The ecosystem role of parrotfishes on coral reefs

Thesis submitted by

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This thesis includes some collaborative work with my supervisor, Prof. David Bellwood, and a reef fish researcher from Brazil, João Paulo Krajewski. While undertaking these collaborations, I was responsible for the project concept and design, data collection, analyses and interpretation, and the final synthesis of results into a form suitable for publication. My collaborators provided intellectual guidance, financial support, technical instruction and editorial assistance.

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Abstract

Herbivorous fishes are widely recognized for their critical importance in coral reef ecosystem processes and in reef resilience. The basis of this role and the specific impact of individual species in different reef habitats, however, remain unclear. The overall goal of this thesis was to provide a better understanding of the impact of herbivores on the benthic community structure of the Great Barrier Reef (GBR). More specifically, this study focused on the influence of grazing by herbivorous fishes, especially parrotfishes, on the structure and dynamics of algal turfs and coral colonies and on the consequences of this activity for reef ecosystem processes.

The basis for the role of parrotfishes in shaping the reef substratum was firstly assessed in Chapter 2 by examining the removal of substratum by different sized parrotfishes. Grazing by six size classes of *Scarus rivulatus* was compared at Orpheus Island, a GBR inshore reef. Individuals in all six size classes strongly selected algal turfs for foraging and rejected other substratum types. However, the size of grazing scars by *S. rivulatus* differed among size classes, with small individuals scraping a greater substratum area per unit biomass while larger individuals removed a greater volume of material per unit biomass. Thus, biomass cannot be viewed as a proxy for ecosystem impact. Per unit biomass, different sized individuals of *S. rivulatus*, and probably other parrotfish species, have a markedly different impact on the reef substratum. These results emphasize the importance of considering the size of individuals when evaluating the role of reef species in ecosystem process.

The specific roles of parrotfish grazing on the dynamics of reef substratum was also assessed by examining the size and dynamics of grazing scars of *Scarus rivulatus* and

Chlorurus microrhinos at Orpheus Island (Chapter 3). These species represent the most abundant scraping and excavating parrotfish species on inshore reefs and differ in jaw morphology and feeding behaviour. *Scarus rivulatus* grazing scars were smaller in area and volume and more rapidly reoccupied by algae than those of *C. microrhinos*. However, because of its higher abundance and feeding frequency, *S. rivulatus* had higher algal removal rates than *C. microrhinos*. These species appear to play distinctly different functional roles in shaping the benthic community of inshore GBR reefs. *Scarus rivulatus* is primarily responsible for algal dynamics dominated by vegetative regrowth, while *C. microrhinos* opens relatively large areas which remain clear for several days. These scars may represent settlement sites which are relatively free from algae and sediment. These results provide new information on the differences between scraping and excavating parrotfishes and emphasize the importance of different functional groups in the structuring of benthic communities on coral reefs.

As parrotfish grazing had direct effects on the structure and dynamics of algal turfs, an experiment was conducted to evaluate the effects of this activity at a broader cross-reef scale (Chapter 4). A combination of herbivore-exclusion cages and transplants of coral rubble covered by algal turfs between reef zones (flat and crest) was used to examine changes in algal turfs over a four day experimental period. In-situ crest turfs had lower algal height, sediment load and particulate content than reef flat turfs. Caged samples on the crest exhibited an increase in all three variables. In contrast, in-situ and caged treatments on the flat presented algal turfs with similar compositions, with high algal height and heavy particulate and sediment loads. In the absence of cages, reef flat turfs transplanted to the crest had decreased algal height, total particulate material and particulate inorganic content, while the opposite was found in crest turf samples transplanted to the flat. These results highlight the dynamic nature of algal turfs and the clear differences in the relative importance of herbivory in shaping both turf length and sediment composition between the reef crest and inner flat.

To assess the impact of parrotfishes on coral colonies across the reef, the abundance, depth and dynamics of parrotfish grazing scars on corals was compared across four reef zones at Lizard Island, a GBR mid-shelf reef (Chapter 5). The abundance of parrotfish grazing scars was highest on flat and crest, with massive *Porites* spp. colonies having more parrotfish grazing scars than all other coral species combined. The density of parrotfish grazing scars on massive *Porites* spp. and the rate of new scar formation was highest on the reef crest and flat, reflecting the lower massive *Porites* cover and higher parrotfish abundance in these habitats. Estimates of the area of massive *Porites* spp. grazed by parrotfishes in one year was highly variable among reef zones, ranging from 1.5% ± 0.6 of total coral area on the backreef to 78.2% ± 56.7 on the reef flat. As the abundance of massive *Porites* spp. was negatively correlated with abundance of grazing scars on these corals, differential grazing across the reef gradient may influence the growth and survival and subsequent distribution of coral colonies among reef zones on the GBR. Overall, parrotfish predation on corals on the GBR is up to 4 - 230 times higher than in Hawaii, Belize and in the Colombian Caribbean. Parrotfish predation on corals may have a more important role on the GBR reefs than previously thought.

Given the possibility that parrotfish grazing may influence the distribution of massive *Porites* spp., a more detailed study was undertaken to examine the relative impact of scraping and excavating parrotfish grazing scars on these colonies among reef zones at Lizard Island. Scraping grazing scars were more abundant in most study sites than excavating scars. Excavating grazing scars were relatively rare but left deeper marks and exposed more coral skeleton than scraping scars. About 70% of excavating scars had some degree of filamentous algal growth in the scar compared to just 5% of scraping scars. Scraping grazing scars on massive *Porites* spp. completely disappeared after two months, while excavating grazing scars remained almost unchanged over this period. Groups of excavating scars were tightly clustered, exposed more coral skeleton and presented higher algal cover than grouped scraping scars. These results highlight the differences between the two parrotfish feeding groups and suggest that they may differently impact coral colonies. The deep, last-long excavating scars probably provide more suitable sites for the settlement of benthic algae and other invasive taxa on coral colonies. In contrast, the abundant and frequent grazing scars of scraping parrotfish may represent a more constant drain on energy supplies for coral colonies. These results highlight the differences between parrotfish species with distinct feeding modes and indicate that they differently impact not only algal communities, but also coral colonies.

Overall, this study found consistent patterns in the effects of parrotfish grazing on the structure of benthic communities on coral reefs, as it provides a general picture of the contribution of different parrotfish individuals and species on algal and coral consumption on GBR reefs. Parrotfishes play a number of unique roles in the removal of algal turfs and coral tissue, with spatial variation in grazing pressure being an important factor shaping the nature of this interaction among reef habitats. Parrotfish activity is focused on the reef crest, where scrapers, especially large individuals, constantly feed on the epilithic algal matrix leading to short algal turfs with low particulate material and reduced sediments. These fishes likewise remove significant quantity of coral tissue in this habitat and may contribute to the low abundance of some coral species in this zone. Unlike many other reef fishes the unusual beak-like oral jaws enable parrotfish to remove algae, sediment and coral tissue. Parrotfishes are one of the few groups that are able to feed on, and change the structure of, almost all coral reef benthic substratum types. In a changing world, where tropical reefs suffer a significant depletion of herbivorous fishes and reduction in coral cover, parrotfish are likely to play an increasedly important role.

Table of Contents

List of Tables

List of Figures