Algal survival after digestion by tropical reef fish

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Abstract

The ability of tropical marine algae to survive digestion by fish is tested in this study. Four species of tropical reef fish (Zebrasoma scopas, Stegastes nigricans, Sufflamen bursa, and Chlorurus sordidus) were collected in Moorea (French Polynesia) and kept in tanks. The feces containing the remains of the fishes’ natural diet were cultured in order to see if algae could survive the passage through the gut of these species. In addition the nutrient concentration in the feces of two species were measured. Algal survival and growth is found in the feces of S. nigricans and Z. scopas. Some nutrients are elevated in S. nigerians and Z. scopas feces.

Introduction

In coral reefs the algal cover and the standing crop of algae is relatively low compared to other coastal marine environments (Hay, 1991). In contrast this, the productivity of algae in tropical reefs is high. The low standing crop of algae is due to the high feeding pressure of herbivorous fishes, which are the main herbivores on coral reefs. They consume almost all the primary production. Because of this tight coupling between production and consumption, herbivory is one of the most important processes in structuring coral reef communities (Hay, 1991). The high predation pressure on algae in tropical reefs has led to the evolution of different forms of defense against herbivores. These include morphological adaptations such as growth forms and calcification, chemical adaptations in the form of toxic secondary metabolites, low nutritional value and spatial or temporal refuges. A less well-studied form of adaptation to herbivores is the tolerance of herbivory (Duffy, 1990). This is the case if algae can survive the digestion by herbivores and regenerate after they have been defecated.
This phenomenon has been demonstrated in temperate regions in invertebrate herbivores, such as gastropods and sea urchins, which are the main consumers of primary production in these regions (Santelices, 1987; Santelice, 1983). It has also been shown in one herbivorous species of clingfish in the intertidal in Chile (Payá, 1989).

In this study I look at the ability of tropical algae in coral reefs to survive the passage though the gut of fishes. If this form of defense is found in the tropics it might play an important roll in algae and herbivore interactions especially because the algal cover is kept low even though morphological and chemical defense is well developed in tropical algae (Hay, 1991). It might be an important form of algal defense and also might contribute to the dispersal of algae in tropical reefs if the herbivorous fish are highly mobile. A different aspect might be important for territorial fishes that protect their own algal mats. For these fishes there might be an advantage to algal digestion survival. In addition to the survival of algae, I examine some nutrient concentrations in fish feces that may enhance algal growth in an otherwise nutrient limited environment.

Methods & Materials

Pilot Study

In a preliminary study I collected one individual each of three species of surgeonfish (Zebrasoma scopas, Naso lituratus, Ctenochaetus striatus) in order to choose my study species from this group of fish. The individuals were kept in separate tanks over night and the next morning their feces were inspected for algae material. From these three species, Z. scopas was selected for the study because algal material was found in its feces. In addition to this species two other herbivorous species: a parrotfish Chlosoeres sordidus and a damselfish Stegastes nigricans were imployed in this study. I also examined one omnivorous species; the triggerfish Sufflamen bursa.

Fish Collection

The study was conducted from the 9th of November to the 3rd of December 2000 at C.R.I.O.B.E. field station in Moorea, French Polynesia, and all fish were collected at two sites
near the station in the lagoon east of Opunohu bay. They were collected from shallow depth (above 5 m) using dip nets. We collected all species but $S. bursa$ at night while they were asleep. The triggerfish were caught the day. Six individuals of $Z. scopas$, two $C. sordidus$, four $S. nigricans$ and two $S. bursa$ were collected.

**Treatment of Fish**

40-liter aquariums were cleaned with fresh water and vinegar to insure they were algal free. The tanks were kept at room temperature which was about 28°C and about 1-2°C higher than the lagoon water the fish were taken from. To get algal free sea water, drinking water of the brand «Tahiti premium water» was mixed with a commercial salt mix for aquariums of the brand «Instant Ocean». The clean sea water was mixed to a salinity of 34S. I dipped the fish in freshwater for 1.5 minutes and then washed them three times in «clean» sea water before they were put in the tanks. The water from the third wash was kept as a control to insure that no algae were introduced into the tanks on the fishes’ surface. All individuals of one species were kept in one tank.

**Feces Collection**

I collected the feces from the bottom of the tanks with a pipette for three days. They were put in open 250 ml clear plastic containers with growth culture «FRITZ F/2» at a concentration of 200 µl/l of each component. Four containers with $Z. scopas$, three with $S. bursa$, and three with $S. nigricans$ feces were put near a window in indirect sunlight. The cultures were kept at room temperature, which was about 28°C in the day and 25°C at night. Salinity in the culture was controlled with a refractometer every day and corrected to 34S with drinking water when it became higher than 36S. The cultures were stirred up once a day to prevent oxygen deficit. The water from the controls was treated in the same way. I inspected the cultures for algal survival and growth at least every second day. Some of the growing algal fragments were kept in separate petridishes to follow their growth.

**Nutrient Measurements**

In addition to the growth experiment, nitrite, nitrate and phosphate were measured in the feces of $S. nigricans$ and $Z. scopas$. «Red Sea Fish PHarm ltd.» aquarium test kits were used to
measure nutrient concentrations. Concentrations were obtained by a visual comparison of colors to a reference chart. Which gave a rough qualitative measurement. The water for taking nutrient measurements was obtained in the following way. One individual of *S. nigricans* was kept for 12 hours over night in two liters of sea water. The individual of *Z. scopas* was kept for 36 hours and its fecal pellets were mixed with 200 ml of sea water. The water and feces were stirred to dissolve the nutrients in the water and filtered through a 0.8 µm filter to remove particulate matter. The sea water that was used to keep the fish in was tested for the same nutrients to control for nutrients already in the water.

**Results**

Algal material was found in the feces of *Z. scopas, S. nigricans* and *S. bursa*. No feces were produced by *C. sordidus*. Their guts may have been empty because of the time of collection. *Z. scopas* feces contained algae, phytoplankton and some sediment. Algal material was very small and no single pieces could be identified without a dissecting microscope. *S. nigricans* feces contained mostly algae and very little other material, algal pieces of considerable size were found (largest about 4 mm). Most identifiable pieces were of filamentous red or brown algal species. *S. bursa* feces consisted mostly of mollusk shells and pieces of crustacean exoskeletons, sediment and some algal material. The algal pieces were rather large (up to 1 cm) and were from filamentous red and brown algae, and from folios green algae. In *S. bursa* feces living fragments of algae were only found in the first two days but after 5 days all fragments had died and no living algae were found after this.

After 7 days of culturing I found macroscopic pieces of algal tissue in the cultures of *Z. scopas* feces. About 1 mm large blade like structures of brown algae were identified (Drawing I). Fragments of this size were not found in the feces before they were put in culture. Also a fragment of filamentous green algae was found. After 10 days, a fragment of brown algae was found that seemed to have regenerated tissue. All tissues were pigmented and therefore photosynthetically active, which I used as criteria for living tissue. These fragments were measured on the 10th day and on the 12th day, but growth could not be determined during this time period. In the cultures of *S. nigricans* feces two large fragments of filamentous red algae
was found on day four. These did not show any growth at this time. Three days later, they had formed new tissue in the form of «sprouts» from the old surviving fragments (Drawing II). These new «sprouts» grew in size over the course of the study.

In the controls of all three species some bacterial and plankton growth was found but it was considerably lower than in the cultures. No macroalgal growth was found in any of the controls.

The nutrient tests showed elevated levels of nitrite (0.1-0.2 ppm) in the feces of Z. scopas, the phosphate (0.1 ppm) and nitrate (2.5 ppm) levels were high but in the upper end of the concentration range of the control. Elevated levels of nitrite (0.2-0.5 ppm) and phosphate (0.2-0.5 ppm) were found in the feces of S. nigricans. The level of nitrate (2.5 ppm) was high but within the nitrate concentration measured in the control. (Figure I).

Discussion

The results of my study show that some tropical algae can survive the passage through the guts of certain species of herbivorous fishes. They are able to regenerate new tissue from fragments of vegetative tissue. These findings show that the phenomenon of algal passage through the digestive tract, which is known from other habitats, is also found in coral reef communities. Survival of digestion has been described as a strategy of defense against herbivores (Hay, 1991). In coral reefs where almost all algal production is grazed down before developing a large standing crop (Hay, 1991) this defense strategy could be even more important for algae than in temperate areas where the algal production is higher than the grazing rate. It also could be an important form of dispersal for algae in coral reefs (Paya, 1988) where fish are the main herbivores, and are much more mobile than invertebrate herbivores of temperate reefs.

Both herbivorous fishes from which fecal matter could be obtained had surviving algal fragments in their feces. Digestion survival in non-territorial species such as Z. scopas can be seen as a form of dispersal. If propagules survive and grow after defecation, as might be suggested by the blade like structure of the algae I found in Z. scopas feces, this form of dispersal can be compared to the development of seed dispersal by animal vectors in terrestrial plants (Hay 1991). In addition to the dispersal advantage from the far range of fish, the higher concentrations of nutrients in the feces increases the chances of surviving algae to grow and get established in an
otherwise nutrient poor environment. In the case of *Z. scopas* survival of algae doesn’t have an apparent benefit for the fish and the passage of undigested algal fragments through the gut could be considered a lost rather than a benefit to the fish because no nutritional value is gained from these fragments. Interestingly the survival and especially the growth of algal fragments in the territorial species *S. nigricans* feces was as high or higher than in *Z. scopas*. Not only the algal survival and growth was higher in *S. nigricans* feces but also nutrient levels were higher than in *Z. scopas* (Figure I).

Previous studies of algal digestion survival focused on benefits algae had from survival in form of defense and dispersal mechanisms (Santelice, 1989; Paya, 1989). *S. nigricans* is a territorial species that «farms» algae and individuals rarely leave their territories. If the fish are not moving very far the mechanism of dispersal does not seem as important. Defense might be an important aspect for the algae growing in territories and losses of tissue could be reduced by surviving digestion (Duffy, 1990). *S. nigricans* protects algal turfs that consist mostly of filamentous red and brown algae, which have a higher standing crop in their territories than in comparable surrounding areas. These turfs collect a lot of organic material and provide a habitat for small invertebrates, which might be used as an additional food source by the defending fish (Choat, 1991). Algal digestion survival in these species might be higher because the fish are not food resource limited. They don’t have to process their food as efficiently as a species that has to forage. Another aspect could be important in this study. Because of its territorial behavior *S. nigricans* returns the surviving fragments of algae to the its own algal mat. It also provides a high nutrient concentration for these fragments in its feces. This could lead to increased algal growth in the individuals territory. This combination could be of a benefit to the fish if the nutrient enriched feces with living algal fragments enhance algal growth in its territory. This leads to the idea that the phenomenon of algal digestion survival is not only an important process in algal life history but also might be of importance to territorial damselfish in respect to their territorial and farming behavior.

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**Literature cited**


Nutrient concentration in the feces of *S. negricans* and *Z. scopas*

![Graphs showing nutrient concentration in the feces of different species](Figure I)
Algal tissue from *Z. scopas* feces

Drawing I
Filamentous red algae fragments with vegetative growth

Drawing I.

Drawing II