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Associations between the Arrow Goby *Clevelandia ios* (Jordan and Gilbert) and the Ghost Shrimp *Callianassa californiensis* Dana in Natural and Artificial Burrows[1]

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ABSTRACT: *Clevelandia ios* is a small estuarine teleost that inhabits the burrows of the Thalassinid crustacean *Callianassa californiensis*. Field observations and laboratory experiments were undertaken to determine the relationship of *Clevelandia ios* and *Callianassa californiensis*, whether it be commensalism, mutualism, or parasitism. *Clevelandia ios* and *Callianassa californiensis* were found to co-occur in burrows less frequently than they would be expected to by chance, under both field and laboratory conditions. In addition, the arrow gobies were found to inhabit the ghost shrimp burrows only during the spring and summer months.

THE ARROW GOBY *Clevelandia ios* (Jordan and Gilbert) is a small estuarine teleost that inhabits the burrows of several invertebrate species, including the ghost shrimp *Callianassa californiensis* Dana, the mud shrimp *Upogebia pugettensis* (Dana), and the fat innkeeper worm *Urechis caupo* Fisher and MacGinitie. The goby is believed to live commensally in the burrows of these species, and it uses the burrows as a refuge from predators and desiccation at low tides (Brothers 1975, MacGinitie 1934, MacGinitie and MacGinitie 1949). However, there have been no quantitative studies to determine whether *Clevelandia ios* is a commensal endokete of these species. The purpose of this study was to elucidate the nature of the *Clevelandia ios–Callianassa californiensis* association through observations of these organisms in the field and in a simulated natural environment. All work was performed in Coos Bay, Oregon, from August 1979 to September 1980.

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MATERIALS AND METHODS

Clevelandia ios and *Callianassa californiensis* were collected from the mud flats at Jordon Cove, Oregon (43°26′ N, 124°14′ W), a small cove of Coos Bay. The animals were obtained from the burrows at low tides with the aid of a suction device known as a "shrimp gun." The burrows were sampled at random. For each burrow sampled, the numbers of *Clevelandia ios* and of *Callianassa californiensis* were recorded. A coefficient of interspecific association (Cole 1949) and a chi-square analysis were performed to determine whether these species occur together in burrows more frequently or less frequently than they would be expected to by chance.

An experimental mud flat aquarium similar to the one used by Grossman and Reed (manuscript) was constructed in order to observe *Clevelandia ios–Callianassa californiensis* interactions under simulated burrow conditions. Clear plastic tubing with outer diameter 1 in. (2.54 cm) and inner diameter 3/4 in. (1.73 cm) was used to simulate burrows. A screen divided the tank in half. One-half contained *Clevelandia ios* alone and one-half contained *Clevelandia ios* with *Callianassa californiensis*. The animals were placed in the tank and allowed to choose their own burrows. Two

TABLE 1

INTERSPECIFIC ASSOCIATION ANALYSIS

		Callianassa californiensis PRESENT	*Callianassa californiensis* ABSENT	ROW TOTAL
Clevelandia ios	PRESENT	64 (70.9)	23 (16.1)	87
	ABSENT	117 (110.1)	18 (24.9)	135
	COLUMN TOTAL	181	41	222

NOTE: Numbers in parentheses indicate expected values; Cole's coefficient of interspecific association (C) = -0.278; $\chi^2 = 5.13$; 1 degree of freedom; $P = 0.05$.

TABLE 2

CHI-SQUARE ANALYSIS OF NUMBERS OF *Clevelandia ios* VERSUS NUMBERS OF *Callianassa californiensis* FOUND IN BURROWS.

		NUMBER OF *Callianassa californiensis*					
		0	1	2	3	> 3	ROW TOTAL
NUMBER OF *Clevelandia ios*	0	21 (30.7)	50 (43.8)	38 (37.6)	28 (28.8)	22 (18.5)	159
	1	22 (11.8)	12 (16.8)	14 (14.4)	8 (11.0)	5 (7.0)	61
	> 1	6 (6.6)	8 (9.4)	8 (8.0)	10 (6.2)	2 (3.9)	34
	COLUMN TOTAL	49	70	60	49	29	254

NOTE: Numbers in parentheses indicate expected values; $\chi^2 = 20.0$; 8 degrees of freedom; $P \approx 0.01$.

days after introduction to the tank, animals were selected for focal observation.

Observations were made to determine whether there was a relationship between the length of a burrow and the number of *Clevelandia ios* in that burrow. Repeated observations recorded the location and number of each species in each burrow. Since the observations were of the same animals, a two-factor analysis of variance was calculated to determine whether there was a significant time variable introduced to this experiment, i.e., whether there was a significant variance in the number of organisms observed in each burrow with respect to time. In addition, a chi-square analysis of the number of *Clevelandia ios* present in a burrow versus the number of *Callianassa californiensis* present in the same burrow determined whether the presence of a ghost shrimp influenced the presence of an arrow goby in that burrow.

RESULTS

During the late spring and the summer, *Clevelandia ios* were found in the field in shallow pools with less than 3 cm of water, as well as in occupied and unoccupied *Callianassa californiensis* burrows. *Clevelandia ios* were found lower intertidally in the spring, were found higher intertidally in the summer, and were not found intertidally in the fall and winter.

Chi-square analyses and Cole's coefficient of interspecific association (Tables 1 and 2) indicate that *Clevelandia ios* and *Callianassa californiensis* occur together in burrows in the field less frequently than they would be expected to by chance. Cole's coefficient of interspecific association has a significant negative value ($C = -0.278$, $\chi^2 = 5.13$, 1 df, $P = 0.05$; see Table 1). The chi-square value based on numbers of each species found in

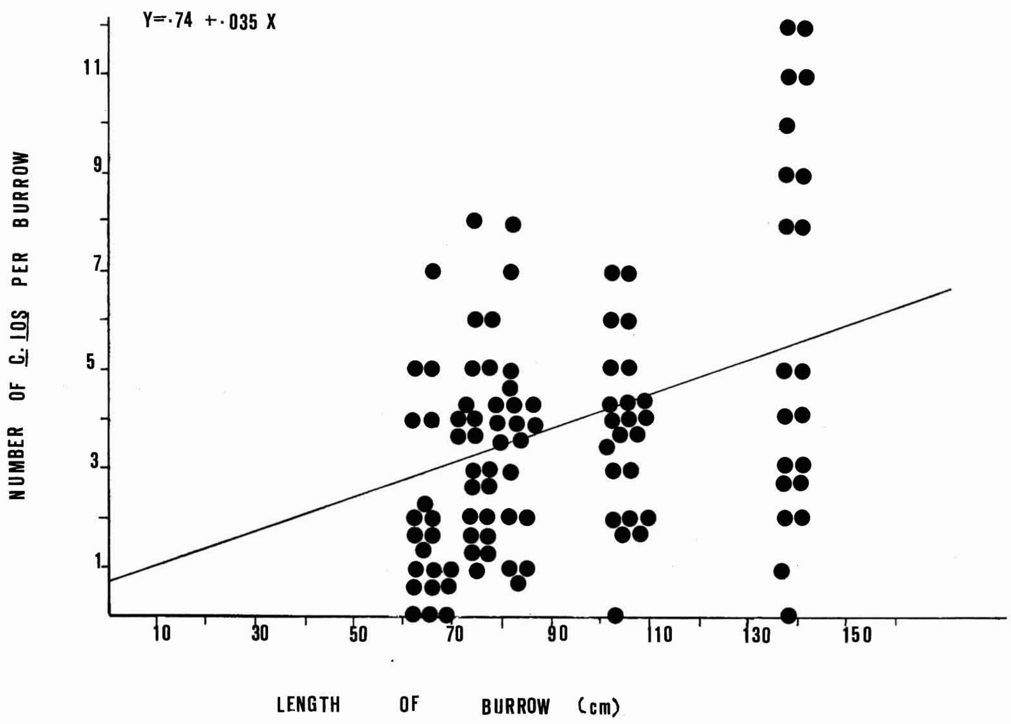

FIGURE 1. Relationship between the length of a burrow and the number of *Clevelandia ios* per burrow: $n = 110$ observations of 60 *Clevelandia ios*, $\beta = \pm 0.019$.

each burrow is highly significant ($\chi^2 = 20.0$, 8 df, $P \approx 0.01$; see Table 2), indicating a negative association of these two species.

When *Clevelandia ios* were present in the experimental mud flat without *Callianassa californiensis*, there were more gobies present in longer burrows (Figure 1). The regression equation is

$$Y = 0.74 + 0.035X$$

where $Y =$ the number of *Clevelandia ios* per burrow and $X =$ the burrow length. An analysis of error reveals a significant positive slope.

However, in the presence of *Callianassa californiensis*, the linear regression is insignificant, and there is no clear linear relationship between the length of the burrow and the number of *Clevelandia ios* in that burrow.

A two-factor analysis of variance (Tables 3 and 4) showed that the variance in the number of *Clevelandia ios* observed with respect to time was not statistically significant. There-

TABLE 3
TWO-FACTOR ANALYSIS OF VARIANCE: *Clevelandia ios* ALONE

VARIABLE	SS	df	MS	*F*	*P*
Burrow length	38.48	4	9.62	3.32	0.05
Time	4.38	3	1.46	0.50	n.s.
Error	34.83	12	2.90		
Total	77.69	19			

NOTE: SS = sum of squares; df = degrees of freedom; MS = mean squares; *F* = *F* ratio; *P* = probability; n.s. = nonsignificant.

TABLE 4
TWO-FACTOR ANALYSIS OF VARIANCE: *Clevelandia ios* WITH *Callianassa californiensis*

VARIABLE	SS	df	MS	*F*	*P*
Burrow length	44.93	4	11.23	4.64	0.05
Time	7.45	3	2.48	1.02	n.s.
Error	29.02	12	2.42		
Total	81.40	19			

NOTE: SS = sum of squares; df = degrees of freedom; MS = mean squares; *F* = *F* ratio; *P* = probability; n.s. = nonsignificant.

TABLE 5

CHI-SQUARE ANALYSIS OF THE NUMBER OF *Clevelandia ios* PER BURROW VERSUS THE NUMBER OF *Callianassa californiensis* PER BURROW IN THE EXPERIMENTAL AQUARIUM

		NUMBER OF *Callianassa californiensis*		
		0–1	> 1	ROW TOTAL
NUMBER OF *Clevelandia ios*	0–1	23 (26.9)	11 (7.1)	34
	2	16 (18.2)	7 (4.8)	23
	> 2	56 (49.9)	7 (13.1)	63
	COLUMN TOTAL	95	25	120

NOTE: Numbers in parentheses indicate expected values; $\chi^2 = 7.6$; 2 degrees of freedom; $P \approx 0.02$.

fore, although observations were not independent, I feel justified in analyzing results by linear regression, as there was no significant bias shown in performing these experiments in this manner.

The presence of *Callianassa californiensis* was thought to inhibit the presence of *Clevelandia ios* in the burrow, since the ghost shrimp were often observed chasing the arrow gobies out of the burrows. Chi-square analysis (Table 5) indicates that the presence of more than one *Callianassa californiensis* per experimental burrow inhibits the presence of *Clevelandia ios* in that burrow ($\chi^2 = 7.6$, 2 df, $P \approx 0.02$). Thus, the two species are negatively associated under laboratory conditions.

DISCUSSION

Clevelandia ios and *Callianassa californiensis* appear to be negatively associated in burrows under field and laboratory conditions. This may also be true of other Gobiid–Thalassinid associations. Grossman and Reed (ms) reported that *Upogebia pugettensis* acted agonistically toward the presence of *Lepidogobius lepidus* in experimental burrows, and attempted to grab the gobies with its chelipeds. *Lepidogobius lepidus* seemed to be in empty burrows more often than in burrows occupied by *Upogebia pugettensis*, but they were in *Urechis caupo* burrows about the same amount as would be expected by chance. In neither case was there a statistical preference for burrows with hosts.

The *Clevelandia ios–Callianassa californiensis* association may be compared to the *Typhlogobius californiensis–Callianassa affinis* association. *Typhlogobius* is a blind goby that lives permanently in the burrows of *Callianassa affinis*. The goby is totally dependent on the shrimp for shelter, and it presumably would be easily preyed upon if it left the burrow. The goby may help drive out predators, eat larvae that enter the burrow, or help clean the burrow. However, *Callianassa affinis* have been reported to live in the absence of *Typhlogobius californiensis* under aquarium conditions with no apparent ill effects (MacGinitie 1939, MacGinitie and MacGinitie 1949). Thus, many researchers believe that the goby derives the primary advantage of this association (Hubbs 1927, MacGinitie 1939, MacGinitie and MacGinitie 1949). This appears to be an obligate commensal association.

The Gobiid–Thalassinid associations may be contrasted with the obligate mutualistic Gobiid–Alpheid associations. In the latter system, the goby and the shrimp communicate with one another through visual and tactile means. The goby obtains the benefit of a shelter and a resting place. The shrimp never leaves the burrow unless its antenna is in contact with the goby. The goby provides warning signals to the shrimp when a predator approaches, and the shrimp and the goby retreat into the burrow (Karplus 1979; Karplus, Szlep, and Tsurnamal 1972; Karplus, Szlep, and Tsurnamal 1974; Karplus, Tsurnamal, and Szlep 1972; Preston 1978).

Field observations indicate that *Clevelandia ios* may be using the *Callianassa californiensis* burrow as a refuge, but only during the spring and summer. Many shore birds, such as Yellow Legs and Dowitchers, migrate from the estuaries to the Arctic during their breeding seasons (Robbins, Brunn, and Zim 1966). Thus, many avian predators are not found in the estuaries during the summer, and the gobies may migrate intertidally to obtain a refuge from predatory fish. They may also migrate to take advantage of a seasonally abundant resource such as food.

There is some controversy in the literature over where *Clevelandia ios* eggs are laid. Prasad (1948) and Carter (1965) state that the nonadhesive eggs are laid in large groups, presumably outside the burrows. The eggs then sink into the sediments. However, Brothers (1975) believes that *Clevelandia ios* lay their eggs inside burrows, though not necessarily in the burrows of *Callianassa californiensis*. Clearly, further observations need to be made to determine where *Clevelandia ios* eggs survive. If the eggs survive in areas other than *Callianassa californiensis* burrows, and the adult *Clevelandia ios* do not always coinhabit burrows with *Callianassa californiensis*, then the two species may be facultative associates. However, if the eggs survive only in *Callianassa californiensis* burrows, then this may be an obligate association.

Callianassa californiensis clearly provides a shelter for *Clevelandia ios*, but no data are available on the function of the goby in this relationship. *Clevelandia ios* may be selecting empty burrows or burrows with a small number of *Callianassa californiensis* to avoid shrimp agonism. Alternatively, the gobies may be chased out of burrows having high densities of ghost shrimp. However, *Callianassa californiensis* probably does not derive any benefits from its associations with *Clevelandia ios*, since the ghost shrimp act agonistically toward the gobies, and the two species are negatively associated. Therefore, this relationship appears to be commensal or even parasitic. Presently, no data are available to show that *Clevelandia ios* detrimentally affects *Callianassa californiensis* in this association.

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