NOTES AND COMMENT

DIFFERENTIAL FOOD SELECTION BY MORAY EELS AND A POSSIBLE ROLE OF THE MUCOUS ENVELOPE OF PARROT FISHES IN REDUCTION OF PREDATION[1]

A mucous envelope which covers certain parrot fishes at night was described by Winn (1955). The mucus forms an ovoid envelope around the parrot fish at a distance from the body with an opening at the mouth and in back of the caudal fin. Such a conspicuous mucous fold might well protect the fish from predation at night.

Moray eels and sharks are the most notable night predators in the fish fauna of coral reefs. Morays especially move over the reefs from dusk to dawn, looking for carrion and live prey. Parrot fishes resting at night in protected areas or places on the bottom are extremely inactive and therefore might be an easy prey for such predators. We have undertaken experiments to test whether or not parrot fishes with a mucous fold are less liable to predation than parrot fishes without a mucous fold. Several species of parrot fish were used as prey. The first, *Scarus croicensis,* secreted a mucous fold and the others, several species of the genus *Sparisoma,* did not. The common spotted moray eel, *Gymnothorax moringa,* which inhabits the reefs where the parrot fish are found, was used as the predator.

The observations and experiments were initiated at the Lerner Marine Laboratory, Bimini, Bahamas, by the first author, and were completed at the Bermuda Biological Station, Bermuda.

Material and Methods

In each experiment (Tables I and II) one common spotted moray eel (*Gymnothorax moringa*) was placed in a tank with a small pile of rocks at each end. Three 36 × 18 × 18 inch stainless steel and glass aquaria were used at Bimini and two wooden tanks 48 × 20 × 15 inches, painted with black asphaltum on the inside and having a glass plate for observation on one long side, were used at Bermuda. The tanks were covered to prevent escape of the eels at night. Sea water flowed slowly through the tanks.

Six series of predator-prey experiments were carried out using 6 different moray eels and 5 tanks. The eels ranged approximately from 45 to 60 cm in total length. From one to 5 days after the morays were set in the tanks, 2, 3, or 4 individuals of *Scarus croicensis* and 2, 3, or 4 individuals of *Sparisoma radians* at Bermuda or *Sparisoma chrysopterum* at Bimini were added (Tables I and II). Also *Cyprinodon* sp. was used as prey with *Scarus croicensis* alone and together with a third species, *Sparisoma chrysopterum* (Table I). The prey individuals were always of nearly the same size. Every morning the prey fish were counted and those that had been eaten were replaced with new individuals of a comparable size. The moray eels ate these fish at night while they were all "sleeping" motionless on the bottom of the tanks. The aquaria were frequently checked just before dark and in the early morning. The results of each series of experiments are presented in Tables I and II and a summary of all experiments and all first day results is given in Table III. Chi-square significance tests were made with the table for minimum contrasts required in fourfold contingency tables by Mainland, Herrera and Sutcliffe (1956).

Table I. Predation by 3 individuals of the common spotted moray eel on 2 species of parrot fishes and a cyprinodont, Bimini, 1955. Fishes eaten at night were replaced so that the predator had a nocturnal choice of equal numbers of prey of all species

	Scarus croicensis Parrot Fish with Mucous Envelope	*Cyprinodon Sp.* Topminnow No Envelope	*Sparisoma chrysopterum* Parrot Fish, No envelope
Moray I			
March 8-13			
Total prey present..	18	18	
Total prey eaten...	1	7	
March 20-23			
Total prey present..	12	12	
Total prey eaten...	6	0	
March 25-26			
Total prey present..	5	6	5
Total prey eaten...	1	0	3
Moray II			
March 11-16			
Total prey present..	18	18	
Total prey eaten...	6	2	
March 22			
Total prey present..	3	3	3
Total prey eaten...	1	1	3
Moray III			
March 23			
Total prey present..	3		3
Total prey eaten...	0		2

Results and Discussion

There appears to be a marked tendency for the moray eel to prey on the species of *Sparisoma* more readily than on *Scarus croicensis.* The total difference in Table III is significant at the one % level. It seems likely that the mucous fold of *Scarus croicensis* reduces effective nocturnal predation by the moray eel. The moray uses primarily the senses of smell, taste and sometimes touch in its feeding activities. Smell is used for location of distant objects but when the front part of the head touches the food object an immediate and well oriented grasping due to taste and touch takes place and the food

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TABLE II. Predation by 3 separate common spotted moray eels on 2 species of parrot fishes at the Bermuda Biological Station, 1956. Fishes eaten at night were replaced so that the predator had a nocturnal choice of equal numbers of prey of all species

	Scarus croicensis Mucous Envelope	*Sparisoma radians* No Envelope
Moray I		
July 5-6		
Total prey present.	4	4
Total prey eaten..	1	2
July 14-15		
Total prey present.	8	8
Total prey eaten..	3	7
Moray II		
July 15-26		
Total prey present.	48	48
Total prey eaten..	7	19
Moray III		
July 16-26		
Total prey present.	39	39
Total prey eaten..	7	13

is swallowed. The grasping reflex is not initiated when the head of the moray touches the mucus and not the body of the fish. Twice mucus was placed in contact with the head of a blinded moray and no grasping or negative reaction occurred, but in several instances a blinded moray grasped a crushed or freshly dead fish when it was placed in contact with the predator's head. Apparently the mucus does not supply the proper taste and/or touch stimuli necessary to elicit the grasping response.

We could not discern any differences in the behavior of the two species of parrot fishes at night. They all remained nearly motionless on the bottom with greatly reduced respiratory movements and they could easily be picked up by hand. A behavioral difference may explain, however, why *Cyprinodon* was eaten as infrequently as

TABLE III. Summary of the data presented in Tables I and II. The total prey offered and eaten in the first 24 hours cannot be seen in Tables I and II. Notations in brackets refer to levels of significance in Chi square tests

	Scarus croicensis Mucous Envelope	*Sparisoma spp. No Envelope*
Total prey offered.....	110	110
Total prey eaten......	20	49 (1%)
Total prey offered on first day..........	23	23
Total prey eaten on first day...........	9	19 (1%)
	Scarus croicensis Mucous Envelope	*Cyprinodon No Envelope*
Total prey offered.....	56	57
Total prey eaten......	15	10

S. croicensis (Table III). *Cyprinodon* were much more sensitive to disturbances than the parrot fish. This greater reactivity apparently made them as difficult to prey on as *S. croicensis* with the mucous fold.

Is it possible that the sparisomid parrot fishes are more palatable than *Scarus croicensis?* The morays did not entirely avoid the envelope secreting fishes at night and individuals of both types fed to morays during the day at Bimini seemed to be eaten readily. There were no observable differences in the way the morays grasped and ate both types.

The daily replacement of eaten fish with fresh individuals might have affected the outcome of the experiments since fish when first placed in a tank might be more readily eaten than those that have been in a tank for several days. If this were true one could expect more *Sparisoma* to be eaten. This is what happened but apparently for another reason. On the first day there was more predation on *Sparisoma* and the difference was significant at the one % level. This initial selection for *Sparisoma* persisted throughout the experiments and demonstrates that prey selection was not directed towards fresh or old tank residents but was due to a difference between the species.

At least 3 factors in the experiments might have operated against a selection for the species of *Sparisoma* and for selection of *Scarus croicensis,* the opposite of our results. Because of the eels' size and the limited space of the aquaria the moray could have brushed the mucous envelope away from the parrot fish. The lights were turned on in the laboratory on rare occasions at night and this caused the parrot fish to break out of their mucous folds. The moray could have eaten one before there was time to remake the fold in the dark. Toward the end of the experiments a careful check had to be made to see whether or not the ability to make the mucous envelope was lost because of starvation. A few parrot fish may have been in this condition. These factors probably would be eliminated in the natural environment so that the fold would be more effective in protection against predation. We cannot say at this time whether or not there is some slight ecological difference between the two types of parrot fishes that would lower the effective predation rate on the sparasomids which are not protected by mucous folds. Moray eels apparently eat parrot fishes as well as other species of fish which are more reactive to disturbances in the dark. In our experiments all 6 morays preyed more heavily on the parrot fish that did not secrete a mucous fold. Also, out of 26 counts at Bermuda more sparisomids were eaten during 17 nights, on 3 nights the number eaten of each species was the same, and during 4 nights more *Scarus croicensis* were eaten while no prey-fish were taken during the remaining 2 nights. It did not seem to matter which species of *Sparisoma* was offered although the data for the Bimini species were rather limited. These results and the fact that we did not find any difference between the species in behavior and palatability leads us to conclude tentatively that the mucous fold secreted around individuals of *Scarus croicensis* is effective in reduction of the predation rate by the common spotted moray eel. It is to be expected that this kind of protection might also work against other nocturnal predators.

SUMMARY

A series of predator-prey experiments were carried out with the common spotted moray eel as the predator. One

prey was either *Sparisoma chrysopterum* or *radians* offered together with *Scarus croicensis*. A mucous envelope is produced only by the last species and it was eaten less frequently. Tentatively we conclude that the mucous fold reduces effective predation by the common spotted moray eel.

REFERENCES

Mainland, Donald, L. Herrera and M. I. Sutcliffe. 1956. Tables for use with binomial samples. Dept. of Medical Statistics, New York Univ., College of Medicine.

Winn, H. E. 1955. Formation of a mucous envelope at night by parrot fishes. Zoologica, **40**: 145-148.

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OYSTER SET OBTAINED IN THE NIANTIC RIVER, CONNECTICUT, ON CULTCH BUOYED NEAR THE SURFACE

The potential for a good set of oysters was discovered in 1955 in the Niantic River estuary in Connecticut. This was observed by suspending bags of oyster shell in the water and thus providing cultch or surfaces on which larvae might set if present. Chicken-wire bags containing the shell clutch were placed at 3 stations and were exposed for successive 4 day periods. At Station B, 0.6 nautical miles from the mouth of the estuary in a region of broad sand flats, the bags of cultch were suspended so that they remained within 1M of the surface. At Station D, 1.25 nautical miles from the mouth and with a depth of 3M, bags were rigged to remain within 1M of the bottom for comparison with others held within 1M of the surface. The same surface and bottom rigging was used at Station G, 1.95 nautical miles from the fall line and with a depth of 5M. The amount of setting by stations, depth, and date is given in Table I.

TABLE I. Oyster set—Niantic River 1955. First number is the count on the smooth surfaces of four shells. Number in parenthesis is a conversion to number per 100 square centimeters of cultch surface, calculated from approximate measurements of each shell examined

Date cultch was removed after 4* days' exposure on station	STATION B Flats, lower River	STATION D Mid-River		STATION G Upper River	
	Cultch in 1st M only	Upper M	Bottom M	Upper M	Bottom M
June 6, 10, 14, 18, 22, 26, 30 July 4, 8..	None	None	None	None	None
July 12...........	**	5 (2)	None	118 (36)	None
July 16...........	3 (1)	31 (10)	1 (0)	48 (17)	None
July 20...........	1 (0)	5 (2)	None	22 (7)	None
July 24...........	None	None	None	3 (1)	None
July 28...........	None	2 (1)	None	None	None
July 31...........	None	2 (1)	None	1 (0)	None
Aug. 4...........	None	None	None	2 (1)	None
Aug. 8***........	None	None	None	None	None
Aug. 13...........	None	2 (0)	None	None	None
Aug. 17, 21, 24 Sept. 1, 5, 9, 13....	None	None	None	None	None

*Occasionally the exposure period was varied slightly and this can be calculated by subtracting the preceding removal date from the one under consideration.
**Rig with cultch was missing on this date.
***Cultch kept at six Niantic River stations by the Milford Laboratory of the U. S. Fish and Wildlife Service for the period July 18 through August 9, 1955 showed set at only one station. This was a small count of 5 spat per 10 shells at a site near the middle of the River.

Hydrographic studies on the River, discussed more thoroughly in another report (Marshall in press), indicate a tendency toward stratification with surface circulation partially independent of deep waters for brief periods. This, coupled with the lack of set in deep water, suggests that the potential for oyster setting in the Niantic River may be confined to upper strata where, except for a few rocks and shells in a narrow belt along the shoreline, there is a dearth of natural attachment surfaces.

An inspection of the shoreline zone in the summer of 1955 showed oysters widely distributed. They appeared to be derived from several successive annual settings. They were not abundant and seemed somewhat stunted. If any good sets had occurred in former years, they had suffered heavy mortalities. Furthermore, the small size of the oysters suggested poor growing conditions. Specimens dissected and examined at the time by Charles A. Nomejko (then with the U. S. Fish and Wildlife Service Laboratory at Milford) were in good spawning condition.

Practical oystermen are constantly on the alert for sources of seed. One common proposal is to restore beds formerly very productive, as suggested by Loosanoff (1955) for certain estuaries of Long Island Sound. The observations on the Niantic River suggested that attention should also be given to areas that have never developed large beds simply due to the lack of suitable natural surfaces in the water strata where setting might take place. Relatively small and scattered populations of adults apparently have the potential for seeding such areas if cultch is suspended at the proper levels. Obviously, further observations are needed before depending on such a source and the set from such estuaries should be tried on various growing grounds to check against the possibility of an inferior, slow-growing stock.

REFERENCES

Loosanoff, V. L. 1955. How to increase production of seed oysters in Connecticut. Proceedings National Shellfisheries Association for 1954, **45**: 19-22.

Marshall, Nelson, in press. Studies of the Niantic River, Connecticut, with special reference to the bay scallop, *Pecten irradians*, limnology and oceanography.

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