

Distribution Patterns of Animals on the Rocky Shores of Chichijima in the Ogasawara Islands

Akira Asakura¹⁾, Yasuo Kondo¹⁾ and Shirou Nishihama²⁾

1) Natural History Museum and Institute, Chiba
955-2 Aoba-cho, Chiba 280, Japan

2) Amakusa Marine Biological Laboratory, Kyushu University
Tomioka, Reihoku-cho, Amakusa-gun, Kumamoto 863-25, Japan

Abstract Distribution patterns of animals were described at 26 stations on the rocky shores of Chichijima, the Ogasawara Islands, in the western Pacific. The splash zone was characterized by three littorinids, *Nodilittorina pyramidalis*, *Nodilittorina* sp. and *Littorina pintado*. The zones from splash to middle intertidal were occupied mainly by the oyster *Saccostrea mordax*, the pulmonate limpet *Siphonaria* sp., the barnacle *Chthamalus challenger*. The lower intertidal zone was characterized by sessile animals such as vermetid shells, tube-dwelling polychaetes, and sometimes the barnacle *Balanus occator*. The sea urchins *Echinometra mathaei mathaei* and *E. mathaei oblonga* inhabited their grooves, and *Colobocentrotus mertensi* was attached on the rock near the lower margin of the wave-exposed sites. Corals were attached to rocks in lower and subtidal zones at a few restricted sites.

Species diversity (H') ranged from 0.565 to 2.648, and J' ranged from 0.243 to 0.862 for the animal community of each site. High similarities of fauna were seen among most of the stations, however there is low similarity between fauna on limestone and on volcanic substratum. The number of species occurred increased with wave exposure, although no particular relationship was found between wave exposure and values of H' and J' .

Key words: Ogasawara, zonation, rocky shore, splash zone, intertidal zone.

The Ogasawara (Bonin) Islands are subtropical, oceanic islands in the north-west Pacific, situated 1,000 km south of the main Japanese Islands. They came into existence due to a volcanic event of 40 Ma in the Eocene period (Yoshiwara, 1902; Umino, 1985). The isolation of marine organisms there has been achieved as a result of the fact that no major oceanic current flow around (JODC, 1969, 1975; Kurata *et al.*, 1975; Hasunuma and Yoshida, 1978).

Asakura *et al.* (1990) first described, in detail, the spatial distribution and characteristics of macrobenthos and algae on rocky shores of Hahajima in the Ogasawaras. This revealed poor assemblages of organisms, a characteristic generally seen in the communities of isolated oceanic islands (MacArthur and Wilson, 1967; Williamson, 1981; Lawrence and McClintock, 1987).

In this paper, we report the distribution and characteristics of animals on another major island in the Ogasawaras, Chichijima Island (Fig. 1), located about 50 km north of Hahajima. In contrast to the monotonous coastal topography of Hahajima, Futami Bay (Figs. 2A) in the north-western part of Chichijima provides a more various environment for marine animals. The changes in distribution patterns of animals along a wave

sheltered-exposed gradient were also described for the fauna at the stations in Futami Bay.

Study sites and methods

1. General observations on the distribution patterns of animals

For this study, 26 stations were selected from rocky shores on Chichijima (Fig. 1). Observations were made at low tide during the spring tide in April 1986, May 1989, and June 1990. No conspicuous changes in the environment or fauna were seen in this period. At each station, the topographical profile was traced, a quadrat (15 cm × 15 cm) was delineated at several points on a transect from the splash to the intertidal zone, and animals in the quadrat were counted. Highly mobile animals, such as the rock crab *Grapsus albolineatus*, were excluded from this study, although they were quite common on the rocky shore at Chichijima.

Qualitative observations on the animals were also made, and their characteristics of distribution patterns were recorded. The nature of the substratum, such as rock type and texture, was examined to clarify the relationship between the substratum and the distribution of the animals.

In this report, tidal level is represented by the

height above the mean sea water level (abbreviated as MSL). The term "intertidal zone" is used to indicate a zone between MSL and 1.10 m above it, since the mean tidal amplitude is 1.10 m in Ogasawara. The "upper" intertidal zone is defined as the upper one-third of the intertidal zone, and the "middle" and "lower" zones are defined in the same manner.

2. Species diversity and faunal similarity

Species diversity was calculated in terms of Shannon-Weaver's function (H') and Pielou's evenness component diversity (J') (see Kimoto (1976) for calculation methods) as follows;

$$H' = - \sum_{i=1}^S \frac{n_i}{N} \log_2 \frac{n_i}{N}$$

$$J' = \frac{H'}{\log_2 S}$$

where n_i is the number of individuals of species i , N is the total number of individuals of all species observed, and S is the total number of species observed.

Faunal similarity between sites was calculated in terms of Colwell-Futuyma's niche overlap index (γ) (see Kimoto (1982) for calculation methods) as follows;

$$\gamma = - \frac{1}{2 \log_2 2} \sum_{j=1}^r [I(P_{ij}) + I(P_{hj}) - I(t_j)]$$

where P_{ij} is relative number of individuals species j at site i , $t_j = P_{ij} + P_{hj}$, and $I(x) = x \log_2 x$.

Based on the values of γ , a dendrogram was calculated by the Mountford method for cluster

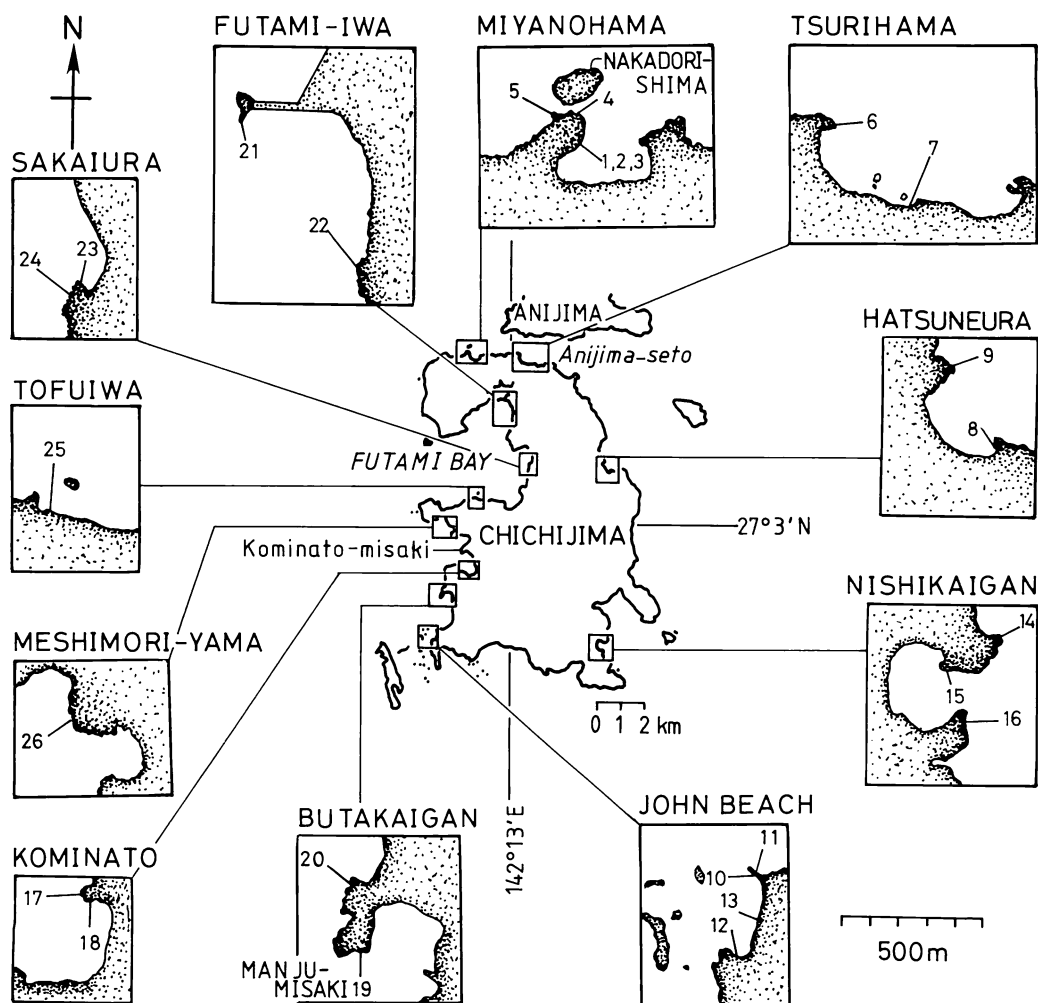


Fig. 1. Chichijima Island in the Ogasawara Islands and location of the study stations along the coast.

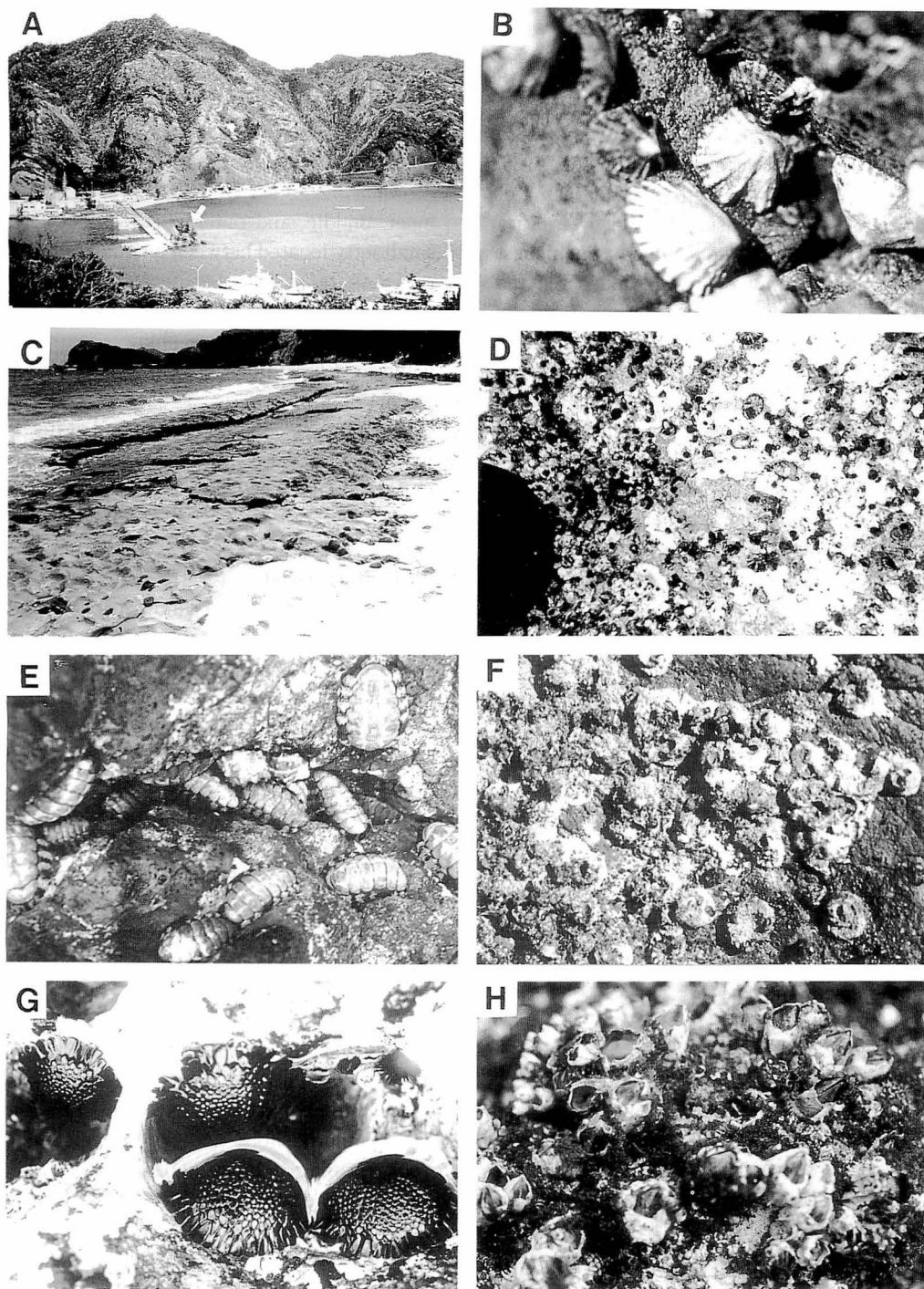


Fig. 2A-H. Selected sites and selected species which characterize rocky shore animal community of Chichijima. A. General view of Futami Bay, the largest bay in the Ogasawaras. A white arrow indicates Futami-iwa (St.21). B. The pulmonate limpet *Siphonaria* sp. C. Beachrock in John beach, Minamizaki. D. Surface of beachrock in John beach. E. The chiton *Acanthopleura japonica*. F. The vermetid shell *Dendropoma* sp. G. The sea urchin *Colobocentrotus mertensi*. H. The barnacle *Balanus occator*.

analysis (see Kimoto (1976) for calculation methods).

3. Degree of wave exposure

At the sampling stations in Futami Bay (Figs. 1 and 2A), the relationship between wave exposure and species diversity was examined in April 1986. Wave Index (WI) was defined as an indicator of the degree of wave exposure (see also Asakura and Nishihama, 1987a). The heights of the highest and lowest levels of waves were measured ten times over a period of a few minutes using a vertically stood ruler. Then, the mean values of both heights were calculated, and WI was represented by the difference between them (in cm). All of the measurements were done at noon on 12 April 1986, when the weather was sunny and very calm, and no large atmospheric depressions or cold fronts occurred around the islands. Thus, the values of WI could be considered to represent the general degree of wave exposure at each station.

4. Taxonomic remarks

The pulmonate limpet *Siphonaria* sp. (Fig. 2B) in this paper is the same as *Siphonaria subatra* in Asakura *et al.* (1990). By detailed re-examination of its morphology, however, the species was found to be a different species, and moreover, different from any other *Siphonaria* species in Japan and its adjacent waters. Thus, tentatively, this species is called "*Siphonaria* sp." in this paper.

The littorinid *Nodilittorina* sp. in this paper is the same as *Nodilittorina miliaris* in Asakura *et al.* (1990) (See Asakura and Kurozumi (1991) for taxonomic discussion).

Coastal topography and substratum of study sites

Chichijima is an ancient volcanic island, and most of the shores consist of thick piles of lava and related pyroclastic rocks. The exception is limestone exposed at the south-western end of the island, Minamizaki. Another type of substratum, beachrock (Figs. 2C and 2D), occurs on John beach near Minamizaki.

Location, coastal topography and substratum are described below.

1. Coast along Anijima-seto (northern coast)

Anijima-seto is a strait situated between Chi-

chijima Island and Anijima Island to the north. The distance is 500 m to 1,000 m. The coastal current along Anijima-seto is very rapid.

Rocks on these coasts are pillow lava and a small number of dikes of andesite and dacite, and generally have linear crevices as well as a number of small pores due to degassing from molten lava. *Miyano-hama* : Sts. 1, 2, and 3 are located at the inner, middle, and outer part, respectively, of a small jetty located between a boulder beach and a rocky shore on its west coast. Sts. 4 and 5 are located on the west and east ends of a volcanic rock mass on the coast along a narrow strait between Chichijima and a small island, Nakadori-shima.

Tsurihama : Sts. 6 and 7 are located at its east and west ends, respectively. The coastal topography and substratum are similar to those on Miyano-hara.

2. Eastern coast

Hatsuneura : This has a sandy beach in the center part. Sts. 8 and 9 are located at its south-west and north-east ends, respectively, which face the open sea and are highly wave-exposed.

Nishikaigan : This lies on the south-eastern coast of Chichijima and has a wave-protected bay, whose diameter is about 250 m. It has most varied habitats, such as a wave-protected sandy beach, cobble and boulder beaches, a bay mouth area, and a wave-beaten rocky shore facing fully open ocean. Sts. 14 and 15 are located on the exposed and sheltered sides, respectively, of the headland on the northern coast. St. 16 is located outside of the bay on its southern coast.

3. Southern coast

John beach : This lies near the south-western end of Chichijima and has an exposure of limestone on the southern shore and well-developed beach-rock forming a large platform (Fig. 2C) at the center of the sandy beach.

Sts. 10 and 11 are located on the southern and northern sides of a lava exposure on the north end of the beach, respectively. St. 12 is on a nearly vertical limestone wall located at the southern end. The limestone surface of the lower half is smooth and devoid of crevices, although the surface in the splash zone is very ragged with many crevices. St. 13 is located on the beachrock, which

slopes very gently seawards. The surface of the beachrock is smoother than that of lava, devoid of small crevices, and densely covered by calcareous algae and the vermetid shell *Dendropoma* sp. (Fig. 2F).

Buta-kaigan : St. 19 is located at the distal end of Manjyu-misaki on its northern coast. St. 20 is located at a proximal position on the northern side of Manjyu-misaki. The rocks of this coast are lava and autobrecciated lava with a highly gnarled surface.

Kominato : This is one of the largest sandy beaches on Chichijima. Sts. 17 and 18 are located at the distal and proximal parts on the north side of the jetty on its northern coast. The rocky shore consists of pillow lava and has a moderately gnarled surface. Crevices between the pillow lava provide habitats for the byssally-attached bivalves, *Isognomon nucleus* and *Hormomya mutabilis*.

Meshimori-yama : This is a dacite lava dome ca. 200 m in diameter. The dacite differs slightly from the most common andesite lava on Chichijima, having a grainy surface and no pores. St. 26 is located at its southern side.

4. Futami Bay (Fig. 2A)

This is the largest bay in the Ogasawaras, being about 1.5 km wide at its bay mouth. The innermost part of the bay is well wave-protected.

Futami-iwa : St. 21 is located on Futami-iwa, which is a small rock projecting to the inner most part of the bay. This rock consists of lava with well developed columnar joints with a diameter of 5-6 cm. The surface of the lava does not have pores.

Kaiyo Center : St. 22 is located at the outer part of the small rock on the coast of Okumura, in the middle-inner part of the bay. The rocky shore is made up of pillow lava and autobrecciated lava. *Sakaiura* : Sts. 23 and 24 are located on the south and north sides of a rock near the south end of the sandy beach. The rocky shore consists of autobrecciated lava with a ragged surface. There is a large wave-cut platform with some tide pools.

Toufuiwa : St. 25 is located on a coast facing the rock called "Toufuiwa" situated ca. 100 m off the coast. The observations were made on a large lava block on the coast.

Results

1. General characteristics of zonation

The zonation patterns of animals at each site are shown in Appendix Fig. 1 (Sts. 1-26). Because their general characteristics are quite similar to those on Hahajima (Asakura *et al.*, 1990), the following description is brief.

Although the distribution was sometimes shifted both horizontally and vertically, probably, due to the degree of wave exposure, topographical characters and so on, the basic patterns can be summarized as follows.

The splash zone was characterized mainly by three littorinids, *Nodilittorina pyramidalis* (at all stations except St. 12), *Nodilittorina* sp. (at all stations except for Sts. 18 and 24), and *Littorina pintado* (Sts. 1-4, 7, 13, 14, 16, 23, 25, 26), *N. pyramidalis* mostly dominated the animals in this zone, and showed the highest vertical position, extending as much as 700 cm above the MSL (St. 20). *Nodilittorina* sp. and *L. pintado* generally occupied lower zones than *N. pyramidalis*.

Zones from the lower splash to middle intertidal were characterized by the pulmonate limpet *Siphonaria* sp. (Fig. 2B) (Sts. 1, 2, 4-12, 14-20, 22, 24, 25), the small barnacle *Chthamalus challengerii* (all stations except St. 13), and the oyster *Saccostrea mordax*, which sometimes formed a large bed (Sts. 4-6, 8, 10, 11, 14, 17, 18, 22-26). The chiton *Acanthopleura japonica* was attached around and/or in the crevices (Fig. 2E) (Sts. 2, 4, 6, 8-11, 13, 14, 16-20, 22, 26). The endemic giant limpet *Cellana mazatlantica* occurred at Sts. 10, 11, 18, 25, and 26.

Sessile animals characterize the middle and lower intertidal zones, such as vermetid shells *Serpulorbis daidai*, *S. imbricatus*, *Dendropoma* sp. (Fig. 2F), or *Vermetus* sp. (Sts. 2, 4, 5-12, 14-20, 22, 23), and patches of the sessile bivalves *Hormomya mutabilis* (Sts. 4, 5, 8, 17, 18, 22-25) and *Isognomon nucleus* (Sts. 1-5, 10, 18, 20, 21, 23, 24). The lower margins of wave-exposed shores were sometimes fringed by zones of *Balanus occator* (Fig. 2H) (Sts. 6, 8, 14, 15, 20, 23, 25, 26). Colonies of corals were attached to the rocks at the lower margin and subtidal zones (Sts. 4-17, 19, 24-26). Sea urchins were also abundant in the lower intertidal zone, such as *Echinometra mathaei mathaei* and *E. mathaei oblonga* (Sts. 4, 6, 8, 13-15, 17, 19, 20, 23, 25, 26), and *Colobocentrotus mertensi* in the highly

Table 1. Number of animal species occurred and diversities (H' and J') at each station

Place	Miyanohama					Tsurihama		Hatsuneura			John beach		
St. no.	1	2	3	4	5	6	7	8	9	10	11	12	13
No. sp.	6	10	7	8	10	9	7	11	13	12	10	7	5
H'	1.781	2.369	1.634	1.986	1.880	2.053	1.236	2.648	1.101	0.565	2.422	2.422	0.565
J'	0.689	0.713	0.582	0.663	0.566	0.648	0.441	0.765	0.255	0.578	0.509	0.862	0.243

Place	Nishikaigan			Kominato		Buta-kaigan		Futami Bay					
St. no.	14	15	16	17	18	19	20	21	22	23	24	25	26
No. sp.	14	12	9	9	11	10	13	5	9	10	6	11	11
H'	1.392	2.422	1.392	0.960	1.672	1.432	1.119	0.980	1.960	2.478	2.099	1.518	1.136
J'	0.366	0.655	0.416	0.303	0.483	0.431	0.303	0.423	0.618	0.746	0.812	0.439	0.328

exposed shores (Fig. 2G) (Sts. 14, 15, 26; outside the quadrats on the sampling transect lines). (See Asakura *et al.* (1990) for photographs of other animals.)

2. Species diversity and faunal similarity

The number of species present ranged from 5 to 14, Shannon-Weaver's function (H') ranged from 0.565 to 2.648, and Pielou's evenness index (J') ranged from 0.243 to 0.862 for a community at each site (Table 1).

Values of Colwell-Futuyma's niche overlap between stations are shown in Appendix Table 1, and a dendrogram based on these values is shown in Fig. 3. High similarity values were seen between most of the stations, however, low values were seen between the limestone station (St. 13) and other stations.

3. Wave exposure and species diversity

Besides the above-mentioned generalization, minor differences in the fauna were seen depending on the wave exposure.

Fig. 4 shows the relationships in Futami Bay, between the degree of wave exposure and three parameters of species diversity, *i. e.* number of species and values for H' and J'. The number of species shows a significant positive correlation with wave exposure ($\tau = 1.0$, $n = 6$, $0.01 < p < 0.05$, Kendall's rank correlation), though there are no significant correlation between wave exposure and other two parameters (in both cases, $\tau = -0.03$, $p > 0.5$, Kendall's rank correlation).

Table 2 shows the 12 main species at the stations in Futami Bay, Miyanohama and Kominato.

The stations at each site are arranged according to wave exposure.

In Futami Bay, *Nodilittorina pyramidalis* and *Chthamalus challengerii* were found at every station. Whereas *Littorina pintado*, *Cellana toreuma enneagona*, and *Cellana mazatlanica* were found mainly in medium to highly wave exposed stations, *Isognomon nucleus* in middle exposed, and *Hormomya mutabilis* in highly wave-exposed stations.

In Miyanohama (Table 2), *I. nucleus* was found at every station, but its density decreased from the inner to outer stations (261, 89, 17, and 8 (/225 cm²), from St. 1 to 4). *H. mutabilis* was found only at the most outer station, St. 4. Similarly, *I. nucleus* was found in inner station of Kominato, St. 18.

No animals occurred specifically in the wave-sheltered habitat.

Discussion

1. Comparison of zonation features to those in other Japanese localities

Asakura *et al.* (1990) reported that the zonation of organisms on Hahajima is more like that on shores in warm temperate Japanese waters (WTJW), such as Kii-Shirahama, Wakayama (Osako *et al.*, 1982), and Amakusa, Kyushu (Mori *et al.*, 1985), than those on coral reefs on the subtropical islands of Okinawa, such as Sesoko (Nakasone *et al.*, 1974), even though Ogasawara is situated in subtropical waters. Since the intertidal animals found on Chichijima are common in those of Hahajima, the zonation patterns on Chichijima are also similar to those on shores in WTJW, for

Animals on the rocky shores of Chichijima

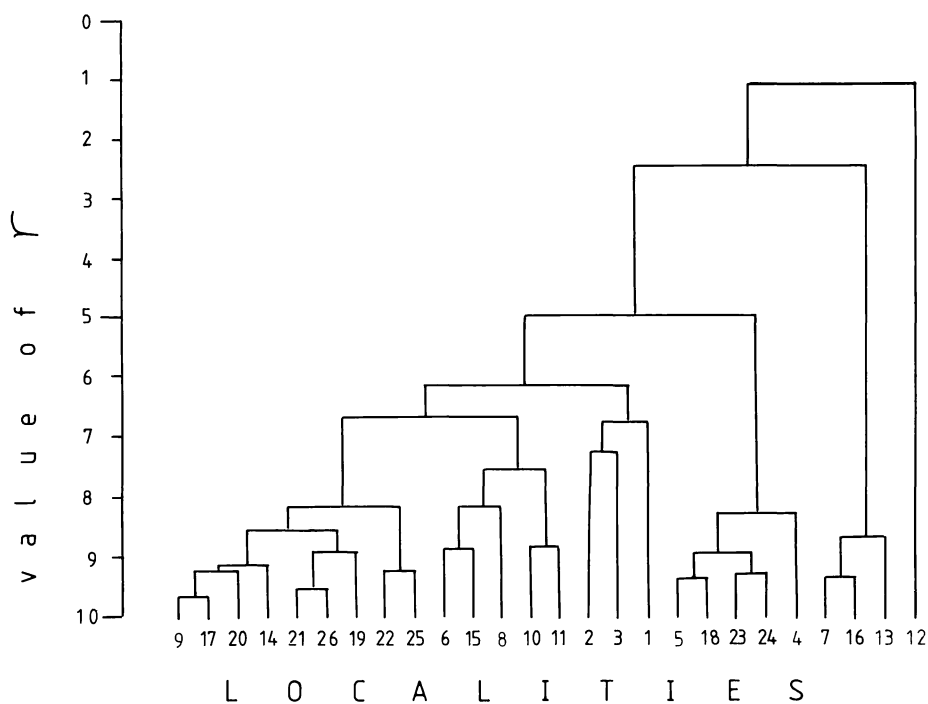


Fig. 3. Dendrogram based on faunal similarity between stations (calculated in terms of Colwell-Futuyma's niche overlap index).

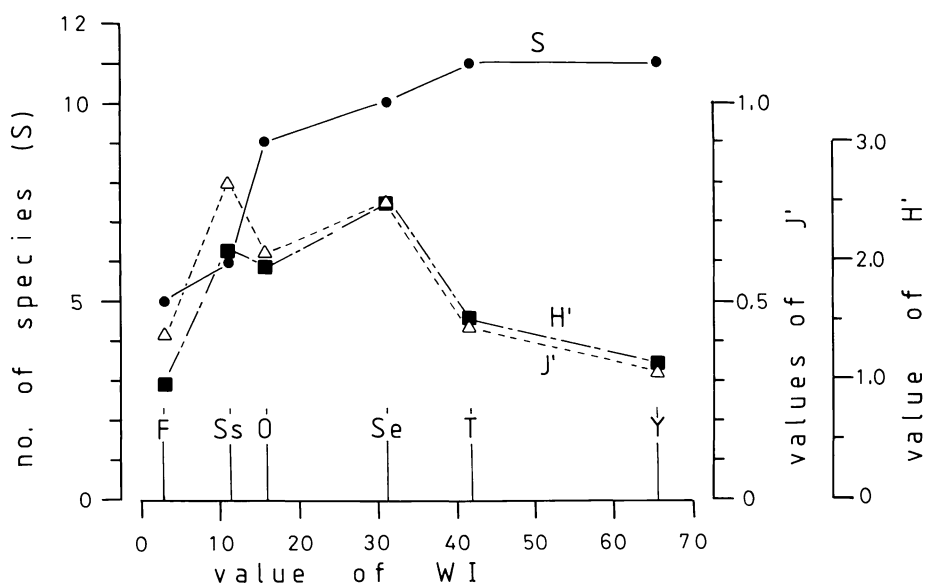


Fig. 4. Relationship between wave exposure (calculated in terms of WI) and three factors of species diversity, number of species occurred, Shannon-Weaver's diversity (H') and Pielou's evenness index (J'). Alphabets in the figure indicate the sampling stations; F: Futami-iwa (St. 21), Ss: sheltered side on Sakaiura (St. 23), O: Kaiyo Center, Okumura (St. 22), Se: exposed side on Sakaiura (St. 24), T: Toufuiwa (St. 25), Y: Meshimori-yama, Yagyusan (St. 26).

example, presence of a *Nodilittorina* zone, a *Chthamalus challenger* zone, and *H. mutabilis* patches.

2. Substratum and fauna

Dominance of limpets is also a common characteristic between the Ogasawaras and WTJW. In WTJW, there commonly occur several species of *Cellana* (ex. *C. grata*, *toreuma*, and *nigrolineata*), *Patella* (ex. *P. flexouosa*), *Patelloida* (ex. *P. saccharina lanx* and *pygmaea*), *Collisella* (ex. *C. dorsuosa*, and *heroldi*), and *Siphonaria* (ex. *S. japonica*, *acmaeoides* and *sirius*) (Mori *et al.*, 1985; Osako *et al.*, 1982; Okutani, 1986)

The rocky shores of the Ogasawaras are commonly inhabited by *Cellana toreuma enneagona*, *Cellana mazatlanica*, *Siphonaria* sp. and *Patella flexouosa* (Asakura *et al.*, 1990; this study). In addition, the chiton *Acanthopleura japonica* also occurs abundantly in both WTJW and the Ogasawaras.

In Okinawa, limpets are more abundant on volcanic substrata than limestones or coral reefs. For example, the shores of volcanic rocks of Okinawa-jima are commonly inhabited by *Cellana testudinaria*, *C. toreuma*, *Patelloida saccharina saccharina*, *Collisella heroldi*, *Notoacmea fuscoviridis*, *Siphonaria laciniosa*, *S. atra* and so on. Whereas limpets are often completely absent on coral reefs or limestone shores, or rarely found, as

is the case of *P. saccharina saccharina*, *S. laciniosa*, *C. heroldi* and so on (Nishihira, 1974).

Vermeij *et al.* (1983) also reported that shores of the northern Mariana Islands, situated south of Ogasawara, were almost volcanic and that limpet-form molluscs (including abalone shells) were abundant, compared with the shell fauna on limestone shores or coral reefs of Guam, southern Marianas.

Thus we believe that dominance of a volcanic substratum is one of key factors characterizing intertidal fauna in the Ogasawaras.

3. Wave exposure and distribution pattern of animals

In Futami Bay, the number of species showed a significant positive correlation with wave exposure, though no correlation was found between wave exposure and H' or J'. This is due to high abundance of such animals as *Chthamalus challenger*, *Dendropoma* sp. and so on at wave-exposed sites (predominance of certain animals decreases values of H' and J').

Table 2 shows clearly that no animals prefer a specifically wave-sheltered habitat. *Monodonta australis* seems to live on sheltered beach (Sts. 21 and 22), however this species is also abundant on the wave-exposed boulder beaches (Asakura and Nishihama, 1987b). The small area of wave-sheltered habitats limits the number of species

Table 2. The relationship between degree of wave exposure and species occurred (for main 12 spp.).

* : Degree of wave exposure was measured quantitatively.

** : Degree of wave exposure was estimated by topography of bays, where observation stations are located.

Species	Locality	Futami Bay						Miyanojima				Kominato	
	Wave	sheltered ←			→ exposed*			shl. ←		→ exp.**		shl. ←	→ exp.**
	St. no.	21	24	22	23	25	26	1	2	3	4	18	17
<i>Cellana toreuma enneagona</i>		—	—	—	—	●	●	—	—	—	—	—	—
<i>Cellana mazatlanica</i>		—	—	—	—	●	●	—	—	—	—	—	—
<i>Diloma suavis</i>		—	—	●	—	●	●	—	—	—	—	—	—
<i>Monodonta australis</i>		●	—	●	—	—	—	—	—	—	—	—	—
<i>Nodilittorina pyramidalis</i>		●	●	●	●	●	●	●	●	●	●	●	●
<i>Nodilittorina</i> sp.		●	—	●	●	●	●	●	●	●	●	—	●
<i>Littorina pintado</i>		—	—	—	●	●	●	●	●	●	●	—	—
<i>Siphonaria</i> sp.		●	—	●	●	●	—	●	●	—	—	●	●
<i>Hormomya mutabilis</i>		—	●	●	●	●	—	—	—	—	●	●	●
<i>Isognomon nucleum</i>		—	●	—	●	—	—	●	●	●	●	●	—
<i>Saccostrea mordax</i>		●	●	●	●	●	—	—	—	—	●	●	●
<i>Chthamalus challenger</i>		●	●	●	●	●	●	●	●	●	●	●	●

preferring sheltered sites, because a small population tends to become extinct easily. This hypothesis seems to be supported by the following facts: in the innermost part of Futami Bay, a population of a fiddler crab *Uca gaimardi* (recorded by Imajima, 1970, and Shigei, 1970) and a dense population of a neritid shell *Nerita squamurata* (recorded by Matsumoto *et al.*, 1970) had become to extinct before 1986 (Asakura and Nishihara per. obs., and 1988).

Ohgaki (1983) reported the distribution pattern of littorinids in Futami Bay, and showed that *Nodilittorina pyramidalis* occupied higher positions in splash zones than *Nodilittorina* sp. (*N. leucosticta feejeensis* in his paper) and *Littorina pintado*. Our results agree well with Ohgaki's observation. He also showed that higher exposure of wave increases the upper level of the distribution of *N. pyramidalis*. However this trend was not clear in our study, probably due to differences in topographical features and texture of rocks.

4. Poor assemblages in rocky shores of Chichijima

Species diversity on rocky shores is low on Chichijima like those on Hahajima (Asakura *et al.*, 1990), in comparison with that on the coral reefs of Okinawa (Nishihira, 1974) and the rocky shores of Amakusa in WTJW (Mori *et al.*, 1985).

Asakura *et al.* (1990) discussed the factors causing low diversity on Hahajima, and the situation is considered to be the same on Chichijima, *i. e.*, a low possibility for introduction due to isolation is the main factor leading to the occurrence of a low species number, in addition, volcanic substrata restrict the introduction of coral-inhabiting or limestone-inhabiting species (Kuwamura *et al.*, 1983), and, further, narrow intertidal zone restricts the coexistence of species which require similar resource.

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小笠原諸島父島の岩礁海岸の動物の分布

朝倉 彰¹⁾・近藤康生¹⁾・西浜士郎²⁾

1) 千葉県立中央博物館

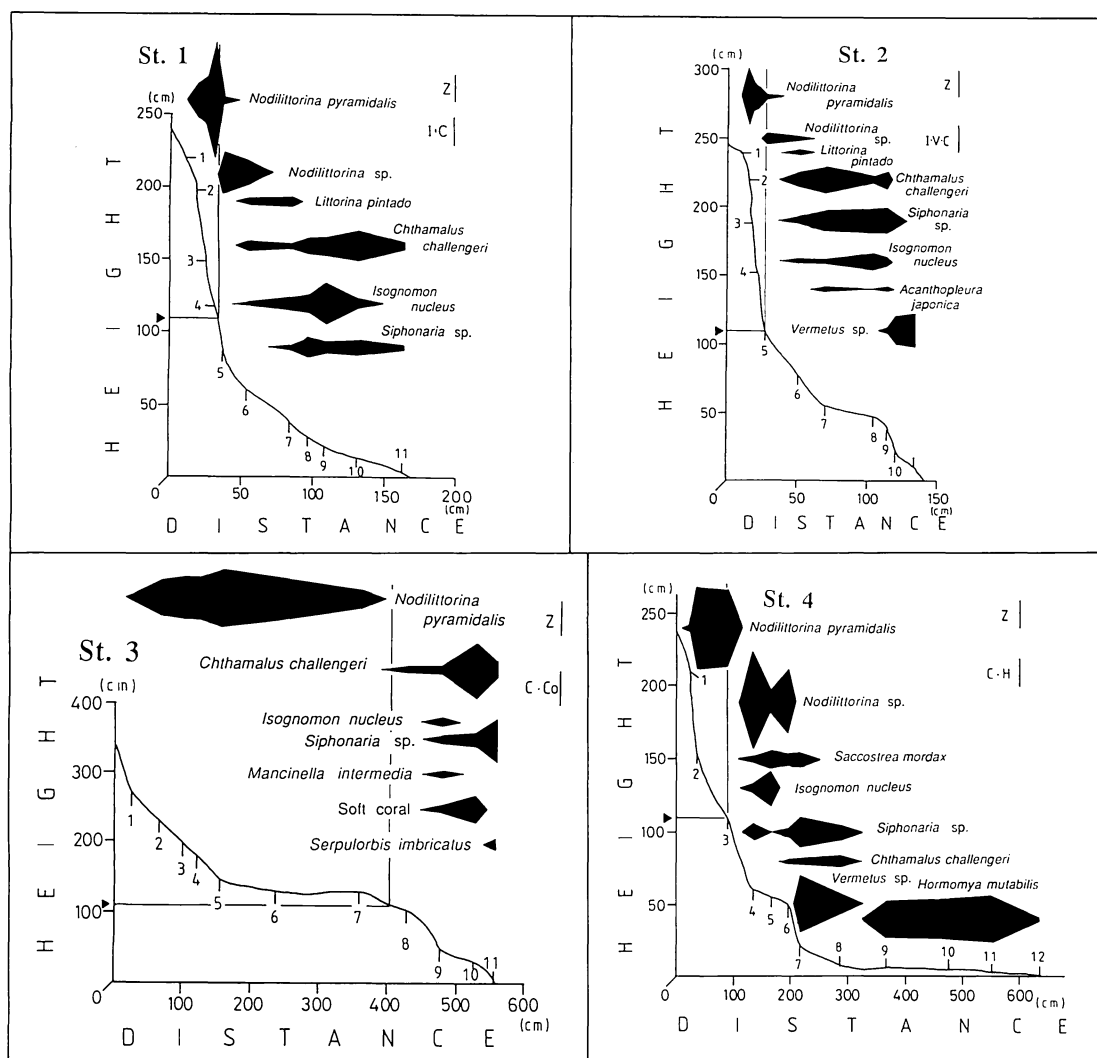
〒280 千葉市青葉町955-2

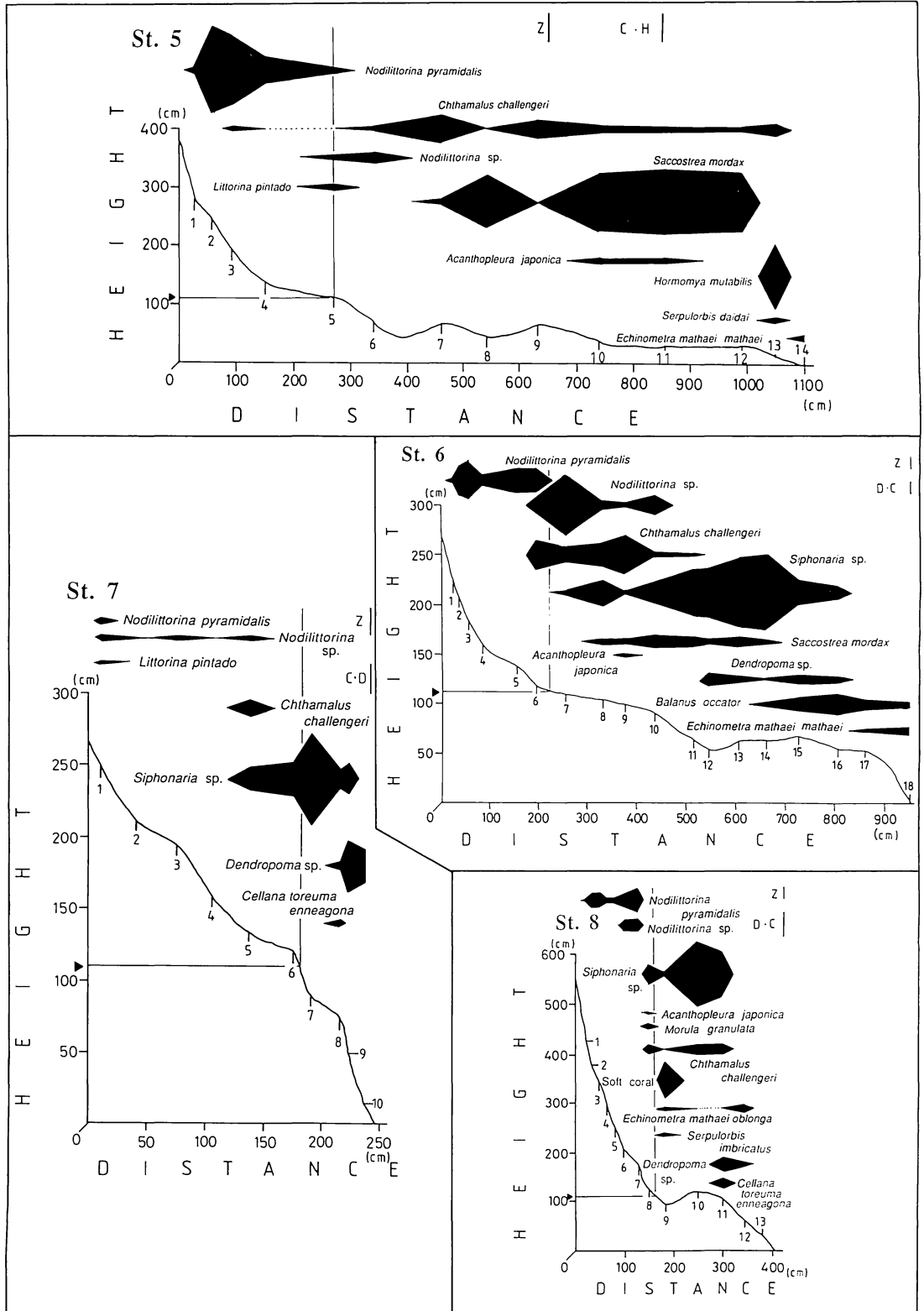
2) 九州大学理学部附属天草臨海実験所

〒863-25 熊本県天草郡苓北町富岡

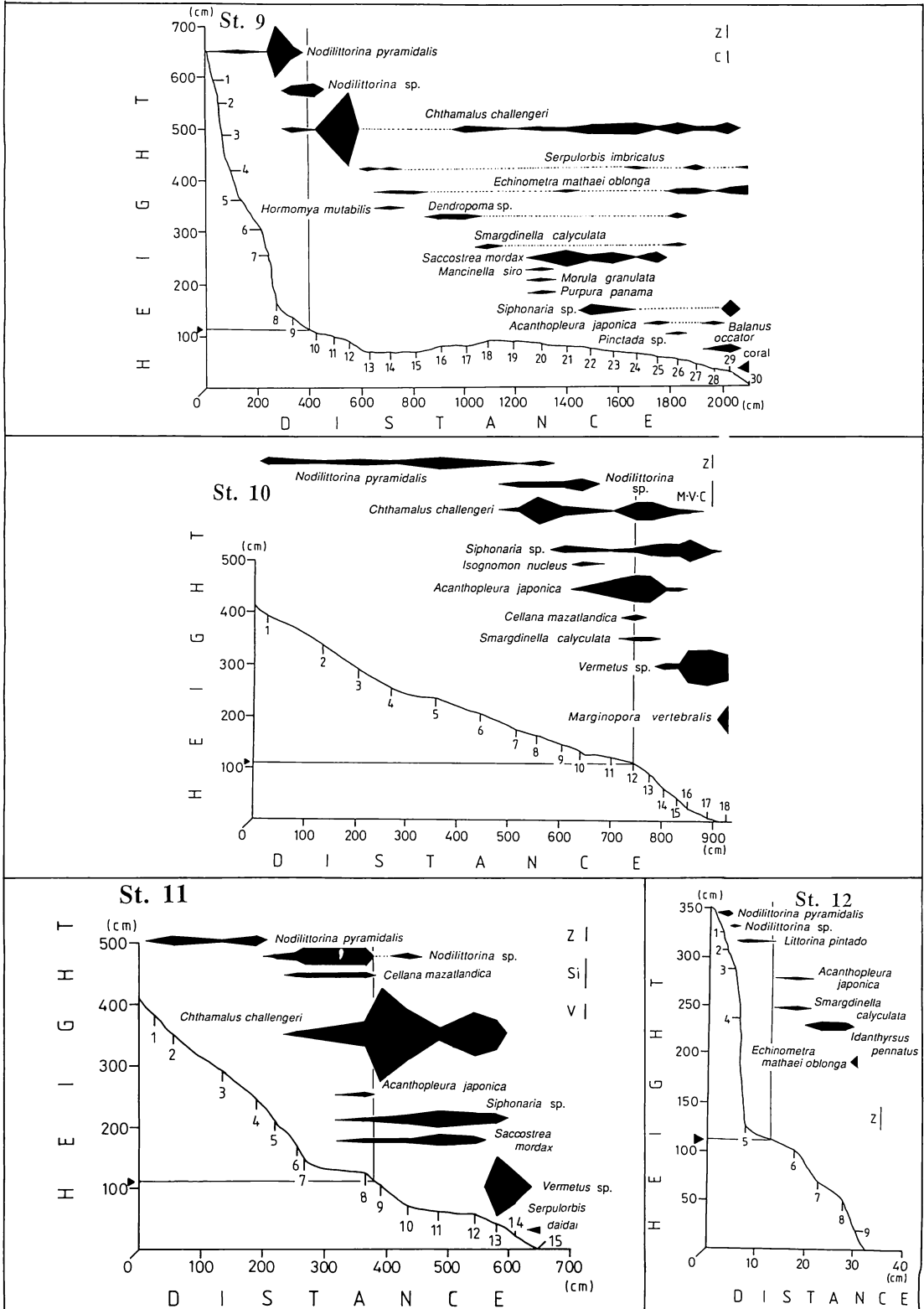
小笠原諸島父島の岩礁海岸に生息する動物の分布パターンを、26地点で調査した。飛沫帯は、3種類のタマキビ類、すなわちイボタマキビ、オガサワラタマキビ、コウダカタマキビの分布で特徴づけられる。飛沫帯から潮間帯中部にかけては、オハグログキ、カラマツガイの一種、イワフジツボ等が分布する。潮間帯下部は、ヘビガイ類（オオヘビガイ、フタモチヘビガイの一種、オレンジヘビガイなど）、管棲ゴカイ、フジツボ等の付着動物、ウニ類（ナガウニ、ナガクロウニ、ジンガサウニなど）が分布する。サンゴは、限られた地域の潮間帯下部から潮下帯に生息している。1地点の潮間帯全域の種多様性はH'の値が0.565から2.648までで、J'の値が0.243から0.862までの範囲であった。地点間の動物相とは大きな違いがみられた。小笠原最大の湾の二見湾で、波浪の強さと動物の分布パターンを調べたところ、波浪が強くなるほど出現種数は増えたが、種多様性の指数（H'とJ'）との関係は見いだせなかった。内湾のみに出現する種類は見られなかった。

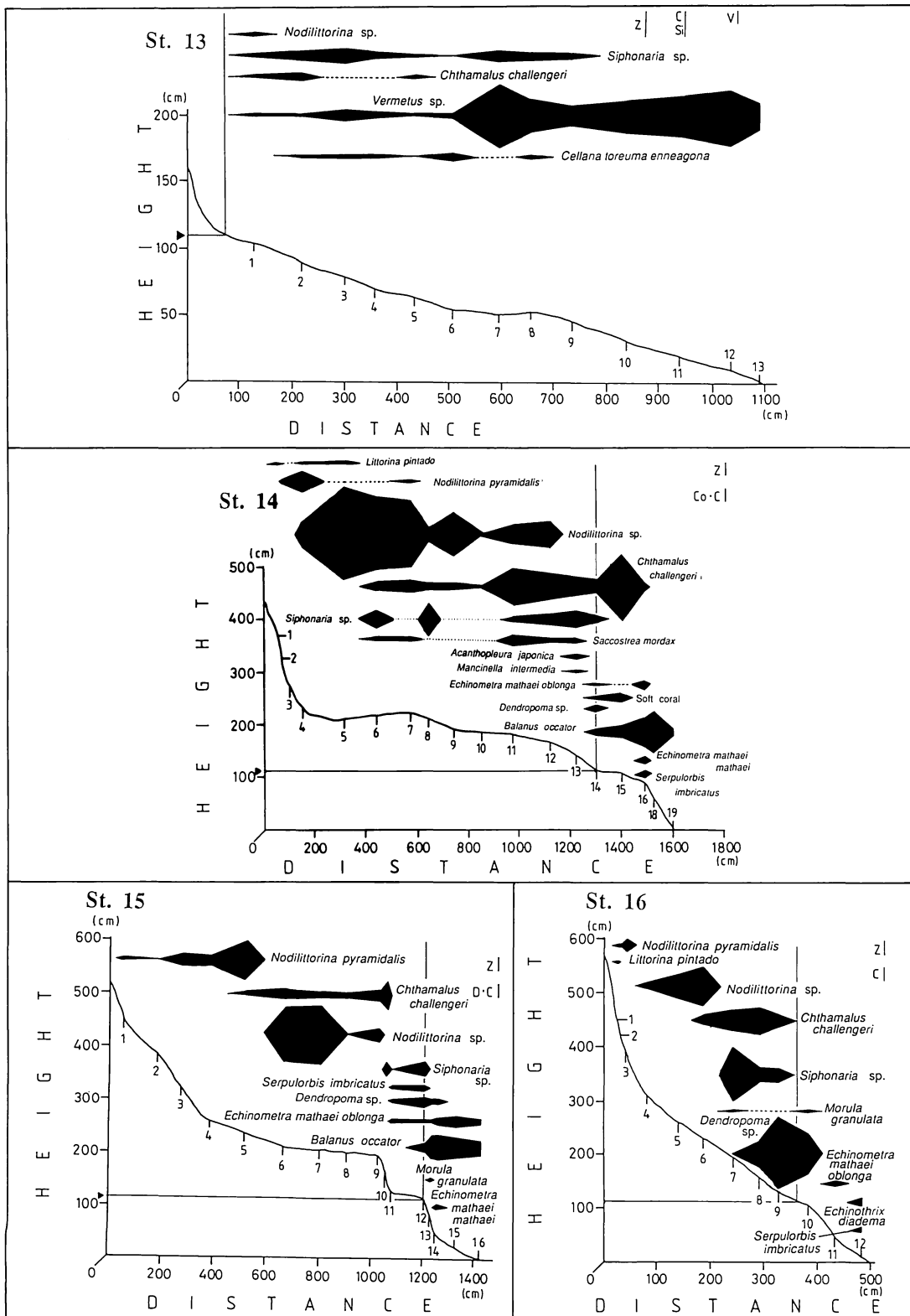
Appendix Fig. 1. Topography and distribution of animals in stations 1-26. Length of bars indicate 100 individuals/900 cm² of *Chthamalus challenger* (C), *Dendropoma* sp. (D), *Vermetus* sp. (V), *Siphonaria* sp. (Si), *Hormomya mutabilis* (H), *Marginopora vertebralis* (M), *Isognomon nucleus* (I), and individuals of corals (Co). Z indicates density of animals other than the particularly-indicated species (10 individuals/900 cm²). Height represents the level above the mean sea water level (MSL). Solid triangle indicates level of the extreme high water in spring tide.



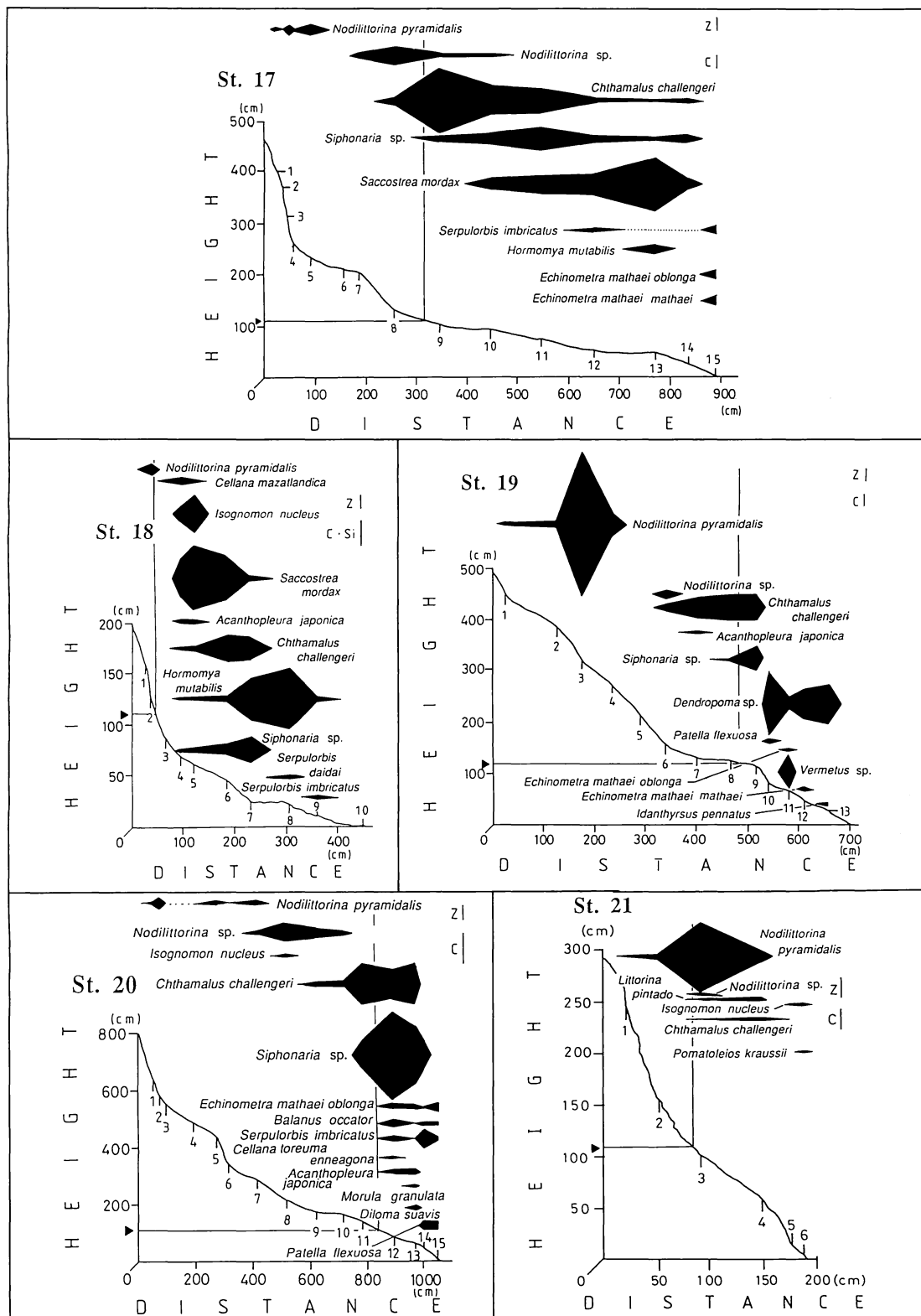


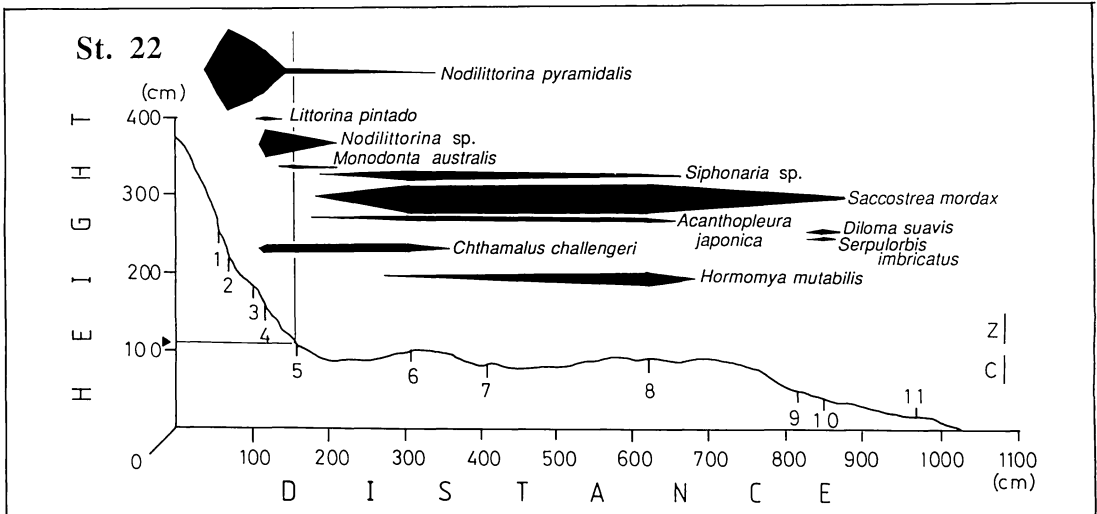
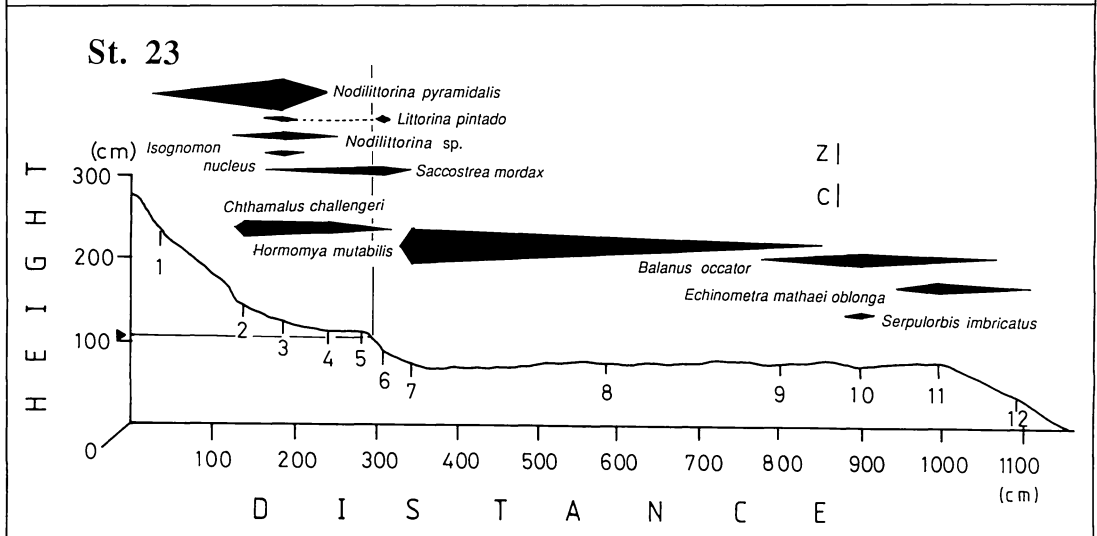
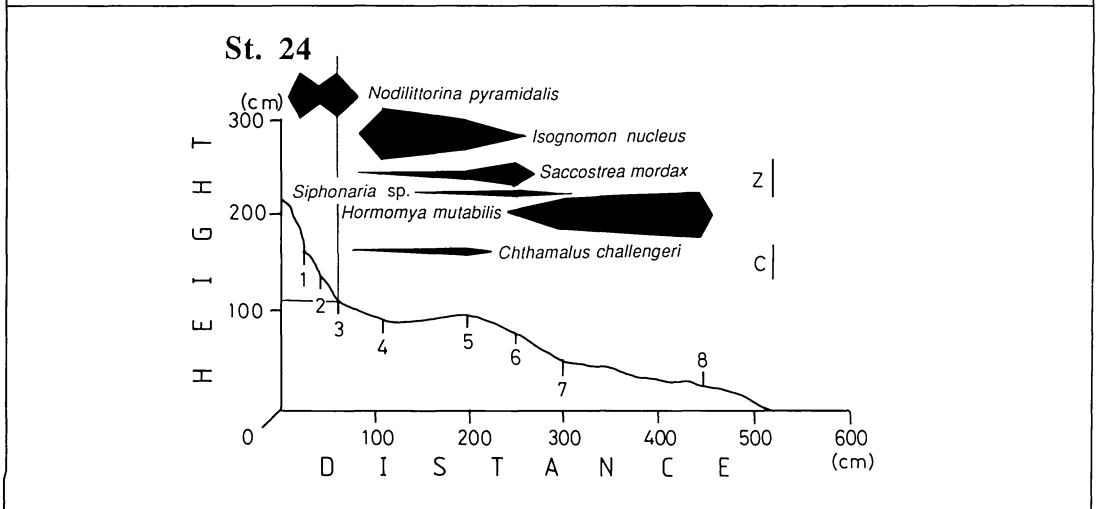
Animals on the rocky shores of Chichijima



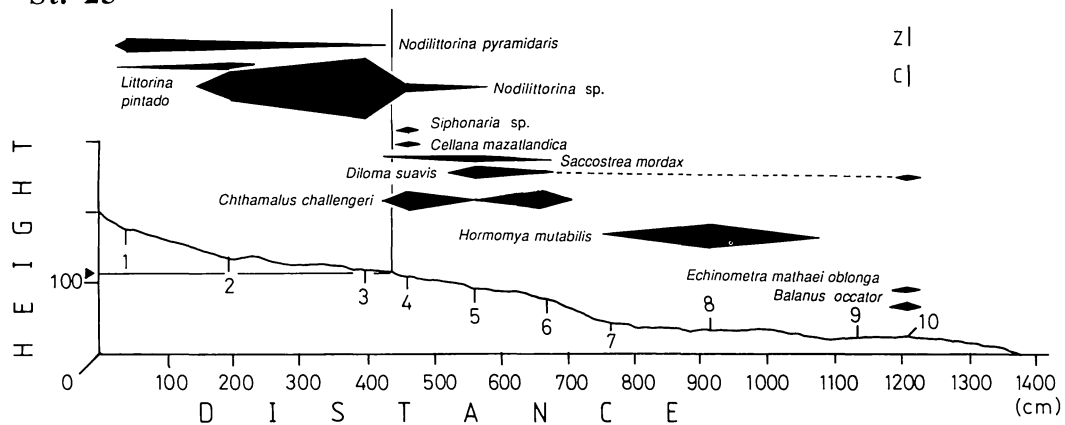


Animals on the rocky shores of Chichijima

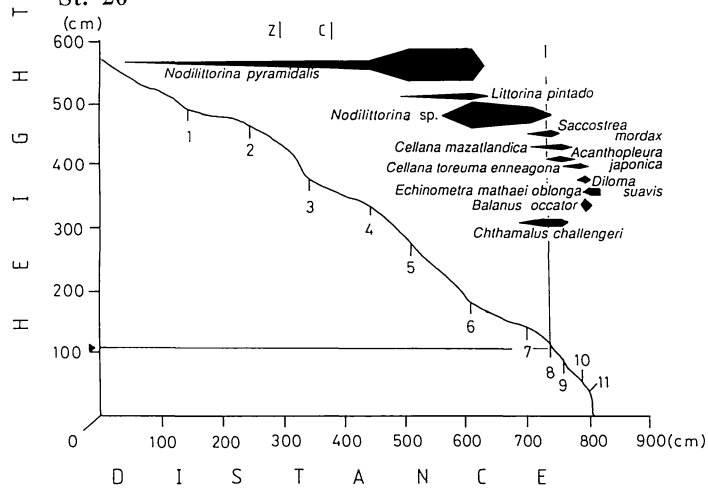




St. 25



St. 26



Appendix Table 1. Similarity value of Colwell-Futuyma's niche overlap index

St.	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	0.662	0.676	0.419	0.513	0.653	0.282	0.586	0.664	0.467	0.560	0.195	0.097	0.663	0.608	0.404	0.663	0.451	0.660	0.676	0.755	0.658	0.581	0.706	0.608	0.695
2		0.718	0.427	0.435	0.562	0.296	0.603	0.608	0.416	0.494	0.123	0.105	0.596	0.482	0.354	0.572	0.402	0.559	0.596	0.608	0.550	0.463	0.550	0.499	0.574
3			0.361	0.560	0.734	0.295	0.796	0.846	0.511	0.653	0.160	0.104	0.784	0.627	0.436	0.789	0.453	0.195	0.799	0.855	0.763	0.567	0.623	0.673	0.827
4				0.798	0.574	0.201	0.435	0.662	0.404	0.511	0.112	0.043	0.593	0.483	0.341	0.714	0.934	0.593	0.590	0.640	0.883	0.915	0.917	0.856	0.645
5					0.426	0.200	0.403	0.348	0.285	0.289	0.205	0.084	0.399	0.382	0.252	0.382	0.853	0.399	0.345	0.396	0.703	0.833	0.811	0.687	0.348
6						0.661	0.852	0.844	0.773	0.851	0.168	0.451	0.847	0.883	0.738	0.824	0.478	0.777	0.846	0.777	0.768	0.573	0.574	0.716	0.784
7							0.669	0.360	0.829	0.637	0.046	0.850	0.331	0.622	0.934	0.310	0.212	0.341	0.365	0.256	0.280	0.192	0.211	0.255	0.258
8								0.697	0.623	0.811	0.128	0.159	0.912	0.777	0.556	0.956	0.529	0.888	0.925	0.899	0.833	0.604	0.634	0.819	0.922
9									0.723	0.700	0.289	0.496	0.667	0.764	0.698	0.609	0.360	0.705	0.671	0.668	0.652	0.514	0.499	0.532	0.647
10										0.879	0.143	0.725	0.572	0.762	0.902	0.558	0.352	0.596	0.581	0.545	0.530	0.372	0.400	0.500	0.545
11											0.186	0.468	0.756	0.779	0.752	0.778	0.447	0.726	0.790	0.707	0.656	0.430	0.488	0.669	0.715
12												0.002	0.113	0.458	0.862	0.098	0.080	0.155	0.139	0.050	0.083	0.040	0.061	0.056	0.053
13													0.169	0.253	0.077	0.091	0.028	0.180	0.116	0.207	0.217	0.277	0.138	0.150	0.219
14														0.840	0.520	0.899	0.486	0.787	0.920	0.847	0.794	0.578	0.553	0.839	0.868
15															0.767	0.717	0.386	0.742	0.766	0.706	0.671	0.554	0.471	0.691	0.728
16																0.493	0.297	0.533	0.512	0.467	0.450	0.320	0.332	0.451	0.456
17																	0.579	0.837	0.931	0.880	0.863	0.622	0.659	0.837	0.894
18																		0.437	0.502	0.471	0.770	0.852	0.896	0.778	0.477
19																			0.843	0.901	0.800	0.602	0.614	0.732	0.885
20																				0.863	0.797	0.549	0.571	0.810	0.892
21																					0.847	0.644	0.680	0.802	0.949
22																						0.862	0.865	0.923	0.839
23																							0.921	0.809	0.654
24																								0.799	0.644
25																									0.822