Temporal comparison of gammaridean amphipods of *Sargassum cymosum* on two rocky shores in southeastern Brazil

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Abstract

Gammaridean amphipods associated with the brown alga *Sargassum cymosum* were obtained by sampling fronds from two rocky shores with different hydrodynamic conditions in Ubatuba, southeastern Brazil. Species richness was similar at the exposed (Grande Beach) and sheltered (Lamberto Beach) sites. However, the exposed rocky shore showed higher species diversity and evenness than the sheltered site. The difference in species composition between Lamberto and Grande Beaches is probably related to the species' requirements for food and shelter and/or their different tolerances to mechanical wave stress. Diversity and evenness tended to increase over time in both areas, probably indicating the replacement of possibly less tolerant and specialist species by more tolerant and generalist ones. Cluster analysis indicated that the composition of gammarideans became more similar between the beaches in the last sampling period, probably due to anthropogenic changes during that time.

Key words: gammaridean amphipods, *Sargassum*, hydrodynamics, diversity, anthropogenic impacts.

Introduction

Since the end of the 1960s, several studies involving the fauna associated with *Sargassum*, a common brown alga on Brazilian rocky shores, were conducted at Lamberto and Grande beaches in Ubatuba, southeastern Brazil. Short-term studies were carried out on sessile organisms (Souza Lima, 1969) and components of the vagile fauna such as gammaridean amphipods (Leite, 1981; Tararam and Wakabara, 1981), caprellid amphipods (Takeda, 1981), isopods (Pires-Vanin, 1977), and gastropods (Montouchet, 1979).

Some investigators evaluated the relationship between the macrophytes and the hydrodynamics at the study site (Nonato and Pérés, 1961; Joly, 1965; Oliveira Filho and Mayal, 1976) and showed that the zonation pattern, species composition of algae assemblages, and morphology of these plants were related to water movement. At Grande Beach, the wave action is stronger and the fronds of *Sargassum* cymosum are short and poorly branched, contrasting with the larger and highly branched plants at Lamberto Beach (Paula and Oliveira Filho, 1980; Széchy and Paula, 1998). These morphological features provide particular habitat conditions for food and shelter to the associated organisms, thus determining differences in faunal composition and abundance (Lewis, 1987).

Over the last 30 years, there have been major environmental changes along the Ubatuba coast, resulting from the human population increase and its effects such as waste-water pollution. The construction of a highway and a harbor generated several changes, increasing sediment deposition and oil spills in coastal waters. Studies comparing benthic communities between distant time periods have indicated changes in the richness and abundance of algal species (Oliveira Filho and Berchez, 1978) and extinction of associated fauna (Adessi, 1994; Lima, 1996). Those comparisons made it possible to identify environmental changes resulting from human disturbance, and to contribute to future management plans.

In this context, the present study compared the changes in composition and abundance of gammaridean amphipods associated with *Sargassum cymosum* at two rocky shores under different conditions of wave exposure, sedimentation and anthropogenic environmental impact over three consecutive decades.

Material and Methods

The study was conducted at two rocky shores: Lamberto Beach (23°30'S, 45°08'W), situated in the innermost area of Flamengo Bay; and Grande Beach (23°26'S, 45°04'W), both in Ubatuba, southeastern Brazil (Fig. 1). Lamberto Beach is sheltered, while Grande Beach is exposed, with strong wave action.

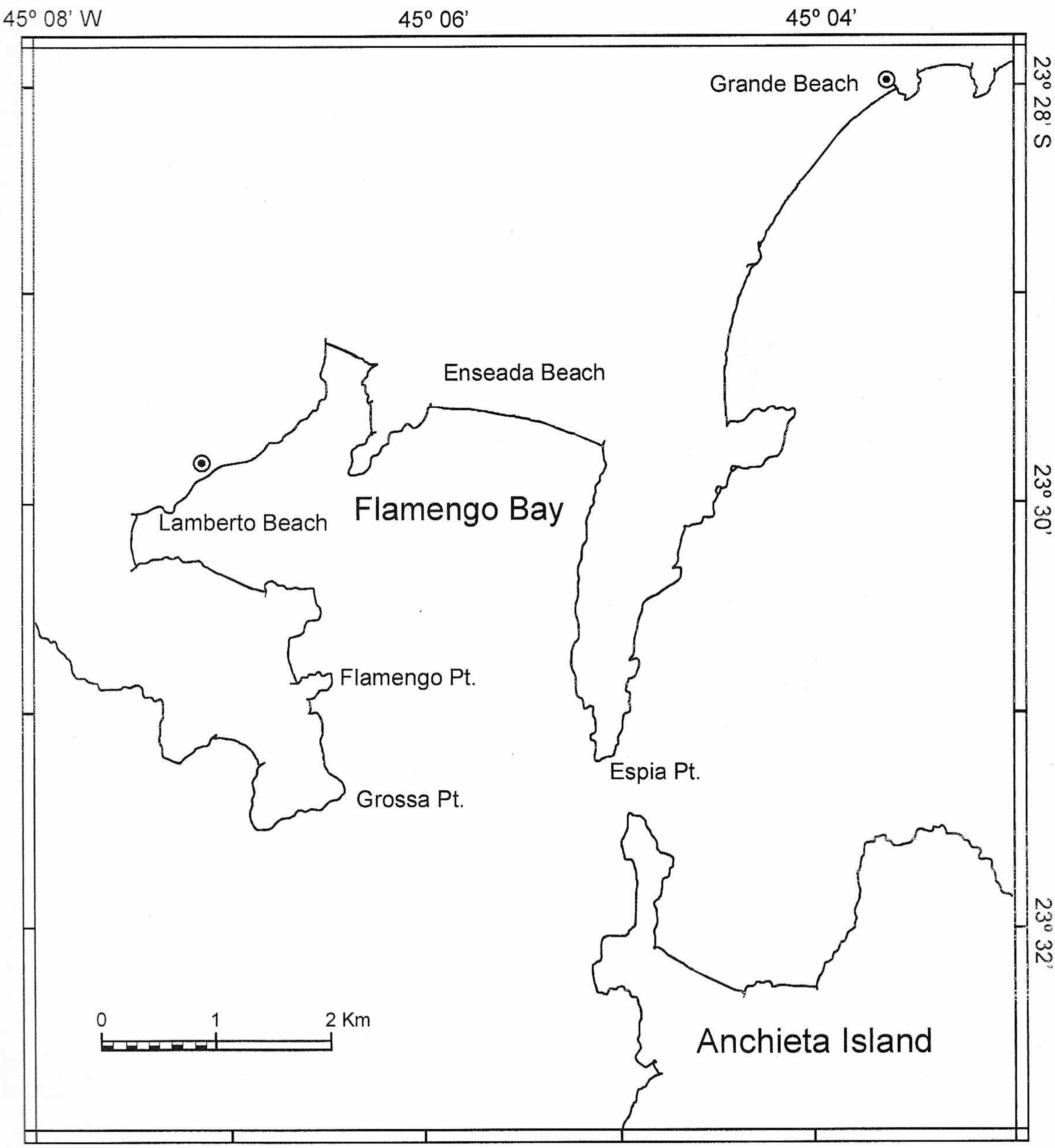


Figure 1: Map of the study area at Ubatuba, Brazil, showing collection locations (black dots).

Data from three sampling periods, 1972, 1987, and 1997, were analyzed. In the first two periods, seasonal samples were obtained for May (autumn), August (winter), October (spring), and December (summer). In 1997, sampling was performed only in winter (July) and spring (September).

Samples from both sites were taken randomly during low tide. *Sargassum* fronds along with their holdfasts were collected and carefully placed in plastic bags. In the laboratory, the fronds were washed successively in four buckets containing fresh water with formalin, to detach the vagile fauna. Epifauna remaining in the buckets was carefully washed onto a 0.285 mm mesh sieve. According to Tanaka and Leite (1998), the 0.2 mm mesh sieve has a sampling efficiency of 99.3 % for gammarideans. Amphipods were preserved in 70% ethanol for further identification and quantification. The wet weight of *Sargassum* fronds was determined after removing excess water on absorbent paper for 1.5 h.

The density of gammaridean amphipods is expressed as the number of individuals per unit wet weight of *Sargassum* fronds. Sorensen's index was used to evaluate the similarity between the beaches and sampling periods, for the presence or absence of gammaridean amphipods. Samples were clustered by the UPGMA technique (Sneath and Sokal, 1973). The Shannon-Wiener diversity index and evenness (Krebs, 1989) were calculated for the 1987 and 1997 samples from both localities.

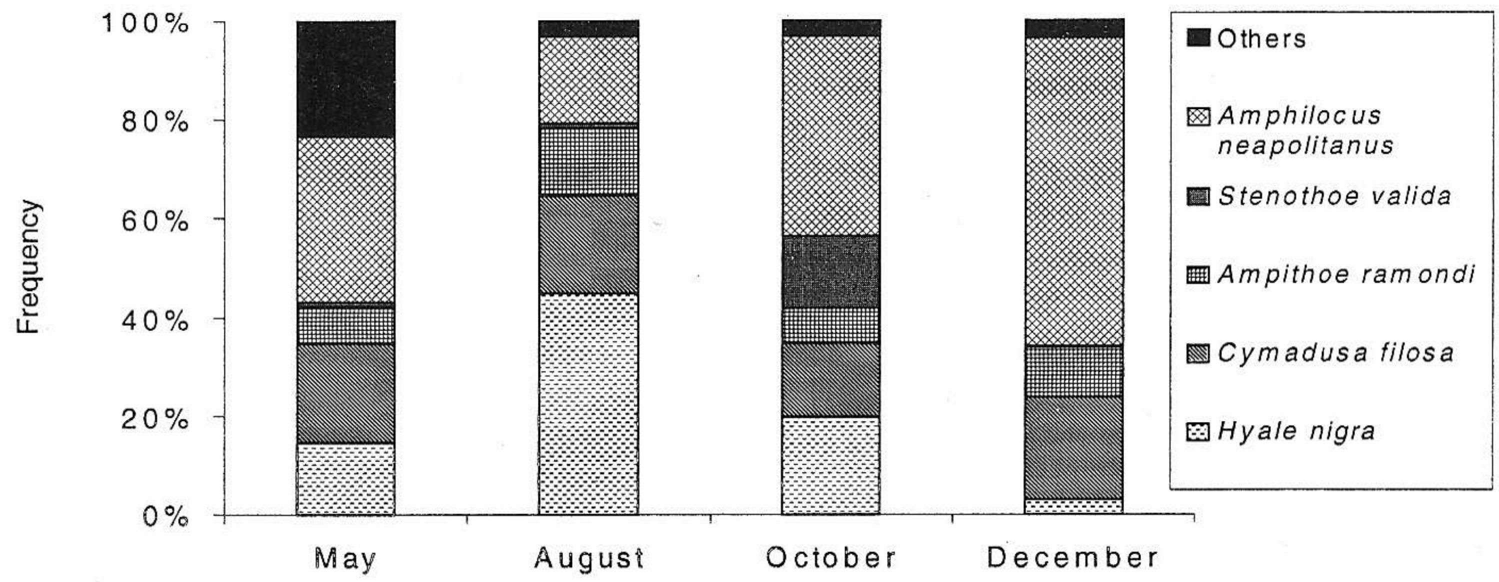
Results

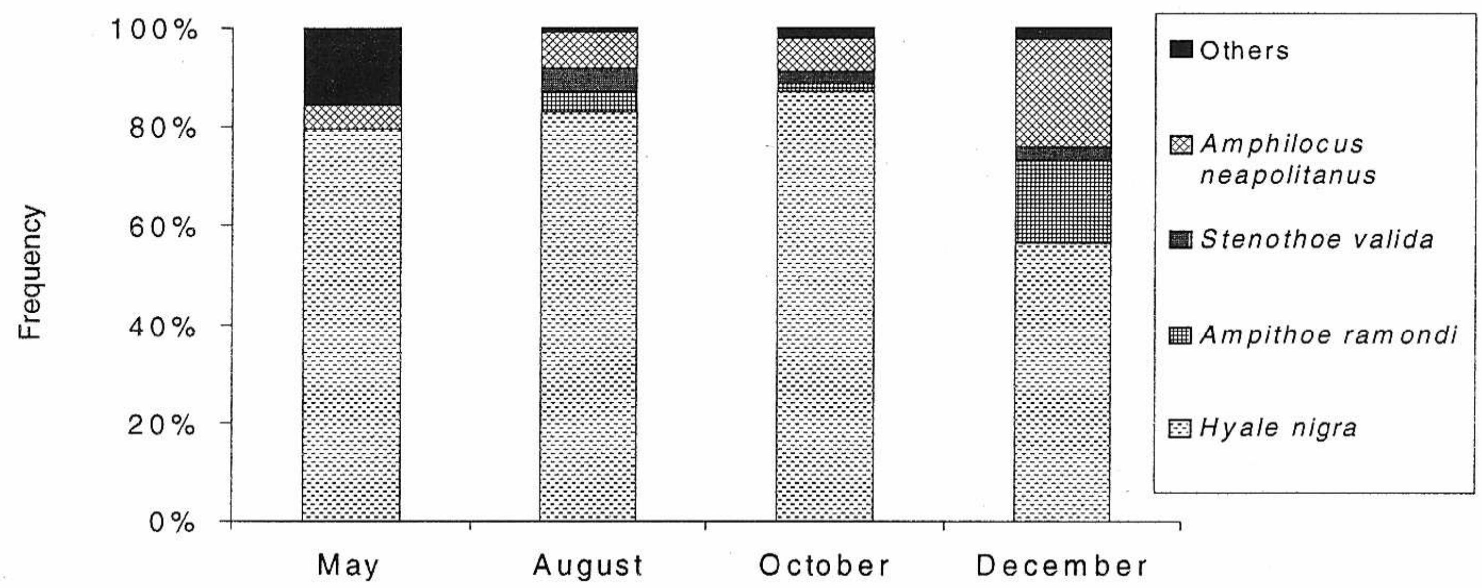
Gammaridean amphipod richness did not change among the beaches and periods sampled, although differences in species composition were evident (Table I).

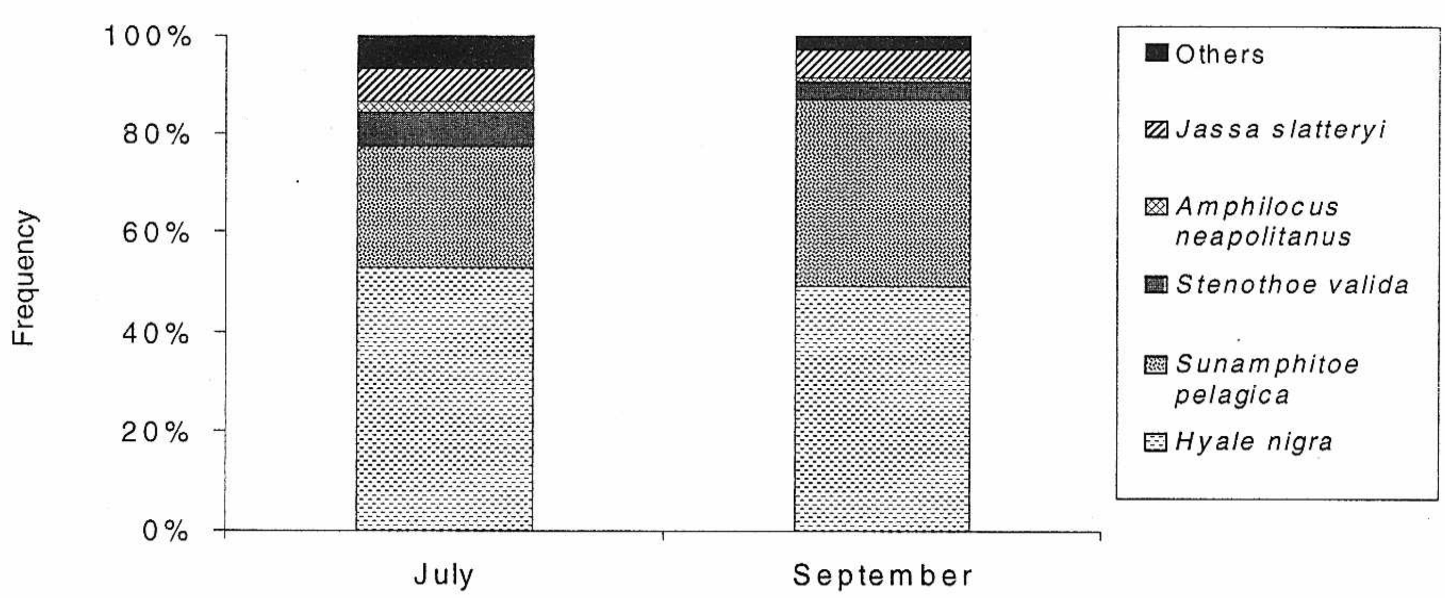
Table I: Gammaridean species occurrence at Grande and Lamberto beaches in 1972, 1987 and 1997.

		Lamberto Beach			Grande Beach	
Family	Species	1972	1987	1997	1987	1997
Amphilochidae	*Amphilocus neapolitanus*	X	X	X	X	-
Ampithoidae	*Ampithoe ramondi*	X	X	-	X	X
	Cymadusa filosa	X	-	X	X	X
	Sunamphitoe pelagica	X	X	X	X	X
Atylidae	*Atylus minikoi*	X	-	-	-	-
Bateidae	*Batea catharinensis*	X	-	-	-	-
Corophiidae	*Corophium acherusicum*	X	X	X	X	X
Gammaridae	*Dulichiella appendiculata*	X	-	-	-	-
	Elasmopus pectenicrus	X	X	-	X	X
Hyalidae	*Hyale macrodactyla*	-	X	X	X	X
	Hyale media	-	-	X	X	X
	Hyale nigra	X	X	X	X	X
Ischyroceridae	*Ericthonius brasiliensis*	X	X	X	-	-
	Jassa slatteryi	-	X	X	X	X
Leucothoidae	*Leucothoe spinicarpa*	X	X	X	X	-
Lyssianassidae	*Lyssianassa sp.*	X	-	X	X	X
Stenothoidae	*Stenothoe valida*	X	X	X	X	X
Species Richness		14	11	12	13	11

At Lamberto Beach, for the three sampling periods, one or two species dominated the gammaridean taxocenosis and comprised more than half of the individuals in *Sargassum fronds* (Fig. 2 A-C). From 1972 to 1997, the dominant species shifted from *Amphilocus neapolitanus* to *Hyale nigra*. Two species, *Sunamphitoe pelagica* and *Jassa slatteryi*, increased in frequency of occurrence in 1997.







: Relative frequencies of gammaridean amphipod species at Lamberto Beach in 1972 (A), 1987 (B), and 1997 (C). The category "others" includes infrequent species.

At Grande Beach, no single species dominated at any time, but the family Hyalidae, represented by *H. nigra*, *Hyale media*, and *Hyale macrodactyla*, dominated the taxocenosis (Fig. 3). In 1987, almost 50% of the individuals belonged to this family (surpassing 90% in May 1987). Other species were also numerous, such as *S. pelagica*, *Stenothoe valida*, and *Elasmopus pectenicrus*. At Grande Beach, as at Lamberto, the species richness remained essentially constant over time.

Knowledge of the lifestyle and feeding modes of the amphipod species found at the study sites is summarized in Table II. Diversity and evenness were higher at Grande Beach than at Lamberto Beach, and increased over time. At Lamberto these indexes almost doubled from 1987 to 1997 (Table III).

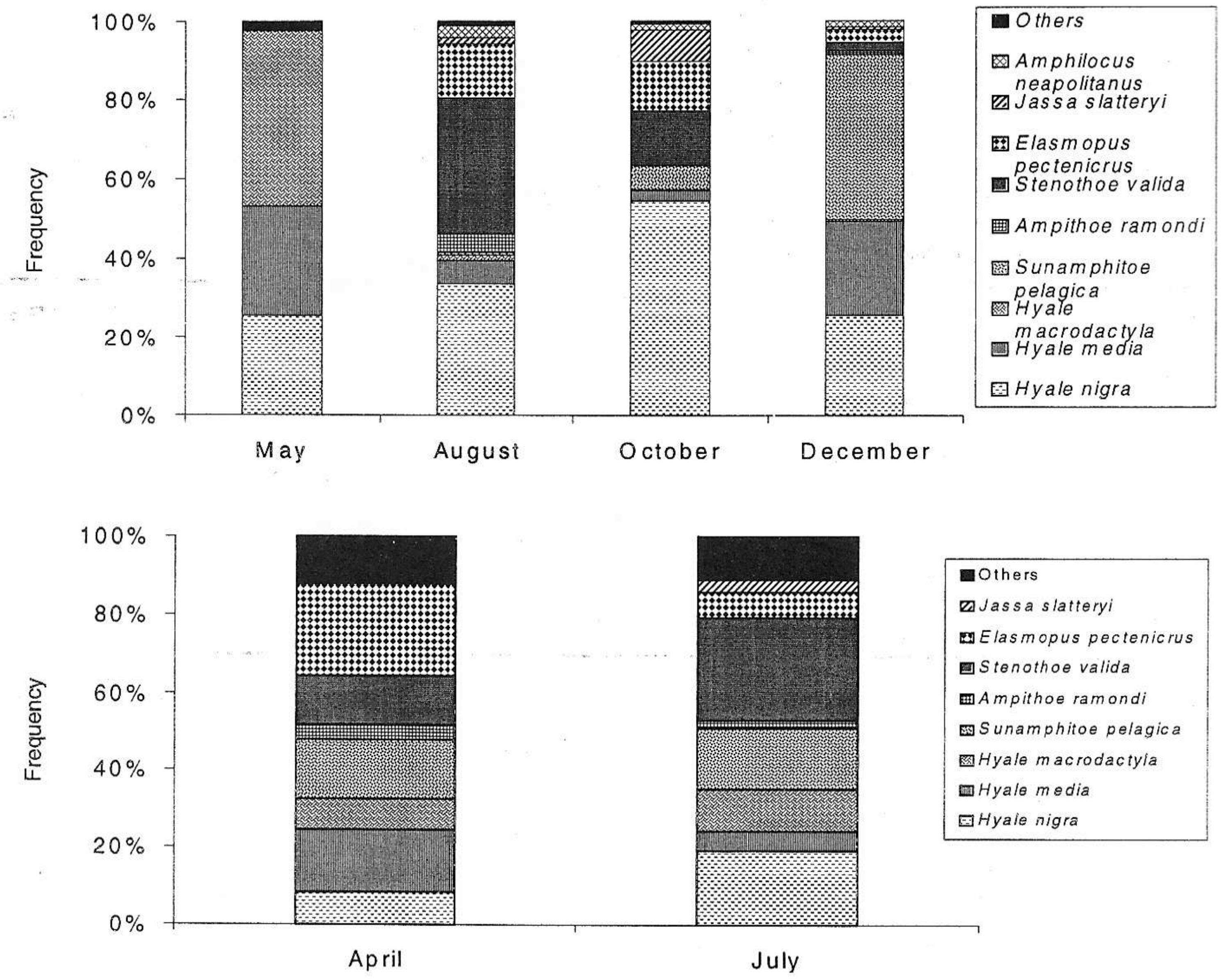


Figure 3: Relative frequencies of gammaridean amphipod species at Grande Beach in 1987 (A) and 1997 (B). The category "others" includes infrequent species.

Table II: Lifestyle and feeding modes of the gammaridean amphipod species occurring at Grande and Lamberto beaches.

Species	Lifestyle	Feeding mode
Amphilocus neapolitanus Della Valle, 1893	N	p
Ampithoe ramondi Audoin, 1826	T	G/H
Cymadusa filosa Savigny, 1816	T	H
Sunamphitoe pelagica (Milne Edwards, 1830)	N	H/Co
Atylus minikoi Walker, 1905	N	De
Batea catharinensis Müller, 1865	N	p
Corophium acherusicum Costa, 1857	T	Sf
Dulichiella appendiculata Say, 1818	N	De
Elasmopus pectenicrus Bate, 1862	N	De
Hyale macrodactyla Stebbing, 1837	N	G/H/O
Hyale media (Dana, 1853)	N	G/H/O
Hyale nigra (Haswell, 1879)	N	G/H/O
Ericthonius brasiliensis (Dana, 1853)	T	Sf
Jassa slatteryi Conlan, 1989	T	G/Sf
Leucothoe spinicarpa Mateus & Mateus, 1956	I	Co
Lyssianassa sp. Milne Edwards, 1830	B	P/Df
Stenothoe valida (Dana, 1852)	I	P

Lifestyle: N, nestler: T, tube dweller; I, inquiline; B, burrower.
Feeding modes: P, predator; H, herbivore; De, plant detritus feeder: G, grazer; Df, deposit feeder
Co, commensal; Sf, suspension feeder.
Lifestyle data are based on Barnard, 1958 and Bousfield, 1973.

Cluster analysis (Fig. 4) yielded two main groups with differences in species composition: the Grande group and the Lamberto group. Samples in 1997 from Lamberto were closer to samples from Grande Beach, because of the occurrence of species more typical of Grande Beach (*H. media*, *H. macrodactyla*, and *J. slatteryi*).

Table III: Shannon diversity indexes and evenness.

Beach	Diversity	Evenness	Richness
Lamberto 1987	0.66	0.289	11
Grande 1987	1.83	0.693	14
Lamberto 1997	1.24	0.499	12
Lamberto 1997	2.15	0.866	12

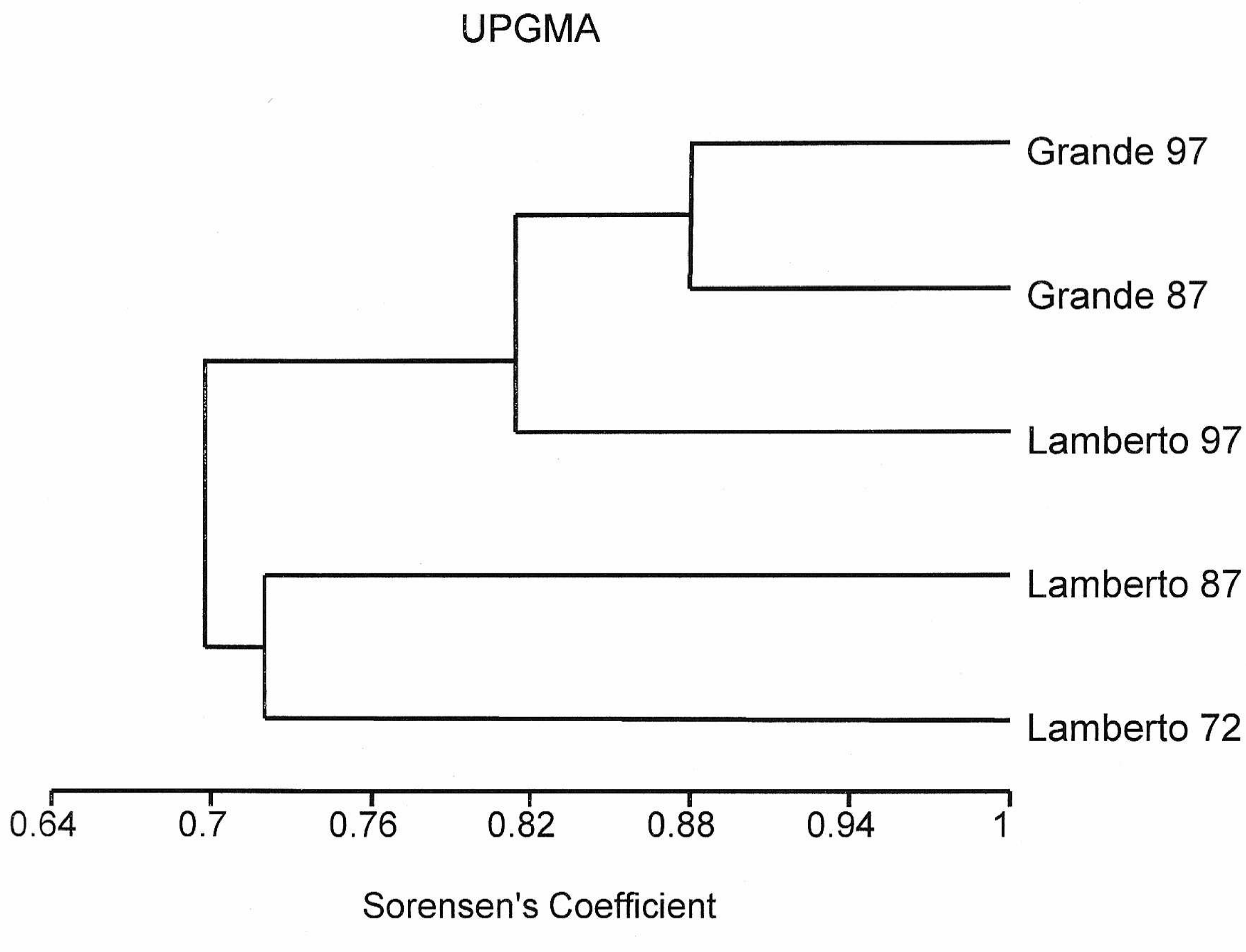


Figure 4: Dendrogram display derived from similarity matrix using Sorensen's coefficient and clustering technique UPGMA for the collected samples.

Discussion

Several investigators have suggested that sheltered sites harbor more diverse communities than exposed sites (Fenwick, 1976; Wakabara et al., 1983; Jacobi, 1987). In the *Sargassum* communities studied, the gammaridean taxocenosis did not follow this pattern, since the exposed site showed greater diversity with lower dominance than the sheltered site.

Since high wave exposure lowers the predation ratio in intertidal communities, competition becomes the main ecological structuring factor (Menge and Sutherland, 1987). So, how to explain high diversity in low predation - high competition habitats? In wave-exposed sites, habitat heterogeneity is maintained by turbulent water that creates an ephemeral patchy environment. This dynamic environment allows less competitive species to escape from superior competitors by moving to newly formed competitor-free patches. Since gammarideans are very mobile, with high turnover rates (Gunnill, 1982; Tanaka, 2000), these animals can easily move from one patch to another, favoring the persistence of less competitive species in the community. This hypothesis may explain the species diversity data obtained at Grande Beach. Otherwise the more stable habitat conditions of Lamberto Beach would imply low community diversity and evenness.

Several studies have suggested a relationship between hydrodynamism and the composition of the amphipod taxocenosis. A clear differentiation was recorded between amphipod populations living in areas with higher hydrodynamism and lower sedimentation, and those living at protected sites with more sedimentation and less water movement (Fenwick, 1976; Jacobi, 1987; Conradi et al., 1997). This fact may be directly related to the mechanical drag tolerances of particular species, but also to morphological differences in the algae, caused by abiotic and biotic factors (Dommasnes, 1968). Wave action seems to be an important factor in determining adaptive strategies of *Sargassum* populations. At exposed sites such as Grande Beach, *S. cymosum* fronds are smaller, less branched, and more compact than plants from sheltered sites such as Lamberto Beach (Széchy and Paula, 1998). The difference in habitat complexity resulting from the dominant morphological type in each area may be responsible for differences in abundance and richness of the *Sargassum* associated fauna (Edgar, 1983 a,b,c; Gee and Warwick, 1994; Dubiaski-Silva and Masunari, 1995). Algal morphology may select for species by offering different kinds of substrate for fixation or varying degrees of sediment deposition (Iribarne, 1996).

The presence of tube-dwelling species seems to be affected not only by hydrodynamic conditions (Nair and Anger, 1979), but also by specific tube construction requirements, since different species with this lifestyle were recorded at both beaches.

The occurrence of the tube-dweller *J. slatteryi* at Grande Beach is probably related to the turbulent waters in this area. The presence of *J. slatteryi* and other species of the same genus, reported for high wave-action sites (Nair and Anger, 1979; Conradi et al., 1997; Jacobucci, 2000), is related to their suspension-feeding habit (Barnard, 1958; Bellan-Santini, 1998). The tube-dwelling ampithoids *Ampithoe ramondi* and *Cymadusa filosa* occurred at the sheltered rocky shore of Lamberto Beach, especially in 1972. This preference for calm water sites was also observed by other investigators (Wakabara et al., 1983; Scipione, 1999).

The high abundance of *A. neapolitanus* at Lamberto Beach confirms the rheophobic (species that prefer calm water conditions) character of this species (Tararam and Wakabara, 1981; Wakabara et al., 1983; Bellan-Santini, 1998). Our results for the occurrence of *H. media* agree with data from the Chilean coast (Lancellotti and Trucco, 1993) indicating that this species is associated with exposed sites. However, other studies (Fenwick, 1976; Jacobi, 1987) have indicated that *H. media* is rheophobic. Differences in hyalid composition between Grande and Lamberto beaches may also be related to varying degrees of desiccation tolerance (Jacobi, 1987). The absence of *H. media* and *H. macrodactyla* from Lamberto Beach may be due to their lower tolerance to desiccation, a kind of stress more intense in this area. At Grande Beach, these hyalids may benefit from the stronger wave action, which keeps *Sargassum* fronds wet for longer periods, thus enabling them to coexist with the more tolerant *H. nigra*.

Feeding mode data (Table II) for the nestling genus *Hyale* suggest an omnivorous diet (Tararam et al., 1985; Bellan-Santini, 1998), which is probably responsible for its high abundance in the taxocenoses of both areas. Moreover, the high numbers of *H. nigra* recorded since 1987 may be related to an increase in organic detritus. *Stenothoe valida* is another species common to both areas, but its frequencies were not as high as the hyalids. Although the feeding habit of *S. valida* is still unclear (it is a filter-feeding commensal or predator), there is an evident relationship between its occurrence and hydroid colonization of the substrates which this species occupies (Vader and Krapp-Schickel, 1996). A study conducted at a nearby rocky shore in Ubatuba (Jacobucci, 2000) showed significant increases in *S. valida* densities in seasons with extensive hydroid coverage on *Sargassum fronds*.

Changes in the composition of the gammaridean taxocenosis were observed at Lamberto Beach after 1972. This period corresponds to the beginning of construction of the BR-101 coastal highway, increased tourism, and local trade development which led to an increase in wastewater, oil spills, and sedimentation, the latter due mainly to erosion caused by clearing of the coastal forest, especially at Lamberto Beach.

These episodes may explain the increase in frequency of the pollution-resistant species *J. slatteryi* (Bellan-Santini,1998) at Lamberto from 1972 to 1997. This ischyrocerid was first recorded at Lamberto in 1987, and increased considerably in 1997. Like the other members of the genus *Jassa*, it is a tube-dweller and was probably favored by an increase in sediment deposition (Franz, 1989).

However, the decrease in *A. neapolitanus* populations may have resulted from the diet and/or habitat requirements of this species. Intensification of sediment deposition would not favor settlement of larvae, such as those of bryozoans and sponges, preyed upon by *A. neapolitanus* (Barnard and Karaman, 1991).

Temporal evaluation of the gammaridean taxocenosis indicated three main patterns. First, environmental modifications generated important changes in the population abundances of some amphipod species. Higher deposition rates and sediment buildup resulted in decreases and exclusion of some species, probably because of their particular food requirements (*A. neapolitanus*). As also recorded by Scipione (1999) in *Posidonia* beds in the Mediterranean, the exclusion of functional groups (here considered as species with equivalent main feeding modes) was observed in *Sargassum* beds at Lamberto Beach. However, this hypothesis is advanced with reservations, because the species that disappeared were rare (*Dulichiella appendiculata* and *Elasmopus pectenicrus*). Simultaneously, opportunistic species with higher pollution tolerance such as *J. slatteryi* studied by Smith and Simpson (1992), and also some with broad diets such as hyalids (Tararam et al., 1985), became more numerous in the taxocenosis (see Table I).

Second, there were species substitutions within the same functional group. This seems to be the case for the decrease in frequency of *C. filosa* and the exclusion of *Ampithoe ramondi* at Lamberto Beach. These herbivorous ampithoids were replaced by *Sunamphitoe pelagica*.

Finally, there was a trend toward increase in gammaridean diversity and evenness at both study sites, as demonstrated by the indexes in Table III. However, the pattern of diversity increase must be evaluated with great care, especially since cluster analysis (Fig. 4) showed that samples from Lamberto became more similar to Grande Beach samples in 1997, than to those of Lamberto in 1972 and 1987. The homogenization of the gammaridean taxocenosis resulting from the increase in tolerant and generalist amphipods, together with the decrease and even extinction of less tolerant and specialist species, may indicate the existence of environmental degradation of coastal ecosystems, including the phytal communities. Our results confirm the importance of long-term studies as a means of distinguishing natural community variability from the variations influenced by anthropogenic changes in environmental conditions. Moreover, we suggest, in agreement with other investigators (Smith and Simpson, 1992; Sánchez-Moyano and García-Gómez, 1998), that seaweed-associated amphipods are potentially important bioindicator organisms for marine monitoring programs.

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