FORAGING BEHAVIOR OF SPOTTED GOATFISH (*PSEUDUPENEUS MACULATUS*) AT DIFFERENT STAGES OF ONTOGENY

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Abstract. Schooling juvenile and solitary adult spotted goatfish (*Pseudupeneus maculatus*) were observed to determine their relative amounts of time spent foraging and to test whether the adults foraged over a greater territory range than the juveniles. These findings and other observations were compared to characterize and explain the changes in behavior which occur during ontogeny.

It was determined that pairing of a juvenile goatfish and a heterospecific provides some sort of benefit to the goatfish, most likely by decreasing the risk of predation. Other juvenile behaviors, such as rubble substrate avoidance and foraging in a smaller area than adults, may also reflect a behavioral modification to reduce predation risks. These differences are also shown to result from foraging methods and requirement changes that result during development. The implications of this study reflect the influence of cost/benefit dynamics on goatfish behavior. (EWG)

INTRODUCTION (EWG)

Behavior often changes during development and this is apparent in the spotted goatfish (*Pseudupeneus maculatus*). Goatfish change modes of foraging from digging through the benthos with barbels to the use of their mouth. They also switch from foraging primarily on soft substrate to hard substrate (Uiblein 1991). These behavioral modifications are thought to reflect a change in diet from benthic invertebrates to polychaetes (Wahbeha and Ajad 1985 in Uibleun 1991). Because polychaetes are deeper in the substrate and more difficult to locate, it seems likely that the adults will cover a larger area than the juveniles while foraging to find dense patches.

Schooling behavior also changes during ontogeny of goatfish; juveniles form heterospecific shoals while adults are solitary (Uiblein 1991). Individual juveniles in a school form close associations following a single foraging fish, usually a parrotfish or wrasse (pers. obs.). In several cases, when the other fish was active, the goatfish stopped foraging and swam to remain in tight formation underneath it. A possible explanation for this shoaling behavior is a benefit of decreased risk of predation and therefore, a decrease in the time vigilant (Shaw 1978). A foraging benefit also would occur when the benthos is stirred by the other fish, causing search time to decrease (Uiblein 1991, Strand 1988). Either or both benefits could have the same effect on foraging, causing the time spent foraging per unit prey captured to be less for juveniles in schools than for individuals. With a prey availability increase, it wouldn't be necessary for the schooling juveniles to forage as long for adequate intake of food. Similarly, the benefits of decreased risk of predation are likely to outweigh the costs of decreased foraging time and energy expended while following another fish. However, at no time in either the fore or back reef were solitary juveniles observed. Observations were made to explore the relative amounts of time spent foraging of the schooling juveniles and the solitary adults and also to test the hypothesis that foraging range will be less in the juveniles than in adults.

METHODS (EWG)

The study area was located in the fore-reef in front of the Discovery Bay Marine Laboratory, Jamaica (Mooring 1). Observations were conducted from 0800-1700 from 20 February to 1 March 1992 while scuba diving at depths of ~10-20m. Observer distance was ~2-3m above the fish and did not appear to disrupt goatfish behavior. Nine juvenile and 14 adult goatfish were studied and fell into 2 approximate size classes, 8-12cm and 20-30cm, respectively. Those of intermediate size were excluded from the study. During observation periods of 5min, time spent foraging was recorded and distance traveled was noted mentally. Foraging consisted of barbel movements and/or a digging action with the mouth while either were embedded in the substrate. At the end of the observation period, the length and width of the foraging area was estimated by swimming along the fish's path and counting the number of head-to-fin tip lengths (~2m) covered. When the width was smaller than 2m, an estimate was made by eye to the nearest 0.5m. Other observations included inter- and intraspecific interactions of the goatfish, the type of substrate in the feeding areas, and any other rare behavior, such as resting or long-distance swimming.

RESULTS (EWG)

Behavioral observations have been summarized to depict development stage differences in fish grouping, foraging range, time spent foraging, and substrate choice (Table 1). Adults foraged in a significantly larger area than the juveniles ($t=4.8$, $p<0.001$). Paired juveniles foraged for 147±33sec and adults for 216±40sec.

Table 1. Behavioral characteristics of juvenile and adut *Pseudupeneus maculatus*.

	Juveniles	Adults
Grouping:	Interspecies Schooling(2-3)	Solitary
Foraging Range/5min	8.2±3.1m^2	20.7±7.8m^2
Foraging Time/5min	147±33sec	216±40sec
Substrate	Sand	Sand/Rubble

Five juvenile goatfish were observed following yellow headed wrasse (*Halichoeres garnoti*) and 4 following striped parrotfish (*Scarus iserti*). Generally, the goatfish and its heterospecifics were of similar size and they remained paired during the 5min observation period. Although no solitary juveniles were observed, one shoaling individual was left alone for 30sec when its heterospecific left. During this time, the goatfish ceased foraging completely to search for another fish to follow and surprisingly rose above the substrate ~1m until it found another leader fish. Yellow headed wrasse of varying size were also observed following 3 adults and 4 juvenile goatfish. They swam a few centimeters above with their heads pointed downward at an approximate 30° angle and appeared to feed on organisms stirred up by the goatfish.

No behavioral change was observed from the few intraspecific interactions which arose. Both adults and juveniles were observed being

chased from dusky damselfish (*Stegastes fuscus*) territories and one adult was even chased by a blue chromis (*Chromis cyanea*), apparently defending its nesting territory (R. Brantley, pers. comm.).

Adults seemed to swim further between foraging bouts than the juveniles, although no long distance swimming was observed. Resting behavior was rare and was observed in only 2 adults lasting ~30sec. Interestingly, adults divided their time fairly equally over sandy and rubble substrate. Juveniles were only observed foraging on sandy substrate and at the edge of the rubble. The only color phase changes from white to reddish-brown were observed when the adults were over the rocky substrate.

DISCUSSION (EWG)

Because schooling juveniles are spending so much time and energy to remain grouped with other fishes, the close interspecific association must provide some sort of benefit to them. The possibility that the heterospecific is causing an increase in prey density by stirring the substrate should allow the juvenile goatfish to forage less, yet still ingest an adequate amount of food. However, from personal observations, it seems likely that the small pelagic fish swimming 10-20cm above the substrate are having little effect on the benthic layer. In this case, the most plausible benefit of shoaling is a decrease in the risk of predation. It would seem difficult for a goatfish to watch for predators while stirring through the benthos. Focusing on the actions of the leader fish might be more beneficial. If a reduction of the risk of predation is the cause of shoaling alone, the benefits of this reduction must outweigh the costs of decreased foraging and energy expenditure.

Juvenile avoidance of the rubble substrate also could indicate an attempt to avoid predation. They would be much more vulnerable to predators working in the substrate, such as groupers and trumpet fish. Even though goatfish are able to change color to reddish-brown and blend with the rubble, they are still more cryptic in the white phase over light-colored sand. Because only the juveniles avoid these areas, it suggests that they are at a greater risk to predation. Avoidance of these might also reflect the inefficiency of barbel searchers on harder surfaces, in which case prey capture would be less than on a sandy bottom.

The juveniles foraging in a smaller area may also reflect an attempt to reduce predation risks, because the likelihood of contact with a predator is reduced. However, this probably is only a secondary benefit. The feeding territory sizes most likely reflect the difference in prey consumption of the juveniles and adults. The polychaetes fed on by adults are more difficult to find than the benthic invertebrates fed on by juveniles. Therefore, as hypothesized, they probably are foraging in a larger area to find spots of high abundance. The possibility that territory size is limited by the wrasse and parrotfish seems unlikely. If the juvenile goatfish would benefit from a larger territory, they would have switched the heterospecific followed more often.

Although comparison was not possible of the time spent foraging of schooling and solitary juveniles, observations have depicted the pronounced shifts in behavior which can occur during ontogeny. The fact that no solitary juveniles were observed is quite important, indicating the strong benefit of maintaining interspecies associations. Furthermore, the observation of a juvenile swimming high above the benthos to search for its missing heterospecific, adds to this indication.

The implications of these findings suggest the importance of cost/benefit dynamics in shaping goatfish behavior, and that the relative importance of the factors involved are often difficult to discern.

LITERATURE CITED

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