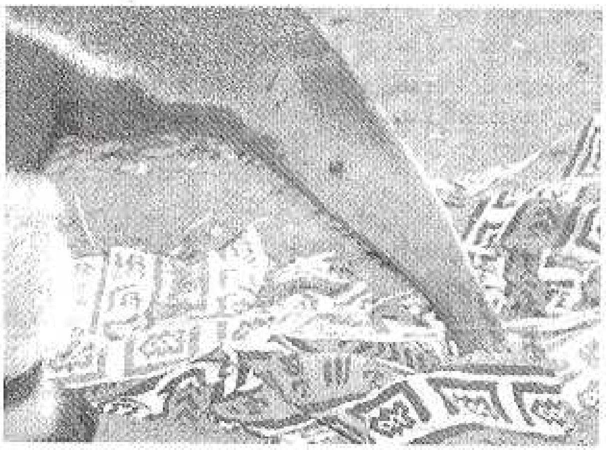
ter, it's the easiest to make, doesn't cost money, and is easy to come by: the rotten log! The easiest way to encourage natural behaviors is to introduce an item that they would encounter in the wild. Anthills are not easily moved, but a termite nest can be. Any zoo is bound to have a few rotting logs lying around. This is the anteater's favorite enrichment. He can be seen interacting with it from anywhere between 30 and 90 minutes at a time. He even revisits the site after the log is completely destroyed.



Kimberly Skelton

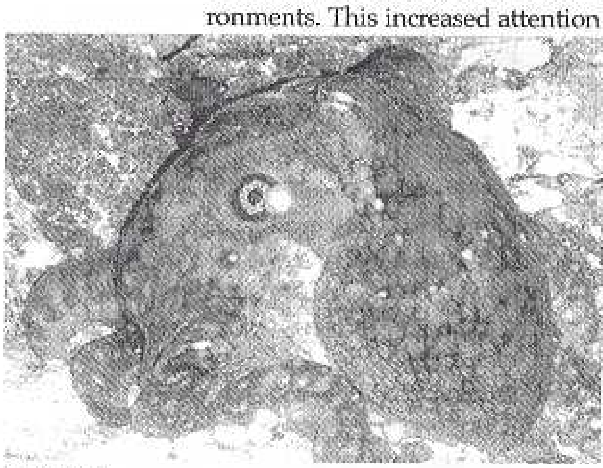
Fabric makes scents!

Eureka now spends approximately 85% of his exhibit time active. Different types of enrichment are offered at various times throughout the day to ensure increased activity levels. All enrichment should be modified over time to maintain the animals' interest, but enrichment can and should be repeated after an adequate amount of time, typically three to four weeks. This provides a sufficient level of challenge and also provides the joy of recognition when a recycled item is presented again. The ideas here are relatively inexpensive and quick to put together, which is perfect for the zookeeper's busy day! ◇

The Effect of Habitat Enrichment on the Mudflat Octopus

By Marie Beigel and Jean Boal, Ph.D.

Environmental enrichment is an intriguing topic for aquarists. Within the past few years, scientists have become more concerned about how the coleoid cephalopod mollusks (octopus, cuttlefish, and squid) are affected by captive environments. This increased attention is due in part to exciting new discoveries about octopuses and their wide variety of behaviors.



California mudflat octopus (*Octopus bimaculoides*)

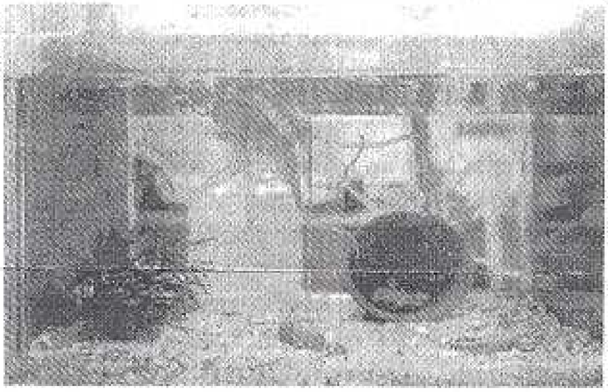
Cephalopods and Enrichment

Since cephalopods are complex animals that have elaborate sense organs, their brains must routinely handle much more information than other invertebrates (Hanlon and Messenger, 1996). They are capable of conditioning and associative learning (Hanlon and Messenger, 1996), spatial learning (Boal et al, 2000), short-term memory recognition (Hanlon and Messenger, 1996), and stimulus enhancement, a simple form of observational learning (Fiorito and Scotto, 1992). If octopuses are so intelligent, how can we limit these complex invertebrates to a bare and confining tank?

Habitat enrichment could also benefit cephalopods by reducing stress, and thereby reducing repetitive, detrimental behaviors. Behaviors indicative of stress include jetting into the sides of the tank, frequent deimatic color patterns (designed to threaten, startle, frighten, or bluff; Hanlon and Messenger, 1996), hiding for most hours of the day (depending on species), white color patterns, and inking (Wood and Wood, 1999). Autophagy, characterized by an animal eating its own appendages, is exhibited in times of high stress; it is possible that enrichment could help to reduce all these types of behavior.

Some Approaches

Aquarists at the Cleveland Metroparks Zoo are collecting ideas in an enrichment notebook with three sections: Environmental Stimulus, Hunting Stimulus, and Interactive/Tactile (Rehling, unpublished work). Jill Forsbacka, Aquarist at the National Aquarium in Baltimore, uses a variety of dog toys and PVC puzzle feeders (PVC pipes with various food items inside) for enrichment (Forsbacka, pers. comm.). Dr. Roland Anderson, Puget Sound Biologist at the Seattle Aquarium, uses many enrichment devices, including a Mr. Potatohead (round plastic object with removable body parts) that is smeared with herring or squid juice to encourage manipulation by octopuses (Anderson, pers. comm.).



One of the octopuses in an enriched tank.

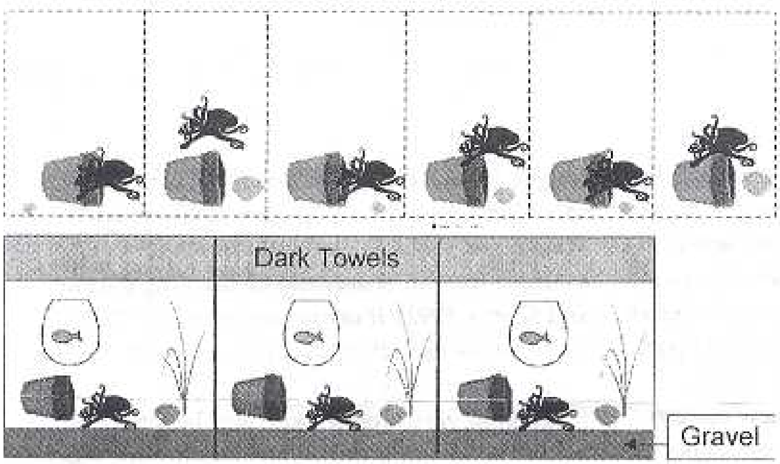


Figure 1: The set up of the two environments—impoverished (top) and enrichmed (bottom).

Study on the Mudflat

I recently completed a study of the effects of habitat enrichment on the activity and body patterning of the California mudflat octopus (*Octopus bimaculoides*). I hypothesized that the repetitive and self-destructive behaviors seen in the laboratory were due to the stark housing typically provided. I predicted that the octopuses would show fewer repetitive, detrimental behaviors in an enriched environment than in the standard laboratory environment.

A second objective of this experiment was to determine if habitat impoverishment affects the activity cycle of octopuses, due to general suppression of physiological functions. Octopuses are typically nocturnal or crepuscular, perhaps to avoid predators (Wood and Wood, 1999). I expected that the octopuses would be more active in the evening hours, but I further predicted that they would be more active overall in the enriched environment than in the standard laboratory environment.

Setting Up

The six California mudflat octopuses in this study varied in age and ranged from about 50 to 75 grams. Two separate environments were constructed for the experiment (see Fig. 1). The impoverished environment was a standard laboratory environment (S1 and S2). Each octopus tank (0.46 x 0.20 x 0.30 m) was fabricated with clear Plexiglas on all sides. Objects in the octopuses' tanks included 2 to 4 glass beads, 3 to 5 shells from gastropods, 1 to 3 small stones, one small terracotta flower pot, and one large terracotta flower pot for the octopus to use as a den. The octopuses could see the laboratory and each other. Natural light from north-facing windows was supplemented by fluorescent lights over the tanks, which remained on from approximately 9 a.m. to 6 p.m. daily.

In the enriched environment (E), each octopus tank was double the volume of the impoverished environment (0.46 x 0.41 x 0.30 m). Grey PVC inserts made the two side walls opaque, and towels covered the top and back of each tank. Objects in the tanks included all the same items as above, plus a substrate of crushed coral, the addition of live plants (*Grassilaria*), and the sight of live fish (wrasses) housed in jars directly behind each tank. These octopuses could not view other octopuses or other activity in the laboratory. The fluorescent lights over the enriched environment remained off for a majority of the day, but the octopuses were exposed to natural light from the north-facing windows.

Conducting the Study

Each octopus was observed in both environments. They were observed in the impoverished environment for two weeks (S1), in the enriched environment for two weeks (E), and then in the impoverished environment again for one week (S2) (see Fig. 1). In each environment, five-minute observations were conducted six times a day at regularly spaced intervals to cover morning, afternoon, and evening. Data were collected by direct observation. Each octopus was observed two times per

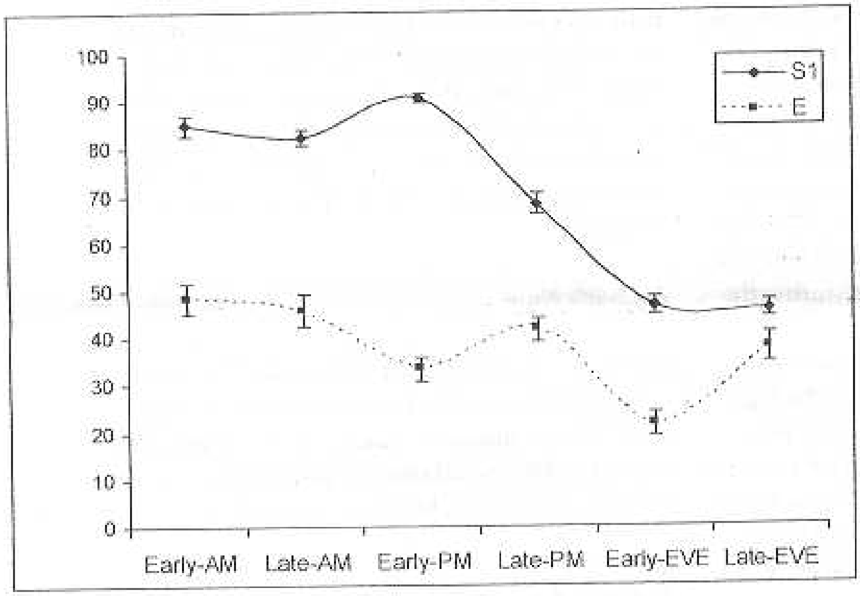
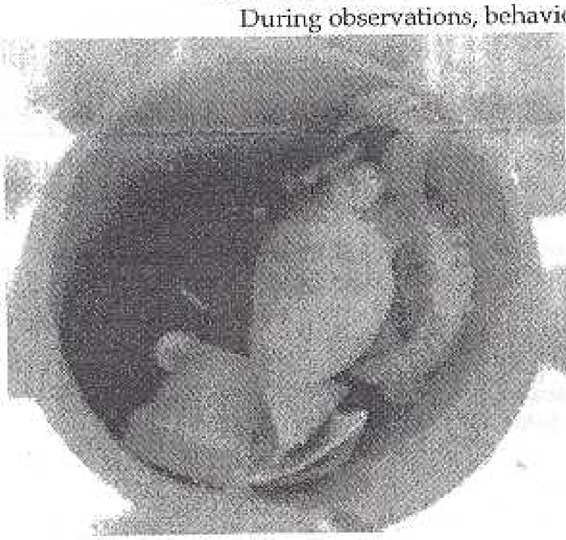


Figure 2. Activity cycles (mean ± SEM) during six different time periods. In the initial standard laboratory conditions (S1), there was less sitting (higher activity) in the pot during late evening hours (Late-EVE), and more sitting in the pot (lower activity) during early afternoon hours (Early-PM). In the enriched conditions, there was less sitting in the pot (higher activity) during early evening hours (Early-EVE) and more sitting in the pot (lower activity) during early morning hours (Early-AM).

week during each of the time periods, so each octopus was observed a total of 12 times per week.

During observations, behaviors were monitored continuously, using a one/zero type of sampling method, and recorded in five one-minute blocks. Behaviors were not mutually exclusive; as a result, different total numbers of behaviors could be recorded during the 1-minute blocks. The following behaviors were recorded: non-movement behaviors (sitting in the pot, sitting on the bottom of the enclosure, and suctioned to an object), movement behaviors (shuffling along the wall, manipulating objects, jetting, hitting walls, cleaning, arm curling, grasping, and picking up objects), body patterns (dark, light, vertical stripes, papillae up, and red suckers), status of the eyes (closed, open, and extended), and other unusual behaviors.



One of the octopuses tucked into a flower pot.

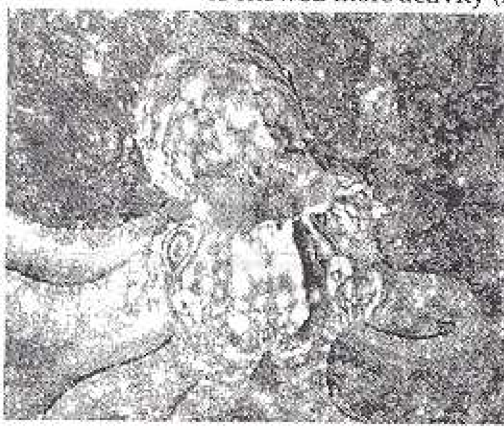
The Results

I found statistically significant differences in the behavior of the octopuses in the two environments. In the enriched environment, octopuses commonly rested on the bottom of the tank and manipulated objects, while in the impoverished environment, they commonly jetted and hit the walls of the tank (S1 and S2). In fact, they jetted into the walls nearly three times more often in the impoverished environment than in the enriched environment. The other activity variables showed potentially important but statistically insignificant trends distinguishing the two environments.

Body patterns tended to vary between environments. The octopuses in the enriched environment appeared more alert and showed less stress-related coloration (light coloration, papillae raised on the skin, and vertical stripes on the body). They camouflaged well in this environment; sometimes I had trouble spotting them. The octopuses in the standard laboratory environment showed more stress-related coloration (dark coloration and red coloration on the suckers), which could be due to the ability to see other octopuses and research students in the laboratory.

Autophagy, although not recorded in the data, was observed when the octopuses were in the impoverished environment. It mainly occurred when the octopuses were in the impoverished environment for the second time (S2), and was never observed in the enriched environment. This could have bee n due to the withdrawal of the enriched environment or the new impoverished conditions. Although sufficient data were not collected on autophagy for statistical analysis, it appeared that environment was an important factor in the expression of this detrimental behavior. Further investigation would be useful.

The octopuses in the impoverished environment appeared to be nocturnal (spending most of the day in pots; See Figure 2). California mudflat octopuses have previously been reported to be strongly nocturnal and difficult to change to a daytime activity pattern (Boal, 1993). In the enriched environment, there was less variation in activity than in the impoverished environment, and there was generally more activity (less sitting in the pot) from 12 to 2 p.m. and 5 to 8 p.m. In the impoverished environment, the mudflat octopuses showed more activity (less sitting in the pot)

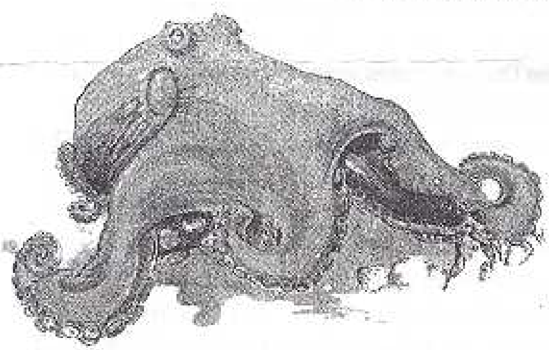


during the late evening hours of 8 to 10 p.m. The least amount of activity (more sitting in the pot) in the impoverished environment was during the early afternoon hours of 12 to 2 p.m. At this time of day, the highest amount of noise and activity was in the laboratory area, which could have disturbed the octopuses. It seemed that habitat did have some affect on the activity cycle of the octopuses.

Implications for Octopuses

Habitat enrichment clearly appeared to affect the behaviors of the octopuses in a constructive way. Not all observable differences were statistically significant; however, the study included only a very small sample size (6). The enriched housing conditions provided in this study were not extensive or costly, yet they appeared sufficient to reduce destructive behaviors.

Habitat enrichment appeared to increase



behavioral diversity by increasing crypsis (the ability to change colors/patterns and camouflage to the environment), grasping, and manipulating. It increased wild or natural behavior patterns by increasing burrowing and camouflaging to the substrate. In the enriched environment, the octopuses displayed more wild behavior patterns, such as shuffling along the tank, sitting on the bottom to camouflage, and manipulating objects; and less destructive behaviors, such as jetting and hitting the walls of the tank.

To understand how these complex invertebrates function, we must develop natural habitats for them so they thrive as they would in a wild environment. The repetitive self-destructive behaviors seen in the laboratory could be due to the stark housing provided. The present study supports the idea that an enriched environment can decrease detrimental behaviors and increase normal (wild) behaviors, behavioral diversity, and the well-being of the California mudflat octopus. ✧

Author's Note

This article has been condensed from an undergraduate honors thesis at Millersville University of Pennsylvania with the assistance of Dr. Jean Boal. For comments or questions, please email me at mebeigel@hotmail.com. Copies of the thesis in its entirety are available upon request.

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