Distribution of Two Species of *Conchoderma* (Cirripedia: Thoracica) over the Body of a Sea Snake, *Laticauda semifasciata* (Reinwardt), from the Kii Peninsula, Southwestern Japan

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Abstract Two species of *Conchoderma* were found on a sea snake, *Laticauda semifasciata* (Reinwardt), collected on the west coast of the Kii Peninsula. A total of 223 individuals of *C. virgatum* and 6 of *C. hunteri* in 19 clumps were attached to the snake's body. The barnacles ranged in size from 1.4 mm (cypris larvae) to 18.2 mm in capitulum length in *C. virgatum*, and from 10.7 to 14.4 mm in *C. hunteri*. The size of the smallest gravid individuals in both species was between 10 and 11 mm. The distribution of *C. virgatum* on the snake was non-random both longitudinally and dorso-ventrally, with more barnacles in the posterior region and on the ventral side of the snake, respectively. The proportion of gravid individuals increased towards the tail.

Key words: lepadomorph barnacle, *Conchoderma*, sea snake, epizoa, distribution on host, sympatric species

Introduction

Lepadomorph barnacles of the genus *Conchoderma* have been found in the open sea both on living organisms (crabs, fish, crustacean parasites of fish, sea turtles, sea snakes, and whales) and inanimate objects (ship hulls, buoys, telegraph cables, and oil platforms) (Clarke, 1966; Roskell, 1969; Hastings, 1972; Harper, 1995). *Conchoderma virgatum* (Spengler, 1790) and *C. auritum* (Linnaeus, 1776) are cosmopolitan species, while *C. hunteri* (Owen, 1830) has a more limited distribution, being found only in the Indo-West Pacific (Darwin, 1851; Liu & Ren, 1985). *Conchoderma hunteri* has sometimes been considered to be a mere variety (Annandale, 1909) or subspecies (Hiro, 1937) of *C. virgatum*. Although *C. virgatum* has frequently been reported, the numbers of barnacles per host have usually been small and population studies have been rare.

We collected an individual of the sea snake *Laticauda semifasciata* (Reinwardt) that was heavily infected by barnacles, both *C. virgatum* and *C. hunteri* (dark-colored form *sensu* Hiro, 1937). The present paper reports in detail the number and position of the barnacles on the snake.

Materials and Methods

The snake (Fig. 1), 140 cm long, was caught with a crab net and landed at the Minabe Fishing Port (135°20'E, 33°44'N) on the west coast of the Kii Peninsula, southwestern Japan, on 4 July 1990. The snake seemed to have died very recently probably from suffocation, while the barnacles on the snake were alive. It was preserved in 10 % formalin for five years prior to scrutiny of the barnacles.

The two species of barnacles, *C. virgatum* and *C. hunteri*, were easily distinguishable by their color and shape (Fig. 2). Since the barnacles formed clumps on the snake's body, the position of each clump of barnacles was noted in terms of distance from the anterior end and dorso-ventral location. The barnacles were removed from the snake by lifting off the scales with fine forceps. The capitulum lengths of all specimens were measured with calipers and the presence of egg masses was checked.

To analyze the distribution of *C. virgatum* with respect to the distance from the anterior end of the snake, the surface of the snake was divided into 14 ring-shaped regions, each being 10 cm long. The surface area of each region was estimated from the girth at both ends of the region as a 10 cm high trapezoid. To determine whether there were any distributional differences of *C. virgatum* on the dorsal and ventral sides of the snake (defined as bearing ventral scutes and dorsal scales, respectively), the surface area of both sides was estimated. The estimation was made by measuring the girth components of the ventral and dorsal sides every 10 cm along the longitudinal axis, and by calculating the area of each 10 cm division as a trapezoid. We excluded the head and tail regions from this analysis, because no ventral scutes occurred there.

Results

The barnacles on the snake formed 19 distinct clumps (Fig. 3). In five clumps *C. hunteri*

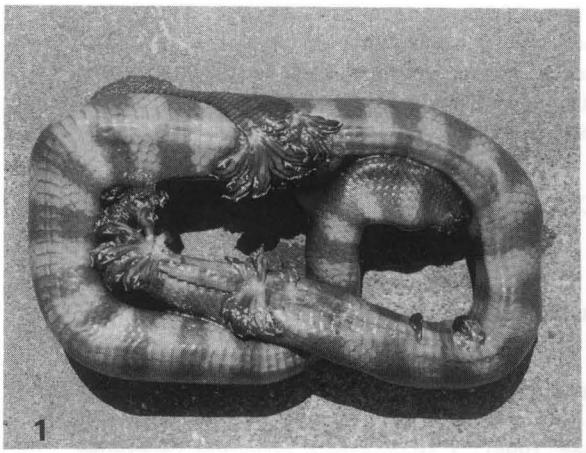
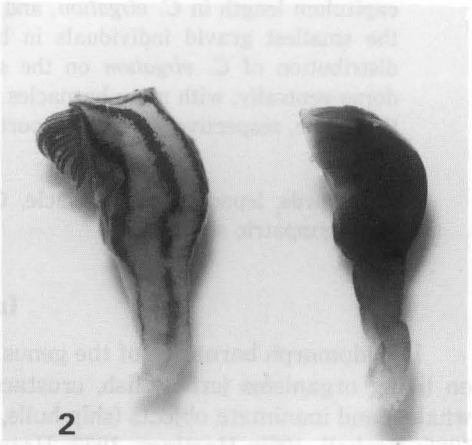


Fig. 1. The sea snake *Laticauda semifasciata* (Reinwardt), infected by *Conchoderma*.



Fig, 2. *Conchoderma virgatum* (left) and *C. hunteri* (right).

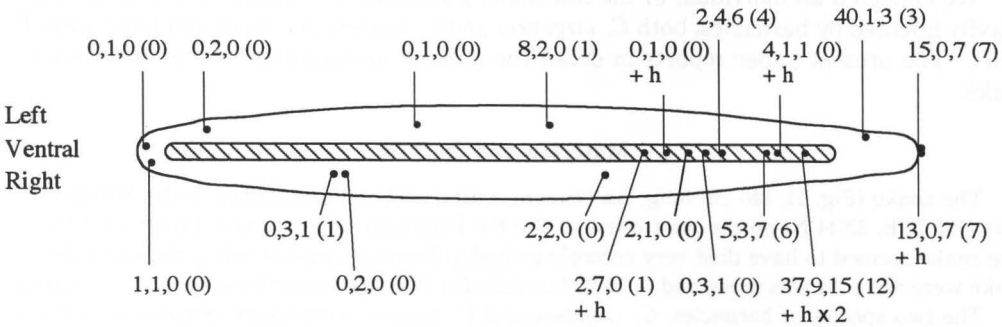


Fig. 3. Diagrammatic representation of the position of *Conchoderma* on the sea snake, unrolled along the dorsal midline. Shaded area corresponds to the area of a row of ventral scutes. Numerals indicate the numbers of *C. virgatum* individuals <2 mm in capitulum length, 2–12 mm, and ≥ 12 mm, gravid individuals in parentheses, respectively. Each individual of *C. hunteri* is indicated as an 'h'.

were found together with *C. virgatum*. The barnacles secreted a large quantity of cement, which sometimes soaked into the gaps between scales, but did not adhere to the 'real skin'. Many smaller individuals encircled the basis of larger individuals, but never attached directly to the middle of the peduncle or the capitulum of larger ones.

A total of 223 individuals of *C. virgatum* and 6 of *C. hunteri* were recorded. The size of *C. virgatum* varied considerably, from 1.4 mm (cypris larvae) to 18.2 mm in capitulum length, while that of *C. hunteri* was rather uniform, varying from 10.7 mm to 14.4 mm (Fig. 4). Individuals of *C. virgatum* smaller than 2 mm seemed to be undergoing or to have just completed metamorphosis from the cypris larvae.

Forty-two individuals (18.8 %) of *C. virgatum* and 6 (100 %) of *C. hunteri* were gravid. In both species the capitulum lengths of gravid individuals were over 10 mm, and the capitula of gravid *C. virgatum* (mean ± SD length = 15.0±1.62 mm) were significantly longer than the capitula of *C. hunteri* (12.7±1.60; U = 37.5, P = 0.006, Mann-Whitney's U-test).

The distribution of *C. virgatum* along the longitudinal axis of the snake was not random (Table 1). The density of clumps in each 10 cm region was not correlated with the distance from the anterior end of the sea snake. However, the density of individuals was correlated positively with the distance, indicating that more individuals were attached in posterior regions than in anterior regions. Likewise, the proportion of gravid individuals within each region increased towards the tail of the snake. The proportions of large individuals (12 mm or larger in capitulum length) as well as small individuals (less then 2 mm, including cyprids)

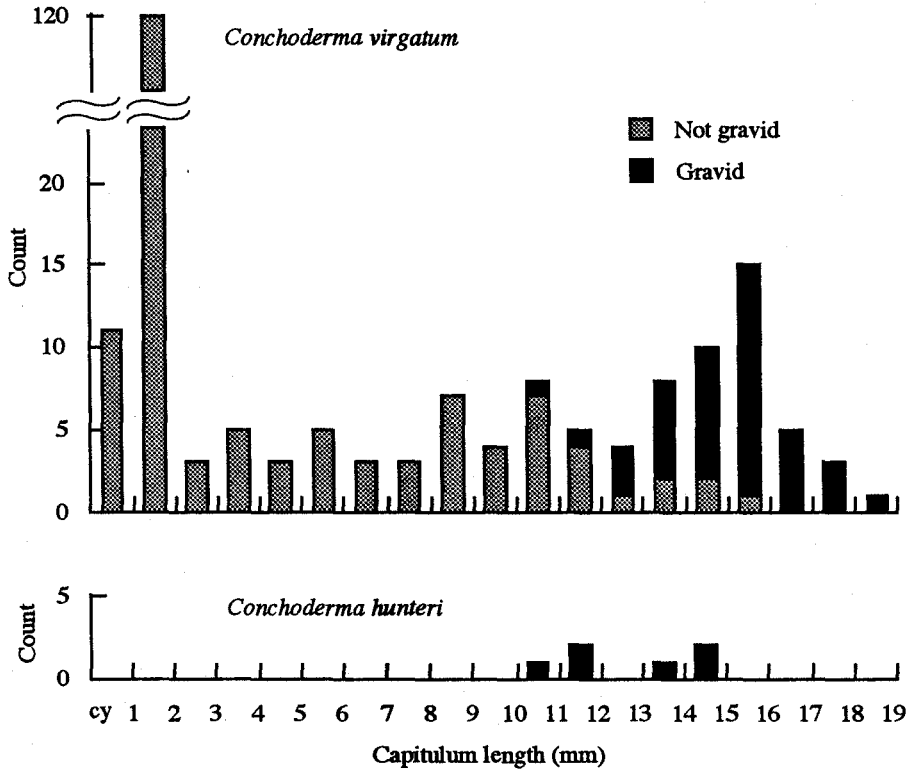


Fig. 4. Size frequency distribution of *Conchoderma virgatum* and *C. hunteri* attached to the sea snake. cy, cypris larvae.

Table 1. Correlations of barnacle population features with distance from the anterior end of the sea snake.

	No. of regions available for analysis	Range	Kendall's rank correlation coefficient (τ) with distance	P
Clump density (No. / cm²)	14	0 - 0.04	0.29	> 0.1
Individual density (No. / cm²)	14	0 - 1.02	0.63	0.002
% of individuals < 2 mm	11	0 - 80	0.41	0.08
% of individuals ≥ 12 mm	11	0 - 38	0.43	0.07
% of gravid individuals*	11	0 - 29	0.51	0.03

*Only individuals whose reproductive states were known were included.

Table 2. Differences of population features between barnacles on the ventral and dorsal sides of the sea snake.

	Ventral	Dorsal	Binomial test against:	P
Area (cm²)	285	1357		
No. of clumps	8	6	Proportion of areas	0.002
No. of individuals	111	23	Proportion of areas	< 0.001
No. of individuals < 2 mm	52	10	Proportion of individuals	> 0.5
No. of individuals ≥ 12 mm	30	1	Proportion of individuals	0.04
No. of gravid individuals	23	2	Proportion of individuals*	> 0.3

*Only individuals whose reproductive states were known were included.

appeared greater in the posterior regions, but these trends were not statistically significant.

The area covered by ventral scutes was much smaller than that covered by dorsal scales, but the number of barnacle clumps was greater on the ventral scutes than on dorsal scales (Table 2). A binomial test against the equal chance of clump occurrence gave a significant value, indicating that the clump density was significantly higher on the ventral side than on the dorsal side. The density of individual *C. virgatum* and the proportion of individuals 12 mm or larger in capitulum length were also higher on the ventral side. The proportions of gravid individuals and of small ones (less than 2 mm) on each side did not differ significantly.

Discussion

Conchoderma hunteri has sometimes been treated as a mere variety (Annandale, 1909) or subspecies (Hiro, 1937) of *C. virgatum*. In some papers the two forms were not distinguished; e.g., the host records listed by Roskell (1969) and Hastings (1972) for *C. virgatum* also included those for *C. hunteri*. On the other hand, Liu & Ren (1985), who found both forms in the same clump on a submarine, clearly discriminated them by their shell morphology and treated both as distinct species. In the present case, the two distinct forms were also found in the same clumps and were easily distinguishable on the basis of their general shapes and color patterns, except for small individuals. As in the previous reports, however, we could find no differences in the morphology of the main body and appendages. Because of the sympatricity, these two forms appear to be neither ecophenotypes (phenotypes in response to different environmental conditions) nor subspecies (geographically separated populations). In this report we treat both forms as distinct species.

The number of *Conchoderma* on the present snake might be exceptionally large. *Conchoderma virgatum* has been found on animate objects, directly or indirectly attached to

the host (Dawson, 1969; Hastings, 1972). In the case of direct attachment to fish, the barnacles attach to special hard structures of the host, such as the sword of a swordfish, the jaw of a shark, the dentary region of a suckerfish, the fin of a halfbeak, the lesion of a sailfish, and the spine of *Diodon* (Crozier, 1916; Jones et al., 1968; Beckett, 1968; Dawson, 1969; Balakrishnan, 1969). Jones et al. (1968) and Balakrishnan (1969), considering the rarity of settling directly on a fish, proposed an inhibitory effect of the fishes' external mucous secretions. In the case of indirect attachment, these barnacles have been found on pennellid and lernaeid copepods parasitizing fishes and whales, on another lepadomorph barnacle *C. auritum* on whales (Clark, 1966), or even on non-permanently attached parasites, such as isopods and copepods (Hastings, 1972; Williams, 1978; Benz, 1984; Williams & Williams, 1986). In all these cases, the suitable attachment sites on each host are limited, and the number of barnacles per host is usually small. In comparison with other animals, sea snakes seem to be more suitable for the attachment of *Conchoderma*. In fact, sea snakes have often been mentioned as the host of various barnacles (Ciurea et al., 1933), but no detailed descriptions of the number and the attachment condition of *Conchoderma* have been provided. As for a smaller lepadomorph barnacle, *Octolasmis grayii* (Darwin, 1851), Annandale (1909) reported that he had seen more than 600 specimens on a single snake. On the other hand, Jeffries & Voris (1979) reported that the number of *O. grayii* per snake was 0–62 among over 1300 sea snakes examined.

An uneven distribution pattern of *C. virgatum* was found on the present snake. The gregariousness we observed agrees with previous reports in which clumped individuals were more common than solitary ones on a buoy (MacIntyre, 1966) and on sea turtles (Eckert & Eckert, 1987). In the present study, the density of individuals was higher posteriorly than anteriorly, and on the ventral scutes than on the dorsal scales of the snake. Moreover, the proportion of gravid individuals was higher posteriorly than anteriorly. Similar longitudinal differences were found by Jeffries & Voris (1979) in *O. grayii* on the sea snake *Lapemis hardwickii* Gray and by Zann (1975) in a small balanomorph barnacle *Platylepas ophiophilus* Lanchester, 1902 on four species of sea snakes. These observations suggest that the posterior, and at least for *C. virgatum*, ventral parts of sea snakes are the most suitable places for these barnacles, either due to enhanced settlement of larvae or to greater survival. The present study has also shown that barnacles on the posterior part are more likely to attain sexual maturity.

Species of *Conchoderma* have been known to grow rapidly. Darwin (1851) observed that a specimen of *C. virgatum* on H.M.S. *Beagle* attained half an inch (13 mm) in capitulum length in 33 days. MacIntyre (1966) reported that *C. virgatum* in Australia reached 20 mm in capitulum length in 17 days, and their brood lamellae were present at 11 mm. The capitulum length at maturation in the present material was similar to MacIntyre's (1966) result, while gravid individuals of *C. virgatum* on sea turtles in Caribbean waters were distinctly smaller (8.8 - 15.4 mm in capitulum length) (Eckert & Eckert, 1987). Eckert & Eckert (1987) considered that the latter population's diminutive size at maturation was due to the stress associated with terrestrial nesting behavior of the host. Based on these previous data on growth rates of *C. virgatum*, this species of barnacles can securely attain sexual maturity on the snake's body during the interval between the sheds in *Laticauda semifasciata* (about three months) (Mays & Nickerson, 1968).

The sea snake *Laticauda semifasciata* is not common around the Kii Peninsula, and only a few specimens have been found accidentally in the last 20 years (Tanase, personal observation). Those individuals might have been brought by the Kuroshio Current from southern Japan, where sea snakes are common. *Conchoderma virgatum* is apparently an oceanic species (Dalley & Crisp, 1981), and its geographic and temporal origins are difficult to establish (Eckert & Eckert, 1987). The wide variation of size in *C. virgatum* and the presence of cypris larvae suggest that continuous settlement had occurred, and that the present snake

had been straying for a certain period in an oceanic area where the cyprids were present.

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