# Analysis of factors impacting fish and coral abundance across management zones on the inshore coral reefs of the Great Barrier Reef Marine Park

https://github.com/cmullane94/ENV_872_Project

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# 1 Rationale and Research Questions

As the demand for seafood products has increased over the last six decades, unsustainable fishing, which can result from both illegal fishing practices as well as poor fisheries management, has been increasingly recognized as a pressing problem (FAO 2018). Coral reef fisheries are especially subject to unsustainability because of increasing coastal populations and the expansion of markets for live coral reef fishes (Pauly et al. 2002; Bellwood et al. 2004). Reef fish overexploitation affects the reef community as a whole – for example, the targeting of large, predatory reef fish at high trophic levels can alter and destablize the structure of reef communities (Pauly et al. 2002; Bellwood et al. 2004; Newton et al. 2007). The negative effects of overfishing on reef ecosystems – along with other coral stressors such as climate change, ocean acidification, and nutrient pollution – continue to impact fish communities through the deterioration of coral, the domination of macroalgae, and decreases in reef structural complexity (Bellwood et al. 2004; Darling et al. 2017).

The use of no-take marine reserves to conserve reef communities and manage fishing impacts has increased over the last two decades and have shown to be effective tools that are capable of increasing fish density, fish species richness, and coral abundance and health (Williamson et al. 2004; Lester et al. 2009; Castro-Sanguino et al. 2017). Australia's Great Barrier Reef is the largest coral reef system in the world, and, like other reefs worldwide, is exhibiting signs of system-wide degradation (Bellwood et al. 2004; Fraser et al. 2017). Zoning was first introduced into the Great Barrier Reef Marine Park (GBRMP) between 1981-1988, and a new zoning management plan was implemented in 2004 (Williamson et al. 2004; Castro-Sanguino et al. 2017).

To examine the effects of GBRMP zoning practices on fish density, fish species richness, and coral abundance, as well as to determine what variables impact fish density and coral abundance, a dataset with varibles concerning zones, fish and coral abundance, and the abundance of specific fish functional groups was selected – the chosen dataset is one of the few projects established with the goal of specifically assessing the ecological effects of multiple-use zoning on the inshore coral reefs of the GBRMP (Lawrey 2014). Choice of dataset was also influenced by timespan – this project is the only long-term monitoring project with a dataset that was established prior to the implementation of the new zoning management plan in 2004 (Lawrey 2014).

This project sought to answer the following questions about the inshore coral reefs of the GBRMP:

1. What variables affect the percentage cover of live hard coral?
2. What variables affect fish density?
3. Do no-take zones established in 1987, no-take zones established in 2004, and fished zones have different mean amounts of live hard coral cover, fish density, and fish species richness?

## 2 Dataset Information

• Describes source and content of data • Details the wrangling process from raw to processed data • Contains a table summarizing the dataset structure

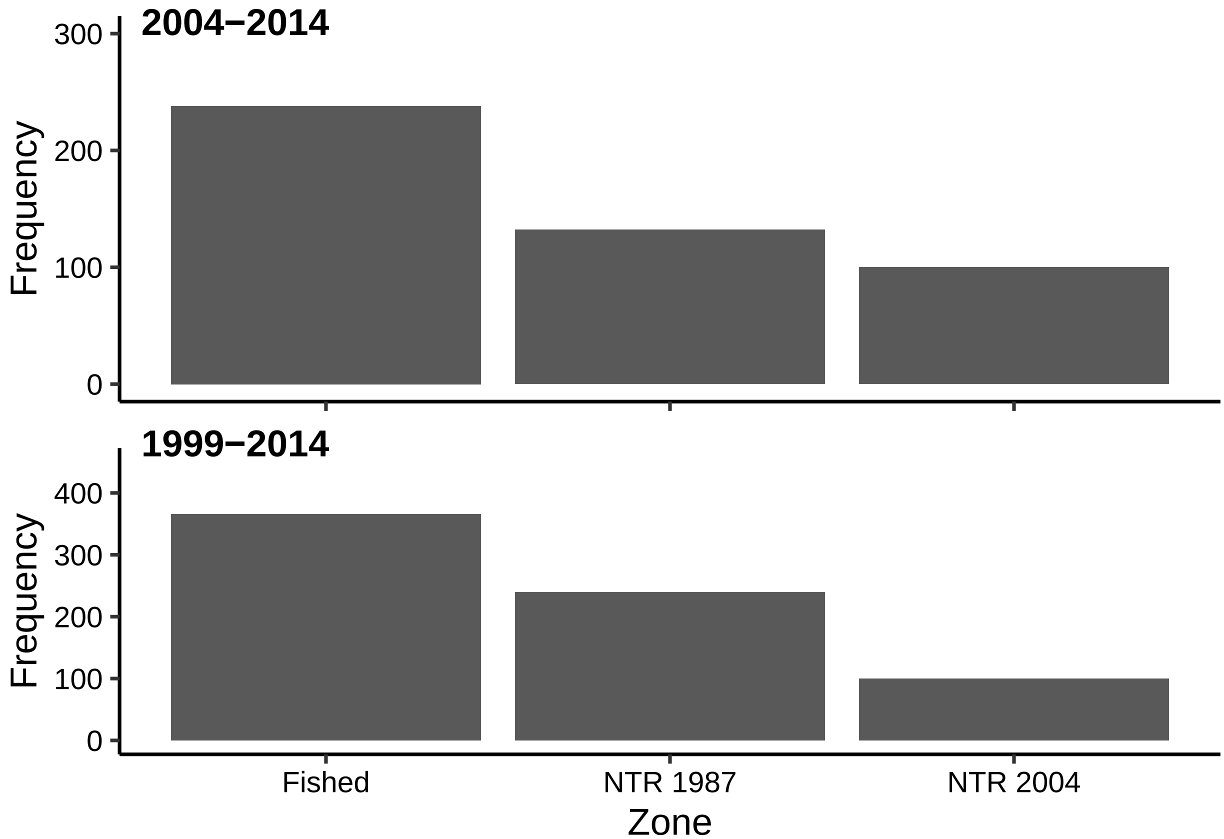


Figure 1: The number of fished zones, no-take zones established in 1987, and no-take zones established in 2004 when data from 1999-2014 are included (bottom) and data from only 2004-2014 are included (top).

# 3 Exploratory Analysis

Although data began being collected in 1999, some data related to fish species density and richness, as well as other fish related data, did not begin being monitored until 2004. Although some viable data will have to be removed in analyses where fish data are involved, there appears to be similar proportions of zone types when looking at data from 1999-2014 and 2004-2014 (Figure 1).

In looking at the frequency of macroalgae and coral percent cover from 1999-2014, macroalgae frequently has 0% cover while live coral most frequently has coverage percentages around 40 (Figure 2); these frequencies indicate that many of the sites sampled remain dominated by coral rather than macroalgae. In examining the relationship between living coral and macroalge further, it appears that mean fleshy macroalge percent cover is negatively correlated with mean living hard coral percent cover (Figure 3).

When examining mean fish density and mean percent live hard coral across 2004-2014, it appears as though fish density has the smallest range in 2004 and 2012-2014 (Figure 4). From 2011-2014, coral coverage has been low compared to 2009, although it has consistently reached values of above 50% (Figure 4). Coral cover appears as though it could be slightly

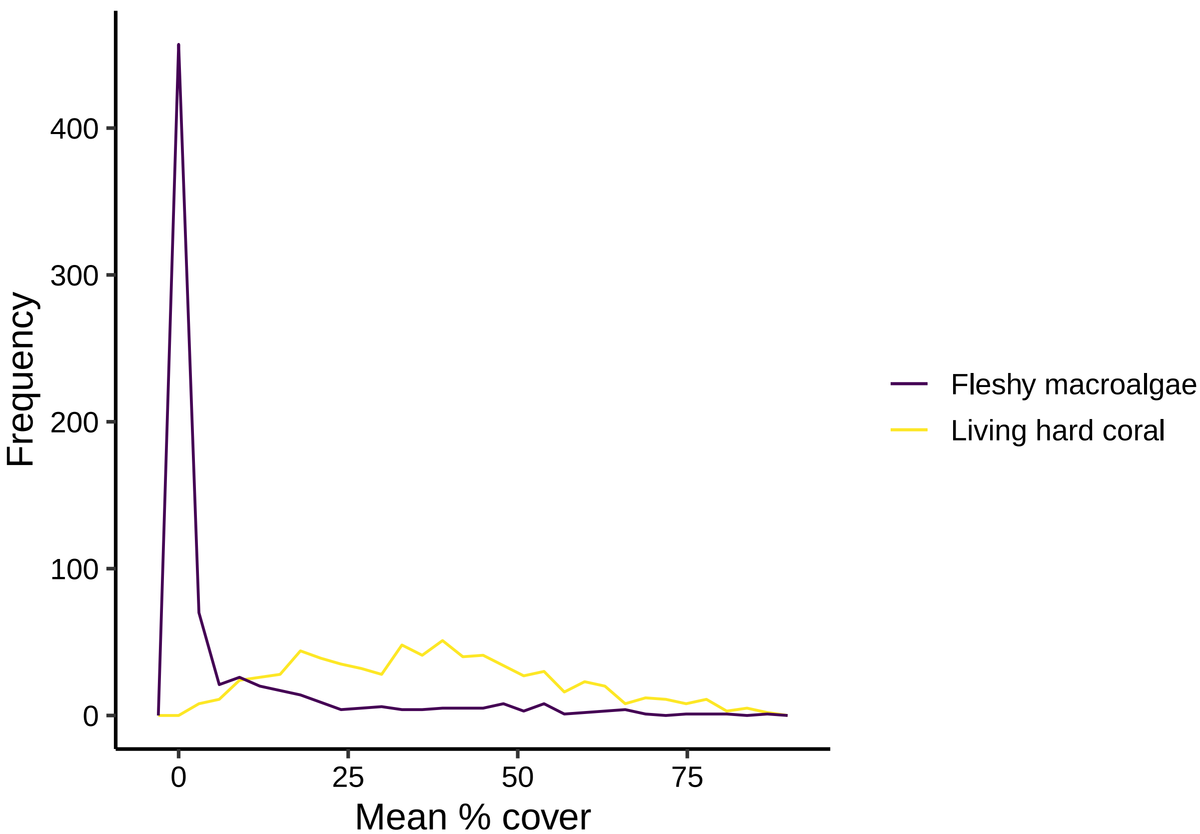


Figure 2: Frequency of fleshy macroalgae percent cover compared to living hard coral percent cover (1999-2014).

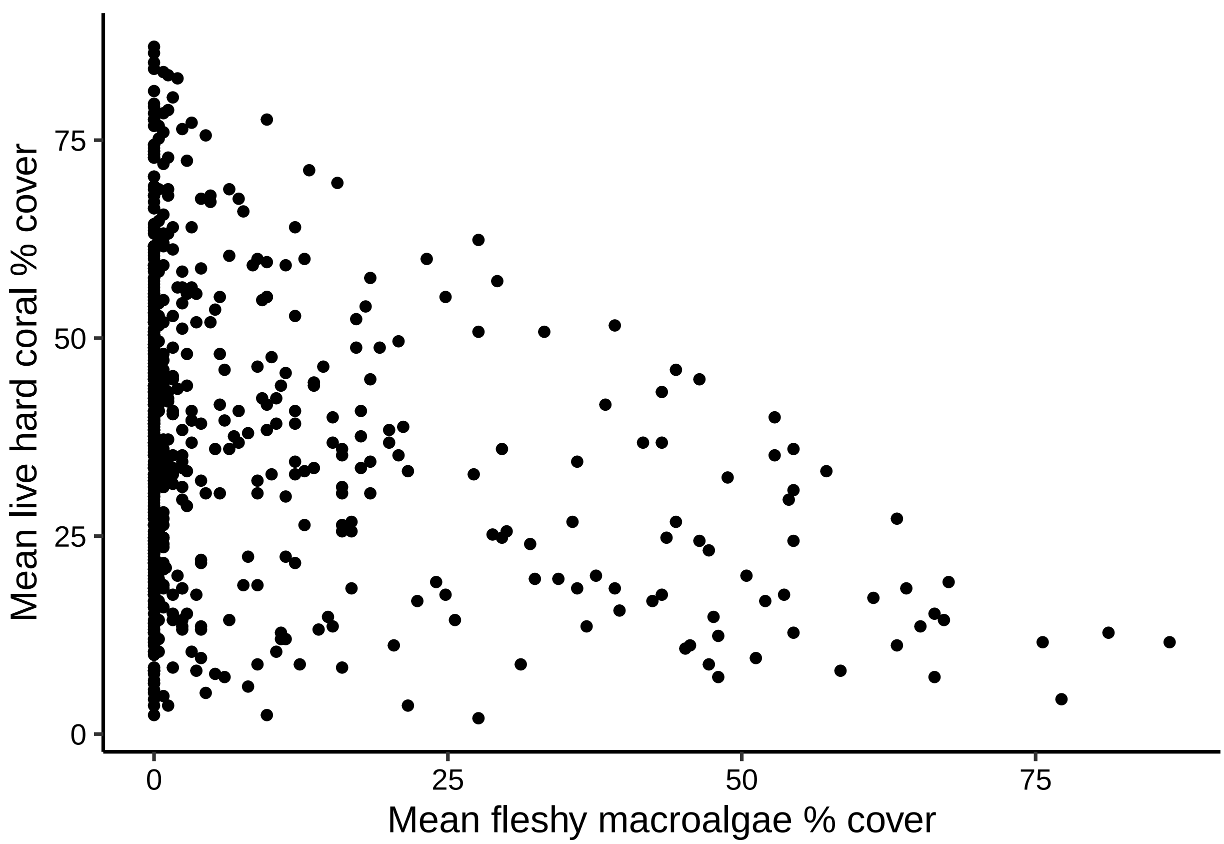


Figure 3: Mean fleshy macroalgae percent cover plotted against mean live hard coral percent cover (1999-2014).

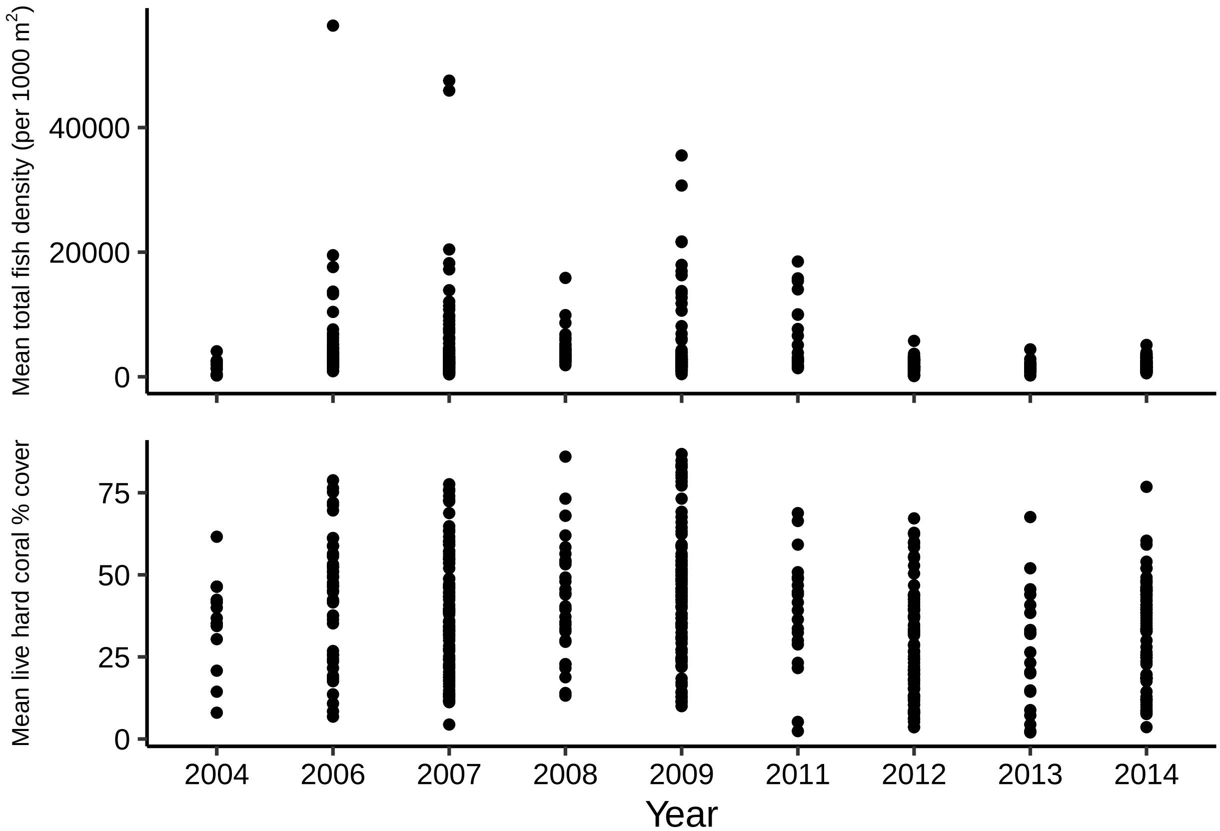


Figure 4: Mean live hard coral percent cover and mean total fish density across 2004, 2006-2009, and 2011-2014.

positively correlated with fish density (Figure 5).

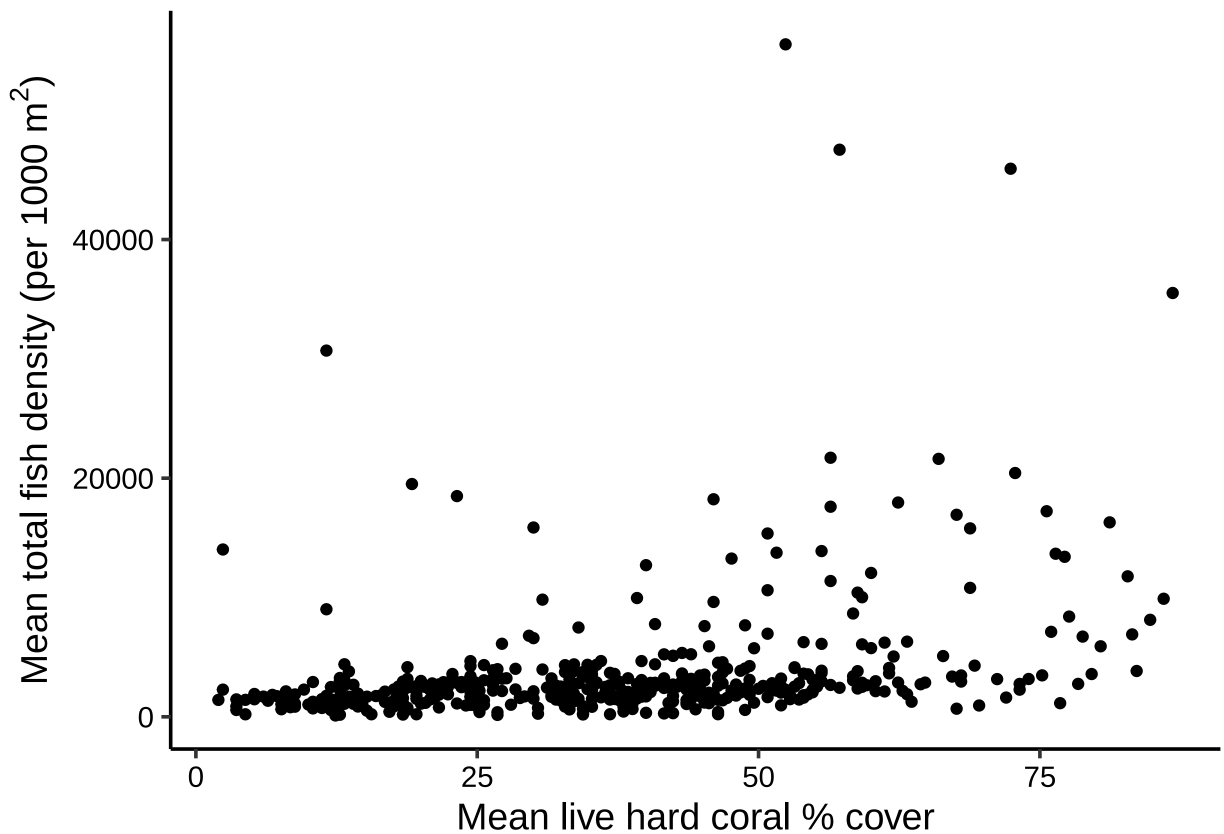


Figure 5: Mean live hard coral percent cover plotted against mean total fish density (2004-2014).

# 4 Analysis

## 4.1 Question 1: What variables affect the percentage cover of live hard coral on the inshore coral reefs of the GBRMP?

To determine factors influencing live hard coral cover within the GBRMP, a mixed-effects analysis of covariance (ANCOVA) model was used. To account for the random effects of study site and allow extrapolation of results to potential study sites not included in the data, site was included as a random effect. The best-fitting model, which was found using stepwise Akaike information criterion (AIC) analysis, contained the explanatory variables of year, the mean number of grazer fish species, the mean number of corallivore fish species, and the mean percentage cover of fleshy macroalgae. Year, the mean number of grazer fish species, the mean percentage cover of fleshy macroalgae significantly decrease the mean percentage of live hard coral cover, while the mean number of corallivore fish species significantly increase the mean percentage of live hard coral cover (pseudo $R^2 = 0.8078$; Figures 6 & 7). When all other variables are held constant, each additional fish included in the mean number of grazers will decrease mean live hard coral percent cover by 0.0227% (df = 358, t = -2.805, $p < 0.05$). Similarly, a one unit increase in the mean macroalgae percent cover will decrease mean live hard coral percent cover by 0.354% (df = 358, t = 7.641, $p < 0.0001$), while a one unit increase in the mean number of corallivores will increase mean live hard coral percent cover by 0.265% (df = 358, t = 7.812, $p < 0.0001$). A post hoc Tukey test was used to evaluate pairwise relationships of different years and extract groupings based on these pairwise relationships (Figures 6 & 7).

## 4.2 Question 2: What variables affect fish density on the inshore coral reefs of the GBRMP?

To determine factors influencing mean total fish density within the GBRMP, a mixed-effects analysis of covariance (ANCOVA) model was used. To again account for the random effects of study site and allow extrapolation of results to potential study sites not included in the data, site was included as a random effect. The best-fitting model, which was found using stepwise AIC analysis, contained the explanatory variables of year and mean percentage of live hard coral cover. The mean percentage of live hard coral cover was found to increase the natural log of mean total fish density (pseudo $R^2 = 0.8087$; Figure 8). When all other variables are held constant, each additional 1% of live hard coral cover will increase the mean total fish density by 1.536% (df = 360, t = 7.429, $p < 0.0001$). A post hoc Tukey test was used to evaluate pairwise relationships of different years and extract groupings based on these pairwise relationships (Figure 8).

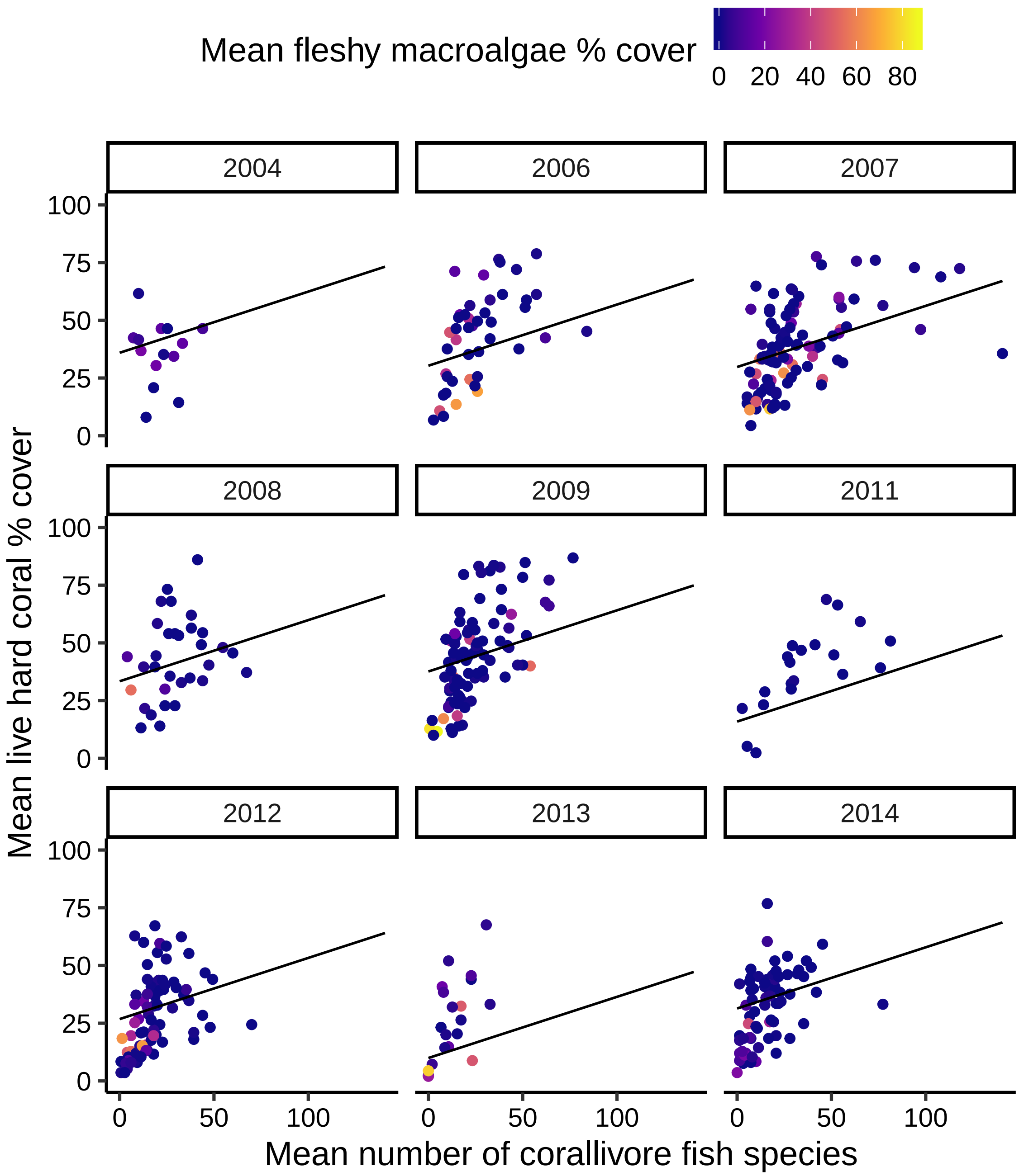


Figure 6: Modeled relationship between the mean number of corallivore fish species, the mean percent cover of living hard coral, and the mean percent cover of fleshy macroalgae for 2004, 2006-2009, and 2011-2014. The mean number of grazer fish species was also included in the model (Figure ).Regression lines are plotted using using the mean number of grazer species and the mean percent cover of fleshy macroalgae for the year corresponding to the facet.

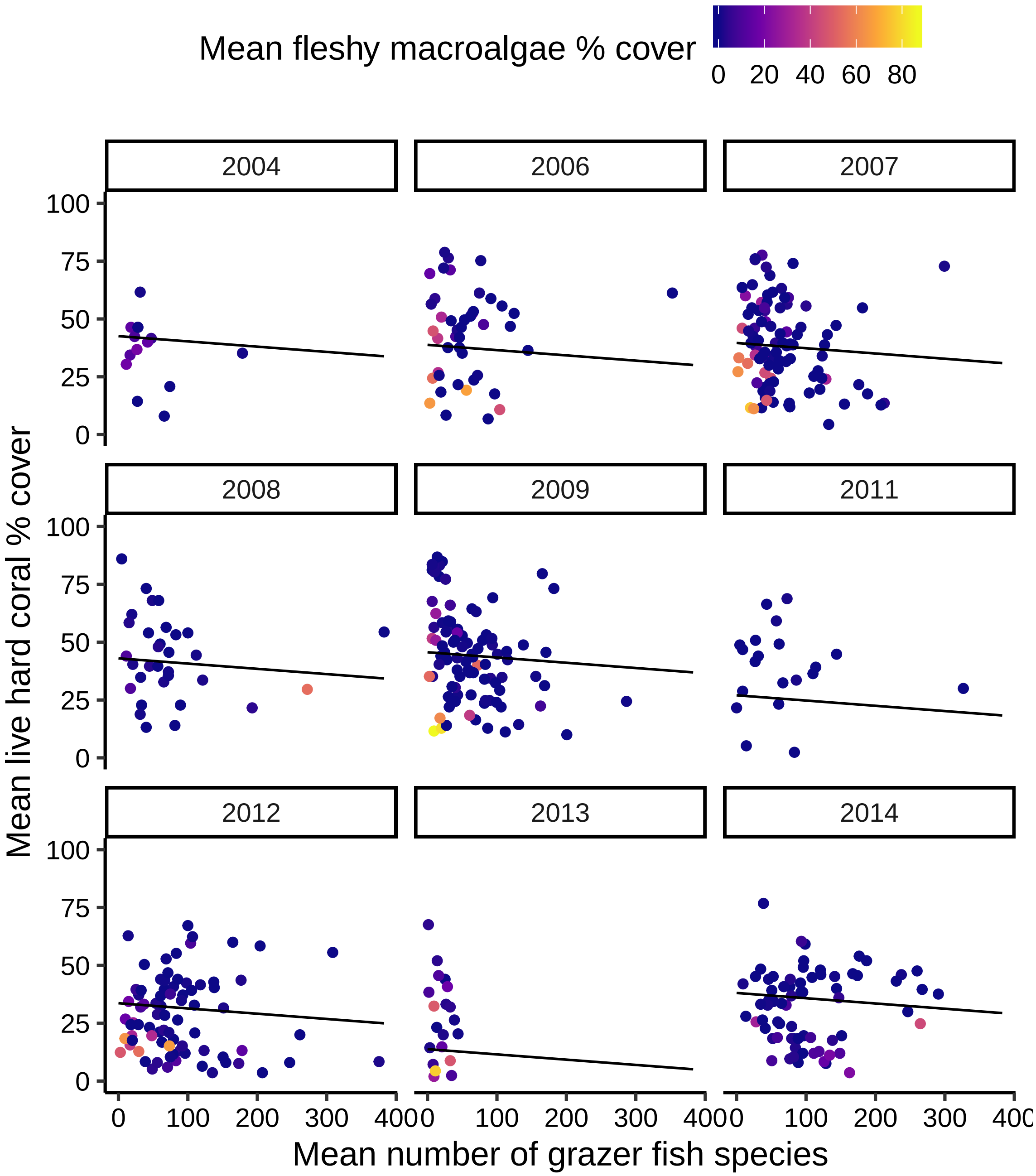


Figure 7: Modeled relationship between the mean number of grazer fish species, the mean percent cover of living hard coral, and the mean percent cover of fleshy macroalgae for 2004, 2006-2009, and 2011-2014. The mean number of corallivore fish species was also included in the model (Figure ). Regression lines are plotted using using the mean number of corallivore species and the mean percent cover of fleshy macroalgae for the year corresponding to the facet.

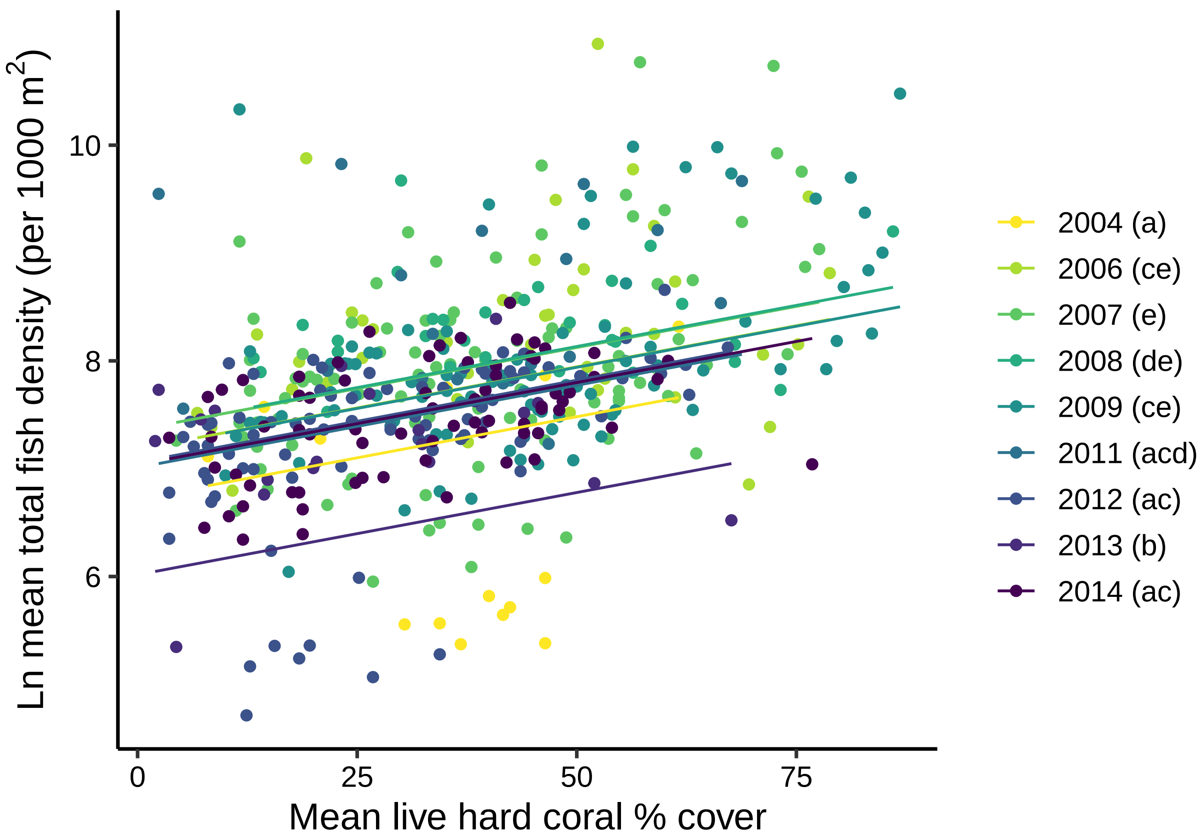


Figure 8: Modeled relationship between the mean percent cover of living hard coral and the natural log of fish density for 2004, 2006-2009, and 2011-2014. Letters indicating pairwise relationships among years are included in the legend; differences in letters between years indicate statistical differences.

## 4.3 Question 3: Do no-take zones established in 1987, no-take zones established in 2004, and fished zones have different mean amounts of live hard coral cover, fish density, and fish species richness?

To determine if mean fish density, mean fish species richness, and mean percent coral cover were significantly different among the three GBRMP zones in the data (no-take since 1987, no-take since 2004, and fished), three analysis of variance (ANCOVA) models were used. Zone was not found to significantly affect mean percent live coral cover (F~2, 703~ = 0.1649, $p > 0.1$) or mean fish species richness (F~2, 467~ = 2.396, $p > 0.05$). However, zone did significantly affect mean fish species density (F~2, 467~ = 6.137, $p < 0.01$) with the no-take zones from 2004 increasing mean fish density by 39.780% ($t = 3.171$, $p < 0.01$). A post hoc Tukey test was used to evaluate pairwise relationships of different zones and extract groupings based on these pairwise relationships (Figure 9).

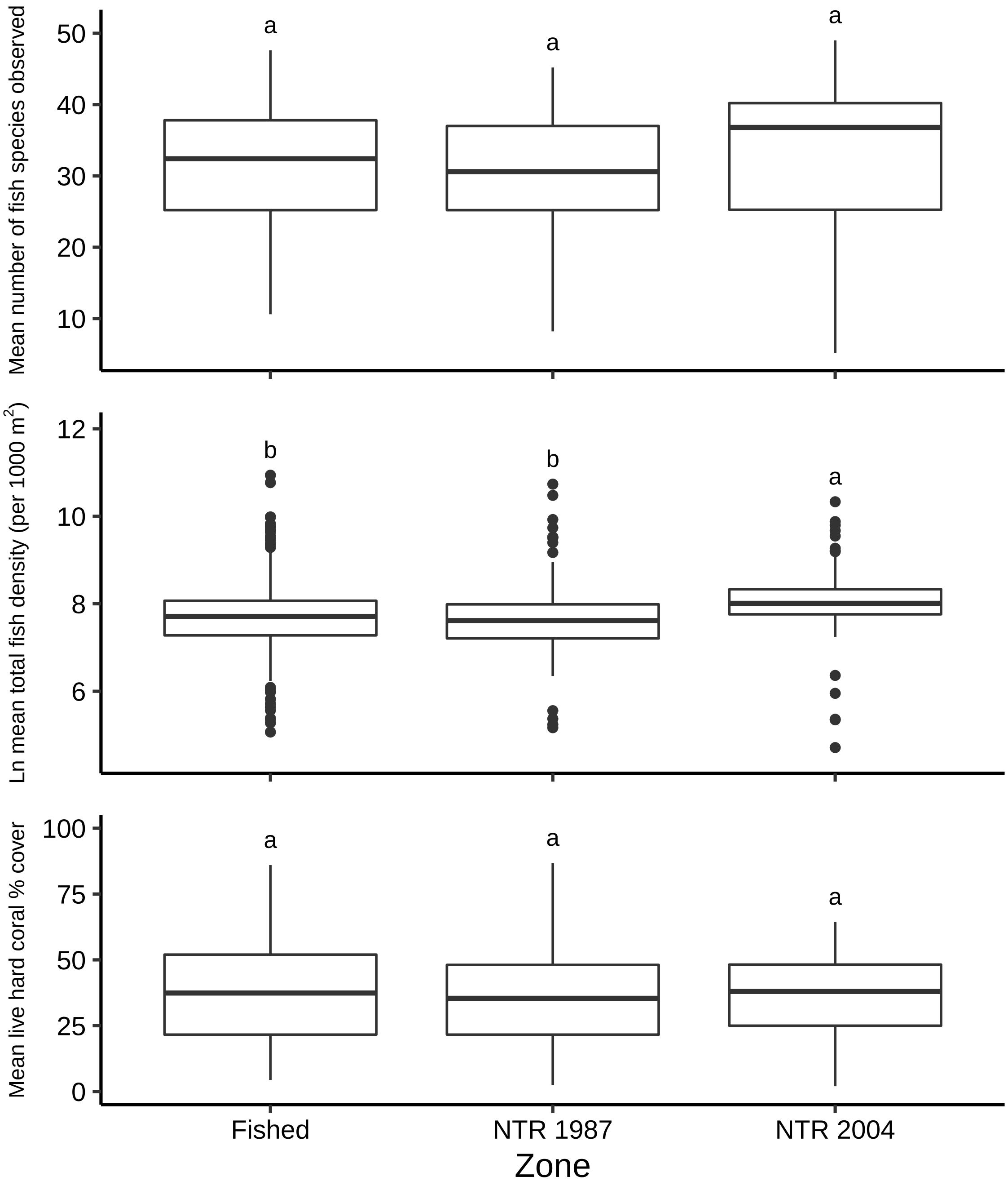


Figure 9: Modeled relationship between the GBRMP zone and the mean percent cover of living hard coral from 1999-2014 (bottom), the natural log of fish density (middle) from 2004-2014, and fish species richness from 2004-2014 (top). Letters indicating pairwise relationships among zones are above each bar; differences in letters between zones indicate statistical differences.

# 5 Summary and Conclusions

- Major findings are summarized
- Conclusions relate back to the original research context

# 6 References


Bellwood DR, Hughes TP, Folke C, Nyström M. 2004. Confronting the coral reef crisis. Nature. 429(6994):827–833. doi:10.1038/nature02691.

Castro-Sanguino C, Bozec Y-M, Dempsey A, Samaniego BR, Lubarsky K, Andrews S, Komyakova V, Ortiz JC, Robbins WD, Renaud PG, et al. 2017. Detecting conservation benefits of marine reserves on remote reefs of the northern GBR. PLoS ONE. 12(11):e0186146.

Darling ES, Graham NA, J, Januchowski-hartley FA, Nash KL, Pratchett MS, Wilson SK. 2017. Relationships between structural complexity, coral traits, and reef fish assemblages. Coral Reefs; Heidelberg. 36(2):561–575. doi:http://dx.doi.org/10.1007/s00338-017-1539-z.

FAO, editor. 2018. Meeting the sustainable development goals. Rome (The state of world fisheries and aquaculture).

Fraser KA, Adams VM, Pressey RL, Pandolfi JM. 2017. Purpose, policy, and practice: Intent and reality for on-ground management and outcomes of the Great Barrier Reef Marine Park. Marine Policy. 81:301–311. doi:10.1016/j.marpol.2017.03.039.

Lawrey E. 2014. e-Atlas Dataset reporting form.

Lester SE, Halpern BS, Grorud-Colvert K, Lubchenco J, Ruttenberg BI, Gaines SD, Airamé S, Warner RR. 2009. Biological effects within no-take marine reserves: a global synthesis. Marine Ecology Progress Series. 384:33–46. doi:10.3354/meps08029.

Newton K, Côté IM, Pilling GM, Jennings S, Dulvy NK. 2007. Current and Future Sustainability of Island Coral Reef Fisheries. Current Biology. 17(7):655–658. doi:10.1016/j.cub.2007.02.054.

Pauly D, Christensen V, Guénette S, Pitcher TJ, Sumaila UR, Walters CJ, Watson R, Zeller D. 2002. Towards sustainability in world fisheries. Nature. 418(6898):689–695. doi:10.1038/nature01017.

Williamson DH, Russ GR, Ayling AM. 2004. No-take marine reserves increase abundance and biomass of reef fish on inshore fringing reefs of the Great Barrier Reef. Environmental Conservation. 31(2):149–159. doi:10.1017/S0376892904001262.