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Research Article

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Quantification of The Effects of Coral Reef Degradation On Butterflyfish Populations in The Southern Great Barrier Reef

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Abstract
Because of their wide abundance on coral reefs, butterflyfishes' presence or absence can function as an indicator for overall reef health. A survey of both healthy and degraded coral reef flats off Heron Island in Queensland, Australia was conducted to determine the effects of decreasing coral cover on corallivorous fishes. During a four-day period at the end of October, 2013, four species of butterflyfish – two obligate and two facultative corallivorous butterflyfish species – were tallied along two transects in the reef flats. From a total of 291 individuals, there was a significant difference in habitat composition choice between healthy and degraded habitats seen by a p= 2.234e-10. Additionally, means extracted from log-transformed data suggest that the twelve percent decrease in live coral between transects of the healthy habitat caused a disproportionate decrease in fish abundance. This suggests that a minor loss of coral cover can result in a dramatic loss of fish abundance and diversity and may point towards a threshold where living coral can no longer sustain original population abundances of coral reef communities.

Keywords: Coral Composition, Coral Degradation, Chaetodontidae, Great Barrier Reef, Corallivorous, Feeding Guilds, Climate Change

Introduction

Corals act as a foundation species that supply a structurally complex habitat to thousands of reef fish and invertebrates that utilize them for habitat, shelter and food [1-5]. Biological and physical disturbances play a role in determining the structure and dynamics of a coral reef community [6, 7]. These habitats are under increased stress with climate change and longer periods of disturbance. The ability for coral reefs to recover and regenerate from biotic and abiotic perturbations often reflects the overall health of the coral reef [2].

Rapid loss of coral presents colonies challenges with repopulating, raising further problems for corals attempting to combat continued stress [8, 9]. Such stressors can include temperature and pH changes associated with global warming [2, 6,10]. A decrease in size and abundance of healthy reefs is positively correlated with a decrease in diversity of reef fishes, making global climate change problematic beyond the immediate effects on coral [7].

Coral reef fishes are highly selective and have formed niches on specific coral species that allow them to avoid excessive competition [5]. However, as coral fragmentation occurs, corallivorous fishes fail increasingly to successfully compete with generalist species for available food [11]. Among the most dramatically affected fish species are butterflyfish (Chaetodontidae), a family that represents more than one percent of the world's total reef fishes [12]. Due to their prevalence and worldwide distribution, butterflyfish can serve as indicators of reef health and overall fish abundance [13,14].

Butterflyfish are diurnal and primarily benthic corallivorous feeders, depending heavily on extensive networks of coral reefs for protection and food [13]. They can be separated into three distinct feeding guilds: facultative, obligate, and generalist feeders [15, 16]. This study examined species abundance of two facultative butterflyfish, the Threadfin (*Chaetodon auriga*) and the Copperband (*Chelmon rostratus*), which depend upon the coral for shelter but can utilize coral polyps, algae, or substrate as sustenance [16-18]. This study also monitored the abundance of two species of obligate butterflyfish in contrast with the facultative, the Blueblotch (Chaetodon plebeius) and the Chevron (*Chaetodon trifascialis*), that depend upon the coral for shelter and utilize its polyps as their exclusive food source [16-18]. While previous studies have found that minor changes in reef ecosystems translate to severe effects on highly specialized fish such as obligate corallivorous butterflyfish, this study sought to quantify the difference in butterflyfish abundance and distribution based on coral degradation and fish guild and monitored fish populations by guild in two distinct sites on Heron Island [18]. We hypothesized that facultative butterflyfish would be found in higher abundance in the more degraded reef while obligate and facultative would be equally prevalent in the healthy reef.

Materials and Methods

Establishing Transects

Four species of corallivorous butterflyfish were tallied to determine their abundance in the reef flat surrounding Heron Island in Queensland, Australia (23°44’20” S, 151°91’40” E) (Fig. 1). In order to determine population density and distribution, two transects were established, one at Shark Bay and the other at the Gantry. Shark Bay was considered the degraded site as it featured high algal overgrowth on dead coral, whereas the Gantry was used as the healthy habitat where live coral cover was extensive. Along these transects, C. auriga, C. rostratus, C. plebeius, and *C. trifascialis* were counted. The first transect started 100 meters from shore and the second was placed 150 meters from shore. The distance to shore was determine by the high tide mark. Each transect was marked with pink flagging tape and yellow stakes, and both ran for 50 meters parallel to the shoreline [5, 14, 19].

Figure 1: Four transects were used to quantify butterflyfish abundance and distribution, two at each the degraded site and at the healthy site. The image shows the high concentration of coral at the Gantry as opposed to the sparse coral coverage at Shark Bay, as well as the direction and location of the four 50 meter transects (“Heron Island, Queensland, Australia”).

During all available diurnal high tides, two study members swam at the water’s surface five meters apart along each transect and, using a slate and pencil, tallied the population densities of one species of butterflyfish at a time. We repeated the swim along the length of the each transect four times to tally all four species, identifying them with laminated identification slides and recording fish seen on waterproof slates [14, 20]. Diurnal high tides fell at different times each day and were used to standardize feeding activities across guilds because facultative butterflyfish have been found to feed primarily diurnally whereas obligate butterflyfish are known to be primarily crepuscular feeders [13, 19, 20]. Neap high tides reached an average of 2.4 meters during the four days in which fish were counted, with an average water temperature of 23°C and average visibility of 4 meters.

Establishing Coral Cover

To quantify the coral cover in both of our sites, the two transects from each site were assessed at low tide. Every 5 meters along each transect a 0.5m x 0.5m quadrant was used to survey substrate cover by percentage using the identifiers of live coral, dead coral, sand, and algae [21]. The different substrates were recorded as a percentage and the results for each transect were averaged to give an overall representation of total coral coverage individually along each of the four transects [5, 19, 21] (Fig. 2).

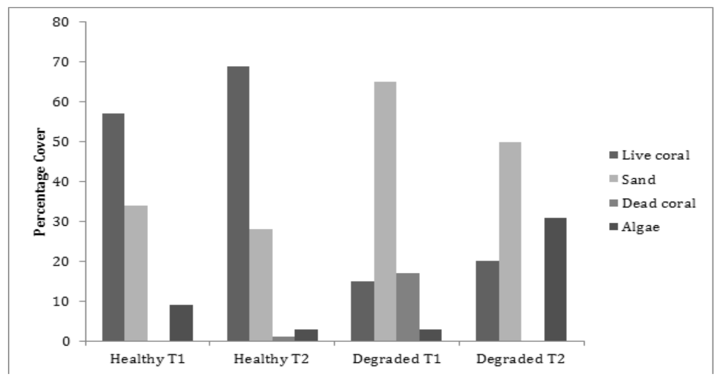

Figure 2: The substrate composition of the two transects at each the healthy and degraded sites is shown against the percentage cover for each of the four substrate types.

Analysis

Normality was tested using histograms to visualize species abundance and coral cover based on location (healthy versus degraded). To test for normal distribution, a Shapiro-Wilk normality test was used and the data were log-transformed before retesting for normality. The Wilcox Ranked Sum test with continuity correction compared the distribution of each butterflyfish species with the location in which it is found (healthy versus degraded) and by the transect at which it is found within each location (transect 1 versus transect 2) to test for significance. Then using a bear package, the means were extracted to determine where the significant differences were within the data. After compiling the means of each species by transect and location, a Pearson’s Chi-squared test was used because of the presence of multiple values to obtain a p-value. With this data, a non-metric multidimensional scaling (MDS) plot was used in conjunction with a principal component analysis (PCA) to determine if there was a clustering of data points explained by a specific axis. The MDS and PCA were plotted using a PRIMER based PERMANOVA in Primer-E version 6.0 and all other statistical analyses were run in R Studio version 0.97.551.

Results

Members of four species of corallivorous butterflyfishes were tallied over four days for a total of 291 fish counted. These fish fell into one of two guilds: facultative and obligate. The two obligate corallivorous species were *C. trifascialis* (Chevron butterflyfish) and C. plebeius (Blueblotch butteflyfish) aptly called "ob1" and "ob2". The two facultative corallivorous species were *C. auriga* (Threadfin butterflyfish) and *C. rostratus* (Copperband butterflyfish) respectfully "fac1" and "fac2". The four species are easily identifiable by distinct morphological characteristics while snorkeling above the substrate.

Originally, all of the species failed the Shapiro-Wilk normality test (p-value < 0.05) until log transformed. After transformations, only *C. auriga* showed normality. Because of the non-normal data, a Wilcox Ranked Sum test with transformed data assigned rankings without requiring a normal distribution for all species. There was a significant difference between overall healthy and degraded habitats, along with all first transects in comparison with the second transects (p <0.05), however there was not a significant difference between transects in the degraded for *C. auriga* and *C. trifascialis* (p >0.05). Both *C. rostratus* and C. plebeius did show significant difference within transects and habitat type (p < 0.05). With the information that transects within the habitats differed, we then used R Studio to extract the means by only location and found that *C. auriga* was significantly more abundant in the healthy habitat (p < 0.05) and within the healthy location there was also a significant difference between the first and second transects (p < 0.05). *C. rostratus* was significantly more abundant in transect two of the healthy location (p > 0.05). The only species with no difference in transects or location is C. trifascialis. Overall abundance showed that generally *C. trifascialis* was generally less abundant which could attribute to the lack of significance.

There was also a significant difference in the average habitat comparison (p > 0.05), which could account for the variation in abundance of each species. For each transect within the healthy habitat, there was not a statistically significant difference in coral cover (p > 0.05), although a graph of habitat comparisons displays a preliminary trend in abundance of species (Fig. 3). The slight reduction in coral cover correlates with a statistically significant reduction in fish abundance. Within the degraded habitat, there was a significant difference among coral coverages (p > 0.05) but there was no difference in fish abundance.

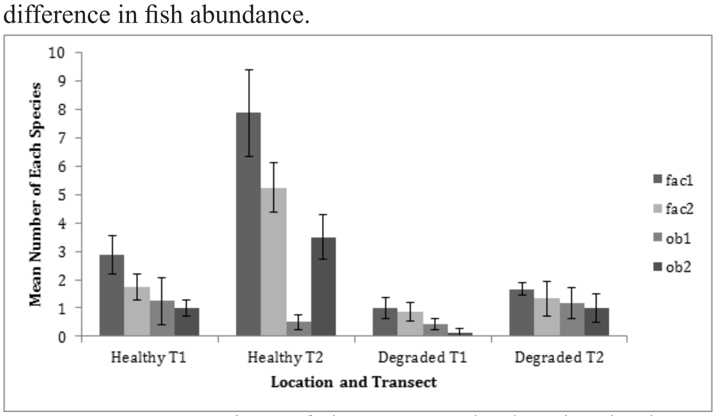

Figure 3: A comparison of the transects by location is shown against the mean number of species of butterflyfish frequenting the site.

The principal components analysis presented a definite shift of facultative fish species, *C. auriga* and C. rostratus, in the direction of the healthy location (Fig. 4). Most of the fish observed in the degraded location are clustered in one area of the graph, displaying the species abundance trends. *C. rostratus* were mainly found in the second healthy transect, and each of the other species showed a trend towards being found in one certain location with the exception of C. plebeius, which was an outlier due to equal distribution. The PC1 axis explained 77.5% of the data, which supports a strong relationship between abundance of fish species and habitat type with transect. Between the healthy and degraded habitats, a statistically significant difference (p = 144 2.34e-10) was found; between healthy transects one and two there was no significant difference (p = 0.1261), but between degraded transects one and two there was found to be a significant difference (p = 2.439e-9).

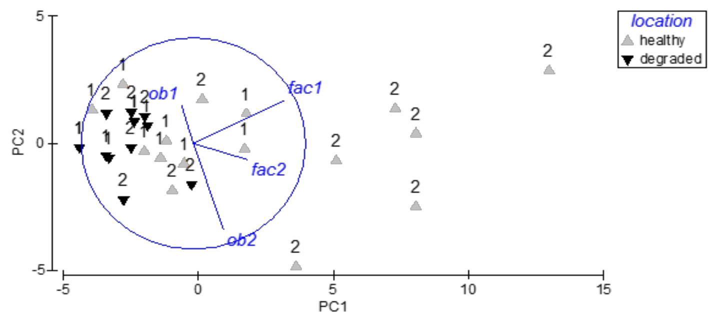

Figure 4: The Principal Component Analysis from Primer 6.0 plots location and transect with relation to species abundance. This graph depicts a definite shift of facultative butterflyfish towards the healthy habitat along PC1, with 77.5% of data being explained by PC1. All species in the degraded habitat are clustered in one direction, and ob2 (Chaetodon plebeius) is an outlier because it is equally distributed between both habitats, resulting in little to no clumping.

Discussion

Previous studies have shown conflicting results regarding butterflyfish distribution. This study demonstrated that butterflyfish abundance is significantly correlated with coral coverage, with facultative butterflyfish appearing more frequently in the healthy habitat and both facultative and obligate guilds appearing in equal abundance in the degraded habitat. The graphs demonstrate clearly the similar species composition and abundance trends in both the transects of the degraded and the first transect of the healthy. This does not support the hypothesis that facultative butterflyfish would have higher population densities in degraded reef while facultative and obligate butterflyfish would appear with equal frequency in healthy reefs. This study demonstrates that facultative butterflyfish are found in significantly higher abundance in both healthy and degraded reef ecosystems, likely due to their increased versatility in feeding ecology, and thus their ability to respond better to certain prey abundances declining [22].

Interestingly, the Chevron butterflyfish (C. trifascialis) demonstrated equal mean distribution between both habitats and was the only fish species to have a not statistically significant difference in distribution between sites. This could be explained by either an overall rarity of this species in the reef flat surrounding Heron

Island, or a stronger effect of coral degradation on this particular species due to possible specialized feeding habits.

A conclusion of greater ecological importance was the sharp decline of fish diversity and abundance associated with minor decline of coral cover, as seen in the difference between butterflyfish populations in transects one and two of the healthy habitat, the Gantry. A twelve percent decrease in live coral translated to a 50% decrease in the number of fish per species, on average. Previous studies found similar results, with coral changes of less than 20% resulting in disproportionate loss of fish life [6, 22]. This finding has crucial implications for the effects of global climate change on the survival of butterflyfishes; as coral reef ecosystems become increasingly fragmented and damaged, butterflyfish populations have severely declined and, in some locations, have disappeared altogether [19, 23, 24].

There was a significant difference in habitat cover between the healthy and degraded habitats corresponding with overall fish abundance. The degraded habitat, Shark Bay, was predominantly sand- and algal-covered and had significantly less fish species and less living coral cover than the Gantry, which was dominated by live corals. Corals in tropical and subtropical environments are currently undergoing phase-shifts from coral-dominated to algal-dominated states (Bellwood et al., 2006). These new states, as observed in the coral composition analysis from our study, lead to changes in fish composition and gradual declines in reef quality. Obligate reef fishes are particularly susceptible to changes in coral architecture in diversity with relation to their abundance and distribution [5]. On the other hand, studies by Prachett et al. and Rendall suggest that omnivorous butterflyfishes must maintain larger territories to obtain sufficient resources [24, 25]. This, in conjunction with the observation that the two facultative butterflyfishes found mainly in the healthy location at transect two supports the claim that coral reef fishes with a varied diet need more resources on healthier reef flats with more nutrients. Conversely this does contradict recent findings that found facultative corallivorous butterflyfish have no significant response to disturbance and greater effects on the obligate corallivores [14].

The relationships between corals and corallivorous fish are important in determining the health of the local environment and general reef degradation. As prevalent species worldwide, butterflyfishes were ideal indicator species to model the decline in total abundance of fish on coral reefs.

As prevalent species worldwide, butterflyfishes were ideal indicator species to model the decline in total abundance of fish on coral reefs. Globally, 20% of coral reefs have already been completely destroyed and 50% are in danger of being destroyed in the near future [10]. In recent years, anthropogenic factors have been especially detrimental to coral health; boat traffic, harvesting fish for consumption, and coral bleaching all cause corals additional stresses that cause portions of otherwise connected reefs to die, fragmenting reef growth and causing a decrease in continuity of shelter for reef fish [10, 16].

The dramatic shifts in substrate coinciding with phase-shifts from healthy to degraded habitats pose a long-lasting threat to not only butterflyfishes, but to the entire ecology of coral reefs. Disturbances, both physical and biological, cause rapid changes in the coral structures leading to dynamic instability in the reef systems on multiple trophic levels [6]. The bottom-up effect of decreased coral cover is already having profound effects on first- and second- order consumers, as well as on predators of higher trophic levels [2, 22]. The differences we observed within community structure, specifically within the healthy habitat transects, although not statistically significant, are indicative of a threshold where the environmental conditions cannot quickly recover [7]. Even with the slight reduction in coral cover between healthy transects there was a decrease in fish abundance and a change in abundance pattern. Although further research needs to be conducted to identify if there is a threshold by increasing the replicates of samples, this study provides insight to the extreme sensitivity of both coral reefs and the fishes that inhabit them and suggests that the health of reefs worldwide faces major challenges in future decades in combating the effects of global warming and the degradation of coral reef ecosystems.

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References
1. Cole AJ, Pratchett MS, Jones GP (2008) Diversity and functional importance of coral feeding fishes on tropical coral reefs. Fish and Fisheries 9: 286-307.
2. Munday PL, Jones GP, Pratchett MS, Williams AJ (2008) Climate change and the future for coral reef fishes. Fish and Fisheries 9: 261-285.
3. Emslie MJ, Pratchett MS, Cheal AJ, Osborne K (2010) Great Barrier reef butterflyfish community structure: the role of shelf position and benthic community type. Coral Reefs 29: 705-715.
4. Cole AJ, Pratchett MS (2011) Effects of juvenile coral-feeding butterflyfishes on host corals. Coral Reefs 30: 623-630.
5. Brooker RM, Munday PL, McLeod IM, Jones GP (2013) Habitat preferences of a corallivorous reef fish: predation risk versus food quality. Coral Reefs 32: 613-622.
6. Wilson SK, Graham NAJ, Pratchett MS, Jones GP, Polunin NVC (2006) Multiple disturbances and the global degradation of coral reefs: are reef fishes at risk or resilient? Global Change Biology 12: 2220-2234.
7. Bauman AG, Feary DA, Heron SF, Pratchett MS, Burt JA (2013) Multiple environmental factors influence the spatial distribution and structure of reef communities in the northeastern Arabian Peninsula. Marine Pollution Bulletin 72: 302-312.
8. Gochfeld DJ (2004) Predation-induced morphological and behavioral defenses in hard coral: implications for coral feeding

butterflyfish. Marine Ecology Progress Series 267: 145-158.
9. Bellwood D R, Hoey AS, Ackerman JL, Depczynski M (2006) Coral bleaching, reef fish community phase shifts and the resilience of coral reefs. Global Change Biology 12: 1587-1594.
10. van der Meer MH, Horne JB, Gardner MG, Hobbes JPA, Pratchett MS, et al. (2013) Limited contemporary gene flow and high self-replenishment drives peripheral isolation in an endemic coral reef fish. Ecology and Evolution 3: 1653-1666.
11. Nagelkerken I, van der Velde G, Wartenbergh SL, Nugues MM, Pratchett MS (2009) Cryptic dietary components reduce dietary overlap among sympatric butterflyfishes (Chaetodonitidae). Journal of Fish Biology 75: 1123-1143.
12. Plaisance L, Kritsky DC (2004) Dactylogyrids (Platyhelminthes: Monogenoidea) parasitizing butterfly fishes (Teleostei: Chaetodontidae) from the coral reefs of Palau, Moorea, Wallis, New Caledonia, and Australia: species of Euryhaliotrematoides n. gen. and Aliatrema n. gen. Journal Parasitology 90: 328-341.
13. Bonaldo RM, Krajewski JP, Sazima I (2005) Meals for two: foraging activity of the butterflyfish Chaetodon striatus (Perciformes) in southeast Brazil. Brazilian Journal of Biology 65: 211-215.
14. Emslie M, Pratchett M, Cheal A (2011) Effects of different disturbance types on butterflyfish communities of Australia's Great Barrier Reef. Coral Reefs 30: 461-471.
15. Pratchett MS (2005) Dietary overlap among coral feeding butterflyfish (Chaetodontidae) on Lizard Island, northern Great Barrier Reef. Marine Biology 148: 373-382.
16. Pratchett MS, Coker DJ, Jones GP, Munday PL (2012) Specialization in habitat use by coral reef damselfishes and their susceptibility to habitat loss. Ecology and Evolution 2: 2168-2180.
17. Pratchett MS (2007) Dietary specialization of coral feeding butterflyfish (Chaetondontidae) on the Great Barrier Reef, Australia. Raffles Bulletin of Zoology 14: 171-176.
18. Pratchett MS, Berumen ML (2008) Interspecific variation in distributions and diets of coral reef butterflyfishes (Teleostei: Chaetodontidae). Fish Biology 73: 1730-1747.
19. Lawton RJ, Pratchett MS (2012) Influence of dietary specialization and resource availability on geographical variation in abundance of butterflyfish. Ecology and Evolution 2: 1347-1361.
20. Gregson MA, Pratchett MS, Berumen ML, Goodman BA (2008) Relationships between butterflyfish (Chaetodontidae) feeding rates and coral consumption on the Great Barrier Reef. Coral Reefs 27: 583-591.
21. Reavis RH, Copus JM (2011) Monogamy in a feeding generalist, Chaetodon trichrous, the endemic Tahitian Butterflyfish. Environmental Biology of Fishes 92: 167-179.
22. Graham NAJ, Wilson SK, Pratchett MS, Polunin NVC, Spalding MD (2009) Coral mortality versus structural collapse as drivers of corallivorous butterflyfish decline. Biodiversity and Conservation 18: 3325-3336.
23. Nicholas AJG, Chabanet P, Evans RD, Simon Jennings, Yves Letourneur, et al. (2011) Extinction vulnerability of coral reef fishes. Ecology Letters 14: 341-348.
24. Pratchett MS, Hoey AS, Feary DA, Bauman AG, Burt JA, et al. (2013) Functional composition of Chaetodon Butterflyfishes at a peripheral and extreme coral reef location, the Persian Gulf. Marine Pollution Bulletin 72: 333-341.
25. 25. Rendall KL (2013) Territoriality of the omnivorous butterflyfish, *Chaetodon auriga* (Chaetodontidae). Environmental Biology of Fishes 96: 961-969.