Assessing the impacts of tourism on sediment feeders in coral reefs: A study of opportunistic sediment feeders on the Great Barrier Reef

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Abstract

To further our understanding of the impacts that human disturbances have on coastal coral reef diversity, we compared the behavior that marine fauna exhibit in response to disturbance events in the shallow reefs off the shore of Heron Island in Queensland, Australia. Data was taken at two beaches on the island. One site that was relatively frequently disturbed by humans, the harbor, and one site that was relatively removed from human activity, research beach. There was a significant difference in organisms’ responses to disturbance events between the two beaches (p=0.001). An average of 12.8 (± 2.77) fish were observed per disturbance event in the harbor, and an average of 4.4 (± 1.34) fish were observed per disturbance event at research beach. The species diversity observed at each site was different as well. The harbor and research beach yielded Shannon-Weiner diversity indices of 2.04 and 1.12 respectively. The findings of this study support the claim that species diversity and richness in coral flats is aided by a certain level of anthropogenic disturbance. This knowledge can be used to establish more accurate and helpful guidelines for coral friendly tourism.

Keywords

Opportunistic feeders, global tourism, coral reefs, anthropogenic disturbance, biodiversity, intermediate disturbance hypothesis

Introduction

Tropical oceans are home to the most species dense ecosystems on earth (Knowlton 2010). The productivity and biodiversity of these ecosystems can be attributed entirely to coral reefs (Cocker 2014). From protecting coastal areas from degradation due to extreme weather events, to providing myriad reef inhabitants with shelter and food, to supporting over a quarter of all marine animal species at some point in their life cycles, coral reef ecosystems are of the utmost importance in keeping our oceans healthy and stable (Spalding 2001). In addition to supporting marine life, coral reefs are of notable economic value as well. These ecosystems are one of the largest nature-based tourist attractions, and the economies of over 100 different countries and territories are supplemented by tourists visiting their reefs (Spalding, 2017). The Great Barrier Reef (GBR) off the coast of Australia attracts millions of domestic and foreign tourists each year (Goldberg 2016). While GBR tourism provides tens of thousands of Australians with jobs and adds billions of dollars annually to the Australian economy, the stresses of human caused reef disturbance, compounded with other natural and anthropogenic stressors such as the rise of ocean temperatures and cyclones, has led to dramatic declines in coral cover in this area (Goldberg 2016, Wilson 2008). When compared with large scale threats to coral such as mass bleaching events, or a typhoon, the effects of tourists and divers polluting and disturbing reefs may seem diminutive; however, the constant and ever-increasing rate of interactions that humans have with coral ecosystems impedes the reef’s ability to recover from larger scale disturbances (Pascale 2005).

The current rate of human interaction at most coral reef tourist destinations far supersedes the healthy limit for reef health; however, the intermediate disturbance hypothesis (IDH) suggests that our coral reefs may be able to benefit from a certain level of human disturbance (Aronson & Precht; Goldberg et al.). The IDH finds that species diversity is greatest when there is an intermediate ratio between disturbance and dynamic stability in an ecosystem (Connell 1979). When disturbance is too low, the dominant species will exclude other competition, when it is too high it will lead to a local extinction, but when disturbance is just right - at an intermediate level - species competition and ecological niches in an ecosystem thrive and species diversity is promoted (Dial 1998). Research has shown that the IDH is exemplified in coral reef diversity on entire reefs after large scale natural disturbances; however, there have been few studies looking to see if the IDH applies to smaller scale anthropogenic disturbances in coastal coral outcroppings and the organisms that dwell within them. (Aronson & Precht 1995). The supply of food in the shallows of a coral reef ecosystem can vary depending on several factors such as disturbance frequency and the nutrient and algal content in the biofilm on the surface of the benthic sediment (Canicci et al. 2007). It is known that sediment feeders and planktivores in these areas of reef systems benefit greatly from sediment mixers such as sea cucumbers, rays, and turtles (Teed et al. 2020). These animals disturb the benthic layer of sand as they search for food, and in doing so they introduce more nutrients to the top layer of the soft sediment sea floor and into the water column for other trophic feeders to then feed on (Leventon 1995). These bioturbation events are unpredictable, yet the opportunities they provide for sediment feeders and planktivores have led to a behavioral trait in which these species respond to disturbances in the substratum for the purpose of feeding (Glasby & Kingsford 1994). Furthermore, it has been observed that significantly more of these types of fish live in disturbed areas than in undisturbed areas and their feeding rates were higher in disturbed areas (Glasby & Kingsford 1994).

Benthic disturbances created by wildlife in the sediment can be relatively similar in nature to the disturbances made by humans interacting with shallow coral reefs. For example, a stingray digging a feeding pit creates a similar cloud of sediment that a snorkeler's fin might produce as they swim over sediment. To that end, this study focuses on the behavior of reef fish in response to anthropogenic disturbances in the sandy shallows of a coral reef flat. Heron Island, a small island with a research station and a resort is where our study took place. To measure the different levels of response after a disturbance event, this study was conducted at two different sites: one site that is heavily frequented and disturbed by visitors on the island – the harbor – and one site that is relatively undisturbed by humans – research beach. We predict that there will be a larger response to disturbance events and that species diversity will be higher at the heavier trafficked area.

Materials and methods

Study Site

To accurately assess the different behaviors fish exhibit in reaction to a disturbance event, this study was conducted at two different beaches on Heron Island in Queensland, Australia. Both sites required a relatively high density of coral, but only one site was to undergo high levels of daily human disturbance, while the study required that other site was to experience little daily disturbance (Fig. 1). The harbor, located on the western tip of the island, is frequented by reef walkers, swimmers and snorkelers from the resort, island staff and the research station, and there is abundant coral cover in this area. This location was selected as the more disturbed site. The undisturbed area selected was Research Beach which is on the south side of the island and is seldom visited by resort guests. This section of beach is mostly used for research purposes and experiences much lower levels of daily disturbance compared to the harbor.

Data collection

Data was collected using five “GoPro Hero 9 Black” cameras positioned next to five different coral outcroppings at each study site. Each camera was fastened to the neck of a hammer using a zip tie so the cameras would remain upright and in one place on the sand for the duration of the trials. Each camera was put on 1080 resolution with 30 FPS, Linear+HL zoom, and the HyperSmooth setting at Boost. They were positioned next to a coral outcropping of at least two metres in diameter. Five of the researchers angled their camera so that the edge of a coral outcropping and about half a metre of the sandy floor were in frame. Once the cameras were in place, the sixth researcher, using a snorkel and mask, checked the position of each camera under the water to ensure the desired structures were in frame. When all the cameras were positioned correctly, a designated timekeeper counted down from five while the remaining five researchers waited by their cameras to start the videos. When the count reached zero, the videos were all started simultaneously. The timekeeper kept track of how much time had passed using their personal waterproof wristwatch. The first five minutes of the video was a period of rest to reset the areas back to undisturbed conditions without the effects of the researchers’ setup procedure. The next five minutes was a control period where no disturbances were made by the researchers. After the control period, five researchers created disturbance events in front of their camera and coral outcropping by swiftly rotating a dive slate back and forth 90º in the sand five times roughly ⅓ of a metre from the coral outcropping in frame, and ⅓ of a metre from the camera lens. After creating the disturbance, each researcher stepped back and made sure not to influence the disturbed area any further as the sediment cloud settled back onto the sea floor. The disturbance events were created in this way every two minutes after the control for a total of five disturbance events per researcher. The cameras were then shut off and this entire process was repeated at site number two.

Data Analysis

The GoPro footage was downloaded onto the researchers' personal computers for analysis and species identification. The first five minutes of each trial were not considered. Any organism caught on camera in the remaining footage was counted and identified using *Field Guide to Marine Fishes of Tropical Australia and South-East Asia Fourth Edition* published by Gerald R Allen (Allen 2009). The species and trial in which each organism was observed in the footage was noted on a spreadsheet. Any unidentifiable organism observed was noted as such. All organisms were counted upon entering the frame regardless of if it were possible that they had been previously counted.

Statistical analysis

A box plot was created to visualize species abundance at each site using R studio (Fig. 3). A Shapiro Wilkes test was run using this data to test its normality. A Welch's T test was run to quantify the different responses at each site (Fig. 2). Shannon-Wiener diversity indices were calculated to quantify species diversity at each site.

Results

It was observed that the harbor had a denser coral population than research beach. More species and individuals were observed at the harbor than at research beach. Eleven identifiable species and an additional 19 unidentifiable individuals entered the disturbance events during our trials at the harbor. A total of 107 individuals were counted at this site, the majority of which were *D. Melanurus*. Four species and 18 unidentifiable individuals were observed at research beach. Thirty-six individuals were observed throughout all trials this site, the vast majority of which were identified to be juvenile parrot fishes. The data from the harbor yielded a Shannon-Weiner diversity index (SWDI) of 2.04; the SWDI for research beach was 1.12 (Table 1).

There was an observed discrepancy in animal activity between the control periods and the disturbance events (Fig. 3). An average of 12.8 (± 2.77) fish were observed in frame per disturbance at the harbor while an average of 4.4 (± 1.34) fish were observed in frame per disturbance event at research beach. A Welch's T test confirmed a statistically significant difference in fish response to disturbance events between the two sites ($p=0.001$) (Fig. 2).

Tables

Table 1: Shows the species and number of individuals observed at each site; Unidentifiable species are noted as UIF.

Research Beach		Harbor	
Species Name	Total Count	Species Name	Total Count
D. melanurus	*1*	*S. talboti*	1
G. Subdasciatus	*1*	*D. melanotus*	2
C. valentini	*3*	*D. perspicillatus*	2
UIF (juvenile parrots)	13	*G. subfasciatus*	2
UIF (juvenile other)	18	*H. ocellatum*	2
		P. picus	4
		A. polyacanthus	7
		H. trimaculatus	10

		C.caudimacula	12
		P. moulccensis	14
		D. melanurus	32
		UIF	19
Total	36	Total	107
SWDI	1.12	SWDI	2.04

Discussion

There was a significantly larger response to disturbance events in the harbor than there was at research beach. These findings support our hypothesis. Furthermore, species diversity in the harbor was nearly double the species diversity at research beach which strongly supports the principles spelled out in the IDH seeing as the harbor is a far more disturbed area than research beach. In conjunction with the IDH, the higher levels of biodiversity and species richness of small, filter feeding fish observed in the harbor suggest that the level disturbance created by humans in this area is conducive to promoting biodiversity by preventing competitive exclusion without causing local extinctions (Aronson & Precht 1995). One factor that contributes heavily to coral reef resilience is functional redundancy (Bellwood et al. 2003). Our data showed at least 12 different species reacting to the disturbance events in our harbor trials. This further suggests that disturbances from human activities such as snorkeling, boating and reef walking create openings for multiple species to fill similar ecological niches by increasing food abundance in this ecosystem. This paradigm suggests a that a feedback loop potentially exists in which disturbance levels have a direct relationship with resilience in coral reefs. Seeing as our study has supported the claim that a moderate level of disturbance increases biodiversity in coral habitats, a new study would help to determine if human disturbance can directly aid coral reefs' resilience to further disturbances. This study would have implications in addressing the issue of harmful and exploitative tourism in coral reef areas.

This study was conducted in the shallow reef flats on the shore of Heron Island at mid to low tide. It was observed in our data that most of the organisms were small grazing and filter feeding fish that remained within the safety of the coral structures until the opportunity to feed arose by way of our simulated disturbance events. This behavior is indicative of opportunistic filter feeders, many of whom practice central place foraging as a means of avoiding predation (Rilov et al. 2007). On a trial day before the proper study took place, the researchers simulated our study by creating disturbance events at a higher tide in the same study sites and observed minimal reactions by fish at either site. These observations suggest that lower tide levels present certain conditions that are more advantageous for small grazers to take advantage of feeding opportunities. Protection from predators and lower current energy are two strong potential explanations for why these fish did not come out to graze at higher tide levels. An increase in coral biomass would also provide these fish with protection from strong currents and predation. This illuminates a possible pitfall in the study: not only was the harbor a more disturbed site than research beach, but it also had a higher abundance of coral. It is likely that our explanation as to why we saw opportunistic grazers in the harbor was oversimplified to emphasize the role of anthropogenic disturbance on biodiversity. Superior habitat availability, protection from currents and predators *and* increased disturbance all are likely explanations as to why we observed a higher degree of species diversity and richness in the harbor. To finetune our results, it would behoove our research team to attempt a similar study at a location with sites of varying disturbance that have comparable coral cover.

Tourism in coral reefs is an integral part of many coastal nations' economies (Goldberg et al. 2016). It would be unfeasible to entirely phase out this sector of their economies; however, as we are already losing much of our coral to disastrous phenomena brought on by anthropogenic climate change, it is in our best interest as a human race to do anything in our power to mitigate the damage to our coral reefs. As this study has shown, there are benefits and compromises that can be made to achieve the goal of helping our reefs instead of hurting them, while still enjoying their beauty. There are numerous opportunities for further study on the impacts of tourism and human disturbances on coral reefs, all of which could bring us closer to preserving one the world's most important and impactful ecosystems.

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Figure Legends

Figure 1: Arial view of Heron Island with our two study sites marked

Figure 2: T test data showing the statistical significance of the difference in fish reaction to disturbance events

Figure 3: Box plot displaying number of fish per event

Figures

Figure 1

Figure 2

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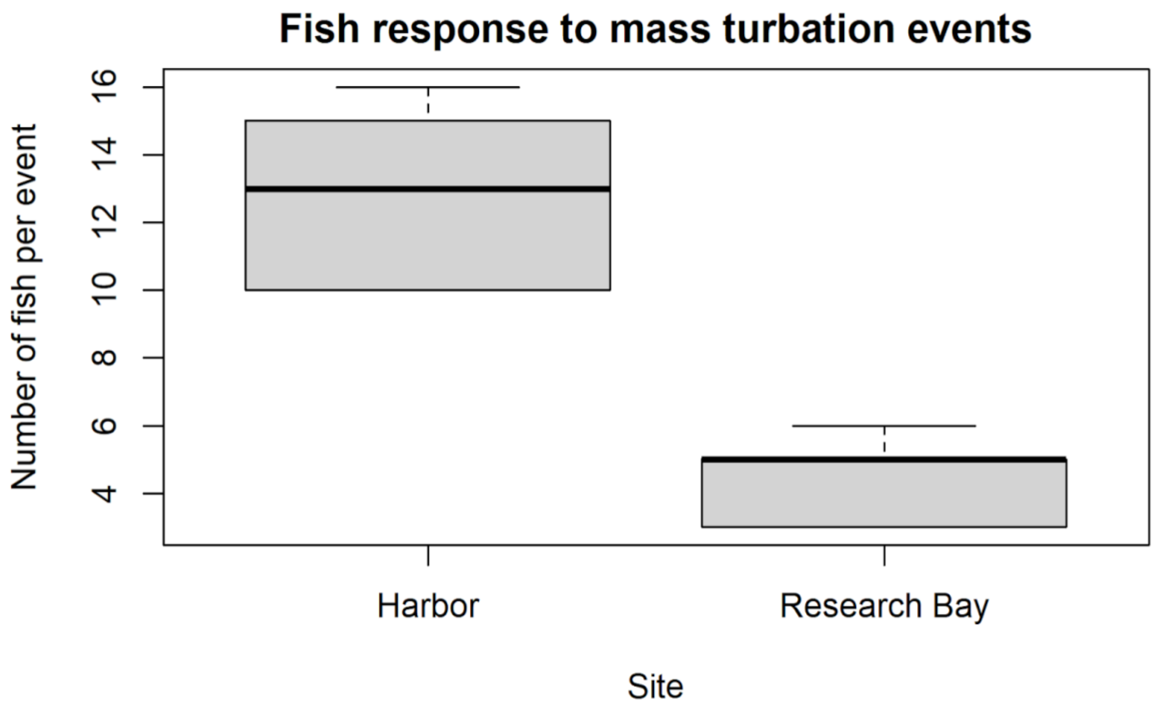
        Welch Two Sample t-test

data:  fish_count by site
t = 6.094, df = 5.7732, p-value = 0.001025
alternative hypothesis: true difference in means between group Harbor and
group Research Bay is not equal to 0
95 percent confidence interval:
  4.994788 11.805212
sample estimates:
      mean in group Harbor mean in group Research Bay
                      12.8                        4.4
```

Figure 3


Fish response to mass turbation events
Number of fish per event
4
6
8
10
12
14
16
Harbor
Research Bay
Site