Title
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Author
Hawkins, Sigrid V.

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FEEDING PREFERENCE OF THE CUSHION STAR, *CULCITA NOVAEGUINEAE* IN MO'OREA

SIGRID V. HAWKINS

Environmental Science Policy and Management, University of California, Berkeley, California 94720 USA

Abstract. Previous studies of the feeding biology of *Culcita novaeguineae* Muller & Troschel in Hawai'i have shown that the cushion star prefers to prey on coral species of the genus *Pocillopora* over the genus *Porites.* Distribution and feeding biology studies of *C. novaeguineae* in Cook's Bay on the island of Mo'orea, French Polynesia have shown that it habitats near *Porites spp.* coral in areas where *Porites spp.* coral is sparse, and prefers to prey on *Acropora spp.* coral. The purpose of this study was to further examine coral prey preference of *C. novaeguineae* in Mo'orea, using specimens from four areas on the island for better representation of its feeding ecology on Mo'orea, French Polynesia. My studies showed that *C. novaeguineae* in Mo'orea prefers *Acropora spp.* and *Pocillopora spp.*, over *Porites spp.* (p=0.0046), and showed no preference for *Acropora spp.*, over *Pocillopora spp.*. The study further determined that *C. novaeguineae* primarily feeds nocturnally, and moves persistently in search for food. As a coral predator, *C. novaeguineae* can affect abundance of certain coral species, and change the overall reef ecology in Mo'orea.

Key words: asteroid, Culcita novaeguineae; *feeding preference; locomotion; Moorea, French Polynesia; predation*

INTRODUCTION

Changes in abundance of certain species of echinoderms can have large-scale effects on reef community structure. To understand the variations in structure and function of coral-reef communities, it is necessary to understand the ecology of coral reef echinoderms (Birkeland 1988). For example: Lessios *et al.* (1984) reported a several-fold increase in benthic algae following the widespread mortality of an echinoid species on Caribbean reefs. Likewise, increases in abundance of an asteroid species can bring about major changes in community structure of corals (Birkeland 1988). A good example of this occurred in Mo'orea, French Polynesia in the 1980s, when the predatory sea star *Acanthaster planci* killed entire coral communities (Moran et al 1988).

C. novaeguineae is an echinoid that is also known to prey on coral. Studies by Goreau et al (1972), Glynn & Krupp (1986) and Birkeland (1988) determined that *C. novaeguineae's* coral feeding is relatively specialized, because it has a large biomass to support in relation to its stomach surface. The studies showed that *C. novaeguineae* prefers to prey on small or encrusting scleractinians, especially pocilloporids and acroporids (Goreau et al 1972, Glynn & Krupp 1986 as quoted in Birkeland 1988).

A study in Mo'orea, French Polynesia determined that the cushion star preferred habitats where *Porites spp.* was present (Roberge 2000). In the study Roberge observed that *C. novaeguineae* was found within 1m of the *Porites spp.* thirty five percent of the time, even though *Porites* represented only 3.75% of the surveyed area. His focus was the distribution and locomotion of the cushion star, and he did not examine food preference as a factor in habitat selection.

The first feeding biology study on Mo'orean cushion stars was done in 2003 (Bertics 2003). In the study Bertics conducted laboratory feeding trials in which the cushions stars were offered three species of coral, as well as algae, sediment, rocks, and fungi. Her study showed that *C. novaeguineae* preferred *Acropora spp.* over all other food choices.

While both studies contributed to the better understanding of the ecology of cushions stars on Mo'orea, French Polynesia, their scope was limited to *C. novaeguineae* found in Cook's bay, and was not representative of the island of Mo'orea. The reef ecology of Cooks Bay differs from other areas on the island, because of the extensive development along the bay, and the associated pollution. For example, in their study sites, Roberge and Bertics found very little *Pocillopora spp.* and *Porites spp.*, whereas I found both coral in abundance in other areas on the island. I also frequently observed cushion stars in the vicinity of *Pocillopora spp.* and *Acropora spp.*

The purpose of my study was to first examine if cushion stars feed diurnally or nocturnally, and then to determine *C. novaeguineae's* coral preference using specimens from different areas on the island for a more representative sample of Mo'orea's cushion star population. In conjunction with coral preference I also observed *C. novaeguineae* movements to determine if cushion stars searching for food move in a persistent pattern, or randomly. My hypotheses were: (1) *C. novaeguineae* feeds nocturnally. During my initial surveys which were all conducted during the day, I did not observe any cushion stars feeding, indicating they prefer feeding at night. (2) *C. novaeguineae* in Mo'orea prefer to prey on *Acropora spp.*, over *Pocillopora spp.*, or *Porites spp.* During field surveys in search of cushion stars, I found more cushion stars near *Acropora spp.*, specifically *Acropora cervicornis* than other coral species indicating that *Acropora spp.* might be a choice prey coral. (3) *C. novaeguineae* moves in a persistent pattern toward food. As a relatively slow mover, cushion stars need to be able to detect their food and move toward it consistently to survive as a predator.

METHODS

Study sites

C. novaeguineae specimen collection, coral gathering, and field observations were conducted at four sites on Mo'orea (Fig. 1) during the period from Oct 11-30, 2006. The first site was located at Cook's Bay near the Richard B. Gump Research Station, were I collected four specimens at distances between 7-50 meters from shore. Another study site,

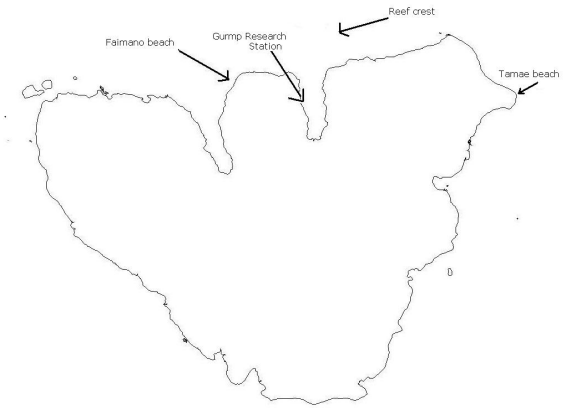

FIG. 1. Collection and field observation sites in Mo'orea, French Polynesia

Faimano Beach, was located approximately two miles east of the Gump Research Station; I collected three specimens there, at distances between 20 and 50 meters from shore. The third site was Tamae beach on the northeastern side of Mo'orea, near the airport, ca 15 km from the research station. Here, I captured three cushion stars in an area 250-300 meter off shore. The last study site was near the Vaihapu reef crest approximately two kilometers north of the Gump Research Station; I collected three cushion stars there.

All *C. novaeguineae* were found in water between 2.5 and seven meters deep.

Coral gathering

Coral for feeding experiments were collected by hand using a mesh bag. Only live coral fragments that were broken off by natural processes were collected, in accordance with laws protecting these organisms. Specimens were transported in plastic tubs with seawater, and then stored in large outdoor rectangular tanks with continuous flowing seawater, 51 cm deep. Specimens from three genera were used: *Acropora, Pocillopora,* and *Porites*. *Porites* was primarily represented by *Porites lobata*, which was abundant at all locations, *Pocillopora spp.* which was scarce near the Gump Research Station, but relatively abundant at the other locations, and *Acropora spp.,* specifically *Acropora cervicornis,* which I found only at Tamae at approximately 300 meters off shore.

Preference for feeding diurnally or nocturnally

My first experiment determined if *C. novaeguineae* prefers to feed during the day or at night. *C. novaguineae* was observed continuously for a period of three hours in the morning between 4:00 am and 8:00 am, and again between 6:00 pm and 10:00 pm.. Thirteen feeding trials were held using the same specimens for both day and night feeding experiments. The experiments were conducted in a 3.5 ft. diameter round tank, and an 8.0 X 4.0 X 2.0 ft. rectangular outdoor tank with continuously flowing seawater. The rectangular tank was divided into three compartments using mesh screen and bricks; one of the compartments was used as a holding tank for newly captured cushion stars, another as storage for food coral, and one for feeding trials. Newly captured cushion stars were isolated from food for 12 hours before starting feeding experiments to purge their digestive system. During the experiments I placed one coral specimen from each species of comparable size at the opposite end of the compartment as the cushion star. In the round tank, I placed the cushion stars around the center pole of the tank, and three coral specimens (one per species) for each cushion star around the outer perimeter of the tank. At the end of the observation period, I removed the corals from the compartments.

Coral preference

My second experiment was to examine coral preference when *C. novaeguineae* was offered three choices of coral: *Acropora spp. Pocillopora spp.,* and *Porites spp.* I held 39 trials in which I placed one coral specimen from each species of comparable size at the opposite end of the compartment as the cushion star in the rectangular tank. In the round tank, I placed the cushion stars around the center pole of the tank, and three coral specimens (one from each species) for each cushion star around the outer perimeter of the tank. I continuously observed the cushion stars for three hours between 5:30 pm and 10:00 pm recording which coral was visited and how often. At the end of the observation period, I removed the corals from the compartments. The cushion stars remained without food for 12 hours.

After I determined that *C. novaeguineae* prefers both *Acropora spp.* and *Pocillopora spp.* over *Porites spp.*, I conducted another experiment. I held 48 trials using the same experimental design, but with only two coral species, to determine if *C. novaguineae* prefers either *Acropora spp.* or *Pocillopora spp.*

I statistically analyzed the results using Wilcoxon tests for 3-coral experiments, and the Rank-sums test for 2-coral experiments.

Locomotion

To determine if *C. novaeguineae* moves toward its food in a pattern or haphazardly, I observed and recorded their movements for

18 days during feeding trials. I recorded the distance each specimen moved during each observation period, whether it moved toward coral or away from it, if it climbed the side of the tank, and if it moved clockwise or counterclockwise. Most locomotion experiments were held in the round tank, therefore it was more practical to use clock, and counterclockwise directions rather than right or left.

Field observations

To observe *C. novaeguineae* in their natural environment, four field observations were made between 29 Oct and 6 Nov, 2006. In Cook's Bay three transects covering approximately 5 X 200 meters were surveyed for *C. novaguineae* at night, using underwater flashlights. Transects started 25 meters from shore at the station and concluded 200 meters north in a path parallel to the shore. Four transects covering approximately 10 X 50 meters were surveyed at Tamae beach. Transects started at the left-hand-side of the beach 300 meters from shore, and paralleled the shoreline. At Faimano beach three transects approximately 7 X 150 meters were surveyed, starting 50 meters from shore near the boat channel marker on the left side of the beach, and progressed parallel to the shore.

For each specimen observed during transects I recorded the substrate composition it was found on, its distance from coral heads, whether of not it was feeding, and what it was eating. To determine if it was eating, I dove down, picked up and turned over *C. novaeguineae* to see if its stomach was extruded.

Turning

To determine a relationship between *C. novaeguineae* size, and the time it takes turn when it is flipped on its back, I conducted 40 experiments with 12 specimens. Each trial I turned the cushion stars over onto their backs and monitored their behavior and how much time they needed to "get back on their feet". To analyze the relationship between *C. novaguineae* size and the time it takes to turn over, I performed a linear regression analysis.

RESULTS

Day vs. night feeding preference

Cushion stars prefer to feed at night. I calculated the frequencies of individuals feeding during the day, and compared them with the frequencies of individuals feeding at night. The results showed that 81.6 percent of the time *C. novaeguineae* was eating was at night, and 23.1 percent during early morning hours (Fig. 2).

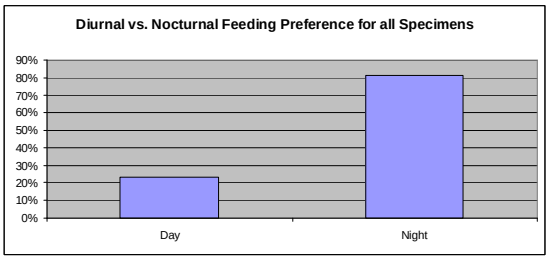

FIG. 3. Diurnal/nocturnal preference

Coral preference

When *C. novaeguineae* was offered three species of coral, it showed a strong preference for *Acropora* and *Pocillopora spp.* over *Porites spp.*. A Wilcoxon test determined a significant difference between groups (p= 0.0046). Of 39 trials overall, *C. novaeguineae* chose *Acropora spp.* 46.2 percent of the time, *Pocillopora spp.* 30.8 percent, and *Porites spp* 10.3 percent. It did not eat 12.8 percent of the trials, and fed on other things such as detritus materiel in the tank, and even pieces of plaster in the tank from a recent repair 11.8 percent. Individual feeding frequencies are depicted in Table 1 in the appendix.

In the experiments when *C. novaeguineae* was offered two species of coral, it showed a slight preference for *Pocillopora spp.* over *Acropora spp.* A Rank-sums test showed

insignificant preferences between the two groups (p = 0.4482). Of 48 trials the cushion stars frequented *Pocillopora spp.* 47.9 percent of the time and *Acropora spp.* 39.6 percent. Individual frequencies are depicted in Table 2 in the appendix.

Locomotion

In 219 observation hours combined, C. *novaeguineae* moved frequently and in a persistent pattern (Fig 3).

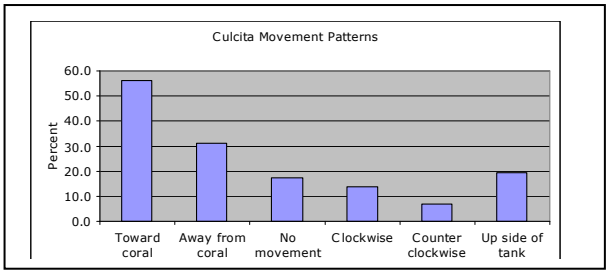

FIG. 3. Movement patterns of *C. novaeguineae*.

Overall the cushion stars moved on average 34.5 cm per hour. The furthest an individual moved in one hour was 4.9 meters. In 56.3 percent of the trials, *Culcita novaeguineae* moved toward coral, in 31 percent of the trials it moved away from coral. 17.2 percent of the trials it did not move, and it moved clockwise 13.8 percent of the time and counter clockwise 6.9 percent. During 19.5 percent of the experiments it climbed up the side of the tanks.

Turning

There was no clear correlation between *C. novaeguineae* size and the time it takes to turn over. Using linear regression analysis P= 0.2317, and Rsquare was 0.03843 (Fig. 4).

DISCUSSION

The hypothesis that *C. novaeguineae* prefers to feed at night rather than during the day was confirmed in both my laboratory experiments and during field observations. *C. novaeguineae* fed approximately four times

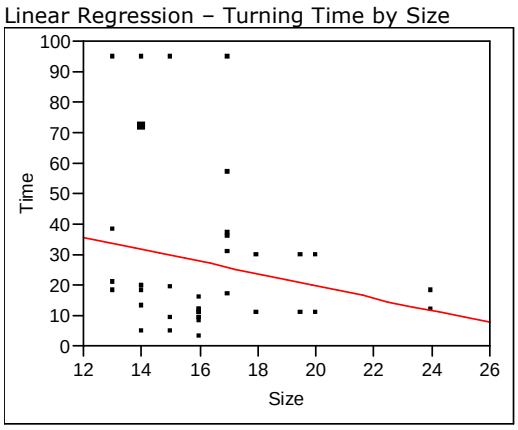

FIG. 4. Correlation experiment between size and time turning over.

more often in the evening than in the morning. In fact, of the 23.1 percent when *C. novaeguineae* was eating during the early morning, it did so before sunrise. Once daybreak advanced, the cushion stars stopped eating, and moved away from coral in search for shelter. During daytime field observations, I rarely observed *C. novaeguineae* on open sand, but generally found them next to coral heads or wedged underneath. During evening feeding and locomotion experiments I observed that cushion stars would stop moving when a flashlight was pointed toward them, and individuals that were climbing the side of the tank would release their hold, and tumble down. *C. novaeguineae* is photosensitive, and it is possible it experiences disorientation in bright light.

In my study *C. novaeguineae* showed a clear preference for *Acropora spp.* and *Pocillopora spp.* over *Porites spp.*. When it had a choice, *C. novaeguineae* would prefer not to eat *Porites spp.* coral even though it was relatively abundant in three of my study sites. It was not abundant in Cook's Bay. In fact, the reef in front of the Gump Research Station in Cook's Bay does not have much live coral. It is mostly composed of sediment, calcified rock, and coral rubble (Bertics 2003). Roberge's study in 2000, suggested *Porites spp.* might be a potential choice prey of *C. novaeguineae,*

because of its close proximity to the coral, however this does not seem to be the case. *Porites* coral is considered a large species, and it is possible that *C. novaeguineae* has difficulties climbing it, and therefore does not eat it (Glynn and Krupp 1986). It might be using *Porites* coral heads as shelter in Cook's Bay.

Bertics' (2003) feeding experiments using only specimens from Cooks Bay, showed a strong feeding preference for *Acropora spp.* In my experiments, *C. novaeguineae* showed a slight, but statistically insignificant (p=0.4482) preference for *Pocillopora spp* over *Acropora spp.*, .suggesting that cushion stars will eat both coral if they are readily available.

C. novaeguineae move in a persistent pattern in search for food. My experiments showed that cushion stars moved toward food more often than not. Eighty percent of the time when *C. novaeguineae* moved away from food it was a new specimen. New specimens generally moved toward a corner of the rectangular tank where they wedged themselves into the corner and remained motionless. In the round tank, the cushion stars climbed up the side of the tank to the waters edge, and then crept along the edge. Once cushion stars sensed that there was no escape, they would change patterns, and either crawl back to the center pole and remain there, or crawl next to another individual and "huddle" together. Somewhat "habituated" cushion stars generally moved and mounted coral within the first hour of an observation period. This suggests that *C. novaeguineae* detects food, possibly by smell, and then purposefully moves toward it.

There was no clear correlation between *C. novaeguineae's* size and turn-over time, but figure 4 shows a slight pattern: larger individuals turned over faster than smaller ones. Turning from their aboral side back onto their oral side likely requires significant energy which larger individuals are more likely capable of.

CONCLUSION

C. novaeguineae in Mo'orea is a coral predator that has exhibited coral preference. Its selective predation on *Pocillopora spp.* and *Acropora spp.* can potentially limit the abundance of these coral species on the island of Mo'orea, especially the coral *Acropora cervicornis,* which in northern Mo'orea, only occurs in the Tamae region. Changes in the abundance of the two preferred coral can affect the overall reef ecology and fish habitat.

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APPENDIX A

TABLE 1. Percent frequency by individuals

Individual Feeding Frequency -Three Coral Species

Specimen	Location	% Acropora	% Pocillopora	% Porites	% Other	% not eating
1	Cooks Bay	33.3	0.0	0.0	33.3	33.3
2	Cooks Bay	33.3	0.0	33.3	0.0	33.3
4	Cooks Bay	100.0	0.0	0.0	0.0	0.0
7	Cooks Bay	28.6	71.4	0.0	14.3	14.3
5	Maharepa	22.2	33.3	0.0	11.1	33.3
6	Maharepa	44.4	22.2	22.2	11.1	22.2
3	Tamae	30.8	23.1	7.7	7.7	38.5
8	Tamae	20.0	20.0	20.0	0.0	20.0

TABLE 2. Percent frequency with Two Corals

Feeding Frequency with Two Coral Species

Specimen	Location	% Acropora	%Pocillopora
7	Cooks Bay	33.3	66.7
9	Faimano	50.0	33.3
10	Faimano	16.7	33.3
12	Faimano	0.0	50.0
5	Maharepa	33.3	50.0
6	Maharepa	33.3	50.0
11	Maharepa	25.0	25.0
3	Tamae	66.7	50.0
8	Tamae	66.7	33.3