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Magnetic Island marine park zones: Effects of fishing restrictions on predatory reef fish populations

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ISP Ethics Review

(Note: Each AD must complete, sign, and submit this form for every student's ISP.)

The ISP paper by Casey Wilson (student) <u>does</u> conform to the Human Subjects Review approval from the Local Review Board, the ethical standards of the local community, and the ethical and academic standards outlined in the SIT student and faculty handbooks.

Completed by: Tony Cummings

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Signature:

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Abstract

Over the past several decades industrialized fishing practices have decimated fish stocks worldwide. Top-down trophic cascades have occurred within many marine ecosystems as top predators are removed. Numerous regions world wide are being designated as marine park "no-take" zones in order to aid in the recovery of these species and with the hope that surplus population will spillover into unprotected zones..

This study aimed to determine if there were significant differences in abundances of three major families of predatory reef fish (Serranidae, Lutjanidae, and Lethrinidae) between fringing reefs located in four bays of various zones around Magnetic Island, QLD. Data were collected by snorkeling over two 50m transects (width determined by turbidity) four times at each bay from April 19, 2015 to April 30, 2015 and recording any fish observed from the aforementioned families.

One-way analyses of variance and Tukey's Honest Significant Difference test determined that significant differences only occurred between Geoffrey Bay, a no-take zone, and Nelly Bay, a take zone that allows all fishing except trawling. Geoffrey Bay had significantly higher abundances of Lutjanids ($F = 3.57$; $df = 3, 28$; $p = 0.026453$) and fish overall ($F = 3.52$; $df = 3, 28$; $p = 0.027817$) when data for *Lutjanus carponotatus* was removed. A marginally significant difference was also found for populations of *L. carponotatus* alone ($F = 2.56$; $df = 3, 28$; $p = 0.075029$). While not significant, there were also definite trends in the no-take zones having the highest abundances while Nelly Bay always had the lowest or was tied for the lowest. Further studies are needed that improve upon this design, though, through timed swims looking at temporal variations in fish stocks between zones to determine if there is a more significant marine park zone effect.

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1.0 Introduction

1.1 The Issue of Overfishing

In the past several decades fishing has risen to an all time high with industrialized fisheries being able to reduce communities by 80% in only 15 years (Myers and Worm 2003). These practices are clearly unsustainable as evidenced by the slow decline of catches since the 1980s (Pauly et al. 2002). Overfishing is particularly threatening to coral reefs due to their high biodiversity, proximity to an ever-growing human population, and an increase in the trade of live reef fish (Roberts 1997; Pauly et al. 2002; Sadovy & Vincent 2002). The fish that have been most targeted and exploited tend to be at high trophic levels (Bohnsack 1998; Jennings and Kaiser 1998) with their current biomass being estimated at only 10% of what it was prior to industrialization (Myers and Worm 2003). This is leading to top-down trophic cascades as the lack of predators causes a rise in prey species followed by declines in some of those same species as depleting stocks of large predators force fisheries to exploit alternatives. Daskalov et al. (2007) showed an example of one such cascade in which the removal of large predators from the Black Sea via overfishing in the 1960s and 1970s led to an rapid increase in planktivorous fish populations. This subsequently caused zooplankton biomass to plummet, allowing for phytoplankton to increase and significantly decrease the concentration of oxygen in the water. Such cases of marine ecosystems being affected by the loss of top predators has been recorded numerous times worldwide (McClanahan and Muthiga 1988; Graham et al. 2003; Williamson et al. 2004; Hughes et al. 2010).

1.2 Relevance of Study – Marine Park Zones

One method by which these issues are being dealt with is the establishment of marine park zones. These are commonly differentiated as take and no-take zones, in which fishing is respectively allowed in varying degrees or not at all (Ashworth & Ormond 2005). The hope is that fish stocks will recover in no-take zones due to decreased mortality of predatory fish associated with the banning of fishing (Davis unpubl.). This marine park zone effect, as it is called, is the driving force behind the creation of marine park zones. Another potential benefit is the spillover effect that occurs when more post-settlement fish are emigrating from a no-take zone to a take zone than the opposite (Roberts 1997; Russ 2002). No-take zones can also increase tourism and maintain high biodiversity with little more needed than surveillance. This simplistic model allows for developing nations to more easily manage their reef fisheries. While it is in no way a panacea for the problems of overfishing, marine park zones are a simple and important step along a more ecologically friendly and sustainable path (Roberts 1997; Bohnsack 1998; Pauly et al. 2002; Russ 2002).

The Great Barrier Reef Marine Park Authority (GBRMPA) has taken classification of zones a step further by categorizing each by what types of fishing is allowed and marking them with colors. Some of the zones include green no-take zones light blue general use zones. The latter allows for virtually any activity, including fishing, trawling, and recreational activities (GBRMPA 2004). Zones that are relevant to this study will be further discussed in section 2.1. It is important to study these zones and the differences in fish abundances in order to determine if marine park zone effects actually occur as expected. This is particularly important in the eyes of the policymakers who decide where marine parks will go. Unfortunately data is often vague and studies can last for years and thus scientists worry that funding for these studies will be cut due to constant pressure for results from legislators who do not realize the enormity of the task (Sale et al. 2005; Walters 2007).

1.3 Explanation of Target Species

This study looked at the abundances of three families of large predatory fish at four fringing reefs around Magnetic Island. These fish were chosen because previous studies have shown population densities of large predatory fish are good indicators of how well a zone is protecting its fish stocks (Alcala 1988; Alcala and Russ 1990) due to their slow growth, low rates of recruitment, and long life spans (Davis unpubl.). In addition, these families tend to be more vulnerable to overfishing for the above reasons as well as their tendency to form seasonal spawning aggregations (Johannes 1981; Roberts 1997; Samoilys 1997; Sadovy and Vincent 2002).

1.3.1 Serranidae

Commonly referred to as groupers, these fish can be recognized by a few external characteristics. Most have three spines on the operculum and the posterior bone of the upper jaw is completely visible on the cheek when the mouth is closed. Jaws have multiple rows of teeth and are quite large. Groupers are generally demersal hunters, feeding on many fish and some invertebrates (Allen and Robertson 1994).

1.3.2 Lutjanidae

Lutjanids generally have ovate or elongated bodies that are somewhat laterally compressed. They have sharp canines on their jaws which they use to actively hunt prey in shallow to intermediate depths. Commonly referred to as snappers, Lutjanids hunt mostly at night and are primarily piscivorous, although they do occasionally eat crustaceans, gastropods, and most other marine invertebrates (Allen and Robertson 1994).

1.3.3 Lethrinidae

Known as emperors, Lethrinids have a similar appearance to snappers in that they are generally ovate and moderately compressed. Unlike snappers, however, these fish have thick lips and powerful jaws with equally strong teeth on the sides for crushing crustaceans and other hard-shelled invertebrates that they dig up from the bottom of the reef (GWADF 2013).

1.4 Aims of Study

This study aims to determine if there are a significant differences in the abundances of groupers, snappers, and emperors between marine park zones around Magnetic Island via direct observation and census of population individuals. This data will be analyzed to determine if the green (no-take) zones around Magnetic Island display significant marine park zone effects in relation to species from these heavily fished families.

2.0 Methods

2.1 Study Sites

Data were collected from fringing reefs at four bays around Magnetic Island (19.13°S, 146.84°E). These were Picnic Bay, Nelly Bay, Geoffrey Bay, and Florence Bay (Figure 1). The aforementioned bays were chosen due to their zonation by GBRMPA. Picnic Bay is a yellow zone, meaning that all fishing except trawling and certain types of net fishing is allowed. Nelly Bay is a dark blue zone, meaning that all fishing except trawling is allowed. Geoffrey Bay and Florence Bay are green zones, meaning that no fishing is allowed. Data were collected during low tide which varied with each day. The depth at Picnic Bay was 0.7m to 1m deep, Nelly and Geoffrey Bays were 2m to 3m deep, and Florence Bay was 1.5m to 2m deep.

2.2 Study Species

Data were collected on the abundance of species within three families of predatory fish. In total, five species of groupers (Serranidae), four species of snappers (Lutjanidae), and four species of emperors (Lethrinidae) were recorded (Table 1).

2.3 Data Collection

Each bay was visited four times between April 19, 2015 and April 30, 2015. Data were collected by swimming at a constant speed along a 50m transect (width determined by visibility in the water, ranging from 1m to 5m) laid out along the reef flat and recording the numbers of observed groupers, snappers, and emperors. Abundance of individual species was recorded when possible. Two transects were sampled each time a bay was visited for a total of eight replicates per bay. Snorkel gear was used and duckdiving techniques implemented in areas of water deeper than 1m in order to better check under rocks, ledges, and algal growth.

2.4 Data Analysis

The data for each family were adjusted to 1m width and analyzed with one-way analyses of variance (ANOVA). When the ANOVA found a significant difference, Tukey's Honest Significant Difference (Tukey's HSD) test was used in order to determine between which values the difference occurred.

Figure 1. Aerial view of Magnetic Island showing the bays from which data were collected (photo courtesy of Google Maps). Color of outline matches the marine park zone. A: Picnic Bay. B: Nelly Bay. C: Geoffrey Bay. D: Florence Bay.

Table 1. Species of predatory fish from three major families recorded at fringing reefs around Magnetic Island.

Family Serranidae	
	Cephalopholis boenak
	Cephalopholis microprion
	Epinephelus fuscoguttatus
	Epinephelus quoyanus
	Plectropomus maculatus
Family Lutjanidae	
	Lutjanus argentimaculatus
	Lutjanus carponotatus
	Lutjanus fulviflamma
	Lutjanus russelli
Family Lethrinidae	
	Lethrinus atkinsoni
	Lethrinus harak
	Lethrinus lentjan
	Lethrinus nebulosus

3.0 Results

3.1 Statistical Results

While some trends were observed, there were only significant differences in predatory reef fish populations between bays on a couple occasions. ANOVA results showed no significant differences in populations of groupers (Fig. 2; $F = 1.17$; $df = 3, 28$; $p = 0.338777$) or emperors (Fig. 3; $F = 1.14$; $df = 3, 28$; $p = 0.350023$) between any of the bays. There was a significant difference in snapper populations ($F = 3.57$; $df = 3, 28$; $p = 0.026453$) with Tukey's HSD test determining the difference was between Nelly Bay and Geoffrey Bay (Fig. 4; $p < 0.05$). This was not observed, however, when data for the most consistently observed fish, *Lutjanus carponotatus*, was removed (Fig. 5; $F = 1.13$; $df = 3, 28$; $p = 0.353851$). The prevalence of *L. carponotatus* between bays was shown in the ANOVA results on their population which found a marginally significant difference between bays (Fig. 6; $F = 2.56$; $df = 3, 28$; $p = 0.075029$). Similar to the snapper populations, there was a significant difference when the data for all predatory fish were combined and analyzed ($F = 3.52$; $df = 3, 28$; $p = 0.027817$), determined by Tukey's HSD test to be between Nelly Bay and Geoffrey Bay (Fig. 7; $p < 0.05$), but not when *L. carponotatus* was excluded (Fig. 8; $F = 1.72$; $df = 3, 28$; $p = 0.185615$).

3.2 Trends

While, statistically, there were only significant differences between Nelly Bay and Geoffrey Bay in a couple cases, some other overall trends were observed. Nelly Bay always had, with the exception of emperors (Fig. 3), the lowest abundance of predatory fish observed, in most cases being a third or less than the next lowest abundance.

Similarly, Geoffrey and Florence Bays, the green zones, always had the highest abundances with Geoffrey almost always having the highest abundance overall for each group. This was particularly noticeable with emperors, which were only spotted in the green zones (Fig. 3). The only exception to this trend was in the numbers of snappers, which were higher at Picnic Bay than Nelly Bay (Fig. 4, Fig. 5). All of these trends were supported by the numbers of fish observed. After adjusting to 1m, there was a total of 9.70 fish observed at Picnic Bay, 3.11 fish observed at Nelly Bay, 18.80 fish observed at Geoffrey Bay, and 15.43 fish observed at Florence Bay.

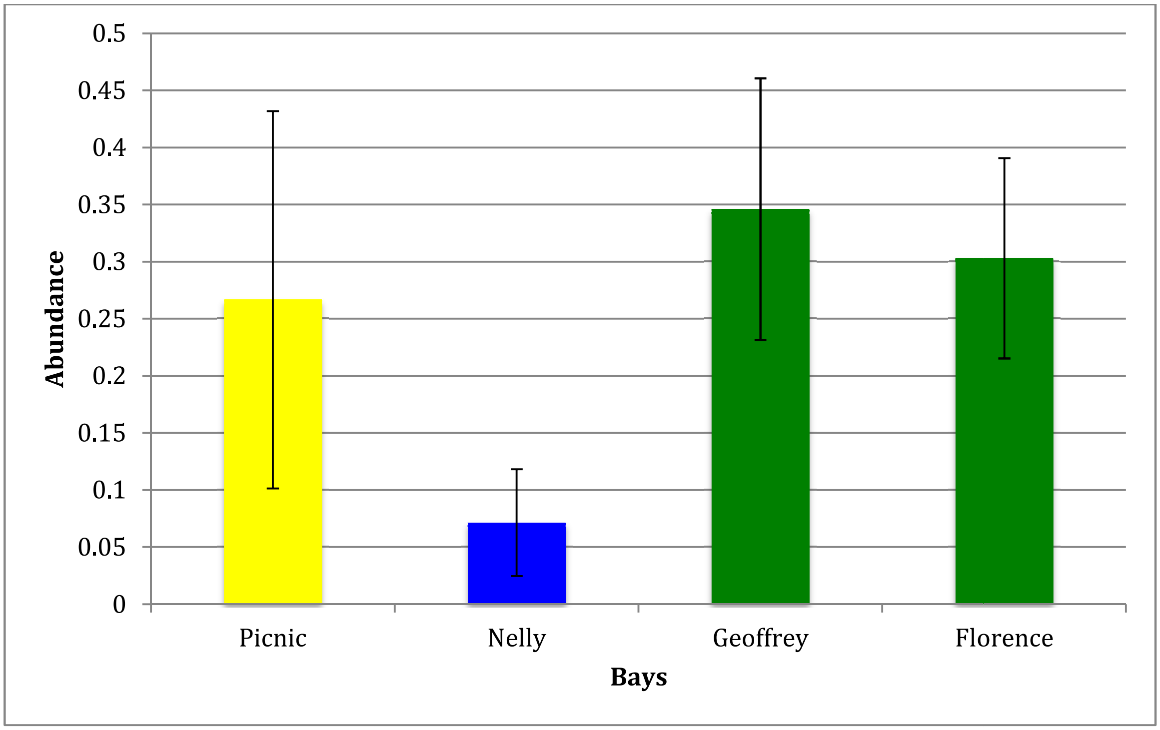

Figure 2. Mean abundances of groupers at reefs in bays around Magnetic Island. Color indicates the marine park zone of each bay. Error bars = ±1 SE.

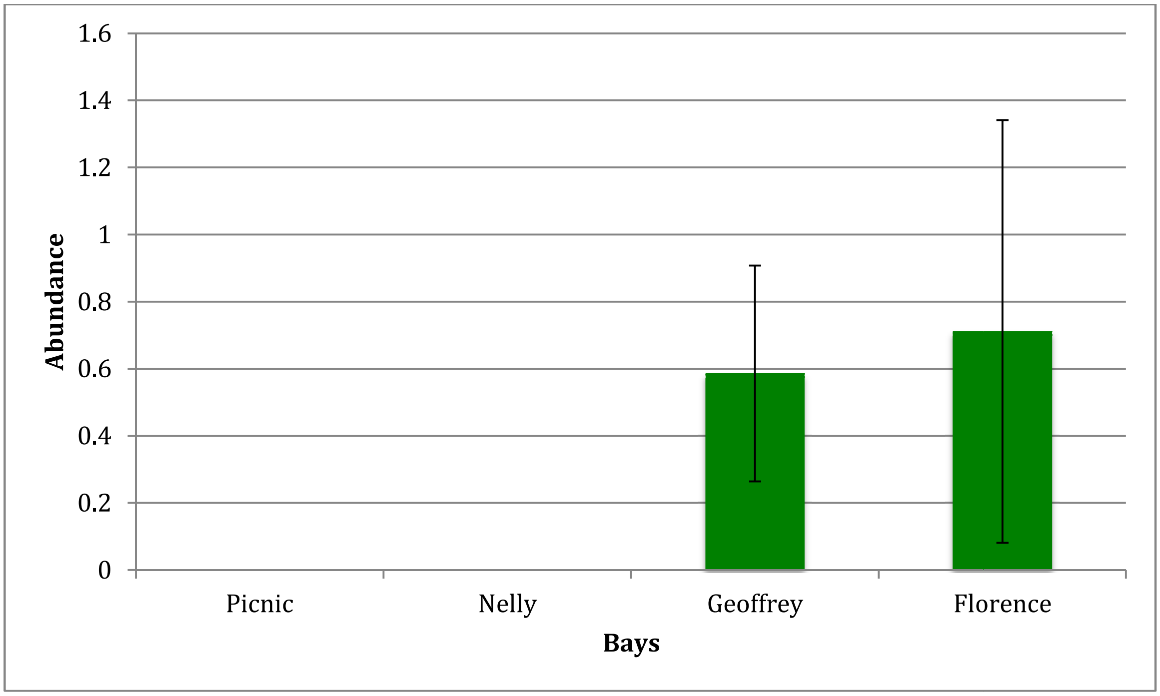

Figure 3. Mean abundances of emperors at reefs in bays around Magnetic Island. Color indicates the marine park zone of each bay. Error bars = ±1 SE.

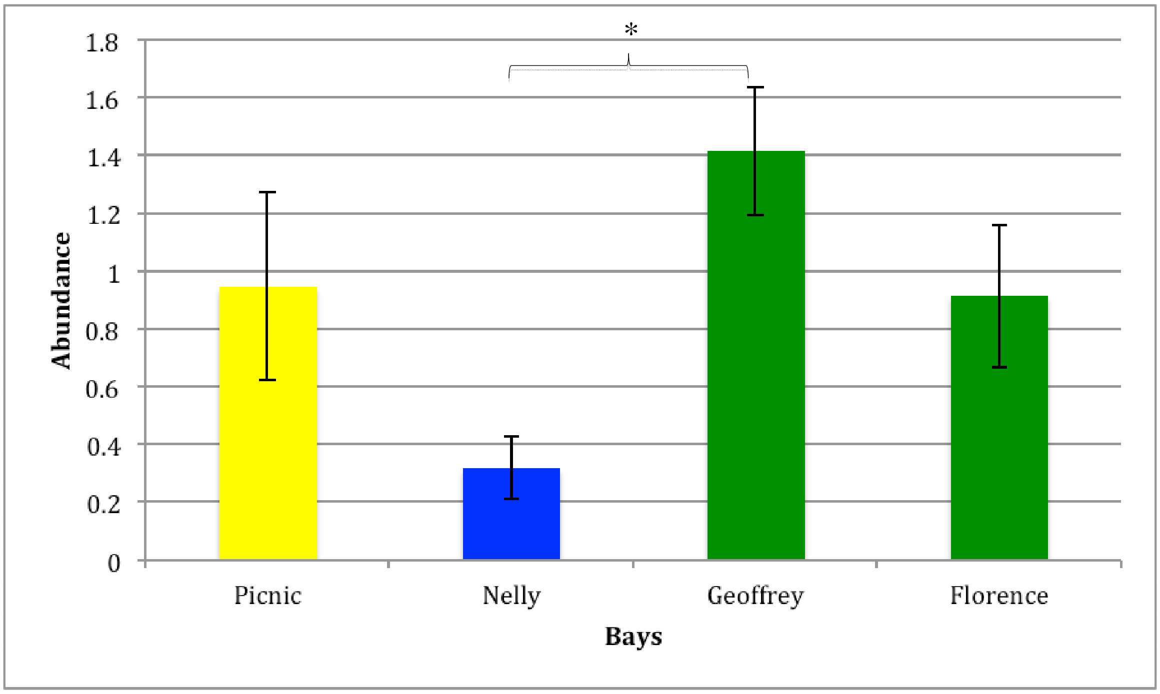

Figure 4. Mean abundances of snappers, including *Lutjanus carponotatus*, at reefs in bays around Magnetic Island. Color indicates the marine park zone of each bay. Error bars = ±1 SE. Tukey's HSD test found a significant difference between Nelly Bay and Geoffrey Bay (denoted by *; $p < 0.05$).

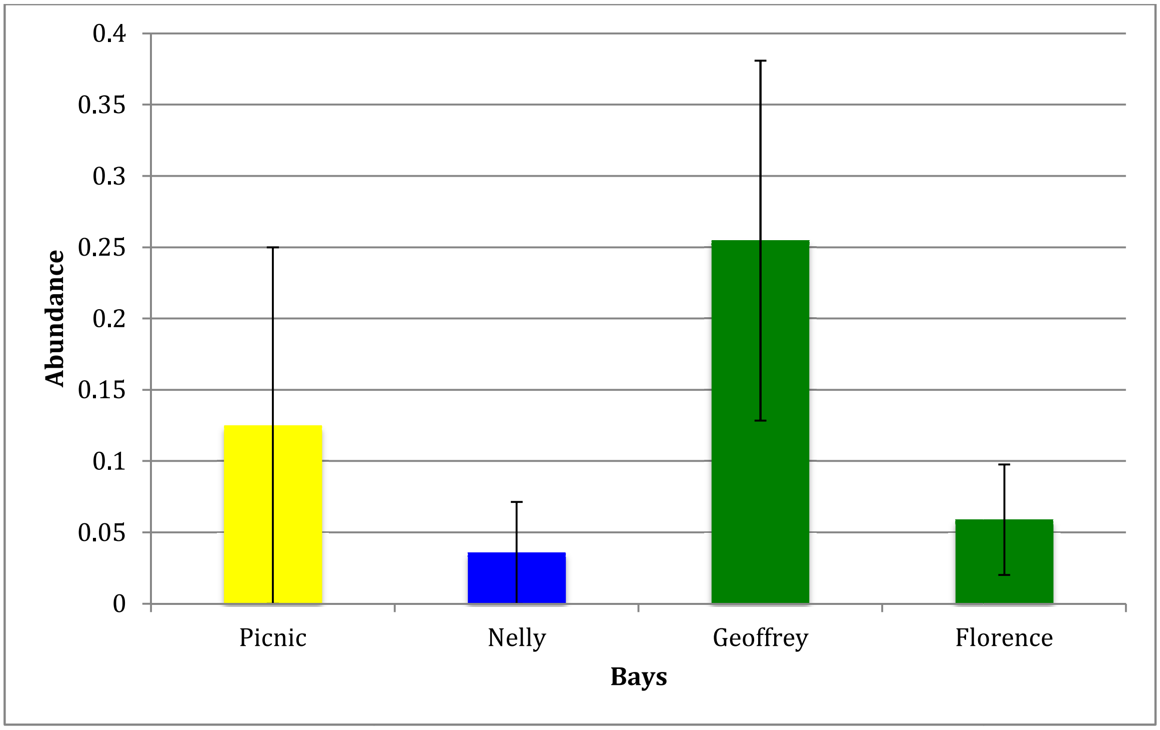

Figure 5. Mean abundances of snappers, not including *Lutjanus carponotatus*, at reefs in bays around Magnetic Island. Color indicates the marine park zone of each bay. Error bars = ±1 SE.

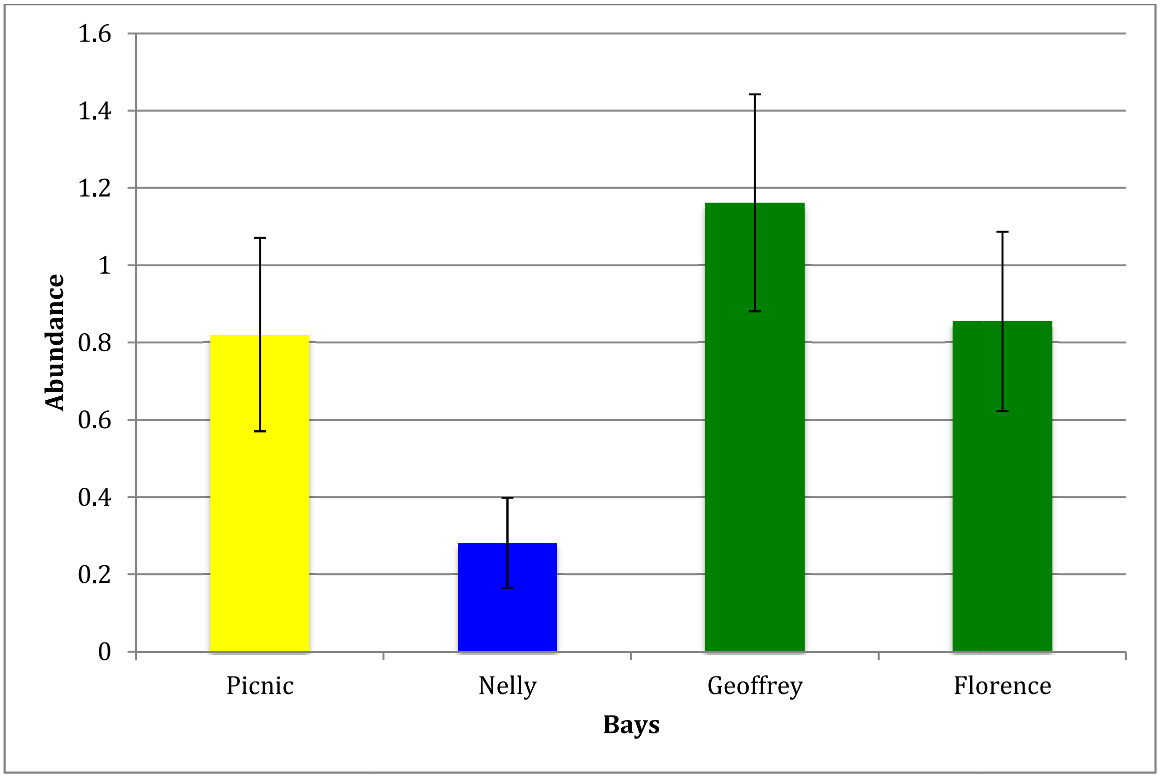

Figure 6. Mean abundances of *Lutjanus carponotatus* at reefs in bays around Magnetic Island. Color indicates the marine park zone of each bay. Error bars = ±1 SE.

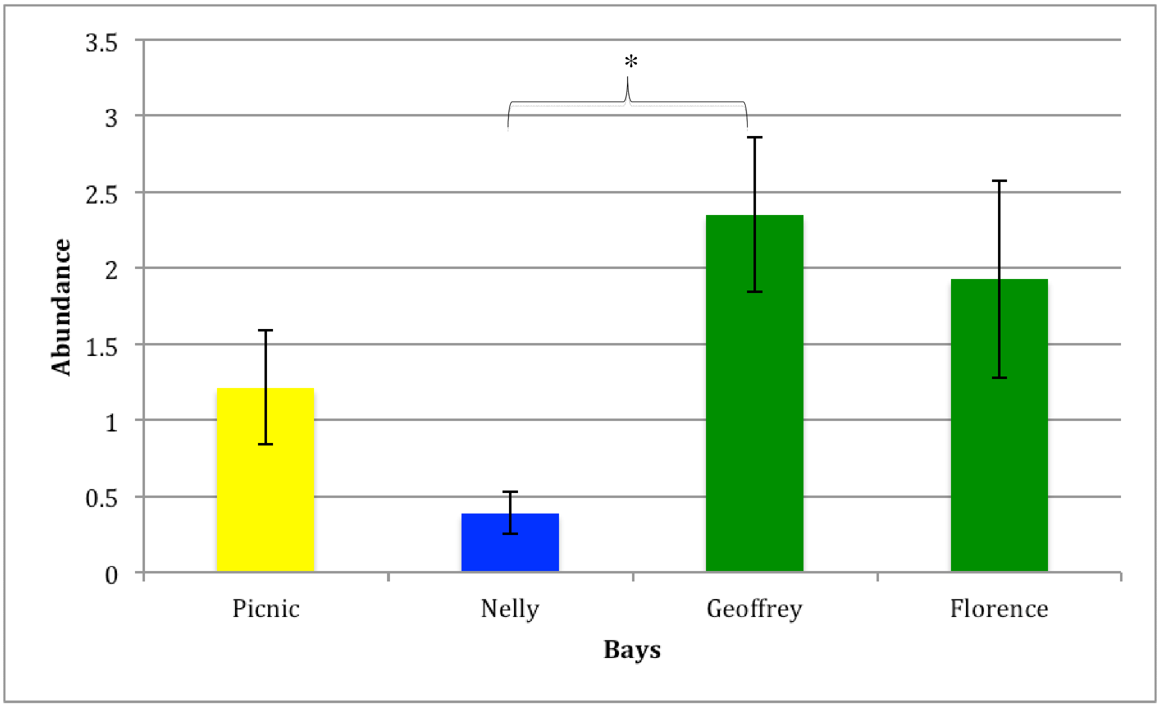

Figure 7. Mean abundances of all predatory fish (groupers, snappers, and emperors), including *Lutjanus carponotatus*, at reefs in bays around Magnetic Island. Color indicates the marine park zone of each bay. Error bars = ±1 SE. Tukey's HSD test found a significant difference between Nelly Bay and Geoffrey Bay (denoted by *; $p < 0.05$).

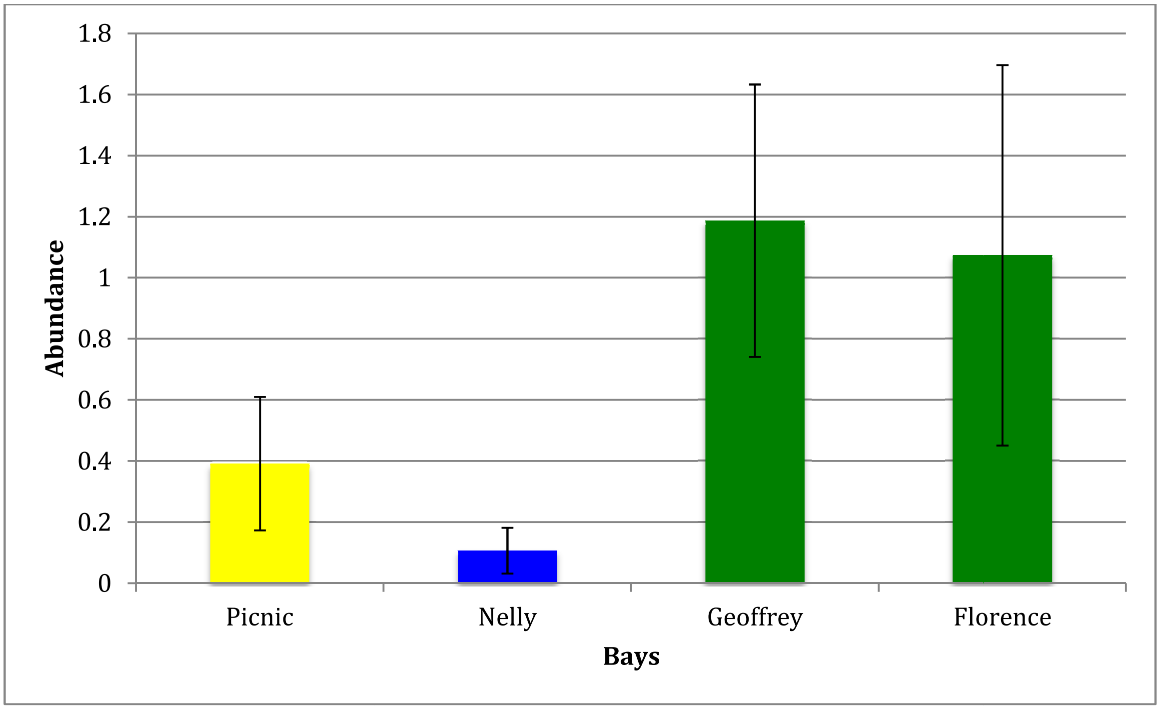

Figure 8. Mean abundances of all predatory fish (groupers, snappers, and emperors), not including *Lutjanus carponotatus*, at reefs in bays around Magnetic Island. Color indicates the marine park zone of each bay. Error bars = ±1 SE.

4.0 Discussion

4.1 Marine Park Zone Effects

Although populations of *L. carponotatus* were found to be marginally higher in Geoffrey Bay compared to Nelly Bay, as well as influence overall snapper and fish populations so that they were significantly higher, for the most part these results do not support a significant marine park zone effect. Previous studies agree with the overall trends, however, with stocks of groupers, snappers, and emperors significantly increasing in no-take zones (Watson et al. 1996; Jennings and Kaiser 1998; Westera et al. 2003). It should be noted, however, that these trends seem to differ between reefs. Ashworth and Ormond (2005) found significant increases in grouper and emperor populations but only a miniscule increase in snapper populations between take and no-take zones in the Nabq Managed Resource Protected Area, South Sinai, Egyptian Red Sea. In contrast, Roberts (1995) found a significantly higher abundance of snappers but only a non-significant increase in abundance of groupers between zones in the Caribbean (emperors are not found there). Thus it is possible that there is little to no marine park zone effect on reefs around Magnetic Island.

More likely, however, is that the disparities between the literature and this study are due to the large amount of variation within the data, as only a few fish, if any, were recorded at most transects. High turbidity, caused by wind and wave action stirring up organic particles into the water column, made it so that most transects were not wide enough to account for the rarity of these predators. Sampling area should have thus been increased not only to account for the small width but also as a whole so that more data were collected per transect. The design as a whole could be improved by forgoing transects entirely in favor of timed swims. These would cover far more ground and thus effectively eliminate the issue of visibility by allowing far more individuals to be observed per transect.

Past studies agree with the results regarding *L. carponotatus* and its higher abundance in no-take zones (Evans and Russ 2004; Williamson et al. 2004). While these studies show significant differences between zones, it can be assumed that only a marginal difference was recorded in this study due to the aforementioned issues with the number of observed individuals. Previous independent studies by students on Magnetic Island support this as they showed significant differences in populations of *L. carponotatus* between Geoffrey and Nelly Bays (Davis unpubl.) as well as a smaller increase in abundance at Florence Bay (Colton unpubl.).

4.2 Green Zone Improvement

Colton (unpubl.) speculated that the reason for the lesser effect at Florence was that it had only been a green zone since 2004 as opposed to Geoffrey since 1984 (Ghani unpubl.). Other studies suggest that there is a lag time between establishment of a no-take area and significant recovery of fish populations that is normally one to three years (Halpern and Warner 2002) but, in some cases, may be as long as six years (Roberts 1995). Halpern and Warner (2002) also found that after an initial increase in abundances values remained consistent for extended periods of time across numerous reserves. It would be thought, then, that Florence Bay would be the same as Geoffrey Bay in terms of the abundance of predatory fish. This does not appear to be the case as, although Florence Bay almost always had the second highest values, no significance was determined between it and the other bays and it was usually second to Geoffrey Bay. While this could be attributed to the aforementioned issues with data collection, the consistency with which Florence Bay is second only to Geoffrey Bay suggests that its abundances may have already peaked without recovering as much as predicted.

4.3 Improvements and Further Studies

Such a conclusion is dubious, however, without further studies that show differences of more significance. Thus, studies must continue to be carried out in order to better determine temporal effects within, as well as differences between, various fishing zones. Such studies should look to better control for the possibility of factors other than fishing that could be depressing predator abundances. Several previous studies used species from the families Chaetodontidae, Acanthuridae, Siganidae, Labridae, Scaridae, and Pomacentridae as controls since they are rarely targeted by fishermen (Davis unpubl.; Evans and Russ 2004; Williamson et al. 2004). Abundances of fish from these families were found to remain constant between zones while numbers of predators dropped. This effect does not seem to be universal, however, as other studies show significant decreases from no-take to take zones in abundances of even families not targeted by fishermen (Watson et al. 1996; Ashworth and Ormond 2005). In order for effects to be measured this way reefs would have to be surveyed on an individual basis. It would be more beneficial to look for differences in populations of non-targeted prey species as these would be expected to increase in take zones with the loss of predators due to top-down trophic cascades. A lack of increase in this regard could thus signify an issue other than fishing that is lowering abundances.

5.0 Conclusions

Although a significant marine park zone effect was seen in comparisons of snapper and overall fish populations that included *L. carponotatus* between Nelly and Geoffrey Bays, overall analysis was inconclusive due to the high amount of variation within the data. Further studies must be conducted to correct for this and obtain viable data as it is crucial that these sites continue to be protected. Techniques such as timed swims can be employed to cover greater distances and thus record more fish per replicate. More replicates would be beneficial as well, especially since the number of replicates was fairly low given the time constraints imposed by the independent study and poor weather conditions in the first week that prevented data collection. An ideal study would look at temporal variation in abundances of fish at each site and take into account other factors as well, such as the shapes, orientations, and compositions of each reef. This would allow for a more certain determination of whether or not no-take zones affect fish stocks around Magnetic Island or if there are other factors that are preventing such effects from taking place.

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