

## ECOLOGICAL STUDY ON LITTORAL AND INFRALITTORAL ISOPODS FROM UBATUBA, BRAZIL

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### Synopsis

*The isopod species of rocky shores and shallow infralittoral zone from Enseada do Flamengo, Ubatuba, were studied. The sampling was done during Autumn (1965) and during Autumn and Springtime (1975) at six stations classified according to wave exposure. The intensity of the waves and the type of substratum showed to be important factors influencing distribution, abundance and diversity of the fauna. The highest density of isopods occurred in Dictyota ciliolata. A relation between species diversity and the degree of wave action was disclosed. Species diversity rised from exposed to moderately exposed sites and decreased with the increase in shelter.*

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### Introduction

The study of the factors which determine the distribution patterns in the sea and the analysis of the causes responsible for the change in abundance of some species from place to place are two important and closely related problems in marine ecology (Field & McFarlane, 1968). Generally the species do not occur in every shore of a coast, but if they are ubiquitous their abundance varies considerably from place to place. The factors influencing local distribution and abundance of the species in rocky shores are of a physical and biological nature: wave exposure, shore topography, freshwater inflow, substratum, shore position in relation to winds and sun, and finally the existence of the plants and animals themselves. The plants and sessile animals can reduce the desiccation giving advantage to the species found normally at lower levels. On the other hand, interspecific competition may limit a given species in a determined level, while predation usually influences more the abundance than the distribution of the species at a particular place (Lewis, 1976).

The ecology and the patterns of distribution of plants and animals in rocky shores were well studied by several authors (Southward, 1958; Stephenson & Stephenson, 1972; Lewis, 1976). Detailed studies on isopod ecology were performed by Naylor (1955), Roman (1970), Dumay (1971) and Jansen (1971). Many

papers on the vertical distribution of organisms on the Brazilian rocky shores have been published (Dansereau, 1947; Oliveira, 1948, 1951; Joly, 1957; Nonato & Pêres, 1961; Costa, 1962; Oliveira Filho & Mayal, 1976), but none on the distribution of isopods.

In the present paper I listed 16 species of isopods, in which distribution and abundance were studied and compared to determine the habitat and ecological preferences of each species. The density and diversity of the fauna were also investigated.

### Material and methods

The littoral isopod fauna was obtained from 29 species of algae and five species of animal substrata, totaling 84 samples; the infralittoral fauna was collected from two species of algae obtained from 1 to 6 m depth, making up 14 samples.

The littoral sampling was carried out at low tide in April and September 1975, and the infralittoral in April and May 1965 at Enseada do Flamengo, Ubatuba, northern São Paulo State, Brazil. Six and seven stations varying in the degree of wave exposure were respectively selected for the littoral and infralittoral sampling (Fig. 1).

Two collecting methods were employed according to the substratum type. Each species of alga was picked off or scrapped with a spatula, put into a plastic bag and washed several times in freshwater, at laboratory. After 1:20 h in the air temperature the alga was

weighed (wet weigh). The isopod fauna was obtained by filtering the water in which the alga had been washed through a sieve with 295  $\mu$  mesh. The animals were preserved in 70% alcohol. The animal substrata were taken from areas of 0.12 m<sup>2</sup>, measured with a 20 x 20 cm rectangular quadrat, and preserved in 5% formalin solution. The specimens obtained were sorted under a binocular stereomicroscope. Relative abundances were expressed in number of isopods per 500 g of each alga and per 0.24 m<sup>2</sup> of each animal substratum.

At Enseada do Flamengo, the *Sargassum* sampled was present in two forms: short tufts with nearly 10 cm in length, and long floating tufts with 30-40 cm. In the text-figures the dwarf *Sargassum* is indicated as *d* and the long as *l*. When not stated, the *Sargassum* is long.

On the rocky shores the tidal ranges were marked based on *in situ* observations, and the belts of the zonation were named according to the dominant organisms (Brattegard, 1966). The terminology employed is that of Stephenson (1949).

Before each sampling, physical parameters were taken: sea and air temperatures, salinity and oxygen content in the water. Salinity was determined by the Harvey's method and the dissolved oxygen by the Winkler's method (Strickland & Parsons, 1968).

The measures of species diversity employed were: a) Shannon-Weaver's index (Margalef, 1974), expressed as  $H = -\sum P_i \log P_i$ , where  $P_i$  is the proportion of individuals belonging to the  $i^{\text{th}}$  species; b) Margalef's index of species richness:  $SD = (s-1)/\log N$ , where  $s$  is the number of species and  $N$  the number of individuals in the collection; c) equitability, calculated as  $J = H/\log S$ , where  $S$  is the number of species in the sample (Odum, 1971). In all formulas it was used the napierian logarithms ( $\log_e$ ), and the index is expressed in nats.

## Results

### Environmental data

During the studied periods air temperature varied from 16.4 to 28.0°C and the surface sea water temperature from 20.0 to 25.0°C, with the minimum values in September and the maximum in April.

Salinity showed to be almost constant

within the surveyed area (33.4 to 35.4‰). Only the station IV, under the influence of the Perequê-Mirim river discharge, presented low values of salinity (20.2 and 20.6‰).

The content of dissolved oxygen in the water varied from 5.0 to 6.8 ml/l for the littoral stations and from 3.8 to 5.1 ml/l for the infralittoral. The saturation values of oxygen in the sea water (ml/l) were also calculated (International Oceanographic Tables, UNESCO, 1973) and showed to be constant for April and May (4.74) and higher in September (5.03), when the temperature was lower. Maximum values were registered in the low-salinity station IV (5.64).

### The littoral zone

#### 1. Studied species

Thirteen species of isopods were found on the littoral substrata: *Cymodoce brasiliensis* Richardson, 1906; *Dynoides castroi* Loyola e Silva, 1960; *Pseudospharoma mourei* Loyola e Silva, 1960; *Dynamenella antonii* Loyola e Silva, 1960; *Cirrolana parva* Hansen, 1890; *Paranthura* sp.; *Janaira gracilis* Moreira & Pires, 1977; Ba-

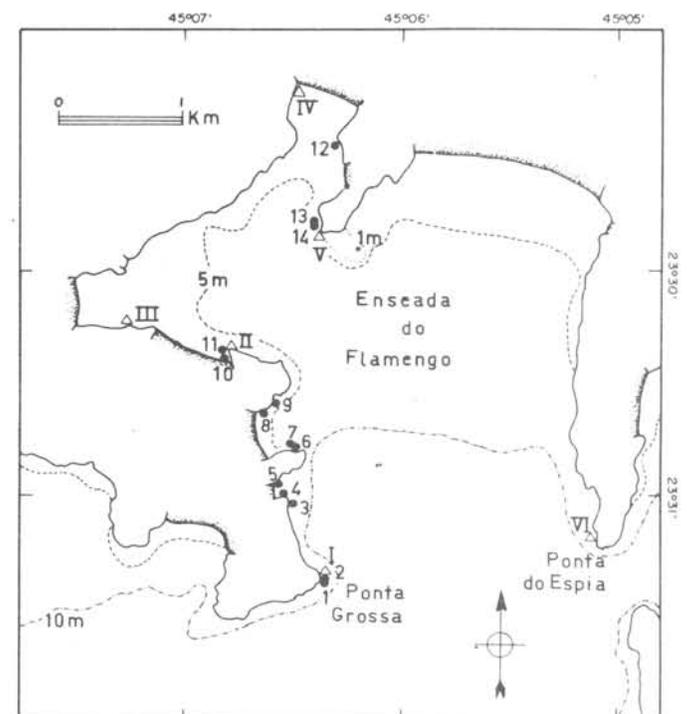


Fig. 1. Enseada do Flamengo, Ubatuba, northern São Paulo State, Brazil, showing the sampling stations. ( $\Delta$ ) Littoral, I-VI; ( $\bullet$ ) Infralittoral, 1-14.

*gatus* sp. 1; *Bagatus* sp. 2; *Jaeropsis dubia* Menzies, 1951; *Idotea baltica* (Pallas, 1772); *Erichsonella filiformis* (Say, 1818); *Ligia exotica* Roux, 1828.

## 2. Description of the rocky shores

Shore classification was somewhat subjective because a scale of exposure does not exist for the Brazilian shores. The present classification is based on the degree of exposure to wave action and on the presence of certain organisms on the shore. The scale of exposure employed is the following: class I, exposed; class II, semi-exposed; class III, sheltered.

The class I shores are submitted to heavy wave action at all tidal levels. It is possible to collect in these places only in the calm weather. Profiles are regular with a slope near 30°. Dominant algae are: *Sargassum cymosum*, *S. vulgare*, *Ectocarpus breviararticulatus*, *Jania adhaerens*, *J. capillacea* and *Amphiroa beauvoisii*. The shores belonging to class I are Ponta Grossa (station I) and Ponta do Espia (station VI).

The class II shores are moderately exposed to wave action. However, heavy wave action is present in rough weather at all tidal levels during the full cycle. Profiles are irregular with large stones in the lower shore. Dominant algae are *Sargassum cymosum* and *Amphiroa beauvoisii*. The shore belonging to class II is Lagosteiro (station V).

The class III shores are exposed to a quite light wave action even in stormy weather. Profiles are irregular and infralittoral water is very shallow. Sand and stones of several sizes lie at lower levels. Dominant algae are *Sargassum cymosum*, *Acanthophora spicifera*, *Gymnogongrus griffithsiae* and *Bostrychia binderi*. Shores of this type are Praia da Ribeira (station II), Saco da Ribeira (station III) and Praia do Perequê Mirim (station IV). The last one receives the influence of the Perequê Mirim river that flows near the studied rock.

## 3. Species distribution

The vertical distribution of the species is represented in Figures 2-3, and the horizontal distribution in Figures 4-5. The horizontal distribution of each species in relation to wave exposure was obtained by calculating the medium value of the relative abundances for each level

on the same rocky shore class.

### *Pseudosphaeroma mourei*

#### Horizontal distribution

This species was only present on class III shores, with special abundance at station III (September) and at station IV (April). In these two shores the greater number of animals was obtained in *Enteromorpha* (431 and 1625 specimens, stations III and IV, respectively).

#### Vertical distribution

*Pseudosphaeroma mourei* occurred from the infralittoral fringe to the midlittoral zone, with greater abundance just below the Mid Tide Level. In general the adults were more numerous than the juveniles and the females appeared in significant higher numbers. At the infralittoral fringe, however, the juveniles were slightly more numerous.

### *Dynamenella antonii*

#### Horizontal distribution

The species was only present on sheltered shores. In April the species was found at station IV with its greatest abundance: 60 individuals in *Brachidontes* spp.; in September the species occurred at station III in *Bryocladia*: 50 specimens.

#### Vertical distribution

In April the species was only present on the midlittoral being more abundant at the Mid Tide Level; in September it only occurred on the infralittoral fringe.

### *Cymodoce brasiliensis*

#### Horizontal distribution

The species was poorly represented on the three shore classes. It was a little more numerous on the exposed shores in September.

#### Vertical distribution

*C. brasiliensis* only occurred below the Mid Tide Level. In September and at station I, where the species was more numerous, the highest number of juveniles was found (24 specimens).

*Dynoides castroi*

Horizontal distribution

The species occurred in all the shore classes and its abundance increased with the wave action. It was more abundant (2,300 animals) in September at station I in *Ectocarpus breviarticulatus*.

Vertical distribution

*Dynoides castroi* was found on the infralittoral fringe and on the midlittoral with greater abundance about the Mid

Tide Level. The vertical amplitude of the species increased with the exposition of the shore. On classes I and II shores the higher limit of the species rised to the upper midlittoral; on class III shores the highest limit was on the lower midlittoral. Besides the algae, *D. castroi* was found in the empty tests of *Tetraclita squamosa* on exposed and semi-exposed shores and in the empty tubes of the polychaete worm *Phragmatopoma lapidosa*. The adults were more numerous at the extremes of the vertical distribution (upper midlittoral and infra-

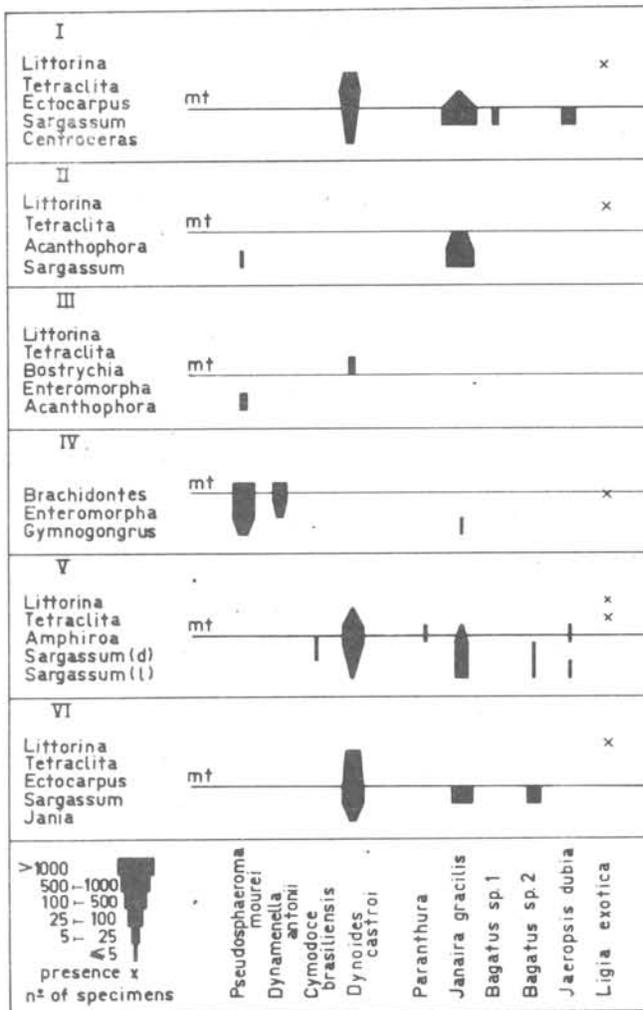


Fig. 2. Vertical distribution of the 10 species of isopods per substratum indicative of the tidal levels, in each station of the littoral zone, April 1975. Each value of abundance is the mean number of the sampled substrata of the same tide level. MT: Mid Tide Level; (d): dwarf *Sargassum*; (l): long *Sargassum*.

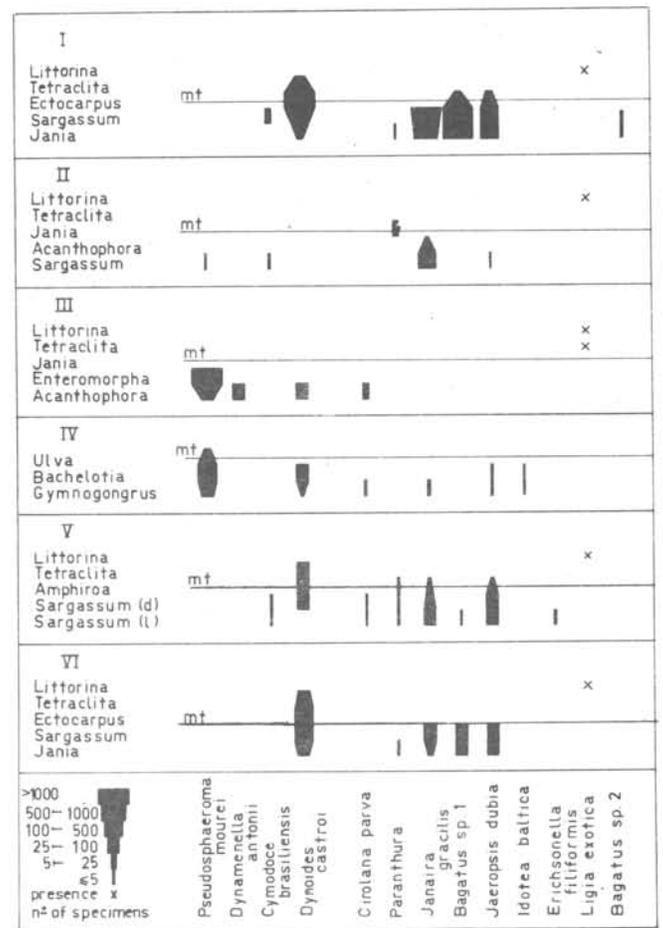


Fig. 3. Vertical distribution of the 13 species of isopods per substratum indicative of the tide levels, in each station of the littoral zone, September 1975. Each value of abundance is the mean number for the sampled substrata of the same tide level. MT: Mid Tide Level; (d): dwarf *Sargassum*; (l): long *Sargassum*.

littoral fringe) on class I and II shores. On class III their concentration core was on the midlittoral in April and at lower levels in September.

#### *Cirolana parva*

##### Horizontal distribution

The species was rare on the studied rocky shores. It was found only in September on class II and III shores, being more abundant in the last ones. The greatest abundance was obtained in *Gigartina acicularis* on station III: 12 specimens.

##### Vertical distribution

*Cirolana parva* occurred on the lower midlittoral and on the infralittoral fringe on semi-exposed shores, and on the infralittoral fringe on sheltered shores. The centre of abundance was, however, on the infralittoral fringe for both classes of shores.

#### *Paranthura* sp.

##### Horizontal distribution

This species was uncommon in the surveyed area. It was present on class II shores in April and in the three classes of shores in September, when the species was more numerous on sheltered places. The greatest number of *Paranthura* was obtained in *Jania capillacea* at station II: 9 specimens.

##### Vertical distribution

The species occurred from the infralittoral fringe to the Mid Tide Level. This distribution is strongly related with the presence of the substratum where the animals live (calcareous algae, principally).

#### *Janaira gracilis*

##### Horizontal distribution

The species occurred on the three classes of shores, with greater abundance on the exposed places. The highest number was 2,650 specimens obtained in *Dictyota ciliolata* at station I, September.

##### Vertical distribution

*Janaira gracilis* occurred from the infralittoral fringe to the midlittoral, with

the upper limit at the Mid Tide Level on class I and II shores, and at the lower midlittoral on class III shores. The species was considerably more abundant on the infralittoral fringe on semi-exposed and sheltered shores, and on the lower midlittoral on exposed shores, regions where there are dense outgrowths of *Sargassum*, *Dictyota*, *Dictyopteris*, *Laurencia* and *Galaxaura*. A comparison between the two periods of sampling showed that the population of *J. gracilis* moved downwards in September. Adults were dominant on the upper limit of distribution while juveniles predominated at all the other levels.

#### *Bagatus* sp. 1

##### Horizontal distribution

The species was present on class I and II shores, and its abundance rised with the degree of exposure.

##### Vertical distribution

*Bagatus* sp. 1 occurred from the infralittoral fringe to the Mid Tide Level, the lower level being the species centre of concentration.

*Bagatus* sp. 1 presented a remarkable

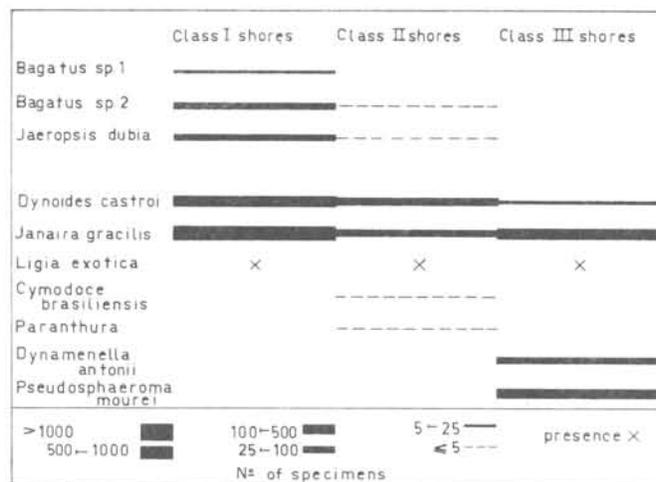


Fig. 4. Horizontal distribution of the 10 species of isopods in the three classes of rocky shores on the Littoral zone, April 1975. Each value of abundance is the mean number of animals in the sampled substrata of a same class of shore. Class I exposed shores; class II; semi-exposed; class III, sheltered shores.

seasonal variation in abundance. In April the species was obtained in small number and at only one substratum (7 specimens in *Sargassum*). In September, *Bagatus* sp. 1 was found on class I and II shores in very high numbers at station I: 7,604 specimens on the infralittoral fringe and 6,122 on the lower midlittoral.

#### *Bagatus* sp. 2

##### *Horizontal distribution*

The species was obtained on class I and II shores, increasing in abundance with exposure.

##### *Vertical distribution*

*Bagatus* sp. 2 occurred at the infralittoral fringe and lower midlittoral, more abundantly in the latter.

#### *Jaeropsis dubia*

##### *Horizontal distribution*

The species was present on the three classes of shores, increasing in number with exposure. It was more abundant and occurred in a greater number of stations in September.

##### *Vertical distribution*

The species was found from the infralittoral fringe to the Mid Tide Level on class I and II shores; on class III it was only found on the infralittoral fringe. Its centre of abundance was on the lower midlittoral. Juveniles were generally more numerous than adults in the sampled populations.

#### *Idotea baltica*

Only juveniles specimens of *I. baltica* were found.

##### *Horizontal distribution*

The species was rare in the studied shores. During the sampled periods it only occurred in September and on class III shores (station IV), in *Bachelotia* and *Bryocladia*.

##### *Vertical distribution*

*I. baltica* was found on the infralittoral fringe and on the lower

midlittoral with the same relative abundance in each level (5 specimens).

#### *Erichsonella filiformis*

The species was found on the lower infralittoral fringe, in September, on the semi-exposed shore (1 specimen).

#### *Ligia exotica*

The species was found in all the studied shores on the supralittoral fringe. Adult and juveniles were present on the rocks but only juveniles occurred in the algae (*Rhizoclonium kernerii* and *Bostrychia binderi*).

#### 4. Types of substratum

From 84 samples collected, 61 were of marine algae (29 species) and 23 of marine animal substrata (5 species). The species of algae were: *Ulva fasciata*, *Enteromorpha clathrata*, *Enteromorpha flexuosa*, *Rhizoclonium kernerii*, *Sargassum cymosum*, *Sargassum vulgare*, *Ectocarpus breviarticulatus*, *Bachelotia fulvescens*, *Dictyopteris delicatula*, *Dictyota cilio-*

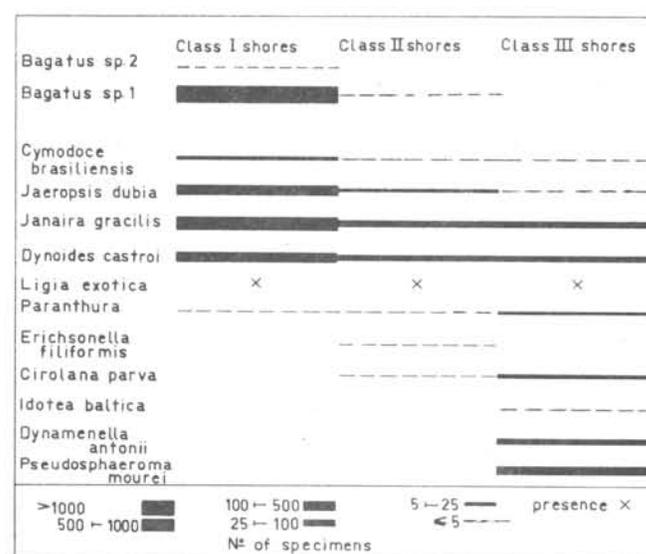


Fig. 5. Horizontal distribution of the 13 species of isopods in the three classes of rocky shores on the Littoral zone, September 1975. Each value of abundance is the mean number of animals in the sampled substrata of a same class of shore. Class I, exposed shores; class II, semi-exposed; class III, sheltered shores.

*lata*, *Porphyra acanthophora*, *Porphyra spiralis*, *Galaxaura stupocaulon*, *Pterocladia pinnata*, *Amphiroa beauvoisii*, *Arthrocardia stephensonii*, *Jania capillacea*, *Jania adhaerens*, *Hypnea spinella*, *Gymnogongrus griffithsiae*, *Gigartina acicularis*, *Centroceras clavulatum*, *Spyridia filamentosa*, *Bryocladia cuspidata*, *Bostrychia binderi*, *Bostrychia radicans*, *Acanthophora spicifera*, *Laurencia obtusa*, *Laurencia scoparia*. The marine animal substrata were: *Balanus tintinnabulum*, *Tetraclita squamosa*, *Brachidontes darwinianus*, *Brachidontes solisianus* and *Phragmatopoma lapidosa*.

The substrata that presented the greatest number of species were: *Sargassum* spp., *Dictyopteris*, *Laurencia* spp. and *Dictyota*. These algae can be found in the infralittoral fringe and lower midlittoral, and are submitted to desiccation only during few hours a day or a few hours a month. The more abundant isopods on these substrata were: *Janaira gracilis*, *Bagatus* sp. 1, *Jaeropsis dubia* and *Dynoides castroi*.

Within the sampled calcareous algae, *Amphiroa beauvoisii* was the substratum with the greatest number of species. *Dynoides castroi* was the most abundant isopod in this type of substratum when the algae are free of macro-epiphytes.

The cavities studied were formed by the empty tests of *Balanus* and *Tetraclita*, the empty tubes of *Phragmatopoma* and the spaces among the byssus of *Brachidontes*. Although the species of isopods found in the cavities were not exclusive of this environment, they were generally more abundant there.

The empty tests of *Tetraclita* were inhabited by *Dynoides castroi*; the spaces among the byssus of *Brachidontes* were occupied by *Pseudosphaeroma mourei* and *Dynamenella antonii*, the former more abundant (336 specimens) than the latter (60 specimens). In the empty tubes of *Phragmatopoma* it was found *Cirolana parva* and *Dynoides castroi*. No isopods occurred in *Balanus* but only brachyuran crabs and sometimes *Bleniidae* fishes (*Blennius cristatus*).

### 5. Density

The isopods showing higher densities in the littoral zone were: *Bagatus* sp. 1, *Janaira gracilis*, *Dynoides castroi*.

There is a great deal of variation in

the density of the phytal animals, partly related to the environmental conditions and partly to the morphology of the alga itself (Colman, 1940; Dahl, 1948; Wieser, 1952; Roman, 1970; Dumay, 1971; Sarma & Ganapati, 1974). Table I shows, for each sampled period, the mean relative abundances of isopods in each type of collected substratum.

The density varied with the sampled period. In April the higher densities were found on the leaf-like algae *Galaxaura*, *Sargassum* and *Pterocladia*. The first one showed the greatest density of isopods: 1,107/500 g. In September the higher densities were also registered for the leaf-like algae. The greatest and most remarkable density was found in *Dictyota ciliolata* (8,881/500 g), followed by *Sargassum*, *Laurencia* and *Dictyopteris*.

The calcareous algae presented a small density of isopods. However, when covered by epiphytes the density increased very much.

The smallest density was obtained in *Ulva fasciata*. No animal occurred in *Porphyra* spp. probably because it remained dry during almost all the full tide cycle due to its high position on the rock.

In the cavities the highest density was obtained in the byssus of *Brachidontes* (396/0.24 m<sup>2</sup>). Each type of cavity showed different animal associations. In the byssus of *Brachidontes* it was found *Pseudosphaeroma mourei* and *Dynamenella antonii*; in the empty tests of *Tetraclita*, *Dynoides castroi* was found; in the empty tubes of *Phragmatopoma* occurred *Dynoides castroi* and *Cirolana parva*.

### The infralittoral zone

#### 1. Studied species

Seven species of isopods were found on the infralittoral hard substrata: *Cymo-doce brasiliensis*; *Heteranthura* sp.; *Janaira gracilis*; *Bagatus* sp. 1; *Jaeropsis dubia*; *Antias milleri* Menzies & Glynn, 1968; *Arcturella sawayai* Moreira, 1973.

Fourteen samples of algae from 1 to 6 m depth were studied. The algae were *Sargassum* sp. (10 samples) and *Amphiroa fragilissima* (4 samples).

#### 2. Distribution of the fauna

This topic was analysed considering:

### 2.1. Variation in intensity of the water movement

The samples were divided according to the degree of water movement: a) samples 1-9 obtained from exposed sites; b) samples 13 and 14 collected in semi-exposed sites; c) samples 10-12 taken in sheltered sites. The horizontal distribution of the species is shown in Figure 7.

*Bagatus* sp. 1 can stand strong water movements successfully since it was always the more numerous species in sites with a high degree of exposition.

*Antias milleri*, *Heteranthura* sp. and *Cymodoce brasiliensis* were more abundant in semi-exposed locals and *Janaira gracilis* and *Arcturella sawayai* were more numerous in sheltered places.

Comparing samples of the same type of substratum in exposed sites that differ in the degree of exposition (samples 4

and 5), it can be seen that there is some variation in the composition and abundance of the species.

Samples 4 and 5 are of the opposite sides of Praia do Flamenguinho (Fig. 1) and *Sargassum* sp. was the substratum common to both. Sample 4, 50 m distant from the shore, was taken from 4 m depth; sample 5, 10 m distant from the shore, was obtained from 3 m depth. The site of sample 5 was more exposed to the open ocean than that of sample 4. In the most exposed site the number of species and specimens showed to be higher. The species common to the two samples were *Janaira gracilis* and *Arcturella sawayai*. *Jaeropsis dubia* was only present in sample 4 and *Antias milleri* and *Cymodoce brasiliensis* were found only in sample 5 (Fig. 6). *J. gracilis* was more abundant in the most exposed site.

On comparing samples of the same type of substratum at sheltered places

Table 1 - Mean density of isopods per substratum type in each sampled period (nº of individuals/500 g). (-): absence of the alga

Substratum	Littoral		Infralittoral
	IV-1975	IX-1975	IV/V-1965
<i>Sargassum</i>	567	581	224
<i>Galaxaura</i>	1,107	130	
<i>Laurencia</i>	42	465	
<i>Pterocladia</i>	460	(-)	
<i>Dictyota</i>	(-)	8,881	
<i>Dictyopteria</i>	(-)	449	
<i>Hypnea</i>	70	(-)	
<i>Ectocarpus</i>	74	1,192	
<i>Centroceras</i>	183	(-)	
<i>Porphyra</i>	(-)	0	
<i>Ulva</i>	(-)	8	
<i>Acanthophora</i>	39	14	
<i>Spyridia</i>	(-)	250	
<i>Gigartina</i>	(-)	19	
<i>Euteromoxpha</i>	437	1,625	
<i>Bryocladia</i>	(-)	146	
<i>Bostrychia</i>	7	29	
<i>Gymnogongus</i>	20	4	
<i>Rhizoclonium</i>	80	0	
<i>Bachelotia</i>	(-)	425	
<i>Jania</i>	12	83	
<i>Jania w/epiphyte</i>	(-)	8,723	
<i>Amphioxo</i>	115	72	431
<i>Anthrocardia</i>	(-)	174	
<i>Tetraelita</i>	11	91	
<i>Phragmatopoma</i>	(-)	3/0.24 m <sup>2</sup>	
<i>Stachidontes</i>	396/0.24 m <sup>2</sup>	(-)	

differing in the degree of shelter, it was found a variation in the composition and abundance of the isopod fauna. This is the case of samples 10 and 11.

The substratum of samples 10 and 11 was *Sargassum* sp. from Praia da Ribeira; both samples differed in the distance from the shore. Sample 10 was 10 m distant and sample 11, 50 m distant from the shore line. Both samples were from 1 m in depth. The site nearer to the shore was the most sheltered.

Sample 10 was poorer in number of species and specimens. This poverty was probably related with the great quantities of sediment present in the sample.

Species common to the two samples were *Janaira gracilis*, *Jaeropsis dubia* and *Arcturella sawayai* (Fig. 6). Species only present in sample 11 were *Antias milleri*, *Heteranthura* sp. and *Cymodoce brasiliensis*.

## 2.2. Variation in type of substratum

The number of species and their abundance in *Sargassum* sp. and *Amphiroa fragilissima* were compared (Fig. 6) to observe the

distribution of the isopod fauna in relation to the substratum.

Seven species of isopod occurred in the two algae, and *Sargassum* showed to be inhabited by a greater number of species. Five species were common to both algae, with differential abundance. *Janaira gracilis* and *Jaeropsis dubia* were more abundant in *Sargassum*, while *Bagatus* sp. 1, *Antias milleri* and *Heteranthura* sp. were more numerous in *Amphiroa*. There were also species that occurred only in *Sargassum*: *C. brasiliensis* and *A. sawayai*. In this study, *C. brasiliensis* showed to have a great preference for *Sargassum*, since the species was never found in *Amphiroa* or any other calcareous alga. *A. sawayai* never occurred in *Amphiroa*; it seems that the species does not live in the shrubby algae because of the relatively great size of the isopod (8.0–8.5 mm). Due to its morphology, *Amphiroa* seems to be a good substratum for small and for elongate animals which live in the spaces among its branches. After Dommasnes (1968) the dimension of these spaces has a direct influence on the composition and size of the fauna

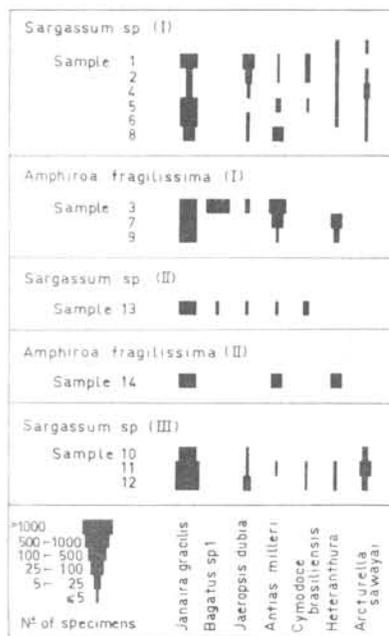


Fig. 6. Relative abundance of the 7 species of isopods per algal substratum in the infralittoral samples. April/May 1965. (I): exposed substratum; (II): semi-exposed; (III): sheltered substratum.

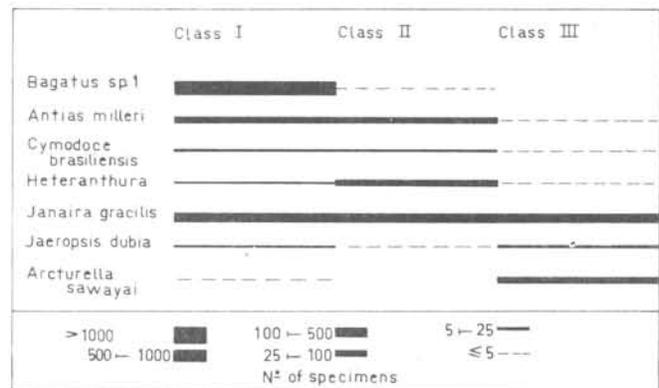


Fig. 7. Horizontal distribution of the 7 species of isopods in the infralittoral samples of exposed, semi-exposed and sheltered places. April/May 1965. Each value of abundance is the mean number of animals in the sampled substrata of places submitted to the same wave intensity.

present. It was also found smaller animals like *A. milleri* and longer ones, like *Heteranthura* sp., more abundant in this type of substratum.

### 2.3. Density

In the infralittoral zone the isopods were more abundant in *Amphiroa fragilissima* (Tab. I). The species that showed higher densities were *Janaira gracilis*, *Bagatus* sp. 1 and *Antias milleri*.

### Species diversity

Species diversity ( $\bar{H}$ ), equitability (J) and species richness (SD) were calculated for each sampled station in the littoral and infralittoral zones (Tabs II - III, respectively).

In the littoral,  $\bar{H}$  varied with the two studied periods, but the general pattern was the same for both. Diversity was higher in the exposed and semi-exposed sites. In April, as well as in September, the maximum value was obtained on the semi-exposed station and the minimum on a sheltered one. The very

small value obtained on station II is due to the high dominance of only one species: *J. gracilis*.

The equitability indices also varied in both periods but they were higher in the exposed and semi-exposed shores. Equitability was specially low in the sheltered station II, confirming the high dominance of only one species.

The species richness showed a temporal variation with higher values being found in September. The indices of species richness and species diversity followed the same pattern: increase from exposed to semi-exposed sites and decrease with the increase in shelter ones.

In the infralittoral the values of species diversity showed a broad variation, specially in the samples of the exposed places. There seemed to be a tendency for smaller values to occur related with sheltered sites, intermediate values with semi-exposed places and extremely varied values with exposed sites. The equitability values followed the Shannon's index of variation.

No clear relation between species richness and water movements was ob-

Table II - Species diversity ( $\bar{H}$ ), equitability (J), and species richness (SD) for isopods in each station and sampled period, in the littoral zone.

Station	April 1975			September 1975		
	$\bar{H}$	J	SD	$\bar{H}$	J	SD
I	0.60	0.37	0.54	1.03	0.53	0.60
VI	0.91	0.66	0.42	0.81	0.45	0.67
V	0.94	0.48	0.93	1.31	0.60	1.22
II	0.01	0.01	0.14	0.24	0.15	0.50
III	*	*	*	0.50	0.36	0.39
IV	0.30	0.27	0.30	0.64	0.40	0.64

\* Not calculated due to the very small sample

Stations I and VI, exposed; V, semi-exposed; II, III, IV, sheltered.  $\bar{H}$  is expressed in nats

Table III - Species diversity ( $\bar{H}$ ), equitability (J), and species richness (SD) for isopods on each infralittoral sample.

Samples 1-9, exposed places; 13-14, semi-exposed places; 10, 11, 12, sheltered places.  $\bar{H}$  is expressed in nats

Sample	$\bar{H}$	J	SD
1	0.62	0.35	0.90
2	1.47	0.91	1.00
3	0.91	0.51	0.44
4	0.51	0.37	0.94
5	0.68	0.42	0.77
6	0.16	0.11	0.54
7	1.01	0.92	0.35
8	0.74	0.53	0.66
9	0.27	0.24	0.40
13	0.51	0.32	0.80
14	0.64	0.59	0.33
10	0.32	0.29	0.37
11	0.40	0.22	0.77
12	0.28	0.17	0.66

tained. The values were extremely varied and seems to be closely connected to the substratum type.

### Discussion

Seven of the sixteen species obtained are common to exposed, semi-exposed and sheltered rocky places. However, every shore class has its characteristic vertical distribution and density of each species, both related with the intensity in water motion and with the substratum.

There were species that increased in abundance with the increase in wave exposure. This fact is closely related with the necessities of the species for the environmental conditions of the exposed rocky shores. With the increase in exposure the algae grow more compactly and form a dense canopy that protects the animals against desiccation and the shock of the waves. Other advantageous factors in exposed places are the greater water oxygenation and the constant food supply. After Lewis (1968) the quantitative variation of most of the animal and vegetal species seems to be linked to an "exposure preference", well defined for each species and evidenced in the quantitative differences of the species in exposed and sheltered places. The results of the present study indicated a strong preference of *Bagatus* sp. 1 and *Bagatus* sp. 2 for exposed rocky shores. On the other hand, species like *Dynamenella antonii* and *Pseudosphaeroma mourei* preferred sheltered places, where they were very abundant. In sheltered sites *D. antonii* and *P. mourei* occurred on the sediment present in the rocks near the base of the algae.

Excepting *Ligia exotica*, which is typical of the supralittoral fringe, the other littoral species had their upper limit of the vertical distribution in the midlittoral. A comparison among the species found on the three shore classes showed that *J. gracilis*, *J. dubia*, *D. castroi* and *C. brasiliensis* had the upper limit of their vertical distribution displaced upwards with the increase in exposure to wave action. On the other hand, *Paranthura* sp. had its vertical distribution controlled more by the type of substratum than by the degree of wave exposure.

It could be seen that different suborders predominated on each zone. The

Flabellifera had more species in the littoral zone and the Asellota dominated in the shallow infralittoral.

Within the Flabellifera, the Sphaeromatidae dominated in number of species and specimens, occupying a large number of available habitats, from the upper midlittoral to the infralittoral zone. They were typical, however, from the littoral, being quite adapted to the conditions of constant stress here present. Jansen (1971) found 10 species of sphaeromatids in the New Zealand rocky shores. This great diversity proves the capability of the group of the group in exploring the different microhabitats of a same habitat. With a thick tegument and usually with the capability of rolling up their body like a ball, these animals can stand high temperatures, desiccation, and the shock of the waves.

The Asellota were found from the infralittoral fringe to the infralittoral. Only some individuals of *Bagatus* sp. 1, *Janaira gracilis* and *Jaeropsis dubia*, were collected near to the mean tide level. With the thin tegument, elongate appendages and delicate body, the Asellota can not stand the long periods of desiccation in the midlittoral.

Another fact that influences the distribution and abundance of the species is the type of substratum. Each type of substratum is a physical support particular for the fauna and with other environmental factors can influence both the presence and abundance of a given species.

The leaf-like algae presented the greatest number of species and specimens. This kind of substratum forms conspicuous belts on the rock, and the structural features of the algae as well as the degree of shelter they offer to the species are factors responsible for the good performance of *Sargassum*, *Laurencia*, *Dictyota* and *Dictyopteris* as habitat. The calcareous algae presented a relatively small number of isopods; however, when epiphytes like *Gelidiella tenuissima* grew on *Jania* the density of isopods increased nearly 45 times (Tab. I). The probable role of the epiphytes is to increase the surface of the alga, diversifying the habitat (Wieser, 1952; Hagerman, 1966).

*Antias milleri* was found with relatively high density in *Amphiroa fragi-*

*lissima* (130 specimens in sample 3) on the infralittoral places submitted to an intense water motion. There is an attenuation of the water speed within the growths of the calcareous alga (Dommasnes, 1969) which gives stability to the habitat and permits extremely fragile animals like *A. milleri* to inhabit such exposed places.

Algae with a flat leaf-like thallus, such as *Ulva fasciata*, had a low number of specimens due mostly to its uniformity as habitat and to the little shelter offered by the foliaceous thallus.

The diversity of isopods is also closely related with the degree of wave exposure: the exposed and semi-exposed shores showed a higher species diversity than the sheltered ones. The literature concerning to the relation between wave exposure and habitat stability is extensive. Generally, the species diversity tends to be lower in ecosystems predominantly physically limited (Odum, 1971), such as the intertidal region (Sanders, 1968).

Even though the species diversity of isopods presented relative low values for the littoral hard substrata, the lower indices were obtained in the sheltered places. The relative uniformity of these sites is responsible for a small number of habitats, which cause low species diversity and high dominance. For the sheltered rocky shores, lower values of diversity were associated with the dominance of a few or sometimes only one species. The intense and constant sedimentation can also be an important factor governing the low species diversity of the isopods, since great amounts of sediment on the algae can be very unfavorable to clinging animals (Hagerman, 1966).

The relatively higher diversity found on the semi-exposed shore (station V, Lagosteiro) can be related with the physical characteristics of the place, since it is halfway between the sheltered and the exposed conditions, that is, between the intense sedimentation and the violent impact of the waves. After Lewis (1968), the greatest species richness on places with moderate action of currents and tides is related with the physical characteristics of such a kind of habitat: water motion, water clearness, absence of chemical gradients due to the lack of excessive violence in the water movements.

The present results also agree with those of Fenwick (1976), for the amphipods of *Caulerpa brownii*. The author found a higher species richness on a semi-exposed place.

The values of species diversity found in the infralittoral samples reflect the existence of several and characteristic environments within a relatively small area. These environments offer distinct ecological conditions for several species, being each microhabitat more favorable to one species than to the others.

#### Resumo

No presente trabalho, foram estudados os padrões de distribuição vertical e horizontal da fauna de Isopoda de costões rochosos, bem como sua abundância relativa nos vários substratos investigados, visando ao conhecimento de alguns aspectos de sua ecologia.

As coletas foram realizadas nas zonas litoral e infralitoral da Enseada do Flamengo, Ubatuba, Estado de São Paulo, Brasil. As estações de coleta variaram quanto ao grau de exposição às ondas e profundidade. As amostras do litoral foram coletadas em abril e setembro de 1975 e janeiro de 1976, enquanto que as do infralitoral referem-se a abril e maio de 1965.

Verificou-se que a exposição às ondas é um fator muito importante na distribuição das espécies, havendo animais que só foram encontrados nas condições ecológicas oferecidas por locais expostos e semi-expostos, e outros que só o foram em locais abrigados. Entretanto, existem espécies que ocorreram nas três situações, sendo geralmente mais abundantes em uma delas em particular.

O tipo de substrato mostrou ser outro fator que exerce grande influência na distribuição das espécies. Substratos diferentes, coletados em um mesmo local e submetidos às mesmas condições ambientais, apresentaram variação na composição e abundância relativa da fauna de Isopoda. Esta variação é dependente da estrutura do substrato, da proteção e da quantidade de nichos que ele oferece às espécies. A maior densidade de isópodes foi obtida em *Dictyota ciliolata*, na franja do infralitoral.

Foi encontrada uma relação entre diversidade de espécies e grau de exposição às ondas. A diversidade de espécies au-

menta dos lugares expostos para os semi-expostos e decresce muito destes para os abrigados. O presente estudo revelou, também, a existência de uma variação estacional na abundância relativa e na diversidade das espécies, sendo ambas mais elevadas em setembro.

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