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ENDOLITHIC FAUNA OF VACATED *ZIRFAEA CRISPATA* L. BURROWS IN BLOMIDON SHALE, MINAS BASIN, NOVA SCOTIA

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At Cape Blomidon, Minas Basin, there are numerous vacated *Zirfaea crispata* burrows in the shale terraces exposed at low tide. About 300 burrows were flushed of sediments and screened for fauna. Eighty-eight species were identified and 16 are new records for Minas Basin. Of the 654 specimens, 67% were attributable to 1 burrowing anemone, 4 gastropods, 3 amphipods, and 3 genera of polychaetes. A group of 11 polychaete species, of the 34 species collected, accounted for 76% of all polychaetes and for 42% of the entire collection.

Introduction

The great piddock clam, *Zirfaea crispata* L., burrows in peat, clay and soft rocks, usually sublittorally, but can occur in the lower eulittoral (Allen 1969; Abbott 1974; Gosner 1979). It ranges from Labrador to New Jersey and along the west coast of Europe but has not previously been reported from Minas Basin. In areas such as Minas Basin which experience daily macrotidal cycles (about 16 m), a band of the lowest eulittoral and adjacent sublittoral fringe can become exposed on certain extreme low-water tides (Bleakney 1972). At this level we have found active *Zirfaea crispata* aggregations, some of which occur as high as 110 cm above chart datum, in Cape Blomidon shales. In contrast, on the Northumberland coast of England (Allen 1969) they extended only 20 cm above datum.

Successive generations of this large pholad (valve dimensions 5.5 x 3.5 cm) have pitted the series of nearly horizontal shale terraces (5° dip to NW) with vertical inverted-cone-shaped burrows in densities up to 158/m^2 although most areas range between 22 and 75 burrows/m^2. As the individual *Zirfaea* lives but 5 to 7 years (Allen 1969) and the rock erodes at a mere 0.01 to 0.05 cm/yr (unpublished data, Bleakney), the original 18 to 22 cm-deep burrows are available for occupancy by other organisms for hundreds of years after the original excavators have died. The age of many burrows can be dated by ^{14}C determination of the entrapped *Zirfaea* valves. One burrow at station No. 6 (Fig 1) was 9 cm deep and the extracted shell was dated 865 ($\pm$ 100) yr B.P. (Dal-318, Dalhousie University Radiocarbon Lab). In terms of life spans of marine invertebrates, these burrows represent a permanently available minihabitat.

A majority of the burrows in the lower eulittoral and sublittoral fringe are not occupied by live *Zirfaea*. They contain 2 empty tight-fitting valves at the bottom and are otherwise filled with accumulated sediments and detritus captured from the water column which because of the macrotidal cycles is turbid with suspended organic and inorganic particles (Amos 1977). From September 1978 to February 1979 the burrows in this area were periodically sampled to determine if the infauna of these sediment cylinders in a rocky shore was the same as that in the contiguous, broad intertidal flats of the western Minas Basin. The latter were intensively surveyed by Gratto (1978) at 930 sampling stations. A total of 88 taxa was eventually extracted from the *Zirfaea* burrows, 16 of which are additions to the reported fauna of Minas Basin and 55 of which were not recorded in Gratto's list of 76 species.

During this preliminary survey such groups as Protozoa, Nematoda, Kinorhyncha, Copepoda, and Ostracoda could not be considered.

As this is the first study of endolithic fauna of vacated *Zirfaea* burrows, no geographic comparisons were possible. Evans (1967) working with *Penitella penita* in Oregon made incidental mention of other organisms in pholad burrows but only by general category (coelenterates, annelids, sipunculoids, crustaceans, molluscs, and urochordates), not by species. Morton (1973) stated that terebellids, cirratulids, and nerids occupy vacated burrows of New Zealand pholads.

Study Area and Methods

The geology of the study area (45°15.6'N, 64°20.2'W) has been described by Crosby (1962) as an outcrop of Blomidon shale dipping 5° to the northwest and composed of soft brick-red shale and argillaceous sandstone that is continually eroding away. The slight inshore tilt of the shale terraces creates long shallow pools as evident in Figure 1. Sea surface temperatures at Cape Blomidon taken at low tide at nearly monthly intervals from April 1977 to February 1979 varied from a high of 17.5° to a low of -1.5°C. Salinities were stable near 29°/oo and suspended sediment loads ranged from 1.5 to 3 mg/ℓ (Pennachetti 1978). Tidal range varies from about 11 m to 14 m and longshore currents sweep the terraces making it extremely difficult to anchor over the area even during "slack" high tide. Macroalgae are generally sparse on these Cape Blomidon terraces but *Chondrus crispus, Gigartina stellata, Corallina officinalis,* and *Lithothamnion* spp. were the most conspicuous near low water.

A transect with sampling stations was established from the uppermost *Zirfaea* burrows to extreme low water (Fig 1), a horizontal distance of about 51 m and a vertical distance of about 135 cm. Stations No. 1 (*Petricola pholadiformis* burrows only)

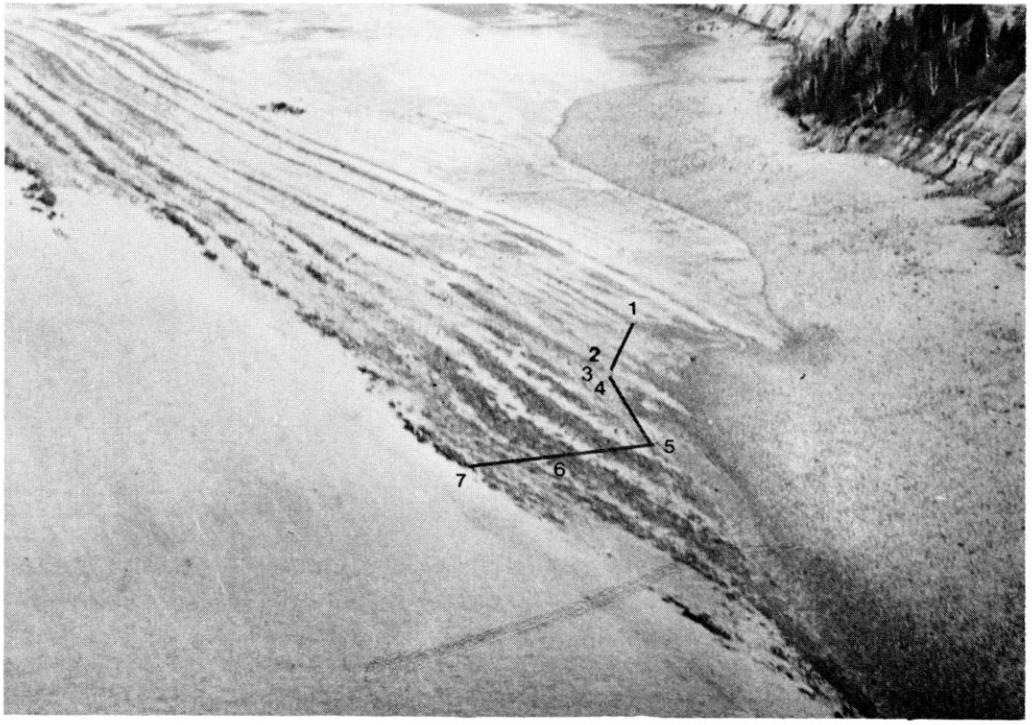

Figure 1. Air photo of Cape Blomidon shale terraces and pools with the transect line and survey stations, at a 0.2 m tide.

and No. 2 were unproductive in terms of endolithic fauna so this report concerns only stations No. 3 to No. 7. The position of the stations relative to each other and to a sample of tidal predictions is plotted in Table II as well as the average depth of burrows measured at each station level.

As the study area was exposed only for a few days each lunar month, only 10 field trips were completed over the 6-month period. In order to sample as many burrows as possible over the brief exposure times, a flushing apparatus was constructed which removed burrow contents with minimal damage to delicate burrowing organisms. A 3.7 cm diameter perspex cylinder 20 cm long was tightly positioned over each burrow and a stream of water from a small bilge pump hosed into the burrow. The overflow was directed out a spout at the side of the cylinder into a coarse sieve (3560 μm mesh apertures) and fine sieve (351 μm). After several burrows were flushed the sieves were separated, the contents washed, placed in separate jars, and another series of flushings begun. One hundred and nineteen of the flushed burrows were measured for depth and diameter for determination of average burrow size at each station level (Table I). Initially the contents of each burrow were kept separate, the burrow measured and its volume determined by measuring its water volume in a graduated cylinder. However, as manpower was limited and few burrows could be processed on a tidal cycle in this detail, the emphasis was shifted to simply obtaining a mass sample from burrows of all sizes and thereby assuring a collection representative of species present. Burrows were then flushed randomly and rapidly in the vicinity of each station. As the burrows were of different volumes and this could not be measured under the circumstances, no record unfortunately was kept of grand total actually sampled. However, with volume determinations of burrows 3, 6, and 10 cm in depth and knowing the average burrow depth at each station, we have roughly estimated the number of burrows flushed at each station and calculated the volumes of substrate sieved (Table I).

The approximate volume of substrate sampled is relatively small when compared with Gratto's efforts (1978). Along each of his 221 transects 700 ml were sieved at each station and by mid-August he had processed 930 samples (ca. 651,000 ml) and identified 76 species.

Results and Discussion

The species and numbers of specimens collected at each station are listed in Table III. From the total 654 specimens extracted from the estimated 300 burrows, 88 species were identified of which 16 had not previously been reported from Minas

Table I. Estimate of volume of burrow sediments sieved at each station based on measurements of 119 burrows.

Station Number	Estimated Flushed Burrows	Average Depth	Average vol/burrow	Total Substrate Sieved
3	20	3.7 cm	40 ml	800 ml
4	40	5.7	60	2400
5	80	5.7	60	4800
6	80	7.9	80	6400
7	80	8.1	80	6400
	300			20800 ml

Table II. Vertical distances between collecting stations and estimated Chart Datum at Cape Blomidon. Tidal predictions in meters are from Saint John, N.B. tables and are therefore only relative. The tides of February and March were atypical when compared with the October to January series.

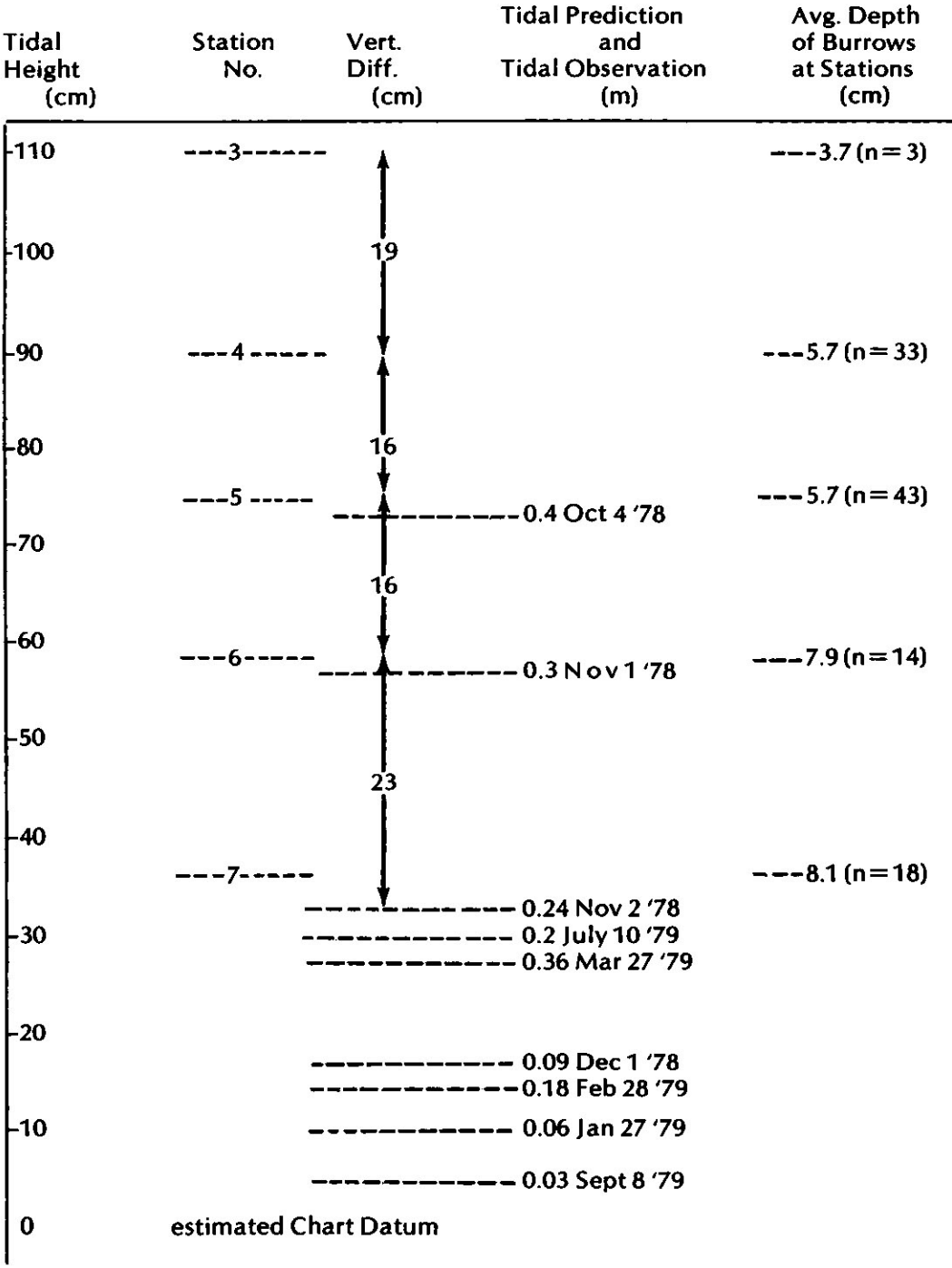

Table III. List of 88 species collected from vacated *Zirfaea crispata* burrows at Cape Blomidon, Nova Scotia. **Sixteen new records for Minas Basin. *Fifty-five species additional to Gratto's 1978 eulittoral survey.

	Stations					
	3	4	5	6	7	Totals
Phylum: CNIDARIA (2 species, 12 specimens)						
****Edwardsia elegans* Verrill				4	7	11
****Tealia felina* (Linnaeus)				1		1
Phylum: NEMERTINEA (6 species, 16 specimens)						
*unidentified species					2	2
*unidentified species					3	3
Lineus sp.				4		4
Cerebratulus sp.				2	2	4
Amphiporus sp.					1	1
*unidentified species				1	1	2
Phylum: MOLLUSCA (23 species, 204 specimens)						
**Ischnochiton ruber* (Linnaeus)					2	2
**Acmaea testudinalis* (Muller)	1			1	1	3
**Lacuna vincta* (Montagu)	1			31	26	58
**Littorina littorea* (Linnaeus)	6	1	27	12	5	51
**Crepidula fornicata* (Linnaeus)				4	16	20
**Mitrella lunata* (Say)		1		7	7	15
Nassarius trivittatus (Say)			1	4		5
***Admete couthouyi* (Jay)		1		2	2	5
**Lora bicarinata* (Couthouy)				2		2
**Acanthodoris pilosa* (Muller)				3		3
**Nucula proxima* Say					3	3
**Musculus corrugatus* Stimpson					1	1
**Crenella glandula* (Totten)				3	1	4
**Astarte castanea* Say					1	1
Gemma gemma (Totten)		1	1			2
Petricola pholadiformis Lamarck				6	2	8
Macoma balthica (Linnaeus)					1	1
Ensis directus Linnaeus					3	3
**Hiatella arctica* (Linnaeus)				6		6
Mya arenaria Linnaeus	1	1	1			3
***Zirfaea crispata* (Linnaeus)				3	2	5
**Pandora gouldiana* Dal					1	1
**Lyonsia hyalina* (Conrad)				1	1	2
mollusca subtotals	9	5	30	85	75	204

	3	4	5	6	7	Totals
Phylum: ANNELIDA (34 species, 277 specimens)						
****Harmothoe extenuata* (Grube)					2	2
**Harmothoe imbricata* (Linnaeus)				5	9	14
**Lepidonotus squamatus* (Linnaeus)				1	4	5
Eteone longa (Fabricius)				2	5	7
***Eulalia viridis* (Linnaeus)				1	2	3

**Phyllodoce groenlandica* Oersted			1	12	13
**Phyllodoce maculata* (Linnaeus)		3	12	17	32
Phyllodoce mucosa Oersted	1	1	3	10	15
Exogone dispar (Webster)			2	2	4
**Exogone hebes* (Webster and Benedict)				3	3
Nereis virens Sars	1	2	1	3	7
**Aglaophamus neotenus* Noyes		2	4	5	11
Nephtys caeca (Fabricius)			3	4	7
***Stauronereis caeca* (Webster and Benedict)			1	2	3
Lumbrineris fragilis Muller		1			1
Aricidea succica Bliason			1	1	2
Polydora ligni Webster		1	1		2
**Scolelepis squamata* (Muller)				1	1
Spio filicornis (Muller)				4	4
Streblospio benedicti Webster			1		1
Chaetozone setosa Malmgren			2	8	10
***Cirratulus cirratus* (Muller)			2		2
**Tharyx acutus* Webster and Benedict		1	2	1	4
***Pherusa affinis* (Leidy)				1	1
Heteromastus filiformis (Claparede)		1	1		2
***Notomastus latericeus* Sars		1	1		2
Clymenella torquata (Leidy)		2	27	10	39
Clymenalla zonalis (Verrill)			10	26	36
***Praxillella* sp.		1			1
**Sabellaria vulgaris* Verrill				2	2
**Amphithrite figulus* (Dalyell)			5	6	11
***Polycirrus phosphoreus* Verrill			12	1	13
***Nicolea venustula* (Montagu)			1		1
***Potamilla reniformis* (Leukart)			2	14	16
annelida subtotals	2	0 16	104	155	277
	3	4 5	6	7	Totals
Phylum: SIPUNCULA					
***Phascolopsis gouldi* (Pourtalès)			1	1	2
Phylum: ARTHROPODA (Crustacea) (18 species, 130 specimens)					
Oxyurostylis smithi Calman		1		1	2
Leptognathia caeca (Harger)			1		1
Chirodotea caeca (Say)			1		1
Idotea phosphorea Harger			1	1	2
Jaera marina (Fabricius)			1		1
**Ampithoe rubricata* Montagu		1	7	7	15
**Leptocheirus pinguis* (Stimpson)			2	1	3
**Unicola irrorata* Say			1		1
Corophium bonelli (Milne-Edwards)			29	5	34
Corophium volutator (Pallas)			3	2	5
Gammarus lawrencianus Bousfield		6			6
**Bathyporeia quoddyensis* Shoemaker			1		1
***Harpinia propinqua* Sars				1	1
**Phoxocephalus holbölli* (Krøyer)			19	17	36
**Pontogeneia inermis* (Krøyer)			11		11
Crangon septemspinosa Say		1		1	2

Pagurus acadianus Benedict				5	2	7
**Cancer irroratus* Say				1		1
arthropoda subtotals		6	3	83	38	130
Phylum: ECHINODERMATA						
**Leptasterias tenera*					*3*	*3*
**Amphipholis squamata* (Delle-Chiaje)					4	4
Phylum: HEMICHORDATA						
**Saccoglossus kowalewskii* (Agassiz)			1	2	2	5
Phylum: CHORDATA						
**Molgula citrina* Alder and Hancock				1		1
Total individuals	11	11	50	288	294	(654)
Total species	6	6	19	62	63	(88)

Basin. Only 33 of these species occurred also in samples from local inter-tidal flats (Gratto 1978). However, such a direct comparison must be qualified by noting that Gratto's transects did not extend to extreme low water and all his samples were from sand and mud, none from rock surfaces or crevices. Many of the *Zirfaea* burrow species are typical of crevice cryptofauna (anemone *Tealia,* several gastropods, isopods, decapods, many polychaetes, and small echinoderms) or are small juveniles of large species that the burrows could not accommodate at the adult stage (*Mya arenaria, Ensis directus, Crepidula fornicata, Macoma balthica).* The paucity of individuals of the species in these categories indicates their incidental utilization of vacated *Zirfaea* burrows.

Another evident group is the typical cold water and/or deeper sublittoral species *(Admete couthouyi, Lora bicarinata, Lacuna vincta, Mitrella lunata, Astarte castanea, Nucula proxima, Crenella glandula)* which have been able to move up to this tidal level firstly because of the lack of temperature stratification (resulting from macrotidal mixing in the Basin) and secondly because of the "subtidal" environmental stability afforded by these burrows. It seems unlikely that during periods of tidal exposure the salinity or temperature in burrows could be altered nor would wave action disturb their contents.

It is evident from Table II that the area of deeper burrows within 60 cm of chart datum is best suited to the development of an endolithic community. Although there are actually more burrows per unit area near station No. 5 and much survey effort was concentrated there, 89% of all specimens extracted came from stations No. 6 and No. 7 (with a near equal distribution, Table III). Similarly, 94% of the 88 species were recorded at those 2 levels and only 5 species were limited to the upper stations No. 3, No. 4, and No. 5.

Considering only stations No. 5, No. 6, and No. 7, one can recognize a community of species which are consistently present in the samples. Employing the usual mystical arbitrary figure of species with 10 or more specimens represented in the survey, these dominant forms are: 1 burrowing anemone *(Edwardsia elegans),* 4 gastropods which together constitute 22% of all specimens *(Lacuna vincta, Littorina littorea, Crepidula fornicata, Mitrella lunata),* 4 amphipods which constitute 15% *(Ampithoe rubricata, Corophium bonelli, Phoxocephalus holbölli, Pontogeneia inermis),* and 11 polychaetes which constitute 32%. These 11 polychaetes also account for 76% of all polychaete specimens.

Of the 4 gastropods, only *Lacuna vincta* is dominant as an adult, the 3 other species being represented by small individuals. The 4 dominant amphipods are 2 tube dwellers, *Ampithoe rubricata* and *Corophium bonelli,* a burrower *Phoxocephalus holbölli,* and one collection of the free-living phycophilic *Pontogeneia inermis,* the latter possibly a sampling anomaly. The 2 *Corophium* species are of particular interest because from the adjacent intertidal flats Gratto (1978) obtained counts of *C. volutator* over 300/m^2 but never a *C. bonelli.* It would be interesting to know if the 2 species could occur in the same *Zirfaea* burrow.

Polychaete collections from transects along 40 km of western Minas Basin tidal flats were analysed by McCurdy (1979). He reported 72% of all eulittoral polychaete specimens (42 species) were attributable to only 3 species: *Heteromastus filiformis, Chaetozone setosa,* and *Streblospio benedicti.* However, in the nearby *Zirfaea* burrows these species are rare (4.6% of total) and instead 3 species of *Phyllodoce* and 2 species of *Clymenella* make up 49% of the polychaete sample. A more interesting comparison is to recognize the unusual situation of 11 predominant species whose total numbers account for 76% of all polychaetes collected.

The endolithic community of vacated *Zirfaea* burrows at Cape Blomidon differs from other communities surveyed thus far in Minas Basin (Gratto 1977; 1978; Fuller & Trevors 1977; Bromley 1978; Yeo 1978; McCurdy 1979). The burrow fauna probably represents a sample of the smaller species that are typical in general of the sublittoral fringe zone of the western Minas Basin. Vacated pholad burrows in themselves represent a unique and presumably extensive Atlantic coast habitat not previously examined.

Summary

At Cape Blomidon, Minas Basin, the shale terraces exposed during extreme low water tides are pitted with vacated burrows of the great piddock clam *Zirfaea crispata.* The accumulated sediments in vacated burrows were flushed and sieved. An endolithic faunal sample of 654 specimens was obtained and totalled 88 species of which 16 are new records for Minas Basin.

The predominant species, together constituting 67% of all specimens, were 1 burrowing anemone, 4 gastropods, 3 amphipods, and 2 genera (5 species) of polychaetes none of which is a dominant species in the adjacent extensive intertidal flats of western Minas Basin.

A group of 11 polychaete species accounted for 76% of all polychaete specimens and for 42% of the entire collection.

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