Managing herbivores for their impacts on Caribbean coral reef ecosystems: A summary report for managers and practitioners

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Preface

Caribbean reefs have suffered unprecedented declines over the last several decades due to a variety of factors. Some of the most rapid and dramatic changes occurred following the region-wide die-off of the sea urchin, *Diadema antillarum,* in the mid-1980s, which resulted in the proliferation of algae on many reefs, especially those with few herbivorous fishes. Thirty years later, *Diadema* remain rare in most locations, algae are abundant on many reefs, and there is concern that fisheries targeting herbivorous fishes, especially parrotfishes, are compromising the function of many reef ecosystems. In some locations, such as the Exuma Cays Land and Sea Park, Bahamas, robust populations of herbivorous fishes have been associated with elevated coral recruitment and positive reef trajectories. Yet other reefs, such as those in the Florida Keys, show no signs of recovery despite abundant herbivore populations. The emerging picture suggests that impacts of herbivores on coral recovery are likely to be highly context-dependent, and that management actions targeting herbivores will vary in their ability to facilitate coral persistence and recovery. This document is intended to serve as a guide on how to manage herbivore populations to facilitate healthy, resilient coral reefs. It is based on our current understanding of the processes that structure reef ecosystems, and summarizes information from a larger scientific review (Adam et al. 2015).

Take home messages

- **Herbivory is a key process** on coral reefs that can facilitate corals by excluding algae that otherwise can have negative impacts on coral settlement, growth, and survivorship. These benefits are most effectively realized in cases where other chronic stressors, such as sedimentation and pollution are also limited; **reducing other stressors is also extremely important**.

- The sea urchin, ***Diadema antillarum***, is especially effective at controlling algae and facilitating corals, but many populations have not recovered following the die-off of the 1980s and **high density populations are vulnerable to future crashes.** This creates an ongoing management challenge in maintaining benthic habitat quality on Caribbean reefs.

- **All herbivores are not created equal**. Understanding how different species of herbivores affect reef ecosystems is critical for developing effective management strategies. For example, parrotfishes are effective at controlling algae and facilitating corals but different species of parrotfishes have unique and complementary impacts on reef ecosystems.

- A combination of **species-specific and/or spatial management** of herbivore populations could reduce trade-offs between different management goals, such as sustaining a fishery while also maintaining high grazing rates to control algae and facilitate corals. **Management strategies should be tailored to specific locations** in order to incorporate local ecological and social factors that will impact management outcomes.

- Parrotfishes and other herbivores are attracted to reefs with high levels of **architectural complexity** and help sustain them via the positive impacts of herbivores on coral growth. **Maintaining or restoring architectural complexity is critical for recovering Caribbean coral reefs.**

Executive Summary

Over the last several decades, coral cover on Caribbean reefs has declined precipitously. On many reefs, large structurally complex corals have been replaced by fleshy algae and other non-reef building organisms, resulting in the collapse of physical structure and a reduction in ecosystem services (e.g., coastal protection, fisheries). Ocean warming, coastal development, pollution, overfishing, and the loss of key species to diseases have all contributed to the decline of Caribbean reefs. The herbivorous sea urchin, *Diadema antillarum*, continues to be rare on most reefs since its region-wide die-off in the 1980's, and populations of herbivorous fishes are likely far below historical baselines due to the impacts of fishing and habitat degradation. On many reefs, this has resulted in the proliferation of algae that hinder coral persistence and recovery.

Several management actions can be taken to help increase levels of herbivory on Caribbean reefs in order to reduce algae and facilitate corals. Managing herbivores for their ecological function on reef ecosystems can greatly benefit Caribbean coral reefs, especially if other chronic stressors such as nutrient pollution and sedimentation are also limited. Appropriate fisheries regulations combined with the protection of seagrasses and mangroves can help maintain or recover healthy herbivore populations. In addition, targeted restoration actions aimed at attracting herbivores and concentrating their grazing activity in specific locations may facilitate the recovery of high-value reefs. In order to maximize ecological function of herbivore assemblages, it is critical to understand and distinguish the distinct life-history, diet and behavior of different species of herbivores. By considering the range of functions and interactions of herbivores on reefs, managers can develop strategies that maximize the benefits of herbivores to reef ecosystems while minimizing potential costs to fisheries.

Importance of herbivore diversity and species identity

Parrotfishes (Scaridae), surgeonfishes (Acanthuridae), and the sea urchin *Diadema antillarum* are the most important herbivores for controlling algae on Caribbean reefs. Loss of *D. antillarum* during the 1980's led to increases in macroalgae on many reefs, especially those with few herbivorous fishes. Localized recovery of *D. antillarum* in recent years has greatly reduced the abundance of macroalgae and enhanced coral recruitment on some shallow reefs throughout the region. Management efforts aimed at recovering populations of *Diadema* could therefore be locally beneficial. However, relying on *Diadema* as the primary herbivore in any location is unwise since it would leave reefs vulnerable to future population crashes.

Diadema are especially effective at controlling algae, in part because they scrape the reef substrate clean while feeding, removing all algal tissue and inhibiting algal regrowth. Many parrotfishes also scrape or excavate the reef substrate, but unlike *Diadema*, which has a very wide diet-breadth, parrotfishes and other herbivorous fishes have specific feeding preferences for particular types of algae. As a result, different species of fishes have unique and complementary impacts on algal communities. For example, by feeding intensely on algal turfs, surgeonfishes and parrotfishes in the genus *Scarus* can prevent macroalgae from becoming established. However, because these fish avoid feeding on the mature stages of many species of macroalgae, they are unable to prevent macroalgae from spreading once established. In contrast, parrotfishes in the genus *Sparisoma* frequently feed on mature macroalgae and can prevent established macroalgae from spreading and overgrowing corals, but are less effective at suppressing algal turfs that may inhibit coral recruitment. A combination of species is therefore required to prevent the spread of harmful algae and facilitate coral recruitment and growth.

Parrotfish functional groups

Parrotfishes are the dominant herbivores on many Caribbean reefs and are often treated as a single functional group. However, parrotfishes vary greatly in size, diet and feeding behavior, factors that will shape how they impact benthic communities. For example, large individuals of several species excavate carbonate material while feeding on epilithic algal turfs and endolithic algae. Like *Diadema*, these species contribute significantly to bioerosion of the reef framework while also potentially creating microhabitats suitable for coral recruitment. Other species of parrotfishes crop or tear algal filaments or browse on erect seaweeds and tend not to excavate large amounts of carbonate material. Based on diet and capacity for bioerosion, Caribbean parrotfishes can be categorized into at least three functional groups (see Appendix for list of common names): 1) macroalgal browsers: *Sp. chrysopterum*, *Sp. rubripinne*, and *Sp. aurofrenatum*, which feed on large seaweeds, 2) excavating/bioeroding grazers: *Sp. viride*, *Sc. guacamaia*, and *Sc. coelestinus*, which feed on epilithic algal turfs and endolithic algae, and 3) scraping grazers: *Sc. vetula*, *Sc. taeniopterus*, *Sc. iseri*, and *Sc. coeruleus* which feed primarily on epilithic algal turfs. Macroalgal browsers play an important role in reducing overgrowth and shading of corals by macroalgae and may be important in reducing the abundance of macroalgae on macroalgae-dominated reefs. Scraping grazers and excavating/bioeroding grazers limit the establishment of macroalgae while grazing on epilithic algal turfs and endolithic algae, and create areas of clean substrate for colonization by crustose coralline algae and corals.

Fisheries management

Functional groups provide a framework for managing parrotfish populations for their impacts on reef ecosystems, but species in each functional group will also vary in their susceptibility to fishing. In general, larger parrotfishes such as *Sc. guacamaia*, *Sc. coelestinus*, and *Sc. coeruleus* have life-history characteristics (e.g., slow growth and late onset of reproduction) that make them more sensitive to a given rate of fishing mortality than smaller species such as *Sp. chrysopterum* and *Sp. aurofrenatum*. In addition, species within each functional group are associated with different habitats and target different substrates while foraging. Some species of parrotfishes, such as *Sc. vetula*, are strongly associated with architecturally complex coral reefs, while others, such as *Sp. chrysopterum*, live in a wide range of habitats, including seagrasses and low-relief hard-bottom, which are less important habitats for most corals. In addition, some species appear to feed in areas of a reef that are better for coral recruitment than others. For example, on high relief reefs in the Florida Keys, *Sp. viride* and *Sc. vetula* tend to target substrates with high structural complexity that are likely favorable for coral recruitment, while other species, such as *Sp. chrysopterum* and *Sc. coeruleus* largely target carbonate boulders and unstable coral rubble with high sediment loads that are poor recruitment habitat for most corals. Thus, species commonly targeted in reef fish fisheries, such as *Sp. chrysopterum*, *Sp. rubripinne*, and *Sp. viride* have fundamentally different impacts on reef ecosystems due to differences in their diets and foraging behavior.

Management strategies could be developed that would limit trade-offs between fisheries and conservation goals. These include both species-specific management plans that limit the take of particular species and/or spatial management plans that limit the take of herbivorous fishes on the architecturally complex reefs where they are most likely to benefit corals. The best strategies are likely to vary among locations, and will depend critically on local ecological, social and economic factors. For example, effective spatial management requires detailed information on the distribution of suitable habitat for different species of coral and herbivorous fishes, and knowledge of the movement patterns of herbivorous fishes, information that will not be available in many locations. In addition to fisheries management, there is a strong need to consider other factors that could limit populations of herbivorous fishes, especially the availability of suitable habitat. For example, some species of parrotfishes which live primarily on coral reefs as adults, such as *Sc. guacamaia*, are dependent on mangroves and/or seagrasses as nursery habitat. Maintaining healthy populations of these species therefore requires protecting mangroves and seagrasses from coastal development and pollution.

Coral reef restoration

Like many reef fishes, herbivorous fishes on coral reefs thrive on architecturally complex reefs. Architectural complexity creates shelter from predators but also influences grazing substrate by influencing sediment deposition and the growth of algae. Herbivorous fishes tend to aggregate on architecturally complex reefs, creating hotspots of grazing activity that can facilitate corals by limiting algal growth. While herbivores can help maintain architectural complexity by facilitating reef-building corals, bioerosion by some herbivores (e.g., *Diadema antillarum* and some large parrotfishes) is a major source of carbonate loss on coral reefs that can decrease architectural complexity if carbonate losses are not balanced by new reef growth. In addition, bioerosion may accelerate with increasing global CO_2 emissions and ocean acidification, highlighting the challenges of managing coral reefs in a high CO_2 world. As corals die and reefs begin to erode they may be less likely to house sufficient numbers of herbivores to control algae and facilitate coral recovery. Reef restoration will therefore be most successful on reefs that retain or restore high levels of architectural complexity. On severely eroded reefs, or reefs that have been flattened by human activities, rebuilding architectural complexity will be key for restoring the ecological processes (e.g., herbivory and coral recruitment) necessary to recover resilient, self-maintaining coral reefs. Restoration efforts targeted at specific reefs will be most successful under strong management of the wider seascape that limits chronic sources of coral mortality and protects key functional groups such as herbivorous fishes.

Further reading

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Appendix

Table 1. List of common names, and proposed functional groups of parrotfishes on Caribbean coral reefs

Latin name	**Common name**	**Functional Group**
Scarus coelestinus	Midnight parrotfish	Excavating/bioeroding grazer
Scarus coeruleus	Blue parrotfish	Scraping grazer
Scarus guacamaia	Rainbow parrotfish	Excavating/bioeroding grazer
Scarus iseri	Striped parrotfish	Scraping grazer
Scarus taeniopterus	Princess parrotfish	Scraping grazer
Scarus vetula	Queen parrotfish	Scraping grazer
Sparisoma aurofrenatum	Redband parrotfish	Macroalgal browser
Sparisoma chrysopterum	Redtail parrotfish	Macroalgal browser
Sparisoma rubripinne	Yellowtail/Redfin parrotfish	Macroalgal browser
Sparisoma viride	Stoplight parrotfish	Excavating/bioeroding grazer