Institution: University of Exeter

Unit of Assessment: Biological Sciences

Title of case study: Legislating to protect the ecological function of coral reefs

1. Summary of the impact (indicative maximum 100 words)

Professor Mumby's research on the impact of parrotfish grazing on the resilience of coral reefs has had a direct impact on the management of Caribbean reefs and fisheries. The results of his research have influenced conservation policy across the Caribbean and have led to the Governments of Belize and Bonaire enacting legislation to ban fishing of parrotfish. The work has also motivated the National Marine Fisheries Service (USA) and the Caribbean Fishery Management Council (Puerto Rico and US Virgin Islands) to set annual catch and size limits for parrotfish caught in US Caribbean fisheries.

2. Underpinning research (indicative maximum 500 words)

Professor Mumby (appointed to Exeter in 2002, Professor, 2006-10, and currently on unpaid leave as an ARC Laureate Fellow at the University of Queensland, 2010-15) and his group have been conducting research on coral reef ecology since 1995, publishing over 112 peer-reviewed articles to date. Their research focuses on a number of areas, including the role of herbivorous parrotfish in maintaining reef resilience, and it is the findings of this work that have influenced conservation and management of coral reefs across the Caribbean. Specifically, this research has resulted in new legislation to ban fishing of parrotfishes in two countries (Belize and Bonaire) and new catch and size limits in US Caribbean fisheries.

The critical balance between macroalgae and corals in reef ecosystems has been disturbed in recent years as a consequence of both natural (e.g., hurricanes) and anthropogenic perturbations (e.g., climate change, over-fishing, pollution) with many Caribbean reefs experiencing a shift from coral to macroalgal dominance. Algal-dominated reefs offer few benefits to people and can be self-reinforcing because macroalgae negatively impact coral recruitment, growth, and fecundity. Grazing by herbivorous fishes and urchins limits the growth and spread of macroalgae, and enhances the recovery of coral populations following disturbance, leading to an overall increase in reef ecosystem resilience.

The link between conservation of herbivorous parrotfish and coral recovery was made by Mumby's group in several steps. First, studies of no-fishing reserves revealed that fishing effects on parrotfish abundance heavily outweighed other controls such as natural predation [1]. A reduction in fishing led to a doubling of fish grazing and four-fold reduction in macro-algal abundance. The reduction of macro-algae led to a linear increase in the density of coral recruitment [2], suggesting that coral recovery could accelerate with management of parrotfish exploitation. This was confirmed three years later by studying the dynamics of Bahamian coral reefs after a major disturbance; reefs with less algae exhibited net recovery whereas those with more algae experienced continued decline. These ecosystem-scale studies were supported by mechanistic, experimental investigations of the effects of algae on coral recruitment, growth and fecundity.

The empirical studies described above were used to parameterise a simulation model of Caribbean reefs which allowed a wider range of scenarios to be explored including pollution and climate change impacts [3-5]. These studies have provided clear evidence that protection of parrotfish can have long-lasting benefits despite the diversity and intensity of external disturbances. In some

cases, local conservation of parrotfish can buy 40 years for reefs to adapt to climate change. Even the subtleties of conserving the nursery habitat of parrotfish [6] can have profound (albeit non-intuitive) benefits to reef resilience. Subsequently, the models developed by Professor Mumby's group have been adapted by other researchers for use in other reef ecosystems outside the Caribbean.

3. References to the research (indicative maximum of six references)

Evidence of the quality of the research: this work has been published in high quality peer reviewed journals.

1. **Mumby, P. J**., C. P. Dahlgren, A. R. Harborne, C. V. Kappel, F. Micheli, D. R. Brumbaugh, K. E. Holmes, J. M. Mendes, K. Broad, J. N. Sanchirico, K. Buch, S. Box, R. W. Stoffle, and A. B. Gill. 2006. Fishing, trophic cascades, and the process of grazing on coral reefs. **Science** 311:98-101. *Citations: **272**, featured study of a review in TREE by Hughes et al 2008.*
2. **Mumby, P. J**., A. R. Harborne, J. Williams, C. V. Kappel, D. R. Brumbaugh, F. Micheli, K. E. Holmes, C. P. Dahlgren, C. B. Paris, and P. G. Blackwell. 2007. Trophic cascade facilitates coral recruitment in a marine reserve. **Proceedings of the National Academy of Science, U S A**, 104:8362-8367. *Citations: **129***
3. **Mumby, P. J**. 2006. The impact of exploiting grazers (Scaridae) on the dynamics of Caribbean coral reefs. **Ecological Applications**, 16:747-769. *Citations: **115**.*
4. **Mumby, P. J**., A. Hastings, and H. J. Edwards. 2007. Thresholds and the resilience of Caribbean coral reefs. **Nature**, 450:98-101. *Citations: **192**.*
5. Hoegh-Guldberg, O., **P. J. Mumby**, A. J. Hooten, R. S. Steneck, P. Greenfield, E. Gomez, C. D. Harvell, P. F. Sale, A. J. Edwards, K. Caldeira, N. Knowlton, C. M. Eakin, R. Iglesias-Prieto, N. Muthiga, R. H. Bradbury, A. Dubi, and M. E. Hatziolos. 2007. Coral reefs under rapid climate change and ocean acidification. **Science** 318:1737-1742. *Citations: **982**, won Thomson-Reuters award for high citation.*
6. **Mumby, P. J**., A. J. Edwards, J. E. Arias-Gonzalez, K. C. Lindeman, P. G. Blackwell, A. Gall, M. I. Gorczynska, A. R. Harborne, C. L. Pescod, H. Renken, C. C. C. Wabnitz, and G. Llewellyn. 2004. Mangroves enhance the biomass of coral reef fish communities in the Caribbean. **Nature**, 427:533-536. *Citations: **342**. Most heavily cited paper on mangroves since 1972*

4. Details of the impact (indicative maximum 750 words)

A major focus of Professor Mumby's research is the key role of herbivorous parrotfish in maintaining reef resilience, and it is this work that has had the greatest impact on the conservation and practical management of Caribbean coral reefs. Specifically, this research has resulted in new legislation to ban the fishing of parrotfishes in two countries (Belize and Bonaire) and has played a significant role in the introduction of new catch and size limits in US Caribbean fisheries.

In 2005, Professor Mumby was invited to give a presentation at the Fisheries Department in Belize where some of the first results highlighting the importance of grazers to reef health and reef resilience were presented. The Chair of the Belize Fishing Cooperative attended the meeting and requested the same presentation be given to fishermen and women. Over 170 fishers attended the meeting and upon hearing the results queried why parrotfish were not protected, given that they have such an important role in reef health. The fishers voted almost unanimously to make a recommendation to the Fisheries Department that parrotfish be protected in Belizean waters. This recommendation, combined with the research into the importance of parrotfish for reef health and

the Wildlife Conservation Society (WCS) programme of fisheries catch data (section 5; source 1), led to the Government of Belize enacting legislation to ban fishing of parrotfishes in 2009 (section 5; source 2).

Over a number of years, Professor Mumby has conducted research on the reefs of Bonaire, Netherlands Antilles, and during his visits to the island gave numerous outreach presentations to the Bonaire Marine Park staff and public, with his collaborator, Prof Robert Steneck. In addition, Professor Mumby contributed to a number of annual reports for the Bonaire Marine Park on the state of the reefs (section 5; source 3). During these presentations and reports, parrotfishes and their importance in enhancing reef health and resilience were frequently discussed. Mumby's publications that detailed how a reduction in fishing mortality of grazers could benefit reef health were a key part of the initial proposal recommending a ban on fishing parrotfishes in Bonaire, which was presented to the Environment Department (section 5; source 4). These activities fed directly into a change in policy that resulted in the Government of Bonaire enacting legislation to ban the fishing of parrotfishes in 2010 (section 5; source 5).

In October 2011, the National Ocean and Atmospheric Administration (NOAA), the National Marine Fisheries Service (NMFS), the Southeast Regional Office (SERO) and the Sustainable Fisheries Division (F/SER2) of the US Government released a Biological Opinion on the continued authorization of the Reef Fish Fishery within the US Caribbean, Puerto Rico and the US Virgin Islands (section 5; source 6). In assessing the status of the reefs and the impact of the Reef Fish Fishery on reef health in the US Caribbean, the Biological Opinion drew heavily on research conducted by Professor Mumby and colleagues. Ten publications were cited which detailed the links between macroalgae and reef health, fishing mortality and parrotfish abundance, and fishing mortality, levels of grazing and reef resilience. While the authors of the Biological Opinion acknowledged the importance of grazers in enhancing reef health and resilience, the decision was taken to introduce Annual Catch Limits (ACL) for herbivorous species (including parrotfishes) within the US Caribbean, rather than introducing an overall ban.

In January 2012, the environmental law firm, Earthjustice, on behalf of the Center for Biological Diversity, challenged NOAA, NMFS, SERO, F/SER2 for failure to comply with the Endangered Species Act in managing the US Caribbean Reef Fish Fishery. Earthjustice filed for a judicial review of the 2011 Biological Opinion, which authorised the continuation of the Reef Fish Fishery in Puerto Rico and the US Virgin Islands (albeit with catch limits for herbivorous species). The lawsuit stated that the Biological Opinion did not go far enough and should have recommended a ban on fishing herbivorous fishes, in particular parrotfishes, in the US Caribbean in order to protect critical habitat for *Acropora palmata* and *Acropora cervicornis* (two coral species listed on the endangered species act). In their review of the Biological Opinion, Earthjustice drew heavily on Professor Mumby's research, highlighting the importance of parrotfishes in enhancing the recovery and resilience of coral reefs (section 5; source 7). On 30th Sept 2013 the Federal District Court in San Juan, Puerto Rico ruled in favour of Earthjustice (section 5; source 8).

Currently, the Caribbean Fishery Management Council is proposing to implement size limits for parrotfish caught within US Caribbean Fisheries (section 5; source 9). The Council drew heavily on Professor Mumby's work in assessing the need for size limits within the fishery and it was the main scientific study cited in a presentation to policy makers (section 5; source 10).

5. Sources to corroborate the impact (indicative maximum of 10 references)

Belize

1. Communication from the Country Director, Wildlife Conservation Society, Belize.
2. Statutory Instrument No. 49, Fisheries (Nassau Grouper & Species Protection) Regulations, 2009, Belize.

Bonaire

3. Steneck, R.R., Mumby P. and Arnold S. (2007) A Report on the Status of the Coral Reefs of Bonaire in 2007 with Results from Monitoring 2003 – 2007
4. Communication from Bonaire National Marine Park Manager, Bonaire.
5. Island Resolution No. 15 - Nature, The Executive Council of the Island Territory of Bonaire, 2010.

NOAA Biological Opinion / Earthjustice Lawsuit

6. Endangered Species Act – Section 7 Consultation – Biological Opinion, NOAA, October 4th 2011. Cites Mumby p.217
7. Communication from Staff Attorney, Oceans Program, Earthjustice, San Francisco, CA.
8. Lawsuit document - complaint for Declaratory and Injunctive Relief, Earthjustice, January 30th 2012. Refers to the Biological Opinion.

Caribbean Fishery Management Council

9. Caribbean Fishery Management Council - Public Hearings and Scoping Meeting Agenda, July 2012.
10. Powerpoint presentation detailing the case for setting size limits on parrotfish caught within the US Caribbean.