Japanese Journal of Ichthyology
Vol. 34, No. 1 1987

魚 類 学 雑 誌
34巻 1 号 1987年

Feeding Habits of Two Sympatric Ostraciid Fishes at Miyake-jima, Japan

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(Received June 24, 1986)

The two ostraciid fishes *Lactoria diaphana* (Bloch et Schneider) and *L. fornasini* (Bianconi) occur sympatrically throughout the year at Miyake-jima (34°05′N, 139°30′E), one of the Izu Islands of southern Japan. These species share broadly overlapping territories on a boulder substrate or in volcanic rubble from depths of less than three meters to greater than 40 m (Moyer, 1979), and often forage in close proximity during the day.

Many ecologists (e.g. Schoener, 1974; Toft, 1985; Ross, 1986) have suggested that most related species exhibit substantial resource partitioning along the three major dimensions of habitat, food, and time. An interesting possibility was suggested, therefore: the two coexisting cowfish species appeared to partition food resources.

The current study was initiated to attempt to quantify trophic interactions between the two species.

Methods and material

The study site. Our study was conducted in Igaya Bay, Miyake-jima, the site of previous studies of the same two species (Moyer, 1979, 1984; Leis and Moyer, 1985). The site consists of a broad plain of volcanic sand, mixed in some places with coral sand and rubble, and containing numerous rocks and boulders of various sizes, many of which support coral outcroppings (Tribble and Randall, 1985). An ancient lava flow of at least 300 years ago covers the southwest portion of the study site. Small patches of coral reef development occur on top of the lava (Tribble and Randall, 1985). Maps of the study site appear in Moyer and Yogo (1982) and Tribble and Randall (1985). Individuals of both species were observed daily between 25 September and 11 October, 1985, weather permitting, over an area of approximately 120,000 m^2.

Analysis of foraging habits. Foraging habits of both species were determined by underwater observations. Four different individuals each of both species were watched by a single diver for 15 min each to determine (1) the number of seconds spent by each fish foraging on specific types of substrates, and (2) the number of bites taken by each study animal on a particular type of substrate. Types of substrates utilized included (1) boulders and rocks, (2) dead corals, (3) living corals, (4) sand, (5) algae, and (6) dead molluscs. Four different individuals were observed for each species. The first adult individual located was observed on each dive. Observations were made at different locations in the bay to prevent the possibility of collecting data more than once on a particular individual. This was done to take into account possible individual variations in food preferences (see Moyer, 1979, 1984, for data on territory and home range sizes for each species). Only foraging time was recorded; i.e., visits to *Labroides dimidiatus* cleaning stations, intraspecific and interspecific social interactions, and "resting" were not included, meaning that actual observation time often greatly exceeded 15 min per individual.

Specimen collection and gut content analysis. Diets of *L. diaphana* and *L. fornasini* were determined by gut content analysis. During the study period 11 specimens of *L. diaphana* and 10 of *L. fornasini* were collected from the Igaya Bay study site between 1,000 and 1,100 h, using a monofilament net. Immediately after collection gut contents of the specimens were preserved by injecting 100% formalin directly into the body cavity. Specimens were then immediately placed in 10% formalin.

The standard length (SL) and snout length were measured for each specimen in the laboratory. Food items from the gut contents were sorted and identified to the lowest possible taxon under a low-power binocular microscope. Each sorted item was weighed in wet condition to the nearest 0.01 g.

The relative importance of each food item to the diet of each species was expressed as percentage frequency of occurrence and percentage gravimetric composition (Hyslop, 1980). Niche breadth (B) and niche overlap (C_λ) for the diets of the two species were computed by the following formulae of Levins (1968) and Horn (1966), respectively:

$$B=\frac{1}{\sum_{h=1}^{s} p_{ih}^{2}},$$

$$C_\lambda = \frac{2 \sum_{h=1}^{s} p_{ih} \cdot p_{jh}}{\sum_{h=1}^{s} p_{ih}^2 + \sum_{h=1}^{s} p_{jh}^2}$$

where p_{ih} and p_{jh} are the proportions of a particular item h in the diets of species i and j, respectively, and s is the total number of food items in the diets. B values range from 1, when food items consist only of one category, to s, when all food items are in equal proportion in the diet. C_λ varies from 0, when species i and j share no food item, to 1, when all items are the same. In these calculations, food items less than 0.1% of the total weight and inorganic material such as sand in the guts were excluded.

Results

Feeding behavior. Observations of feeding behavior of both species suggested major differences in the diets. Territories of *L. fornasini* and *L. diaphana* invariably greatly overlapped each other, and individuals were often seen foraging within 30–40 cm of each another. However, close inspection revealed the following general behavioral differences: *L. fornasini* frequently foraged over sand, swimming directly over boulders and rocks from one patch of sand to the next without pausing to forage on the hard substrate (Table 1). For *L. diaphana* the situation was exactly the reverse, with individuals blanching in color to swim directly over sand from one boulder to another. More than 80% of the foraging of *L. diaphana* was over boulder and rock substrate (Tables 1 and 2). *L. fornasini* was observed foraging over boulders and rocks considerably more frequently than *L. diaphana* foraged on a sand substrate.

L. diaphana was frequently observed biting at polyps of faviid corals (Table 2). Loud "clicks" could be heard accompanying such bites. *L. fornasini* was never seen eating live corals. Feeding by *L. diaphana* on sea hare eggs attached to *Gelidium* algae was also observed, but this food item was similarly ignored by *L. fornasini*.

No interspecific aggression or other social interactions were observed, although Moyer (1984) noted that recently settled juveniles of *L. diaphana* often responded to courtship behavior of *L. fornasini* males.

Gut content analysis. Of the 11 specimens of *L. diaphana* (124.0–207.0 mm SL: mean 164.8) and the 10 *L. fornasini* (69.4–93.6 mm SL: mean 84.5) collected, all were from adult social groups (Moyer, 1979, 1984) and had guts full of benthic prey. The diets of the two species differed considerably from each other (Table 3). Dietary overlap value (C_λ) was extremely low (0.062), indicating very little dietary overlap between them. The diet of *L. diaphana* consisted largely of sponges, gastropod eggs, and scleractinian coral

Table 1. Comparison of microhabitat preferences of foraging *Lactoria diaphana* and *L. fornasini* at Miyake-jima, Japan. Four 15 min watches of four different individuals of each species (3,600 sec per species). Values indicate total time in seconds of four individuals of each species at each substrate.

Species	Substrate type and foraging time in seconds					
	Rocks and boulders	Dead corals	Living corals	Sand	Algae	Dead molluscs
L. diaphana	3,341 (92.8%)	19 (0.5%)	76 (2.1%)	40 (1.1%)	124 (3.5%)	0 (0%)
L. fornasini	1,397 (38.8%)	36 (1.0%)	0 (0%)	2,089 (58.0%)	63 (1.8%)	15 (0.4%)

Table 2. Comparison of feeding behavior of *Lactoria diaphana* and *L. fornasini* at Miyake-jima, Japan, as indicated by bites at the substrate. Four 15 min watches of four different individuals of each species (1h per species). Values indicate total number of bites of four individuals of each species at each substrate.

Species	Microhabitat where substrate bite occurred					
	Rocks and boulders	Dead corals	Living corals	Sand	Algae	Dead molluscs
L. diaphana	115 (83.9%)	1 (0.7%)	7 (5.1%)	2 (1.5%)	12 (8.8%)	0 (0%)
L. fornasini	72 (34.1%)	1 (0.5%)	0 (0%)	123 (58.3%)	14 (6.6%)	1 (0.5%)

polyps and mucus. These prey made up 89.0% of the gut content weight of *L. diaphana*. On the other hand, polychaetes and ascidians were the major prey of *L. fornasini*, constituting 78.9% of the gut content weight.

The niche breadth values (B) calculated from the diets of both species indicate that *L. fornasini* had a slightly higher food breadth (3.716, $1 \leqq B \leqq 10$) than *L. diaphana* (3.093, $1 \leqq B \leqq 8$). However, food niche breadth was low in both species, suggesting that both are food specialists.

Morphology. Snout length expressed as percentage of standard length was 21.7±0.5% (mean ±95% confidence limits of the mean) for *L. diaphana* and 25.9±0.7% for *L. fornasini*, indicating a significantly longer snout for the latter (t-test, $t_0 = 10.359$, $P < 0.001$). In addition, the snout of *L. fornasini* is more sharply pointed anteroventrally when compared to that of *L. diaphana*. This morphological difference is clearly shown in Figs. G and H of Plate 328 by Masuda et al. (1984).

Table 3. Percentage frequency of occurrence and percentage wet weight of food items in the diets of *Lactoria diaphana* and *L. fornasini* at Miyake-jima, Japan. N, number of fish examined; +, less than 0.1% weight; —, not consumed.

Food items	*L. diaphana* (N=11) % freq.	*L. diaphana* (N=11) % weight	*L. fornasini* (N=10) % freq.	*L. fornasini* (N=10) % weight
Sponges	100	46.5	30	3.4
Sea hare eggs	55	9.1	—	—
Unidentified gastropod eggs	100	22.7	10	0.2
Unidentified invertebrate eggs	—	—	30	0.4
Scleractinian corals	27	10.7	—	—
Algae	91	4.8	60	0.4
Alcyonaceans	9	0.1	—	—
Didemnid ascidians	—	—	80	13.3
Pleurogonan ascidians	9	0.1	—	—
Gammaridean amphipods	27	+	80	4.2
Terebellid polychaetes	—	—	100	31.4
Errant polychaetes	—	—	60	34.2
Crabs	—	—	10	1.1
Gastropods	—	—	10	+
Pycnogonids	—	—	10	+
Detritus	—	—	30	5.9
Unidentified animal material	27	0.7	—	—
Sand	100	5.3	100	5.5

Discussion

Distinct food and feeding microhabitat segregation between *Lactoria diaphana* and *L. fornasini* was recognized. Data on foraging habits (Tables 1 and 2) and gut content analysis (Table 3) indicate that *L. diaphana* takes mostly sponges and gastropod eggs on rocks and boulders and sometimes feeds on scleractinian coral polyps and mucus, whereas *L. fornasini* captures largely polychaetes from sandy bottoms and ascidians on rocks and boulders. Snout morphology and diet differences may be related. *L. fornasini* with a relatively longer and sharply pointed snout is well adapted for a strategy of feeding on prey buried in sand or concealed between and beneath rocks and in crevices. *L. diaphana* with a relatively shorter and bluntly protruded snout may be better adapted for tearing off prey that encrust rock surfaces.

Food resource partitioning has been recognized among several marine and freshwater fishes which show spatial overlap (e.g. Alevizon, 1975; McEachran et al., 1976; Targett, 1978; Ellison et al., 1979; Nordlie, 1979; Yoshiyama, 1980; Edlund and Magnhagen, 1981; Paine et al., 1982; Greenfield et al., 1983; Magnan and FitzGerald, 1984; Gunn and Milward, 1985; Hallacher and Roberts, 1985). Resource partitioning between the two *Lactoria* species at Miyake-jima provides still another example.

At Miyake-jima, *L. diaphana* and *L. fornasini* were found to occur spatially in broadly overlapping territories over the entire depth range surveyed. This does not always appear to be the case elsewhere. J. Randall (pers. comm.) reports *L. diaphana* to be strictly a deep water species in Hawaii, never occurring on shallow reefs where *L. fornasini* is found. Leis and Moyer (1985) reported that reproductively active *L. diaphana* adults are found in the pelagic realm, more than

1,000 km from land in the Eastern Pacific Barrier. *L. fornasini* has not been reported to occur as adults in the pelagic realm (but see Okamura, 1985). This information and our study suggest, therefore, that the two species show habitat segregation in some areas, while they distinctly partition food where their habitats overlap completely. The question is why *L. diaphana* does not coexist with *L. fornasini* on shallow reefs in Hawaii through food partitioning. Unfortunately, we have no useful information on this question.

Acknowledgments

We wish to thank Yukio Nose, Makoto Shimizu, Keiichi Matsuura, Yusuke Suda, and Sandie Wilson for interesting discussion. Ren Kuwabara provided invaluable assistance in identifying the gut content material. This study was made possible by Grants-in-Aid for Special Project Research on Biological Aspects of Optimal Strategy and Social Structure from the Japan Ministry of Education, Science and Culture (Nos. 58121004, 59115004, and 60107002) and is contribution number 66 of the Tatsuo Tanaka Memorial Biological Station.

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三宅島において共存するウミスズメとシマウミスズメの食性

Jack T. Moyer・佐野光彦

三宅島の伊ケ谷湾ではウミスズメとシマウミスズメのなわばりがかなり重複するため，両種の食性を調べ，食いわけを行っているかどうかを明らかにした．

ウミスズメは岩や転石に付着する海綿類や腹足類の卵を主に食べていたのに対し，シマウミスズメは砂地に生息する多毛類や，岩や転石に付着するホヤ類を主に摂餌していた．両種の餌には明瞭な差があることが判明した．

(Moyer: 100–12 東京都三宅島阿古　田中達男記念生物実験所: 佐野: 113 東京都文京区弥生 1–1–1 東京大学農学部水産学科)

設置が承認された会則等の改正のための小委員会について検討し以下の案を作成した.

委員長: 岩井, 副委員長: 上野, 委員: 望月, 谷内, 丸山, 松浦, 仲谷, 中坊, 小沢.

8. その他

日本学術会議だより No. 5 (昭和 62 年 5 月)

日本学術会議は昭和 62 年 4 月 22 日から 24 日まで第 102 回総会 (第 13 期の 5 回目の総会) を開催した. 本総会では「地域型研究機関 (仮称) の設立について (勧告)」と「大学等における学術予算の増額について (要望)」の提案を, いずれも賛成多数で採択し, 政府に勧告要望した.

編集後記・Editorial notes

34 巻から図書紹介のページに, 紹介文を伴わない書名だけのものも載せるようにしました. これはと思われる出版物で, 特に人に知られにくいローカルなものなどご存知の方はぜひ編集幹事までご一報下さい.

訂　正・Errata

魚類学雑誌 34 巻 1 号に以下の誤りがありました. お詫びして訂正いたします.

Japanese Journal of Ichthyology, 34(1), Moyer and Sano: page 108, right column, second paragraph, 6th line, read "1000" and "1100" for "1,000" and "1,100" respectively.