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7. A Record of Observations on *Nautilus pompilius* in Laboratory Aquariums

by

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Introduction

In September, 1983, some new observations were made by the writers on twenty-four healthy living specimens of *Nautilus pompilius* in the laboratory aquariums at the Institute of Marine Resources, the University of the South Pacific. The specimens observed were ten female and fourteen male nautili fished by trapping off Suva, Fiji. The writers obtained some new informations through the observation on their behavior such as diurnal activities.

Materials and Methods

The nautili were fished by the university-owned ship in the sea area off the southeast coast of Viti Levu, Fiji. The laboratory observations were continued on the animals for various periods of time ranging from about five hours to two weeks after being captured.

Three aquariums, 48 by 92 cm and 46 cm high, made of 5 mm thick acrylic resin were set up on three steps, respectively (Pl. 1, fig. 7 of this volume). The sea water was circulated in a closed system from the highest to the lowest aquariums, where the water was filtered by sand. The water levels of the aquariums were always kept about 45 cm high. The water temperature was kept usually between 14°C and 18°C.

Observations

Modes of Life

In the day time, each specimen of *Nautilus* takes one of the four types of behavior, such as (1) attaching its tentacles to the wall or bottom of the aquarium, (2) swimming movements, (3) rising to the surface by shrinking its tentacles, and (4) settling on the bottom. In addition to the nectonic and benthic modes of life in the aquariums, the animals showed movements of neutral buoyancy in surface streams, that is, the so-called planktonic mode of life. As a matter of fact, these animals were judged to have all types of life mode of marine organisms. This suggests that they are originally endowed with the wide adaptability to the various environmental conditions.

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Types of Movement

The types of swimming hitherto known are upward, downward, forward, backward swimmings and rotation. Besides these patterns, the nautili showed a rotation in the horizontal plane in an aquarium (2 × 2 × 3 m) in the ship and in a round backet and a tank.

Immediately after transference to the aquarium in the laboratory, the animals rotated forward and backward. Moreover, when touching some foreign substance, the nautili reflexively jumped up. They turned their backs to a block of coral and extended their tentacles backward and splashed water on it. Right after being captured the animals were very active. By using tentacles alternately, they crept around the bottom. At night, searching movements by the tentacles elongated twice were also observed.

Daily Cycle of Behavior

Like the results obtained from the observations in the aquariums of Silliman University in Dumaguete, the Philippines and of the Kamoike Marine Park, Kagoshima, Japan (HAYASAKA, *et al*., 1983), nautili showed much more active movements in the nighttime than in the daytime and they were most active at sunrise and sunset. On the day when they were captured, however, there was no difference in behavior between daytime and nighttime.

At the most powerful movements, a certain swimming pattern continued for 4 - 15 minutes alternating with 10 - 20 minutes intermission. This behavior lasted for 2 - 5 days after capture. During this period of time, the water temperature was kept between 14°C and 15°C.

Feeding Activities

A block of coral (about 20 cm high) was placed at the center of bottom surface of the aquarium. When a shrimp (about 10 g)was put on the top of the block by a pair of tweezers, a nautilus attaching to the wall of the aquarium immediately took the following actions: First, it detached the tentacles from the animal and then turned toward the shrimp. Second, the animal went straight on to the food without hesitation and rolled the bait with a tentacle to the mouth. The length of time of this activity varied depending mainly on the difference in individual. To catch the food, some nautili took two seconds, fifteen seconds, or two minutes, and rarely even fifteen minutes. The fact that they move straight to the food even in the stream of opposite direction indicates that the nautili possess keen perception for finding the location of food.

Simulating the behavior of nautili entering into an offshore trap, a mini-trap (40 × 30 × 30 cm) was set up in the aquarium to make some observations on animals' reaction to the trap (Plate 28).

The mini-trap is a net made of black cords of vinyl resin and has holes (10 × 12 cm) on four sides. The trap was left in the aquarium for a day. One of the six nautili touched the net and jumped aside about 10 cm by reflex action. The other nautili avoided the trap and attached to the net only a few times. No nautili positively entered the trap.

The next day, a shrimp was hung by a wire at the center of the trap and eight nautili, kept unfed on the previous day, were put in the aquarium. In the daytime, all animals clung at first to the wall, but 1-3 minutes later all of them approached to the trap leaving the wall (Plate 28,b). A nautilus carefully touched the trap as if inspecting it. Then it extended a tentacle into the trap through a hole and attempted to catch the food. When failed, it entered the trap through the hole. In spite of the position close to the shrimp, the nautilus crept up carefully towards the food extending a tentacle and at last rolled in the shrimp. After that, it was swimming around for a while and rolled out through a hole.

Some other nautili showed the same careful and complicated behavior while a few did simple behavior to catch the food. No difference in behavior between male and female was observed.

When a nautilus was put in the trap with a shrimp inside, at once it started swimming. Whenever it touched the net, it positively tried to keep away from the net. The nautilus never tried to catch the shrimp even when it touched the shrimp. Until getting out of the trap, it kept swimming backward changing its direction. Even after escaping from the trap, it still kept swimming around for a while and then finally clung to the wall of the aquarium. This behavior suggests that the nautili seem to have the same function of highly sophisticated patterns of activity as that of octopuses.

Breathing

The breathing was counted 15 - 98 times for a minute. The number of breathing was observed to be depending on the patterns of activity in the aquarium. In general, the smallest number of breathing was counted while the animals were floating with their tentacles drawn in or quietly settling on the bottom. The number was a little more than that while they were attaching to the walls, or moving and inspecting with their tentacles. The swimming movements resulted in the highest number of breathing. There existed, however, some fluctuation of the breathing number during the same type of activity. The number of breathing was solely depending on individual and neither on size nor sex. The breathing numbers of the younger individuals were higher than those of the matured ones (Table 1).

Table 1. Number of breathing during each type of activity in aquarium.

Specimen			Number of Breathing/minute				
Specimen Number	Total Weight (g)	Shell Diameter (mm)	Swimming	Searching	Attaching to the Wall	Settling down on the Bottom	Floating
Male:							
SV 5- 1	310	118.2	80	-	60	60	-
SV 5- 2	175	100.1	88	-	60	60	-
SV 6- 1	545	150	60	52	46	40	36
SV 7- 1	485	134.8	64	60	32	-	30
SV 9- 1	545	150	75	68	60	48	40
SV13- 2	490	138.6	66	-	60	-	40
PH 5- 2	475	100.1	88	-	66	60	-
PH 6-12	585	154.4	68	-	38	36	32
Female:							
SV 8- 1	540	147.1	50	-	40	32	15
SV 8- 2	480	143.6	60	50	40	40	35
SV12- 7	260	114	84	-	66	60	-
SV12-11	650	154.3	52	-	40	40	32
SV13- 3	250	112.4	80	70	62	54	40
SV13-15	580	150.8	84	66	60	38	15
SV14- 1	460	135.4	50	-	45	40	30
Sex Unknown:							
SV10- 6	170	96.8	96	88	66	60	-

Opening and Closing Function of the Pupils of the Eyes

As is well known, the nautili have the pinhole pupils. In order to examine the reaction of their eyes against illumination, the writers took photographs of a pupil in the light of various intensity (lux), and measured the widths of the pupil, the black pigment at the circumference of the eye. In the daytime, widths were measured under the two different condition : (1) using a fluorescent light and (2) using a 300 watts electric lamp in addition to the fluorescent light. The differences between the widths of the two cases were within the range between 0.5 - 1 mm.

A pupil of a young and small nautilus, photographed in the nighttime at about 420 m deep sea bottom, had a 5-3 mm difference in width of eyes. This clearly shows that the pupils of *Nautilus* perform opening and closing movements by the stimulation of flashlight. Fluorescent was found inside the eyes.

Excreta

Two long pieces of red excreta were found when the nautili were transferred to the aquarium. These pieces were 5 mm wide and 5 cm long. Furthermore, the excreta consisting of spiral threads (about 1 mm wide) thickly tangling together was also found. The red color seemed to originate from the color of indigestible shrimp carapace. Through an optical microscope, we also observed something like pieces of crustacean carapace and of vegetable fibers. It is especially noticeable that 136 individuals of light brown zooxanthelae were found in part of excreta. It is suspected that these represent a *Symbiodinium* species, a symbiont of coral.

The esophagus of a nautilus was crammed with fish. This suggested that these fish were eaten by nautilus just before trapping.

During observation of the nocturnal activity, it was observed that a piece of excreta from a nautilus was fluorescing. The fluorescence of excreta is judged to be caused by the occurrence of some luminous bacteria in the nautilus body or by eating some luminous bodies such as of photic coral. But this is still an open question.

Moreover, three cases of copulative behavior and some interrelations between individuals were observed, but these were not so distinct as the case of specimens captured in the Philippines.

Concluding Remarks

Concerning the natural behavior of *Nautilus*, there are many problems still remained unsolved. The writers wish to try to understand hereafter the functional mechanisms of their behaviors through the detailed observation on them in some controllable aquarium under the various environmental conditions analogous to those of their habitat.

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Explanation of Plate 28

Behaviors of nautili in the aquarium, in which a trap is settled without food (a) and with food (b).