Light perception and brittlestar behavior

Megan E. Harrison, Jennifer L. Butcher,
Kristin N. Nowak and Erik R. Schoen

Abstract: Most brittlestars hide under protective rubble during the day and only extend their arms from their refuge to feed during the night. While brittlestars may rely on tactile and chemosensory cues to find shelter, previous studies have shown that some brittlestars are able to detect light and use phototaxis to find shelter. We tested whether the brittlestars on the West back-reef at Discovery Bay possess light detection capabilities. Additionally, we investigated whether their ability to detect light influences their diel rhythm. We did this by testing the direction of brittlestar movement when exposed to a rock shadow and by recording brittlestar activity in a control treatment and in an experimental treatment where the light/dark cycle was reversed. We found that brittlestars did not seem to be able to detect the presence of a rock without physical contact, nor were they likely to move under a rock when one of their arms was placed in its shadow. Even so, a diel manipulation study showed that brittlestars respond to detected differences in light and dark with different activity levels. It is likely that visual predators, especially diurnal fishes, have constrained brittlestar activity and selected for light sensitive behavioral patterns.

Key Words: coral reef, Ophioderma brevispinum, Ophiocoma echinata

Introduction

Brittlestars (Echinodermata: Ophiuroidea) are abundant throughout tropical coral reefs, but are seldom seen during daylight hours. Predation pressure, primarily from diurnal fishes, is thought to cause brittlestars to seek cover under coral rubble, inside sponges or in rock crevices during the day. Though most brittlestars remain relatively concealed during day and night, they will extend some of their arms to both suspension and deposit feed (Hendler et al. 1995, Paine and Platt 1999). Paine and Platt (1999) found that brittlestars are more active (exposing four or five of their arms) at night than during the day. Brittlestar activity may be regulated by visual sensory input cues, such as an ability to discern light/dark differences, and a circadian rhythm, and it may be affected by relative food abundance during the day and night.

We focused on the photosensory hypothesis, based on existing research suggesting that some brittlestars have relatively advanced photosensory abilities, and that these abilities vary widely between species. Aizenberg et al. (2001) showed that *Ophiocoma wendtii* is able to detect dark refuges from up to 10 cm away, while a congener (*Ophiocoma pumila*) exhibits a very limited direct response to light (Hendler et al. 1995). In the latter case, innate diel cycles may time brittlestar activity.

We sought to determine whether any of the common brittlestar species found in Discovery Bay perceive light and whether this perception affects their behavior. We hypothesized that brittlestars seek shelter from open, well-lit environments. We predicted that brittlestars placed in the open would move towards a rock shelter. Additionally, we hypothesized that activity levels are directly triggered by the presence and absence of light. We predicted that if brittlestar activity is a response to light, brittlestars would show similar activity in a light environment regardless of time of day.

Methods

Experiments were conducted on 22 - 26 February 2002 at the Discovery Bay Marine Laboratory, Jamaica.

Cover Experiment

We collected 17 brittlestars (predominantly *Ophiocoma echinata* and *Ophioderma brevispinum*) from the West back-reef for use in experimental trials. We allowed them to acclimatize in containers with running sea water (sea tables) for three hours. Using string as markers, we divided a 50 x 75 cm section of the 9 cm deep sea table into 4 equal quarters and placed a rock (approx. 15 x 8 x 6 cm) 15 cm from the center in one of the quarters. To determine whether the brittlestars can detect the presence of a rock for cover, a single brittlestar was placed in the center of the arena. We observed the movements and recorded the time for each brittlestar to reach the edge of the sea table or move under the rock. We moved the rock to a new quarter after each trial to avoid directional bias. We repeated this protocol once for each individual. Data were analyzed using a chi-square test.

Diel Activity Experiment

On 24 February, we collected 40 brittlestars to test their activity in response to light and dark. Species composition is given in Table 1. At 17:00 we placed 20 individuals in each of two 150 x 50 x 9 cm sea tables, with species divided equally between the 2 tables. Both tables had 5 rocks providing approximately equal refuge space sufficient for all individuals. One table (the control) was covered with plywood from 18:00 until 06:00 (night) throughout the sampling period and left under natural and fluorescent light during the daylight hours. The other table (day-night reversal treatment) was covered from 06:00 until 18:00 and left under fluorescent light from 18:00 until 06:00. We recorded brittlestar activity in each arena every 3 hrs (taking approximately 1 min to assess activity) from 21:00 on 24 February to 18:00 on 26 February. We used the total number of brittlestar legs exposed or extended from under a rock as a measure of activity level. We analyzed patterns in activity of all species together and also separately for the two most common species, *O. echinata* and *O. brevispinum*. We used a two-way ANOVA to test for an effect of time of day, light treatment or an interaction between these factors on brittlestar activity.

Results

We found that brittlestars did not orient towards cover (a rock) when placed in an uncovered arena. Individuals traveled within 45° of the rock in 4 out of the 17 trials, and only took cover beneath it once. Overall, direction of travel was random ($\chi^2 = 0.182$, df = 3, P = 0.98). We observed that an individual's direction of movement appeared to be random even when its arm and/or body was placed in the shadow of a rock.

Brittlestar activity levels varied with respect to light treatment but not to time of day. Brittlestar activity was greater during dark treatments than light treatments regardless of time of day ($F_{1,56} = 20.75$, $P < 0.001$; Fig. 1). Brittlestar activity did not differ between nighttime hours (18:01 to 06:00) and daytime hours (06:01 to 18:00) when summed across the control and experimental cycle tables ($F_{1,56}$

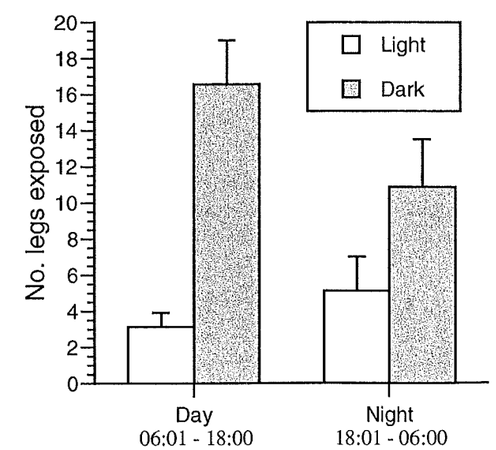

FIG. 1. Mean (± SE) number of brittlestar legs exposed per observation for dark and light treatments during both day and night.

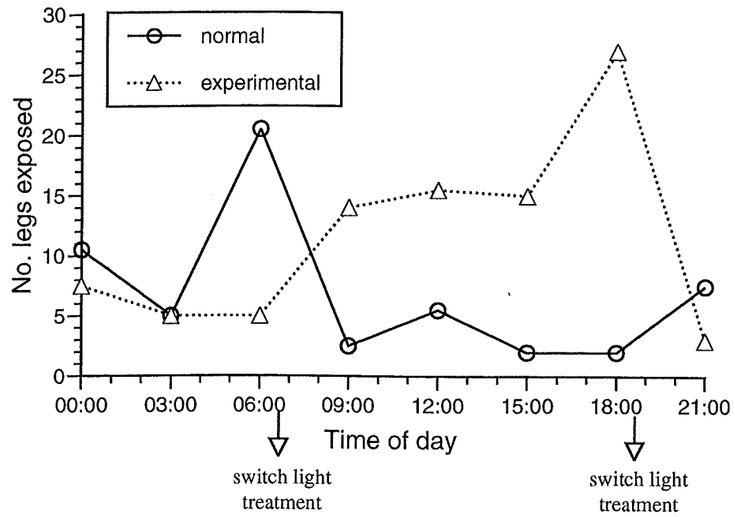

FIG. 2. Activity of brittlestars in normal (light during day, dark at night) and experimental (dark during day, light at night) treatments across a time gradient.

= 0.78, P = 0.39; Fig. 1). The interaction between the time of day and light treatments was marginally significant ($F_{1,56}$ = 3.33, P = 0.08). Brittlestars were most active at the end of the dark period, just before they were exposed to light (06:00 for the normal treatment, 18:00 for the experimental treatment; Fig. 2).

When analyzed separately, both *O. echinata* and *O. brevispinum* showed the general pattern of high activity in the dark, regardless of time of day. Small sample size prevented the separate analysis of the behaviors of the other species observed.

TABLE 1. Species distribution of brittlestars collected from west back-reef, Discovery Bay, Jamaica for use in the diurnal cycle manipulation experiment.

Species	Frequency*
Ophiocoma echinata	22
Ophioderma brevispinum	5
Ophiocoma pumila	3
Ophionereis reticulata	2

*Note: Represents number of brittlestars collected at the end of the experiment, when 8 individuals had either escaped from the sea table or were irretrievable from within rock crevices.

Discussion

The difference in activity levels associated with dark and light treatments indicate that *Ophiocoma echinata* and *Ophioderma brevispinum* perceive changes in light availability and base their foraging patterns on these changes, foraging more in the dark. The marginally significant interaction between light treatment and time of day and the high activity observed just before the end of each dark cycle may indicate that brittlestars employ some type of light-regulated circadian rhythm. Future studies might further test the presence of a circadian rhythm by holding dark and light treatments constant and monitoring differences in feeding activity over time.

We found no evidence that either species uses visual cues to find refuge. The light sensory abilities of *O. echinata* and *O. brevispinum* are apparently intermediate between those of the relatively insensitive *Ophiocoma pumila* and the highly sensitive *Ophiocoma wendtii* (Aizenberg et al. 2001). Assuming that light sensitivity confers some advantage to those brittlestar species possessing it, the wide variation in sensory ability of

a relatively ancient taxon suggests that some cost is associated with well-developed light sensation. In the absence of such a cost, we would expect species with well-developed visual capabilities to replace other species over time due to their greater ability to evade predators.

Brittlestars were most active just before the transition from low to high light levels. We observed several brittlestars completely remove themselves from cover and move from rock to rock minutes after this transition in the experimental arena. This may indicate high brittlestar activity at dawn, which is a quiescent period for many small fish species in backreef habitat (Woessner et al. 1980). Brittlestars may be less vulnerable to predation during dawn and dusk due to lower predatory fish activity. However, it is possible that Discovery Bay, due to the absence of many predatory fishes, has no distinct quiescent period. Further research might quantify this pattern *in situ* and determine whether brittlestars in the back-reef are most active at dawn and dusk.

The increased activity of brittlestars in darkness suggests that their activity patterns, like those of many other reef invertebrates, may be constrained by fish predation and other visual predators. Individuals and species with greater light response may be more adept at locating refuge and thus may be selected for in areas with high predation risk. As a result, light sensitivity may be an important factor in the natural selection of these organisms.

Literature Cited

Aizenberg, J., A. Tkachenko, S. Weiner, L. Addadi and G. Hendler. 2001. Calcitic microlenses as part of the photoreceptor system in brittlestars. *Nature* 412 (23): 819 - 822.

Hendler, G., J. E. Miller, D. L. Pawson and P. M. Kíer. 1995. *Sea Stars, Sea Urchins, and Allies*. Washington, D. C. : Smithsonian Institute Press.

Hobson, E. S. 1975. Feeding patterns among tropical reef fishes. *American Scientist* 63.

Paine, C. E., and J. P. Platt. 1999. Factors affecting distribution of brittlestars (Echinodermata: Ophiuroidea). Pp. 136 – 140 *in* M. R. Babineau and D. R. Hogan, eds. Dartmouth Studies in Tropical Ecology. Dartmouth College, Hanover, NH.

Woessner, J. and B. Hunt. 1980. A study of the nocturnal-diurnal transition periods of tropical reef fishes on a Jamaican fore-reef. Dartmouth College, Hanover, NH.