

**Corallivore Abundance and Biomass and Coral Reef
Degradation in the Line Islands: Christmas Island, Fanning
Island, and Palmyra Atoll**

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Abstract:

This paper seeks a relationship between corallivore abundance and biomass in the Line Islands and coral reef degradation/anthropogenic influence in these locales. Specifically, three randomly chosen sites at each of Palmyra Atoll, Fanning Island, and Christmas Island, were tested. Through six thirty-meter transects, abundance of predetermined *Chaetodon* and *Labropsis* were tallied and run through a GMAV 5 statistical package with an ANOVA analysis to determine significance between islands. However, no significance was observed between islands but was found within the nested sites ($P=0.0133$). Using a biomass equation, abundances were converted into average biomass calculations both by island and site. Again, the differences in biomass were not significant between islands and were skewed by two isolated sites: one each from Site 1 of Christmas Island and Site 4 of Palmyra Atoll. Corallivore biomass, when plotted with live coral cover in the same sites, showed no significance nor correlation. The two outlying sites differ from the remaining locations in their shallow depth (at or less than one meter in depth) and protection from major wave motion and currents. This suggests that corallivores are dependent not on the availability of live coral cover but are limited in their migration scope as small demersal species and thus must live in shallow and protected areas. While the primary food source of these corallivores is nutrient-packed, other lower functionalist groups may have different requirements for continued existence. However, it appears that the corallivores of the Line Islands are impervious to anthropogenic influences in the selected islands.

Introduction:

Today, degradation is a major threat to most, if not all, of the world's coral reef ecosystems. Coral reefs, according to Kleypas et al. (2001), are a unique marine ecosystem in being characterized by a geologic component, the deposition of calcium carbonate by corals, mollusks, foraminifera and algae. Hence, fossil records show significant changes in reef ecosystems over millions of years; some changes have been genetic, while more recent alterations are likely due to anthropogenic inputs. Few, if any reefs, can today be considered pristine. Jackson (1997), among others, showed that over recent centuries, large-scale, rapid changes to coral reef ecosystems have taken place throughout the world. Anthropogenic-induced issues include changes in water temperatures and seawater chemistry, the spread of diseases, removal of species and food web alterations (McClanahan, 2002). In turn, a large ecological reorganization is under way in coral reef ecosystems, which reduces the number of species at

higher trophic levels and increases the number of generalist species of lower trophic levels that are highly adaptable to variable environments. It is likely that non-commercial invertebrates, like sea urchins, starfish, and coral-eating snails, along with smaller demersal fish species, will soon dominate many coral reefs (McClanahan, 2002).

Recent work suggests that the depletion of consumer fishes by exploitation may indirectly modify the structure and function of coral reefs (Roberts 1995; Hughes et al. 2002; McClanahan et al. 2002). Especially, trophic cascades occur in which predator removal correlates with elevated prey abundance, which then influences the base of the food web (He et al., 1993). Pace et al. (1999) reviewed trophic cascades in coral reefs from multiple earlier studies. Dulvy et al. (2004) suggests that predator removal in 13 Fijian islands allowed outbreaks of the crown-of-thorns starfish, a coral predator, indirectly resulting in cascading changes in ecosystem structure and function. Using a fishing intensity index calculated for each island by dividing the human population by the length of the reef front, Dulvy et al. (2004) concluded that large increasing starfish populations occurred at islands with higher fishing intensities and lower predator densities. Also, the authors showed that in areas with higher densities of coral-feeding starfish, repeated benthic shifts allowed the domination by non-reef building organisms in place of previously dominant carbonate accreting reef-building organisms (Dulvy et al. 2004).

To this date, research does not exist regarding the abundance of demersal corallivorous species on the reefs of Palmyra Atoll, Fanning Island, and Christmas Island. Dulvy et al. (2002) assert that a positive correlation exists between starfish abundance and coral reef degradation. However, his research did not inventory corallivorous fish such as *Chaetodon* species, commonly known as Butterflyfishes, a plentiful and diverse group of species. *Chaetodon* and

several other corallivorous species are common in many of the world's coral reef ecosystems, including those along the planned cruise track. To date, no research has quantified the effects of overfishing on corallivorous species and reef degradation in Palmyra Atoll, Christmas Island, and Fanning Island. Thus, although previous researchers have found a link between corallivore abundance and coral reef degradation, the generality of this link assumption has not yet been investigated and requires further research at more sites. Moreover, the Line Islands offer a combination of pristine and exploited reef systems. While Palmyra once had significant military involvement and environment reconstruction, it today is owned by the Nature Conservancy and is experiencing a revival of flora and fauna, both marine and terrestrial, under strict reserve rules. On the other hand, Fanning Island and Christmas Island both have histories of intensive fishing. Today, both islands export shark fins to China and Christmas Island also partakes in the international aquarium fish industry. Also, Fanning Island receives a cruiseship with thousands of passengers once a week. Thus, a gradient of anthropogenic influence and fishing can be seen throughout the Line Islands.

The main objective of this study is to determine the relationship between overfishing and/or anthropogenic influence, corallivore biomass and abundance, and coral reef degradation in the above-mentioned locations. This relationship was evaluated via pre-determined transects of randomly selected areas in the coral reef zones, and a qualitative analysis of anthropogenic involvement to compare with corallivore biomass and reef degradation. Transects inventoried corallivore presence, including length, species, and number. Also, underwater photography data assessed coral reef health throughout the sites.

Since research suggests that anthropogenic inputs negatively affect coral reef ecosystems, I expect to find more coral reef degradation in areas with higher fishing intensity. Likewise, as

found by Dulvy et al. (2004), I expect that corallivorous fish will be more abundant in areas of higher fishing intensity, as will coral reef degradation, in comparison to areas with lower fishing intensity or anthropogenic influence.

Materials:

- Snorkel Gear
- Data Sheet
- Transect tape (to measure length of individual transects)
- Fish measuring stick (length estimation)
- Waterproof pencil

Methods:

Three islands were evaluated: Palmyra Atoll, Christmas Island, and Fanning Island. Three sites were randomly selected at each island with six replicate thirty-by-four meter transects conducted at each site. In Christmas the three sites consisted of Clam City ($1^{\circ} 56.417' N \times 157^{\circ} 29.214' W$), Cook Island ($1^{\circ} 57.580' N \times 157^{\circ} 29.053' W$), and Paris Point ($1^{\circ} 56.424' N \times 157^{\circ} 29.357' W$). The three sites in Fanning Island were Norwegian Cruise Lines mooring ($3^{\circ} 51.786' N \times 159^{\circ} 22.170' W$), Whaler's Anchorage ($3^{\circ} 54.605' N \times 159^{\circ} 23.477' W$), and a mooring south of the lagoon channel ($3^{\circ} 50.506' N \times 159^{\circ} 21.640' W$). The three sites in Palmyra were Tiger Shark Point ($5^{\circ} 52.255' N \times 162^{\circ} 06.612' W$), NW of channel ($5^{\circ} 52.622' N \times 162^{\circ} 06.993' W$), East of Tiger Shark Point ($5^{\circ} 52.171' N \times 162^{\circ} 06.701' W$), and Coral Gardens.

As transect is run, the number and size of each corallivorous species present was marked in a tally format. Photographs of reefs were utilized to assess coral reef damage. A concurrent

study by Laure Katz information assessed total fish biomass and apex predator biomass at all of the above sites. Data was analyzed using analysis of variance (ANOVA), in the GMAV 5 statistical software, to compare corallivore abundance between sites and islands in Palmyra Atoll, Christmas Island, and Fanning Island. Our ANOVA model used randomly chosen sites nested in the three islands, with six random replicate transects at each site. The possible development of a trophic cascade effect was assessed, in which a decrease in the abundance of one species creates an increase in the abundance of lower-trophic-level species.

Data consists of fish species counts and size estimated for each transect at each research site. These counts were grouped by estimated length in five centimeter increments. Counts were added and averaged for each location to compare between islands. Using Pauly and Froese's (1999) Biomass equation, total corallivore biomass was calculated. This equation; $W=asL^b$, with a and b as length-to-weight constants, was attained through FishBase's online database of fish information. Also, the relationship between corallivore biomass and coral degradation was assessed using the photographs and live coral cover analysis attained by fellow researcher Noah Hawthorne.

Results:

Throughout the three islands, eleven species of corallivorous fish were observed: ten *Chaetodon* species and one *Labropsis* species. The differences in the abundance of corallivorous fish was not significant between the islands. In Christmas Island, an unusually high twenty three Threadfin were seen totaled over the three sites. Also, the Wedge-tailed Wrasse, the only non-*Chaetodon* species, was seen but twice in all transects. The Reticulated butterflyfish, *C. trifascialis*, was seen in some of the selected research sites but never during a transect.

	Christmas	Fanning	Palmyra	
Bennett	3	1		0
Ornate	4	4		15
Raccoon	4	2		6
Meyer's	6	2		0
Saddled	8	3		8
Oval	7	2		5
Chevron	1	6		4
Wedge-tailed Wrasse	1	0		1
Teardrop	0	2		0
Lined	0	3		1
Threadfin	23	5		7

Figure 1: Total corallivore species observed at each island.

This analysis shows that, although corallivore abundance between islands is not significant, species abundance is extremely site-specific, with site being significant ($P=0.0133$). For example, Christmas Island Site #1, Clam City, represents an extreme outlier in the data set (Fig. 3). Total abundance data was used for the ANOVA analysis as well.

Source	SS	DF	MS	F	P	F Versus
Island	20.2593	2	10.1296	1.11	0.3890	Si(is)
Site(island)	54.7778	6	9.1296	3.07	0.0133	RES
Residual	134.0000		45	2.9778		
Total	209.0370		53			

Figure 2: ANOVA total abundance data sheet, including degrees of freedom for nested island sites.

Using the above-discussed biomass equation, corallivore abundance was translated to corallivore biomass for further analysis. For the purposes of analysis, a fourth site was included from Palmyra. The Coral Gardens data, gathered by fellow researcher Laure Katz, consisted of fifty meter transects and was scaled to match the thirty meter transects of corallivore counts. Of the ten sites for which biomass was calculated, two represent significant outliers from the rest of the data. Clam City (Site 1) at Christmas Island and Coral Gardens (Site 4) from Palmyra Atoll deviate greatly from the rest of the sites (Fig. 3). The average biomass of the eight remaining sites is 110.1405 grams, while Clam City and Coral Gardens have site biomasses of 1488.297

grams and 683.5273 grams, respectively. These two sites were shallower and more wave-protected than the majority of the other sites.

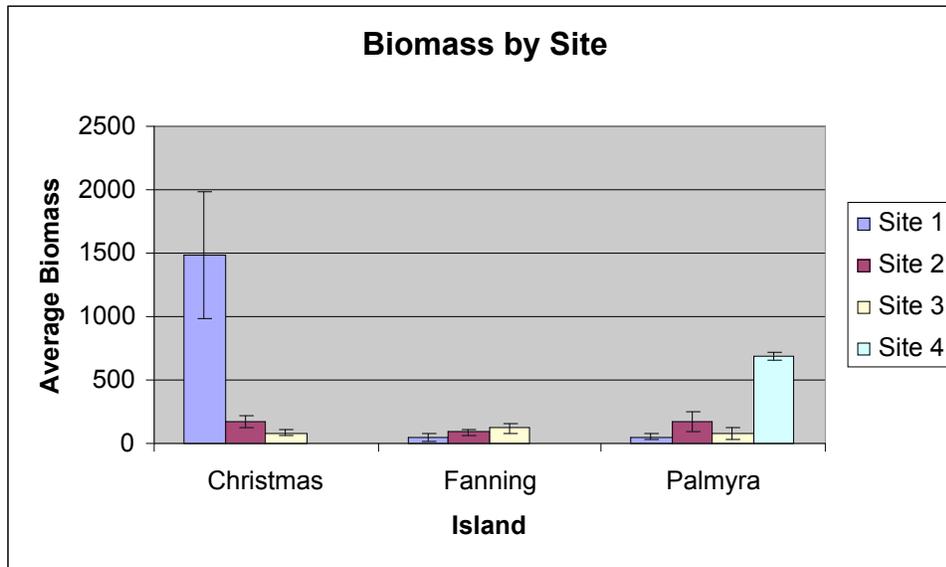


Figure 3: Average biomass by site, between islands, with standard error bars

Using the coral cover data of fellow researcher Noah Hawthorne, corallivore biomass was correlated with live coral cover in nine sites. Coral Gardens data replaced my Palmyra site number three to match with the coral cover data. Average biomass does not correlate with live coral cover, again emphasizing the between-site variability.

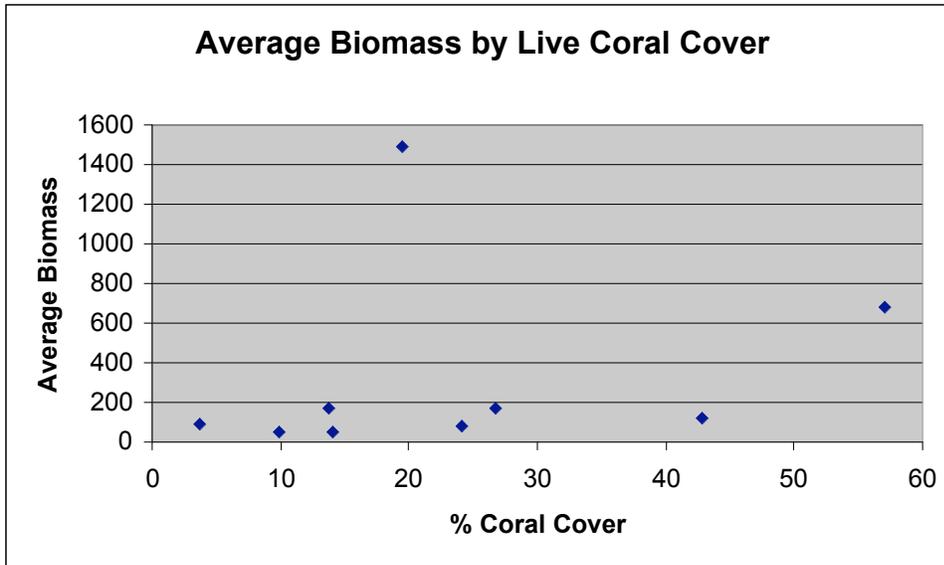


Figure 4: Average biomass of each site correlated with percent live coral cover at same site.

Discussion:

Although eleven different species of corallivores were noted in transects throughout the Line Islands research locations, the differences in species abundance were not significant and in fact were skewed by two outliers. At Palmyra, an unusually high fifteen Ornate (*C. ornatissimus*) were counted, while at Christmas Island, twenty-three Threadfin (*C. auriga*) were found in a total of six transects. Most likely, these results are also site specific, and represent more isolated anomalies than important or significant patterns. Overall, corallivore abundance in all sites was relatively low when visually compared to overall reef fish biomass in the selected areas. However, these results too are site specific: in some transects, no corallivorous fish were counted, while in others, small groups of *Chaetodons* skewed abundance results. Barring the two above-mentioned outliers, total counts of species in an island ranged from one to eight-in total, a definitively small range of corallivores.

Multiple analyses show that differences in both corallivore abundance and biomass are site specific and are not significant between islands. Interestingly, the randomly chosen sites

represent very different coral reef habitats, as do the histories and current states of each island. After running analyses, it became apparent that both of the proposed hypotheses were proved false. Corallivore abundance and biomass are not dependent on the percent of live coral cover in a given site. As shown in Figure 4, Coral Gardens has 57.06% live coral cover and an average corallivore biomass of 683.53 grams. Interestingly, Clam City at Christmas Island, with only 19.41% live coral cover supports an average corallivore biomass of 1488.30 grams. Thus, a gradient of corallivore abundance is seen regardless of the percent live coral cover, suggesting that corallivores such as the *Chaetodon* species may not be limited by a relative shortage of available coral for eating. It is possible that their primary food source is so densely nutritious that they require a relatively scarce amount of live coral cover to survive and only trivially decimate the coral cover in their habitat.

Likewise, plotting biomass by site proves the importance of site selection, rather than island composition. The outliers at Clam City (Christmas Island) and Coral Gardens (Palmyra Atoll) are different from all other sites: average depth is much shallower (see appendix) and the reefs are largely wave-protected. This suggests that corallivores may be limited not by coral availability, but are possibly limited by their movement range as a functional group of small, demersal species. The abundance of corallivores at these two sites could thus be attributed to extremely shallow waters (in some places, depths of less than one meter) and wave protection (both sites protected from intense currents by island and reef formation). This not only implies that corallivores are limited in habitat types, but also that they require relatively low percents of live coral cover to survive. This disproves the hypothesis that corallivore abundance and biomass would be higher in areas of little coral degradation.

These results suggest that corallivores may be impervious to some trophic cascades that occur as a result of overfishing or other forms of anthropogenic influence. Perhaps lower functionalist groups, like the corallivores, are limited by the physical constraints of their habitat and not the amount of coral available. Also, it appears that an abundance of corallivores does not correlate with significantly lowered coral cover, as evidenced by the high percent of coral cover and large number of corallivores present at Coral Gardens (Site 4) in Palmyra Atoll. Hence, whereas Dulvy (2004) found that in areas of more coral-feeding starfish, live coral cover declined, these results show that areas of high corallivore abundance and biomass can also have high percentages of live coral cover. Thus, while trophic cascades in many marine, and especially reef, environments today are affecting entire systems of functional groups, it appears that the *Chaetodon* species in the Line Islands are resilient to such movements. However, this data is limited in scope; more transects at more sites and a greater number of islands could greatly enhance the veracity of these findings. Also, research on other lower functionalist groups in similar areas could be helpful in comparing relative abundances and biomasses of species and their interactions.

Conclusions:

In researching corallivore abundance and biomass among the Line Islands, it is apparent that the corallivores of Christmas Island, Fanning Island, and Palmyra Atoll depend not on live coral cover or anthropogenic influences at the island level, but instead on habitat depth and the protection of their environment from waves and currents. Moreover, the existence of various *Chaetodon* species and the one observed *Labropsis* species shows again that this lower functionalist group is dependent on specific locales, not the general environment of an entire

island. In the future, research in other coral reefs could add to this small data set. The corallivores are but one of many lower functionalist groups in coral reef ecosystems, and it would be both helpful and interesting to greater understand the environmental constraints of more lower-trophic level species.

References Cited

- Baums, Iliana B. et. al., 2003. Ecology of a corallivorous gastropod, *Coralliophila abbreviate*, on two scleractinian hosts. I: Population structure of snails and corals. *Marine Biology*, v. 142, no. 2, p. 1083-1091.
- Dulvy et. al., 2004. Coral reef cascades and the indirect effects of predator removal by exploitation. *Ecology Letters*, v. 7, no. 5, p. 410-416.
- He, X., et. al. 1993. Food web structure and long-term phosphorus recycling: A simulation model evaluation. *Transactions of the American Fisheries Society*, v. 122, no. 5, p. 773-783.
- Hughes, TP et. al., 2002. Biodiversity hotspots, centres of endemism, and the conservation of coral reefs. *Ecology Letters*, v. 5, no. 6, p. 775-784.
- Jackson, JBC 1997. Reefs since Columbus. *Coral Reefs*, v. 16, suppl. S, p. S23-S32.
- Kleypas et. al., 2001. The future of coral reefs in an age of global change. *International Journal of Earth Sciences*, v. 90, no. 2, p. 426-437.
- Knowlton, Nancy, 2001. The future of coral reefs. *PNAS*, v. 98, no. 10, p. 5419-5425.
- McClanahan, Timothy R., 2001. The Near Future of Coral Reefs. *Environmental Conservation*, v. 29, no. 4, p. 460-483.
- Pace et. al., 1999. Trophic cascades revealed in diverse ecosystems. *Trends in Ecology and Evolution*, v. 14, no. 12, p. 483-488.
- Reyes-Bonilla, Héctor and Calderon-Aguilera, Luis Eduardo, 1999. Population density, distribution and consumption rates of three corallivores at Cabo Pulmo Reef, Gulf of California, Mexico. *P.S.Z.N.: Marine Ecology*, v. 20, no. 3, p. 347-357.
- Roberts, CM 1995. Effects of fishing on the ecosystem structure of coral reefs. *Conservation Biology*, v. 9, no. 5, p. 988-995.
- Wellington, Gerard M., 1982. Depth zonation of corals in the Gulf of Panama: Control and facilitation by resident reef fishes. *Ecological Monographs*, v. 52, no. 3, p. 223-241.