$y = 0.0003x^{3.2672}$	1.93
254-12	Sergestid	Uropod	11.84	$y = 4.125x^{1.1438}$	69.68	$y = 0.0003x^{3.2672}$	0.96
300-18	Sergestid	Mandible	1.60	$y = 35.447x^{1.271}$	64.42	$y = 0.1338x^{4.0222}$	0.89

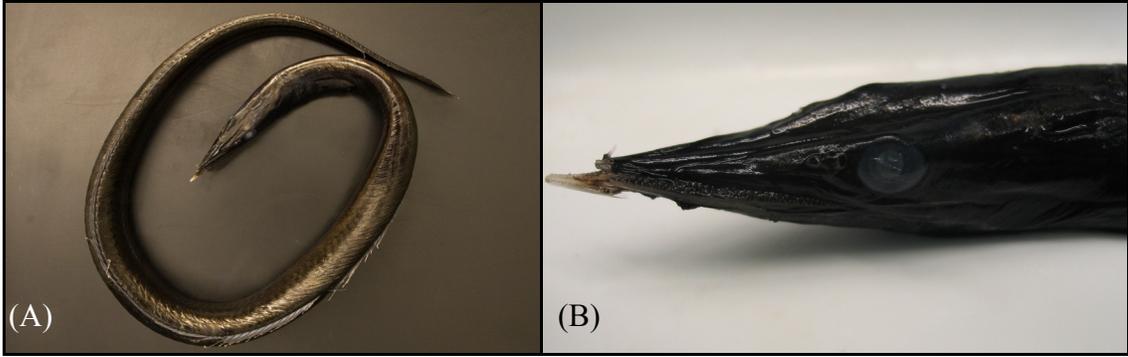


Figure 1: Sawtooth eel, *Serrivomer beanii*. A. Body shot. B. Head shot. Photo A credit: VanOs (2007).

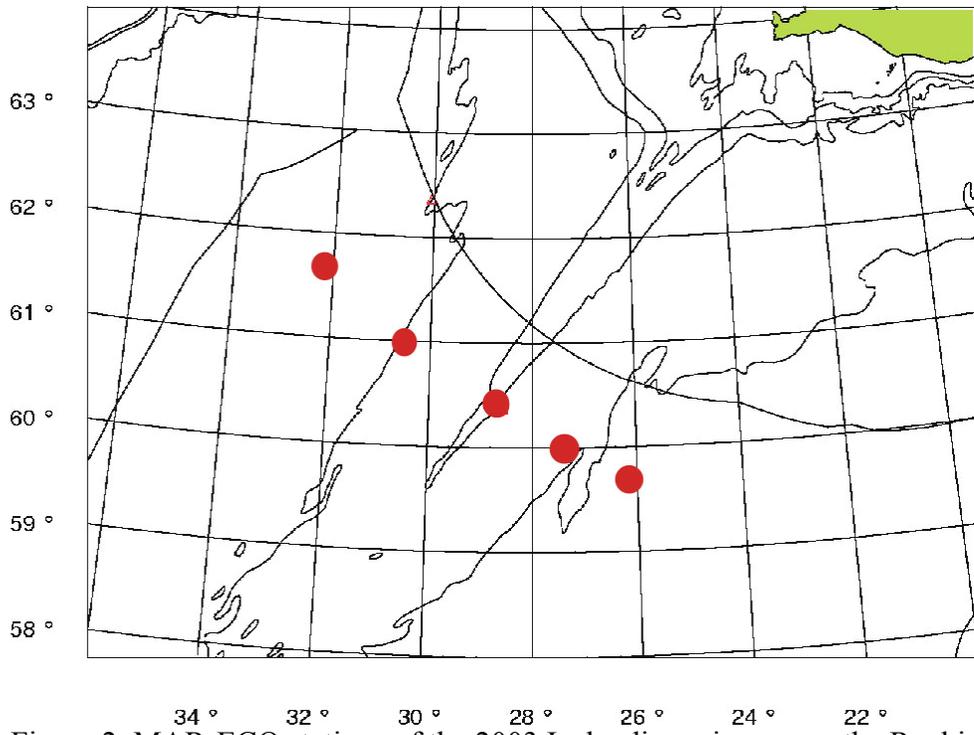


Figure 2. MAR-ECO stations of the 2003 Icelandic cruise across the Reykjanes Ridge.

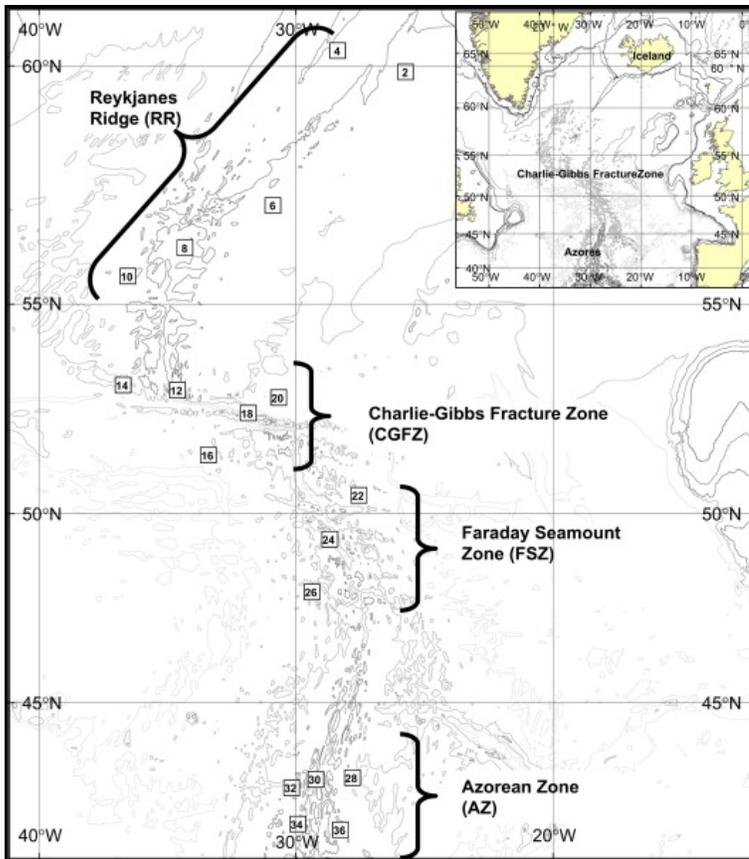


Figure 3. Trawl sampling stations of the 2004 MAR-ECO Expedition, with designation of the four primary ridge regions (after Sutton et al., 2008).

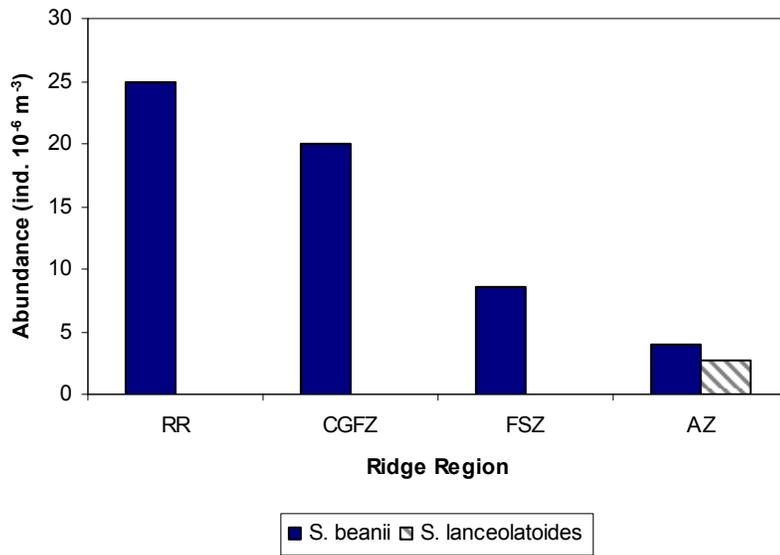


Figure 4. Abundance of *Serrivomer beanii* and *Serrivomer lanceolatoides* in the four ridge regions of the northern Mid-Atlantic Ridge. RR = Reykjanes Ridge, CGFZ = Charlie-Gibbs Fracture Zone, FSZ = Faraday Seamount Zone, and AZ = Azorean Zone.

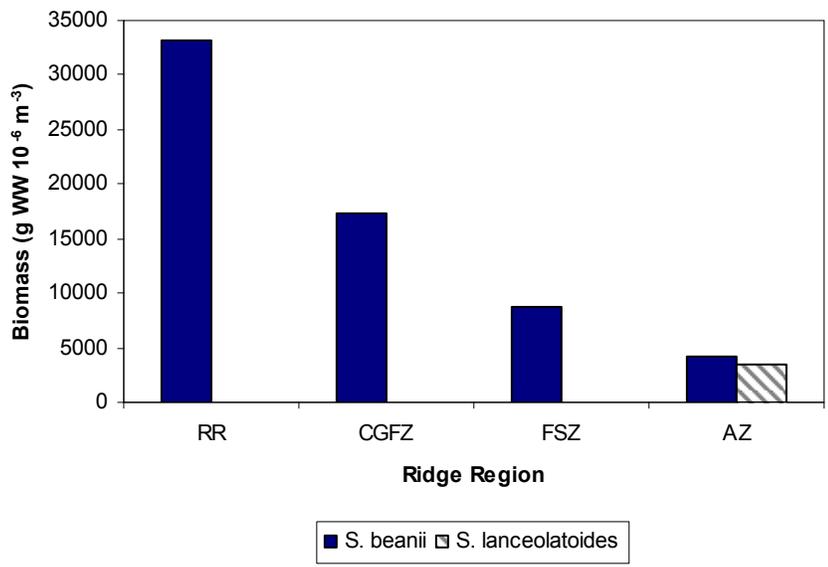


Figure 5. Biomass of *Serrivomer beanii* and *Serrivomer lanceolatooides* in the four ridge regions of the northern Mid-Atlantic Ridge. RR = Reykjanes Ridge, CGFZ = Charlie-Gibbs Fracture Zone, FSZ = Faraday Seamount Zone, and AZ = Azorean Zone.

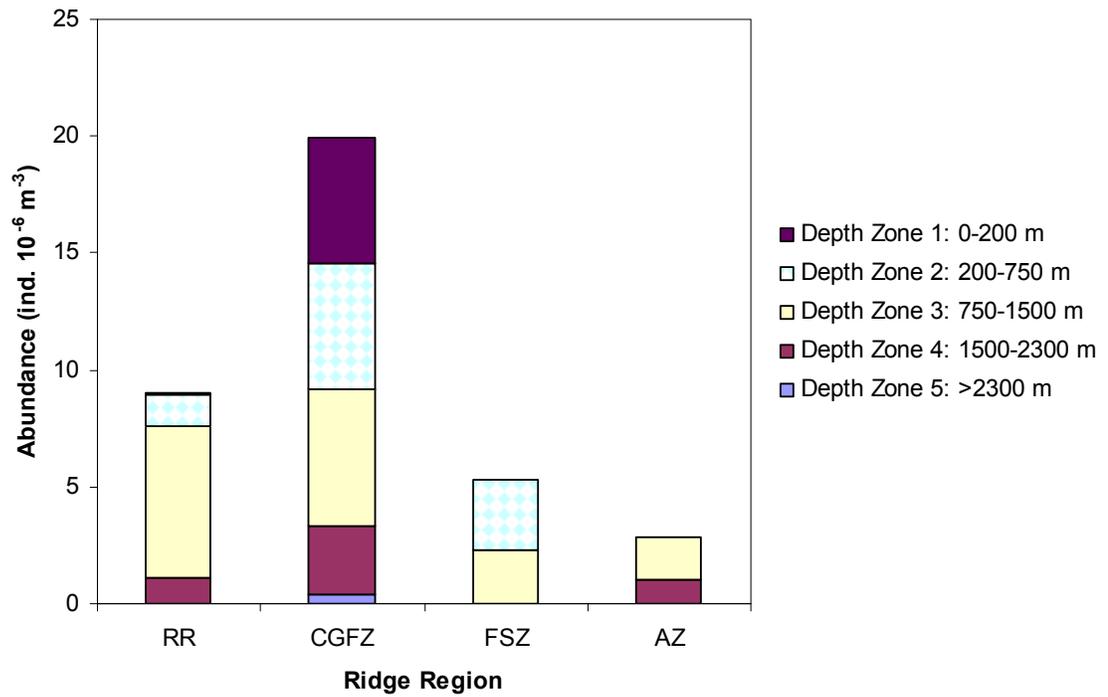


Figure 6. Abundance of *Serrivomer beanii* throughout the five depth zones along the northern Mid-Atlantic Ridge. RR = Reykjanes Ridge, CGFZ = Charlie-Gibbs Fracture Zone, FSZ = Faraday Seamount Zone, and AZ = Azorean Zone.

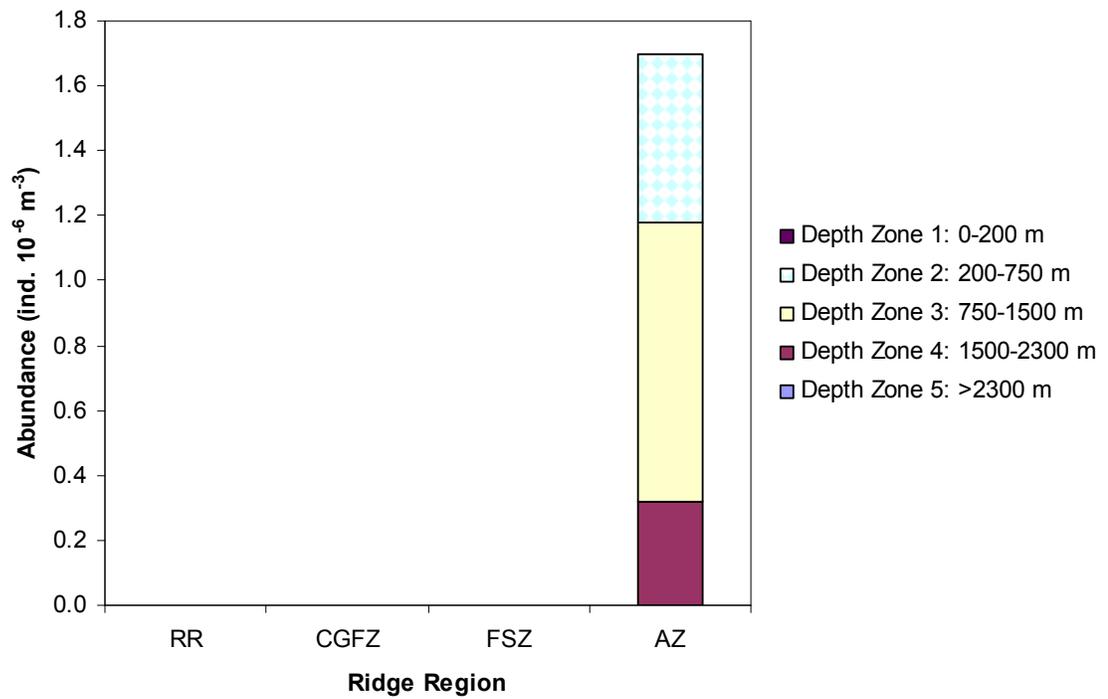


Figure 7. Abundance of *Serrivomer lanceolatus* throughout the five depth zones along the northern Mid-Atlantic Ridge. RR = Reykjanes Ridge, CGFZ = Charlie-Gibbs Fracture Zone, FSZ = Faraday Seamount Zone, and AZ = Azorean Zone.

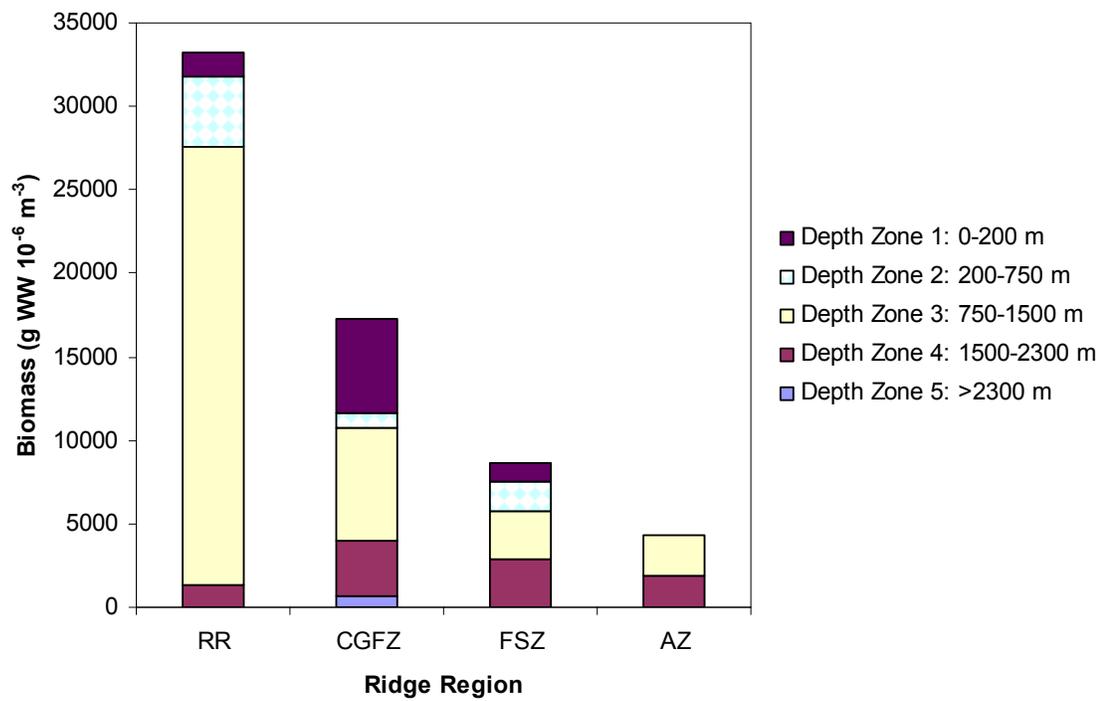


Figure 8. Biomass of *Serrivomer beanii* throughout the five depth zones along the northern Mid-Atlantic Ridge. RR = Reykjanes Ridge, CGFZ = Charlie-Gibbs Fracture Zone, FSZ = Faraday Seamount Zone, and AZ = Azorean Zone.

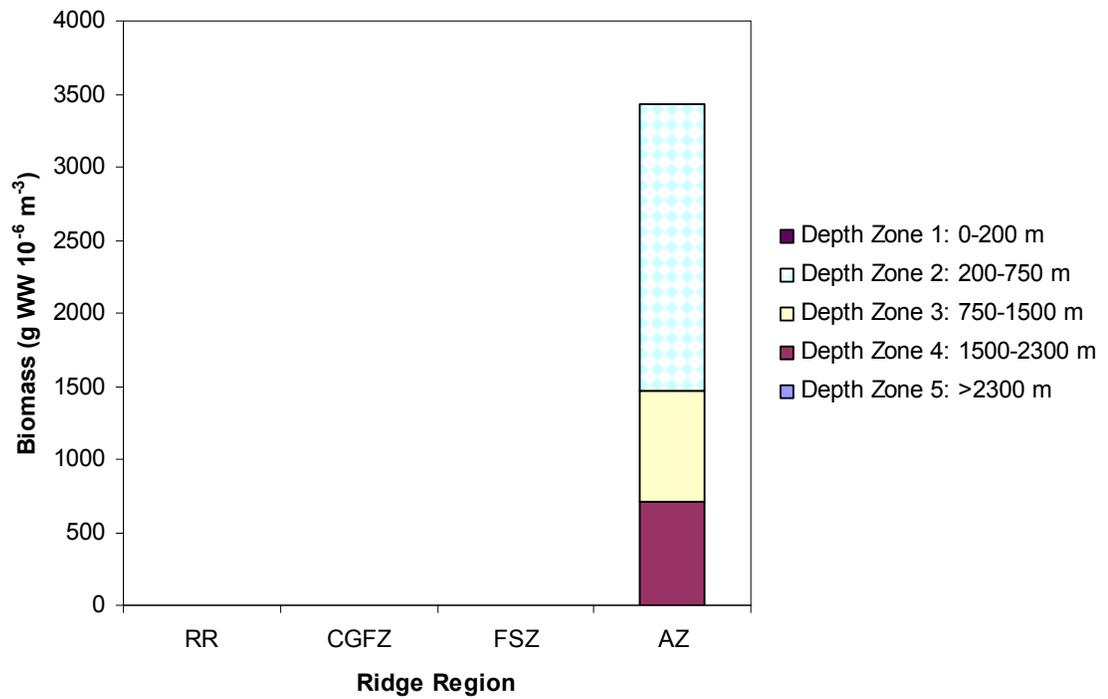


Figure 9. Biomass of *Serrivomer lanceolatooides* throughout the five depth zones along the northern Mid-Atlantic Ridge. RR = Reykjanes Ridge, CGFZ = Charlie-Gibbs Fracture Zone, FSZ = Faraday Seamount Zone, and AZ = Azorean Zone.

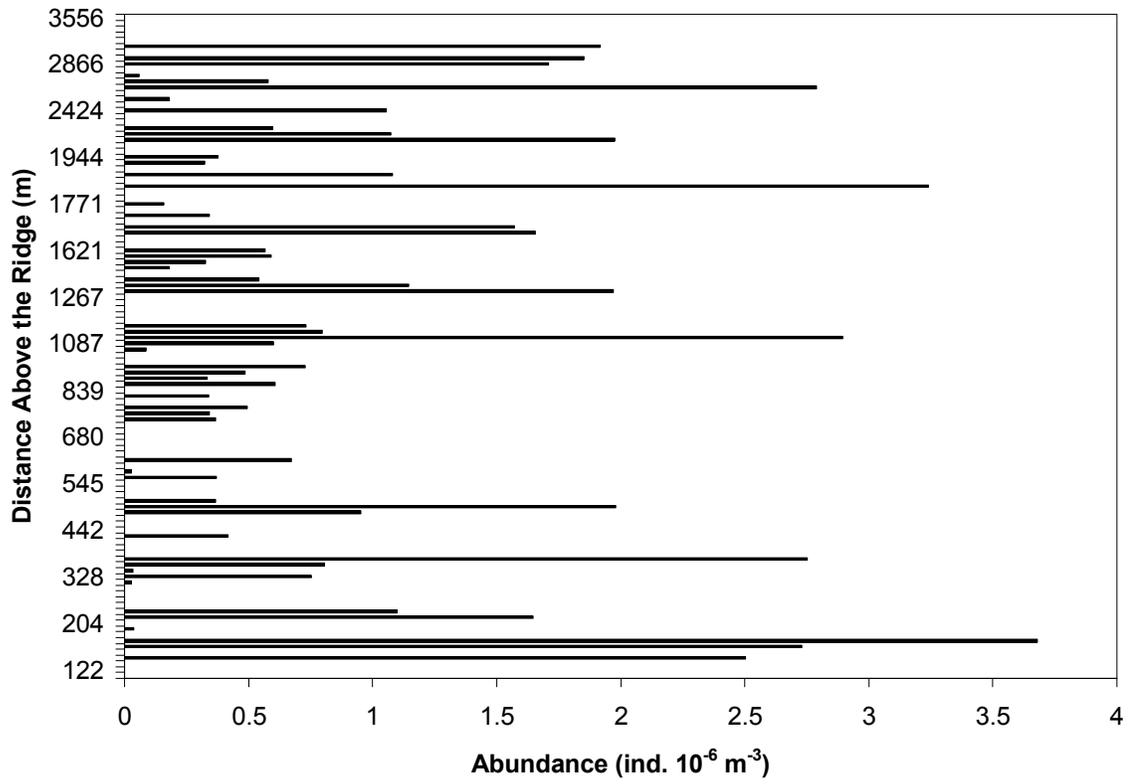


Figure 10. Abundance of *Serrivomer beanii* in relation to distance above the ridge.

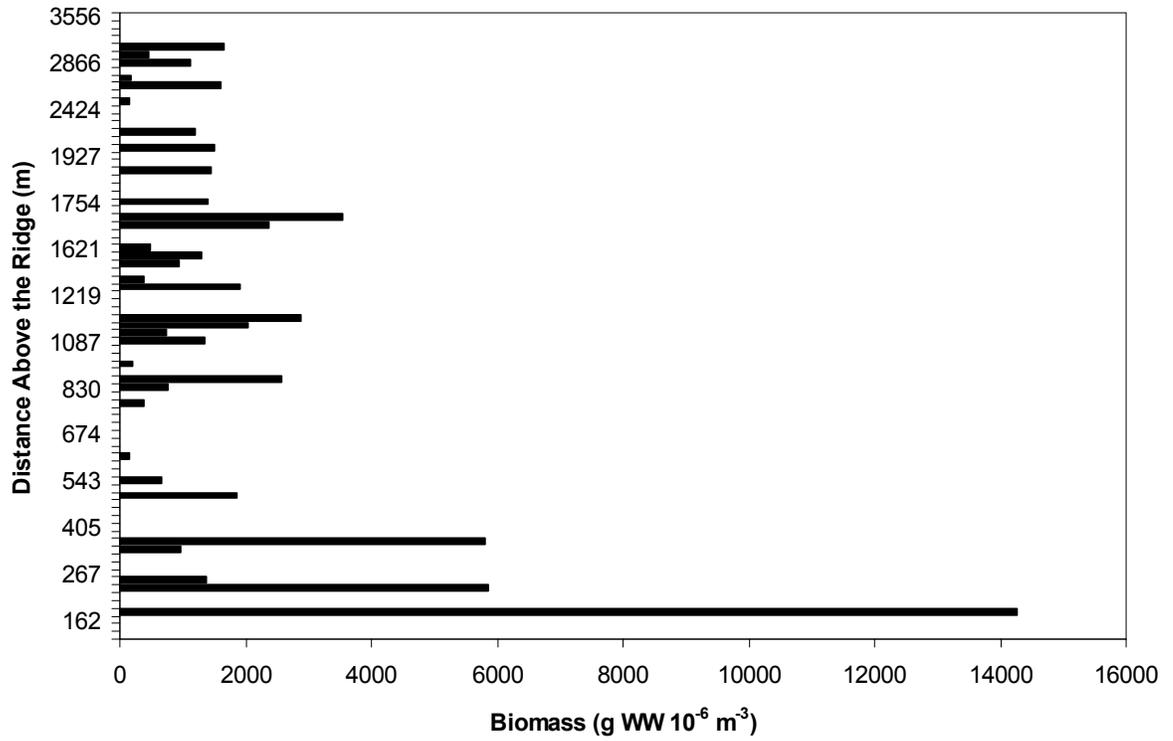


Figure 11. Biomass of *Serrivomer beanii* in relation to distance above the ridge.

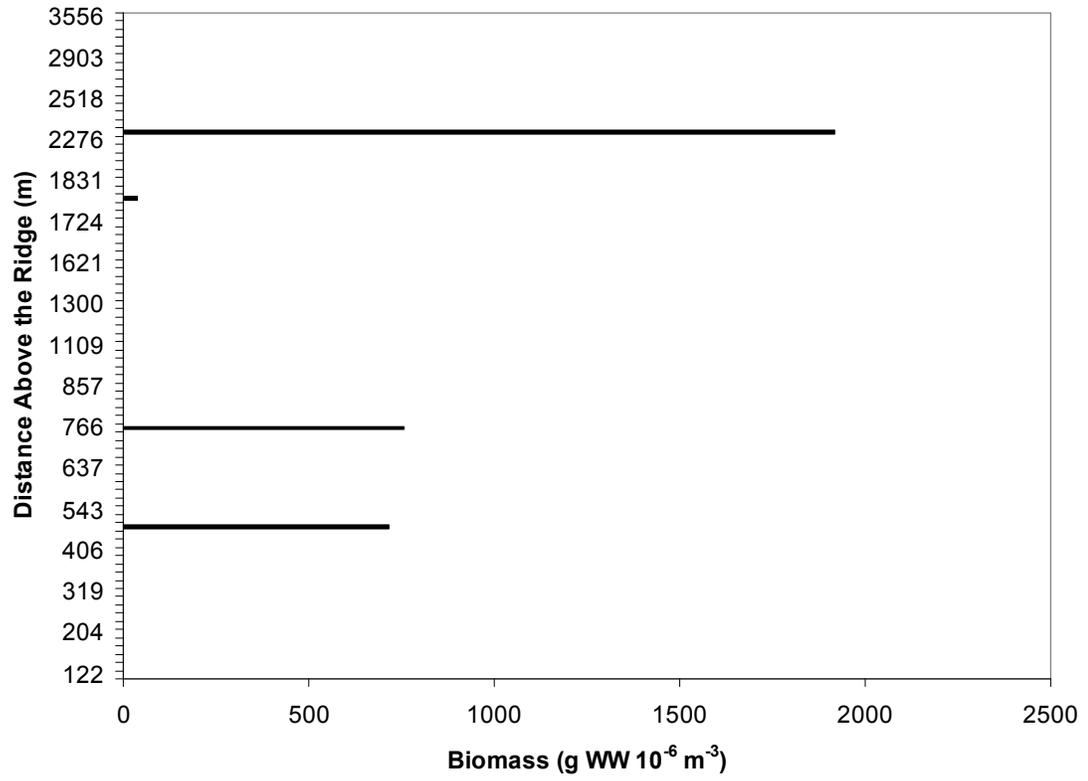


Figure 12. Biomass of *Serrivomer lanceolatooides* in relation to distance above the ridge.

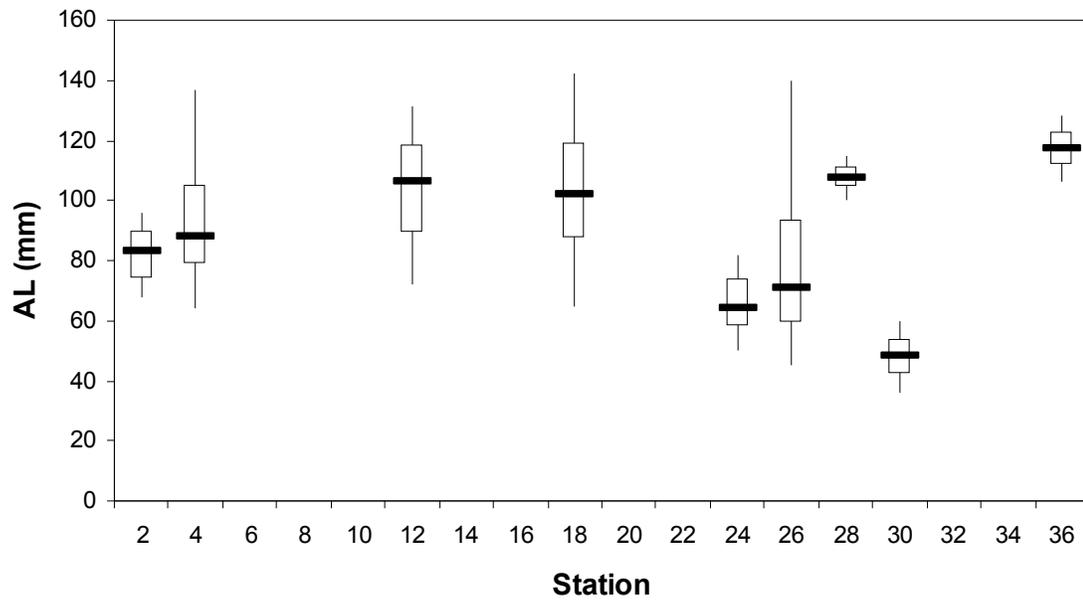


Figure 13. Pre-anal length (AL) of dissected *Serrivomer beanii* specimens (N = 300) by station along the northern Mid-Atlantic Ridge. Reykjanes Ridge = Station 2-10, Charlie-Gibbs Fracture Zone = Station 12-20, Faraday Seamount Zone = Station 22-26, and Azorean Zone = 28-36.

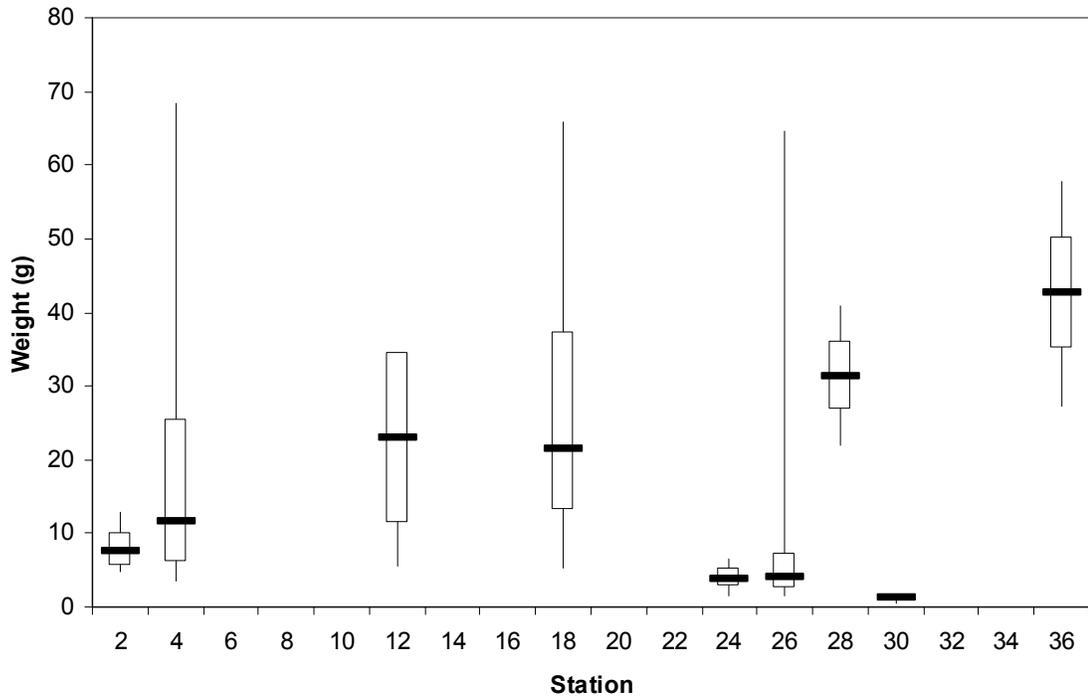


Figure 14. Weight of dissected *Serrivomer beanii* specimens (N = 300) by station along the northern Mid-Atlantic Ridge. Reykjanes Ridge = Station 2-10, Charlie-Gibbs Fracture Zone = Station 12-20, Faraday Seamount Zone = Station 22-26, and Azorean Zone = 28-36.

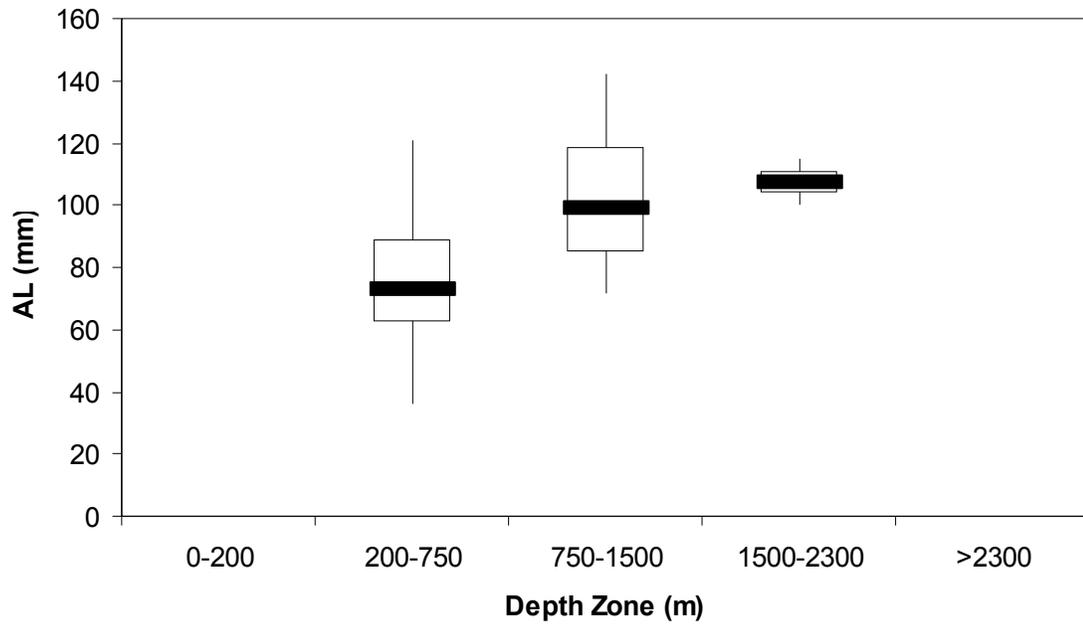


Figure 15. Anal length (AL) of dissected *Serrivomer beanii* specimens (N = 300) by depth zone along the northern Mid-Atlantic Ridge.

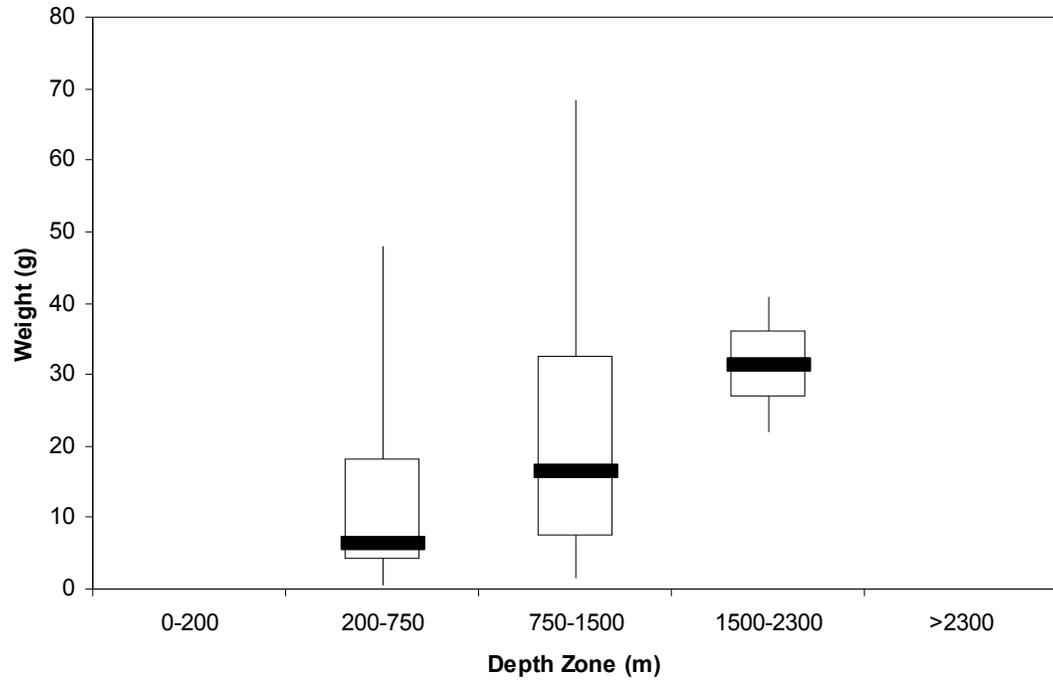


Figure 16. Weight of dissected *Serrivomer beanii* specimens (N = 300) by depth zone along the northern Mid-Atlantic Ridge.

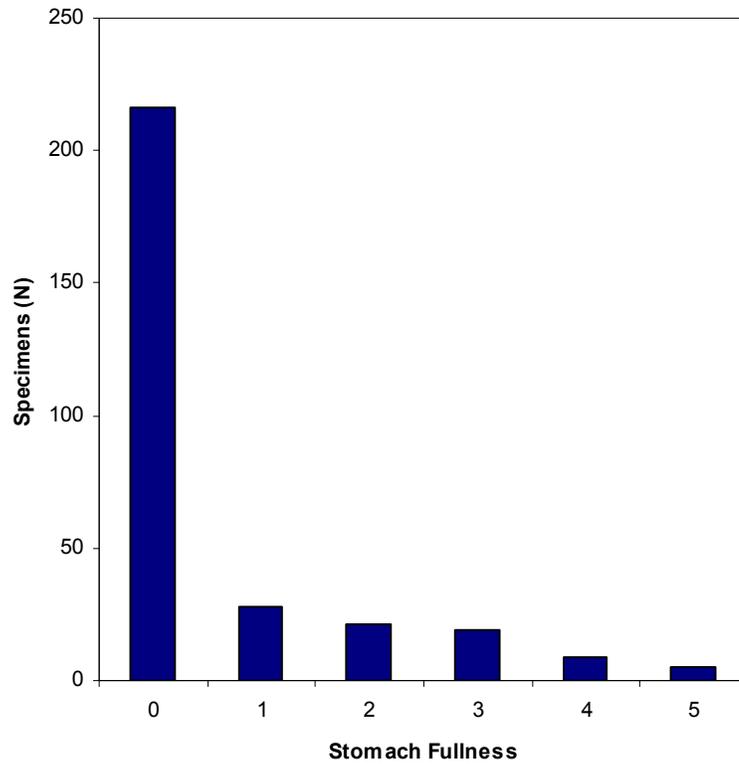


Figure 17. Stomach fullness of *Serrivomer beanii*. Stomach fullness: 0 = empty, 1 = stomach 1/4 full, 2 = stomach 1/2 full, 3 = stomach 3/4 full, 4 = stomach full, 5 = stomach full and stretched.

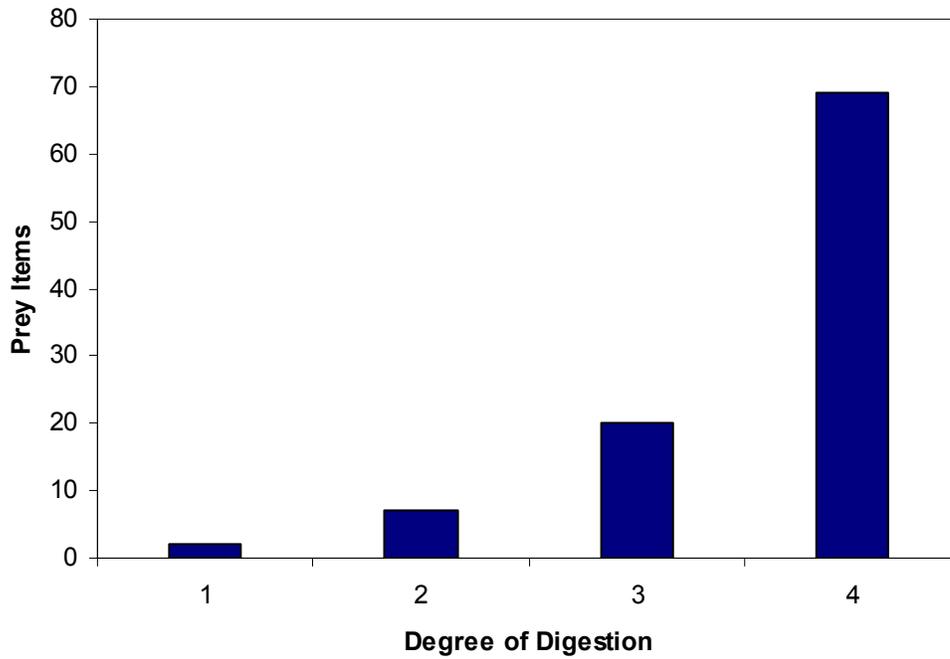


Figure 18. Degree of digestion of *Serrivomer beanii*. Degree of Digestion: 1 = no digestion (fresh), 2 = partially digested, 3 = well digested, 4 = digestion nearly complete.

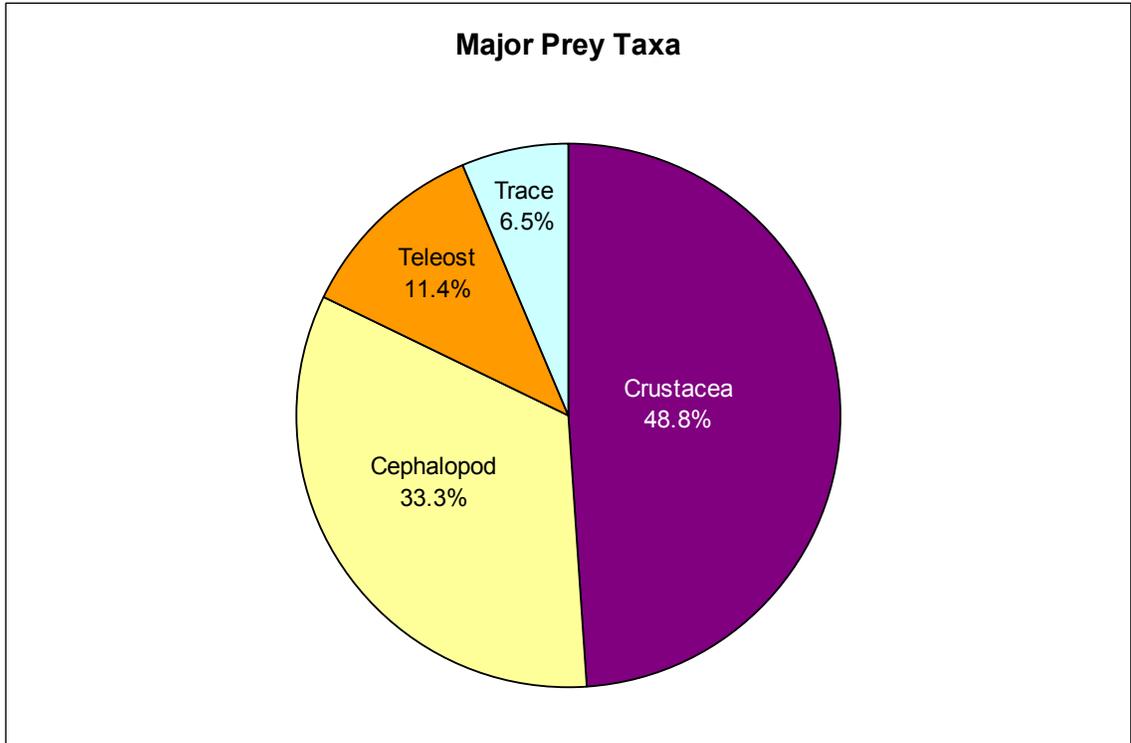


Figure 19. Relative occurrence (%) of major prey taxa within the diet of *Serrivomer beanii*.

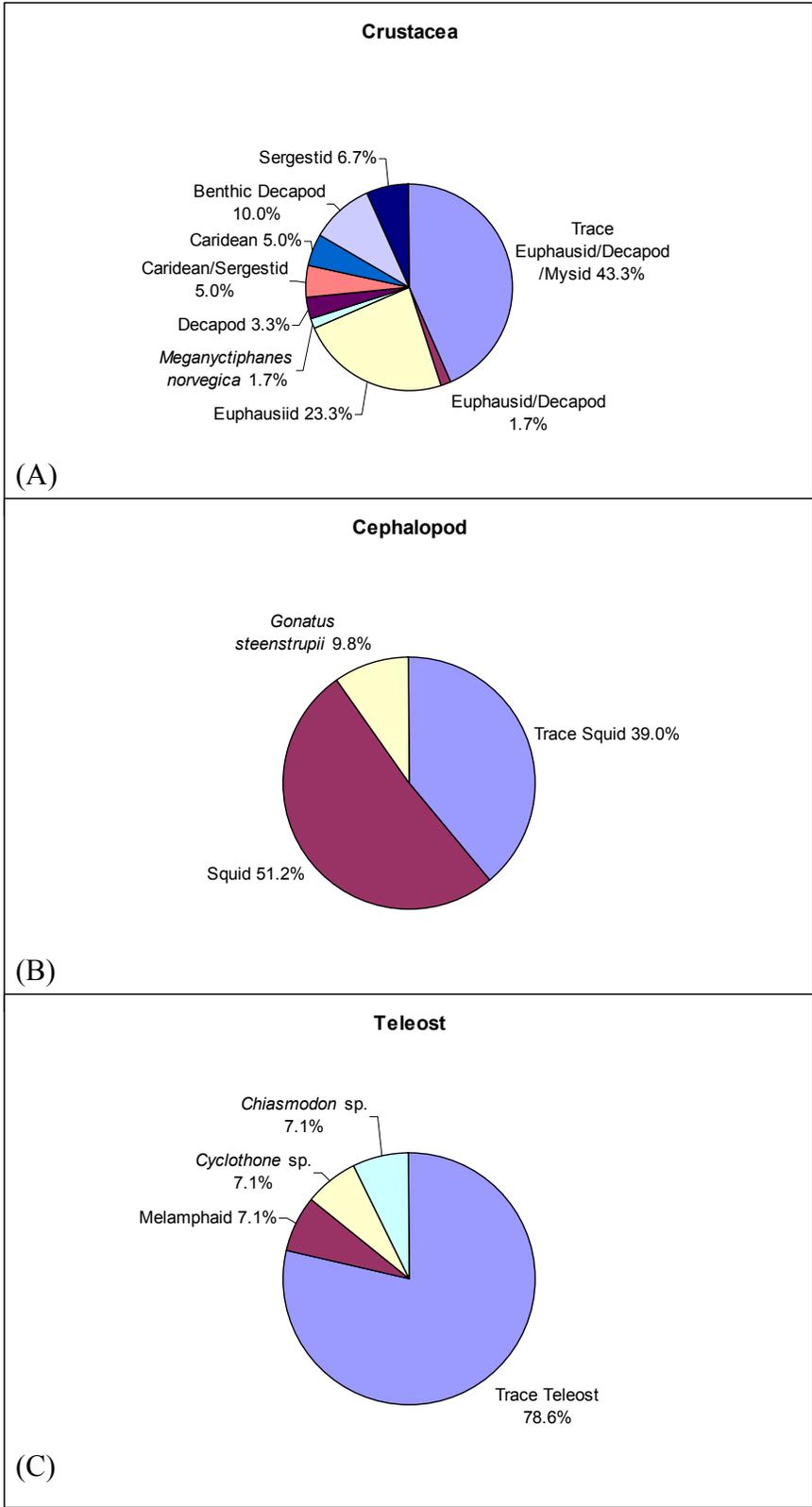


Figure 20. Relative occurrence (%) of (A) crustacean prey items, (B) cephalopod prey items, and (C) teleost prey items found within *Serrivomer beanii*.

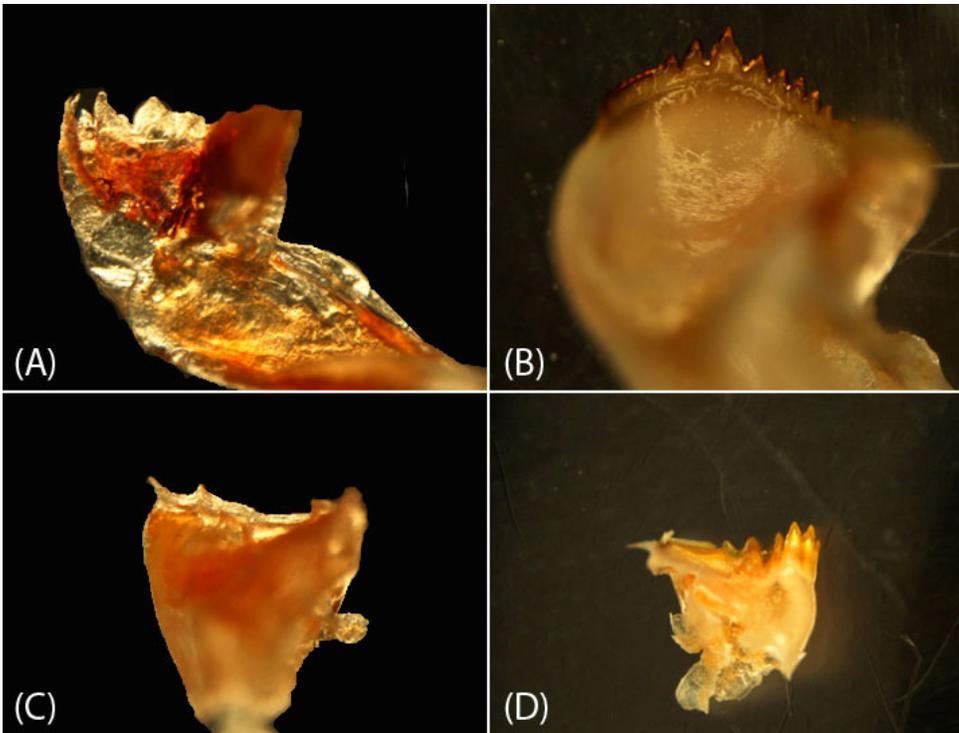


Figure 21. Crustacean mandibles from (A) euphausiid, (B) caridean, (C) sergestid, and (D) mysidacean specimens.

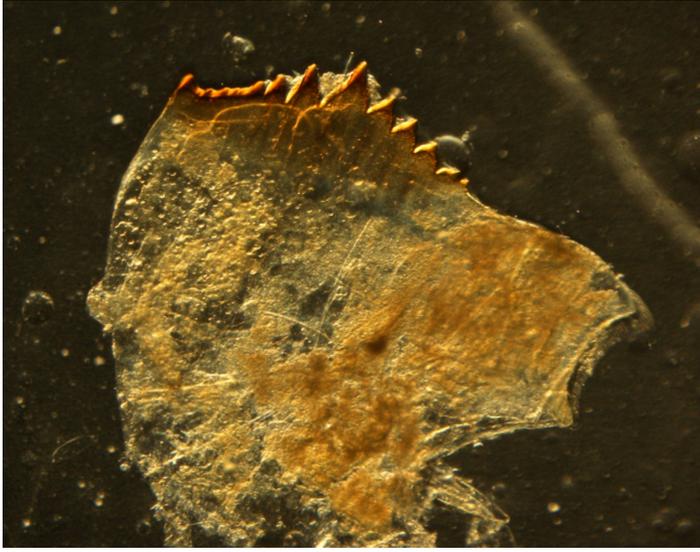


Figure 22. Mandible of benthic decapod prey found within *Serrivomer beanii*.

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