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Surveys of the effects of rezoning of the GBR Marine Park in 2004 on some fish species – preliminary findings

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Summary

A new zoning scheme for the Great Barrier Reef Marine Park (GBRMP) came into effect on July 1, 2004. A much larger proportion of the park area was closed to fishing under the new zoning scheme. In order to examine the effects of such closures, two sets of surveys have compared the abundance and biomass of the most important target fish species, coral trout (*Plectropomus* spp.), on areas of reef that had been open to fishing before 2004 but were rezoned as no-take areas and on nearby areas that had been open to fishing and remained so.

Surveys of near-shore sites in the Whitsunday Is 21 months after rezoning, found that density and biomass of coral trout had increased by a factor of 1.7 in areas that had been closed to fishing in 2004, while density and biomass decreased slightly over the same period in the areas that remained open to fishing. Another target species, the stripey sea perch (*Lutjanus carponotatus*), showed a similar pattern. Though the trends were consistent, the limited number of near-shore sites and local variability meant that differences were not statistically significant (at the 0.05 level) for either taxon.

Surveys of 25 pairs of similar mid-shelf and offshore reefs in five regions between Cairns and the Capricorn – Bunker group also found that density and biomass of coral trout were consistently higher on reefs that had been open to fishing but were rezoned as no-take areas in 2004 compared with nearby reefs that had been open to fishing and had remained so after 2004. There were estimates of coral trout populations before 2004 for only a few of these reefs, and these also suggested that numbers had increased in no-take areas.

Abundance of butterflyfishes that are not targetted by fishers, showed no consistent pattern with zoning in either set of surveys. Nor was cover of living coral consistently higher on reefs in either of the zones.

The life history of coral trout means that the full effects of closure to fishing can be expected to develop over a much longer period than has elapsed so far and surveys spanning 5-10 years will be needed to confirm any effects. Though first post-rezoning surveys of both the near-shore and the mid-shelf and offshore sites are not yet complete, these early results show a consistent pattern: one that would be expected if populations of target species in no-take areas are beginning to recover to pre-exploitation levels.

Introduction

The rezoning of the Great Barrier Reef Marine Park in 2004 was a major undertaking with consequences for all reef users, particularly the fishing sectors. The effects of the rezoning on biodiversity and on fish populations are subjects of broad interest to the Australian general public and to conservationists the world over as well as to reef users. As a multiple use marine park, spatial zoning, including highly protected "no-take" areas, is a key management tool employed by the Great Barrier Reef Marine Park Authority (GBRMPA) to ensure sustainable use.

Here we report on some early results from two sets of surveys that aim to measure the effects of highly protected no-take areas on populations of the main target species of fishes. A basic expectation of establishing no-take zones is that fishing mortality should be reduced, resulting in an increase in abundance of species targeted by fishing. Simple comparisons of fish populations in limited numbers of fished and no-take areas at one time may give spurious results because of temporary and localised random variation in population dynamics (Russ 2002). An ideal protocol is the "Before-After-Control-Impact-Pair" (BACIP) design, with several surveys before and after implementation of zoning. The surveys of near-shore reefs, such as those in the Whitsunday Islands reported below, are based on such a design. There are no data on fish populations from before rezoning on most of the mid-shelf and offshore survey reefs, but any consistent patterns that emerge from surveys of sites on 56 reefs distributed over 1,000km of the length of the GBRMP are very unlikely to be due to temporary or local random variation.

The two complementary sets of surveys aim to track the changes in fish communities in areas that were rezoned from being open to fishing to no-take status and compare those with changes on nearby areas that have remained open to fishing. Data presented here provides the first quantitative assessment of the effects of the rezoning plan within the GBRMP. The programs used similar methods to look at the effects of the rezoning on near-shore reefs and on mid-shelf and offshore reefs.

Methods

Survey design- Studies of fishes on near-shore reefs

Between November 2003 and June 2004, baseline fish community and benthic data were collected using Underwater Visual Census (UVC) surveys at 56 sites in the Palm, Magnetic, Whitsunday and Keppel Island groups and on a cluster of mid-shelf reefs in the Central section of the GBRMP. Twenty-eight of these sites were in areas that were scheduled to change from open to fishing to 'green' no-take zoning and 28 were sites that had been open to fishing and were scheduled to remain so after

rezoning. A Site was defined as a 300m stretch of reef edge. Sites were chosen haphazardly and were positioned at least 200 m apart.

Nine protected sites and nine fished sites in the Whitsunday Is were resurveyed in March 2006. The GPS coordinates for each site in the Whitsunday Island group are given in Appendix 1. The remaining 38 sites will be resurveyed before December 2006.

Survey design – Studies of fishes on mid-shelf and offshore reefs

In order to assess the effects of no-take areas, pairs of reefs were identified that had been open to fishing prior to 2004, but one reef in each pair had been rezoned as a no-take area in 2004 while the other reef remained open to fishing. Otherwise, reefs in each pair were located close to each other, were in the same Representative Areas Program bioregion and had similar geomorphology of the NE reef face. Only a small minority of the AIMS Long-term Monitoring Program reefs that had been surveyed since 1993 were rezoned as no-take areas in 2004 after having been open to fishing before then.

Six pairs of mid-shelf or outer-shelf reefs with the appropriate zoning history were selected in each of four regions: Cairns-Innisfail, Townsville, Mackay and the Swain Reefs, while four pairs of reefs were selected in the Capricorn-Bunker Group (see Appendix 2). Unlike the study on near-shore reefs, information on the coral trout populations on the mid-shelf and offshore survey reefs before rezoning in 2004 was very limited.

As at 1 September 2006, five reefs in the Townsville region remain to be surveyed. Fieldwork will be completed in September 2006 and a more complete report on the surveys of mid-shelf and offshore reefs will be produced after that.

Survey Methods - Studies of fishes on near-shore reefs

Five replicate transects were surveyed within each site using an underwater visual census (UVC) technique. Approximately 160 species of fish from 13 families were surveyed. Two scuba divers swam side by side along a 50m transect line, observing fish 3m either side (total area per transect = 300m^2). A third diver swam directly behind the first two, laying out the transect tape to measure the distance covered. This UVC technique minimised the effect of diver-avoidance behaviour of several of the species. To ensure accuracy of the fish counts the species list was divided between the two observers. To avoid any bias in counts and size estimation of the different families, the observers alternated roles within protected and fished areas. Size estimation training was carried out at the start of each day, using wooden fish models of known length.

A line intercept method was used to sample benthic organisms every metre along each transect tape (50 samples per transect). The following categories were distinguished: live hard coral (by life form, for example branching, solitary, tabular, massive, foliose, encrusting), soft coral, sponge, clams (*Tridacna* spp.), other invertebrates (such as ascidians and anemones), macro-algae and turf algae, dead coral, rock, rubble or sand. All transects were laid within a depth range of 2-9m with an average depth of 6m. Visibility was recorded for each transect and typically ranged from 6 to 12m. Surveys did not proceed if visibility was less than 4m.

Survey methods – Studies of fishes on mid-shelf and offshore reefs

Surveys of offshore reefs used the standard AIMS LTMP methods (see http://www.aims.gov.au/pages/research/reef-monitoring/methods.html and Halford and Thompson (1996)). Three sites were chosen in a standard habitat: the NE face of the reef. In each site, five 50m transects were laid out at 6-9m depth and following the depth contour. Surveys estimated the cover of benthic organisms on the transects using underwater video and >200 spp of reef fishes were counted. Large mobile species, such as coral trout, were counted using UVC in a 5m wide belt transect. An experienced observer swam slowly along the reef recording the number of fishes sighted within the belt, and their estimated size, on an underwater slate, while a dive buddy ran out a 50m surveyor's tape. With three sites on each reef, each with five 50m transects, the total area surveyed was 3,750m^2 per reef.

The first post-rezoning surveys were made in a series of field trips beginning in October 2005. Because surveys in the Townsville region are incomplete, we report data on 25 matched pairs of reefs over the five regions (Appendix 2).

Results

Fishes on near-shore reefs in the Whitsunday Is

In the near-shore sites in the Whitsundays, the mean population density of the primary target fishes, *Plectropomus* spp. (coral trout), changed from being 1.2 times higher in the fished than the proposed no-take areas before the rezoning, to 1.6 times higher in the no-take than in fished areas after rezoning, an increase from 5.2 to 9.0 fish per1,000m^2 (Figure 1). Similarly, mean biomass of *Plectropomus* spp. changed from 1.1 times higher in the fished than proposed no-take protected areas, to 2.2 times higher in the no-take protected than fished areas. Mean *Plectropomus* spp. biomass increased by 1.7 times from 7.6 to 13.5 kg per 1,000m^2 (Figure 1) in the new no-take areas after rezoning. In contrast, density and biomass of *Plectropomus* spp. decreased slightly in the areas that remained open to fishing (Figure 1).

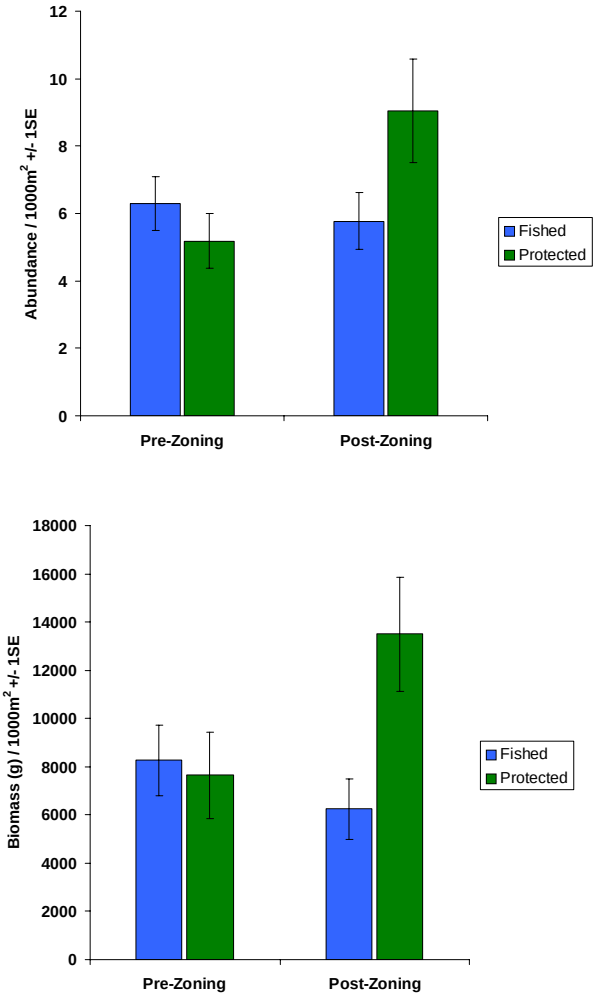

Figure 1: Mean abundance per 1,000m^2 (top figure) and biomass per 1,000m^2 (bottom figure) of *Plectropomus* spp. in fished and protected areas of the Whitsunday Island group before (2003-04) and after (2006) the rezoning of the GBRMP in 2004.

However, observed differences in both density and biomass between zones and years were not statistically significant (p>0.05, Table 1).

Table 1. Results of Repeated Measure ANOVAs on abundance and biomass of target indicator species (*Plectropomus* spp. & *Lutjanus carponotatus*), abundances of non-target species and coral cover in the Whitsundays before (2003-04) and after (2006) the rezoning of the GBRMP in 2004. Values for density and biomass of *Plectropomus* spp. were Log (x + 1) transformed. *L. carponotatus* density was Log (x) transformed and *L. carponotatus* biomass was Log (x + 1) transformed. F statistics and Probabilities (P) are shown. Statistically significant (0.05 or smaller) probabilities shown in bold.

Source of Variation	Year*zone *site (8,72 df)	Year * site (8,72 df)	Year * Zone (1,72 df)	Year (1,72 df)	Zone* Site (8,72 df)	Site (8,72 df)	Zone (1,72 df)
***Plectropomus spp.* density**	F=4.99 **P=0.000**	F=3.61 **P=0.001**	F=1.65 P=0.20	F=218.33 **P=0.000**	F=4.80 **P=0.000**	F=2.40 **P=0.02**	F=0.23 P=0.63
Plectropomus spp. biomass	F=1.54 P=0.16	F=3.00 **P=0.006**	F=2.41 P=0.12	F=0.05 P=0.82	F=3.58 **P=0.002**	F=1.06 P=0.40	F=0.04 P=0.83
***L.carponotatus* density**	F=0.77 P=0.63	F=1.22 P=0.31	F=1.66 P=0.20	F=0.28 P=0.59	F=6.39 **P=0.000**	F=4.82 **P=0.000**	F=0.03 P=0.87
***L.carponotatus* biomass**	F=1.30 P=0.26	F=3.42 **P=0.002**	F=0.11 P=0.74	F=5.07 **P=0.03**	F=3.07 **P=0.005**	F=3.45 **P=0.002**	F=0.04 P=0.85
Chaetodon aureofasciatus	F=4.29 **P=0.000**	F=1.82 P=0.09	F=0.57 P=0.45	F=9.61 **P=0.002**	F=3.42 **P=0.002**	F=5.03 **P=0.000**	F=29.79 **P=0.000**
Chaetodon rainfordi	F=3.67 **P=0.001**	F=3.31 **P=0.003**	F=0.24 P=0.62	F=0.55 P=0.46	F=3.43 **P=0.002**	F=3.10 **P=0.005**	F=1.34 P=0.25
Chelmon rostratus	F=1.17 P=0.33	F=2.71 **P=0.01**	F=0.002 P=0.97	F=15.30 **P=0.000**	F=3.44 **P=0.002**	F=1.23 P=0.29	F=2.06 P=0.16
% Live coral cover	F=5.81 **P=0.000**	F=0.82 P=0.59	F=0.40 P=0.53	F=5.37 **P=0.02**	F=6.35 **P=0.000**	F=8.86 **P=0.000**	F=21.53 **P=0.000**

The mean biomass of legal sized (>38cm TL) *Plectropomus* spp. in fished and protected areas of the Whitsunday Island group before (2003-04) and after (2006) the rezoning of the GBRMP in 2004 is shown in Figure 2. Based on surveys from 2003-04, differences in biomass between sites that were scheduled to stay open to fishing and adjacent sites that were scheduled to be no-take areas were calculated before the rezoning. These nine differences were compared to the equivalent differences from surveys made after rezoning (2006). A paired t-test indicated that the increase in biomass of legal –sized coral trout was substantial, but not statistically significant at the 0.05 level (t 8 df = 2.02, p = 0.08).

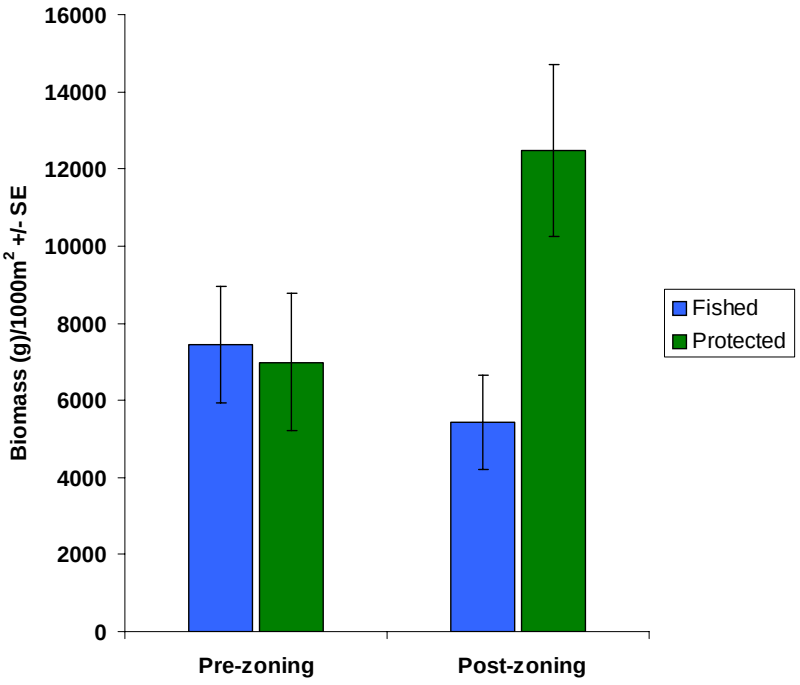

Figure 2: Mean biomass per 1,000m² of *Plectropomus* spp. above legal size (38cm TL) in fished and protected areas of the Whitsunday Island group before (2003-04) and after (2006) the rezoning of the GBRMP in 2004.

The stripey sea perch, (*Lutjanus carponotatus*) another species that is taken by line fishers, showed patterns similar to *Plectropomus* spp. on the near-shore Whitsunday sites. The mean density of *L. carponotatus* increased from being 1.1 times higher in the fished than the proposed no-take protected areas before the rezoning, to 1.6 times higher in the no-take protected than fished areas after rezoning (Figure 3a). This was an increase from 8.4 to 14.9 fish per 1,000m² (Figure 3a) in the sites that were rezoned as no-take areas in 2004. Similarly, mean biomass of *L. carponotatus* changed from 1.1 times higher in the areas that were scheduled to remain open to fishing than in the proposed no-take protected areas in 2004, to 1.7 times higher in the no-take protected areas than in the fished areas in 2006. Estimated mean biomass of *L. carponotatus* in the new no-take protected areas doubled from 2.6 to 5.3kg per 1,000m² after rezoning (Figure 3b). Density and biomass of *L. carponotatus* changed little in the areas that remained open to fishing (Figure 3a and b). However, for both density and biomass, the observed differences between zones and years were shown not to be statistically significantly (Table 1).

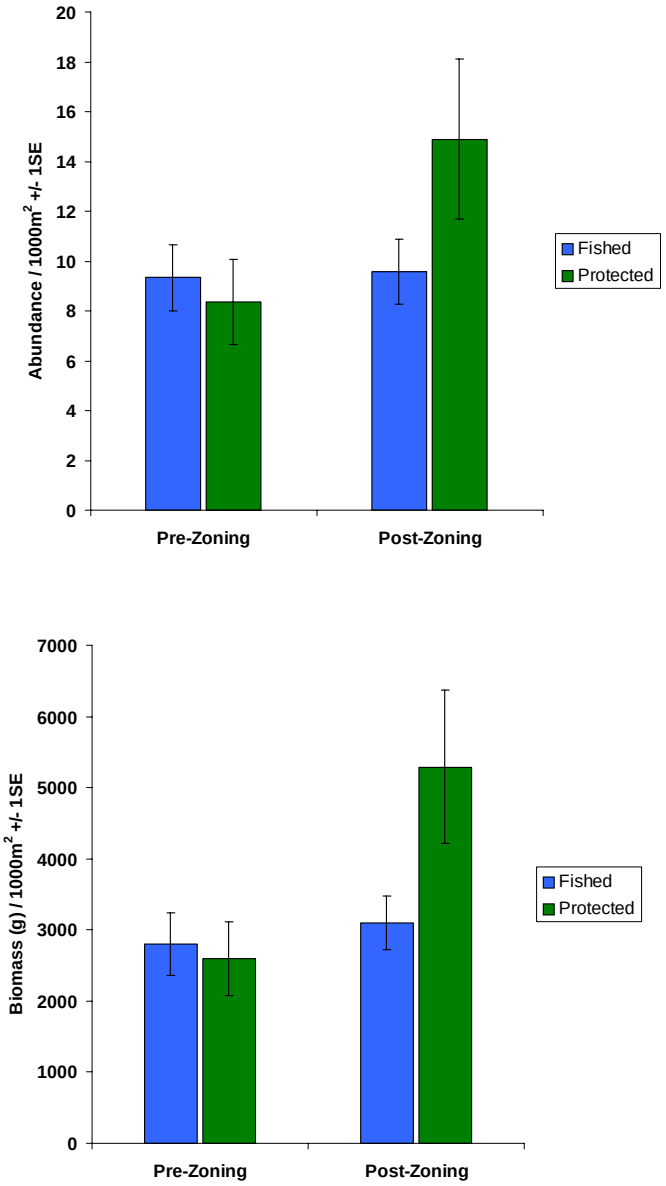

Figure 3: Mean abundance per 1,000m² (top) and biomass per 1,000m² bottom) of *Lutjanus carponotatus* in the fished and protected areas of the Whitsunday Island group before (2003-04) and after (2006) rezoning of the GBRMP in 2004.

Three species from the family Chaetodontidae were used as indicator non-target species. These were *Chaetodon aureofasciatus*, *C. rainfordi* and *Chelmon rostratus*. The patterns of distribution did not change after rezoning for any of the three species (Figure 4). *C. aureofasciatus* had significantly greater densities (Table 1) in the fished than the protected areas before and after the rezoning in 2004 (Figure 4a). *C. rainfordi* had slightly higher densities in the fished than in the protected areas before and after the rezoning (Figure 4b) but this difference was not significant (Table 1). The density of *Chelmon rostratus* was higher in the protected than the fished areas before and after rezoning (Figure 4c) but was also not significantly different (Table 1).

C. aureofasciatus is a corallivore and its distribution tracks the distribution of its main food source. The percentage of live coral cover in both zones did not change significantly from before to after the rezoning in 2004 (Table 1). Mean live coral cover was significantly higher in the fished areas than in the protected areas in both surveys (Table 1, Figure 5).

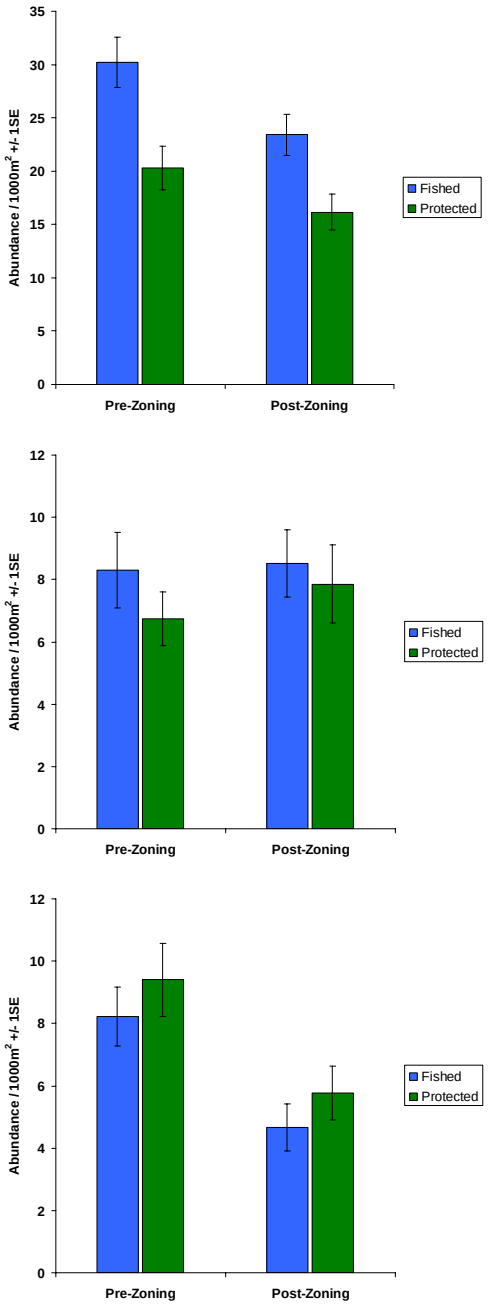

Figure 4: Mean abundance of non-target species: A) *Chaetodon aureofasciatus* (Top) B) *Chaetodon rainfordi* (Middle) and C) *Chelmon rostratus* (Bottom) in the Whitsunday Island group before (2003-04) and after (2006) the rezoning of the GBRMP in 2004.

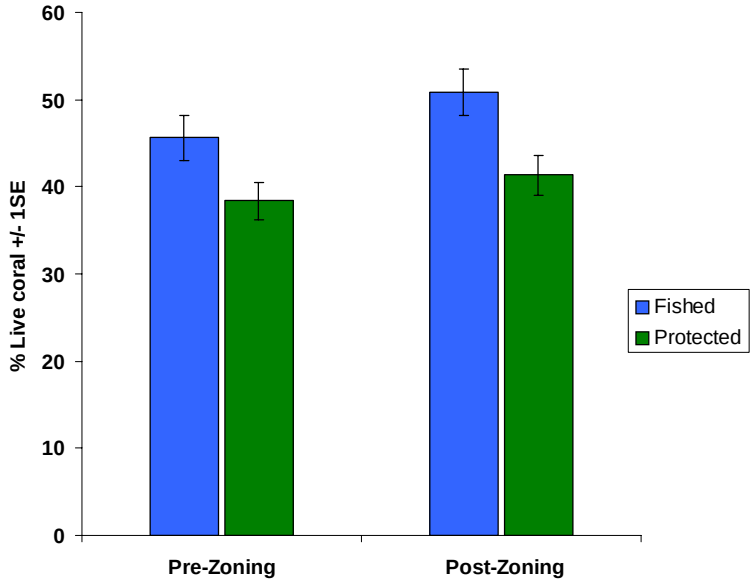

Figure 5: Mean percentage live coral cover in fished and protected areas of the Whitsunday Island group before (2003-04) and after (2006) the rezoning of the GBRMP in 2004.

Fishes mid-shelf and offshore reefs

The overall average numbers of coral trout on mid-shelf and offshore reefs in 2006 (4.4 and 6.6 fish per 1,000m^2 on fished and no-take reefs respectively) were lower than on the near-shore sites in the Whitsunday Is (Figure 1). Average numbers of coral trout varied considerably among the regions, being much lower in the northern Cairns / Innisfail region (~1.1 fish per 1,000m^2) than in the Mackay (~7.9 fish per 1,000m^2) and Swains regions (~7.7 fish per 1,000m^2, Figure 6). Mapstone *et al.* (2004) found a similar gradient in numbers with latitude on mid-shelf reefs. However, the average numbers of coral trout (all *Plectropomus* spp. combined) were higher on the no-take reefs than on the fished reefs in each of the five regions (Figure 6), ranging from 1.3 times as many on no-take reefs compared with fished reefs in the Swains to 1.7 times average difference between the two zones in the Mackay region. Estimates of the biomass of coral trout show a similar pattern (Figure 6). Surveys in the Townsville region are incomplete and the values may change. The differences were not due to unusually high numbers of trout on just a few reefs, but were generally consistent across 25 pairs of matched reefs that have been sampled so far (paired t-test on abundance data, p=0.004 , one-tailed).

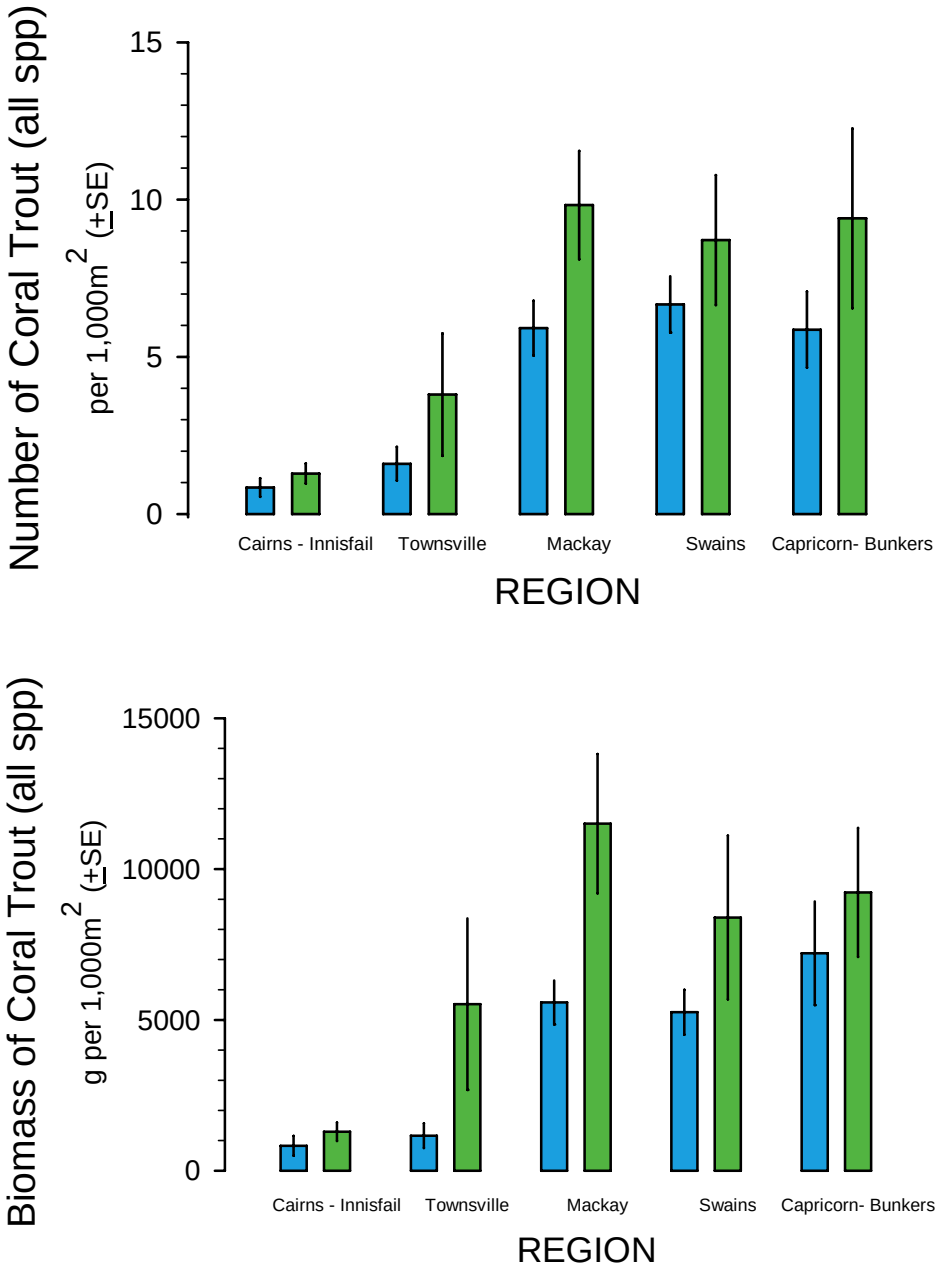

Figure 6. Mean density (upper graph) and biomass (lower graph) of all *Plectropomus* spp. on survey reefs in each region. Green bars refer to reefs that were rezoned as no-take areas in 2004 having previously been open to fishing; blue bars refer to reefs that were open to fishing prior to 2004 and remained so. Error bars are sample SEs.

The *relative* densities of coral trout would become higher on the no-take reefs in each pair if the densities of fishes on the reefs that remained open to fishing have declined since the rezoning. Estimates of coral trout densities over ten years prior to rezoning in 2004 are available for seven of the reefs that were surveyed in this current program and that remained open to fishing after 2004 (Figure 7). These reefs were from three regions. On two of these reefs (St Crispin and Chinaman) the numbers of coral trout recorded in 2005-2006 were well within the historical

range. Coral trout numbers were lower than expectation on one reef (Thetford) and higher than expectation on four other reefs. On this basis, there is no evidence that the difference in numbers of coral trout between reefs that had been fished but were re-zoned as no-take areas in 2004 and reefs that remained open to fishing throughout is due to a consistent drop in coral trout numbers on the reefs that remained open to fishing. Coral trout numbers have increased on all reefs since 2004, but the increase has generally been greater on reefs that were rezoned as no-take areas in 2004.

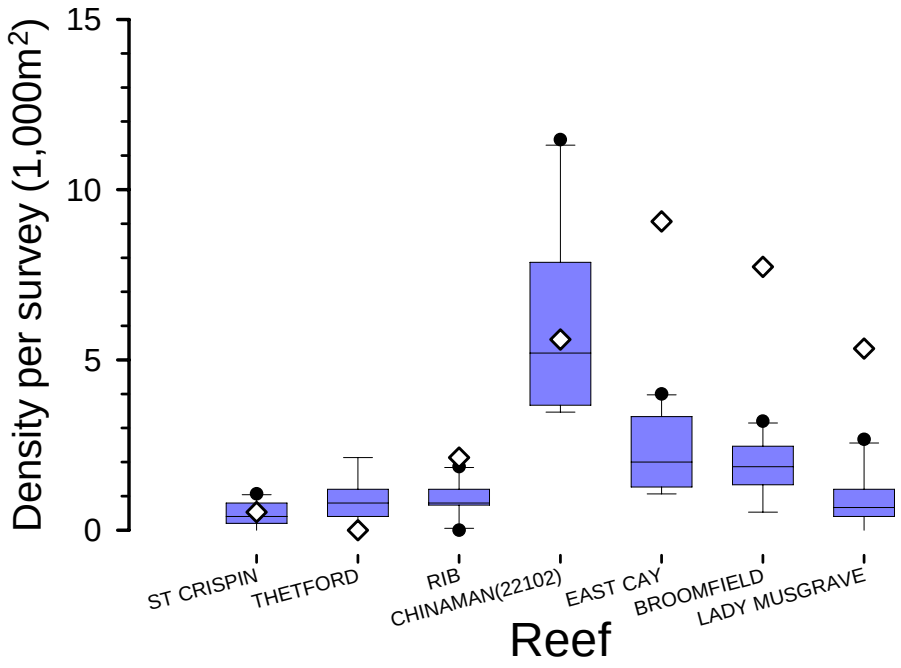

Figure 7 Distributions of densities of *Plectropomus* spp. per 1,000m^2 on survey reefs that were open to fishing 1995-2004 compared with values from surveys of the same reefs, which are still open to fishing, in 2005-06. Body of the box marks the 25th and 75th percentiles, bars includes 90th percentile. Horizontal line indicates the median value. Filled circles indicate more extreme records. Un-filled diamonds represent values from after rezoning, 2005-2006.

A group of reef fishes that are not targeted by fishers, the butterflyfishes, did not show any consistent pattern of abundance on reefs that were open to fishing compared with reefs that were re-zoned as no-take areas in 2004 (Figure 8, paired t-test, p=0.55 one-tailed), though there were regional differences in abundance.

Video transects are still being processed, but estimates of coral cover are currently available for the mid-shelf and offshore survey reefs in two regions, Cairns-Innisfail and the Swains. Coral cover is variable, but is not consistently higher on fished or no-take reefs (Figure 9, paired t-test, p=0.49 two-tailed).

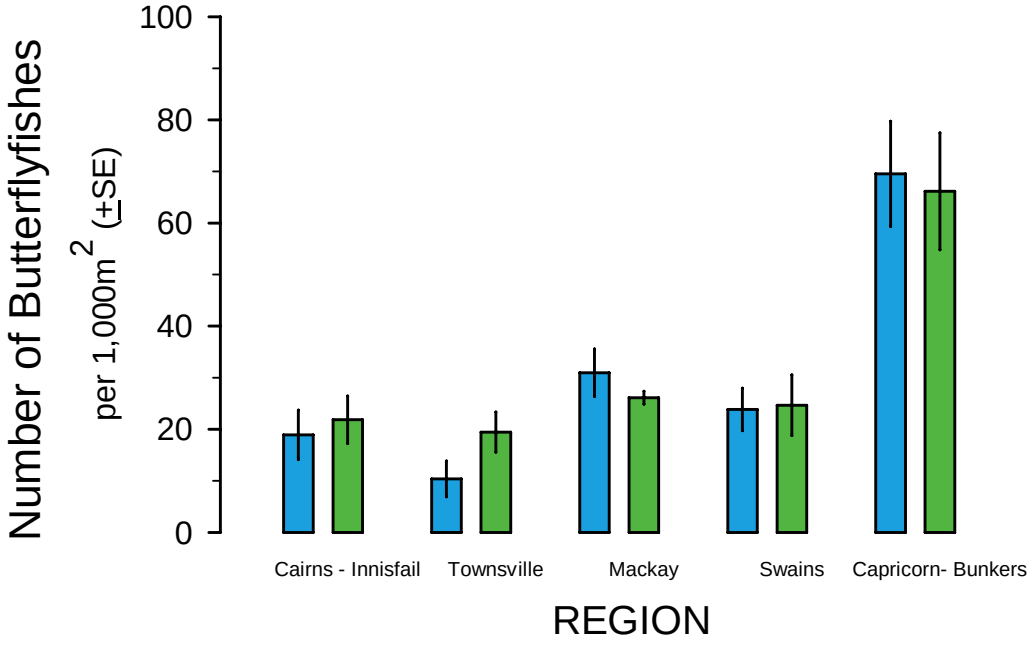

Figure 8. Mean numbers of butterflyfishes (*Chaetodon* spp., *Chelmon* spp. *Forcipiger* spp.) on survey reefs in each region. Green bars refer to reefs that were rezoned as no-take areas in 2004 having previously been open to fishing; blue bars refer to reefs that were open to fishing prior to 2004 and remained so. Error bars are sample SEs.

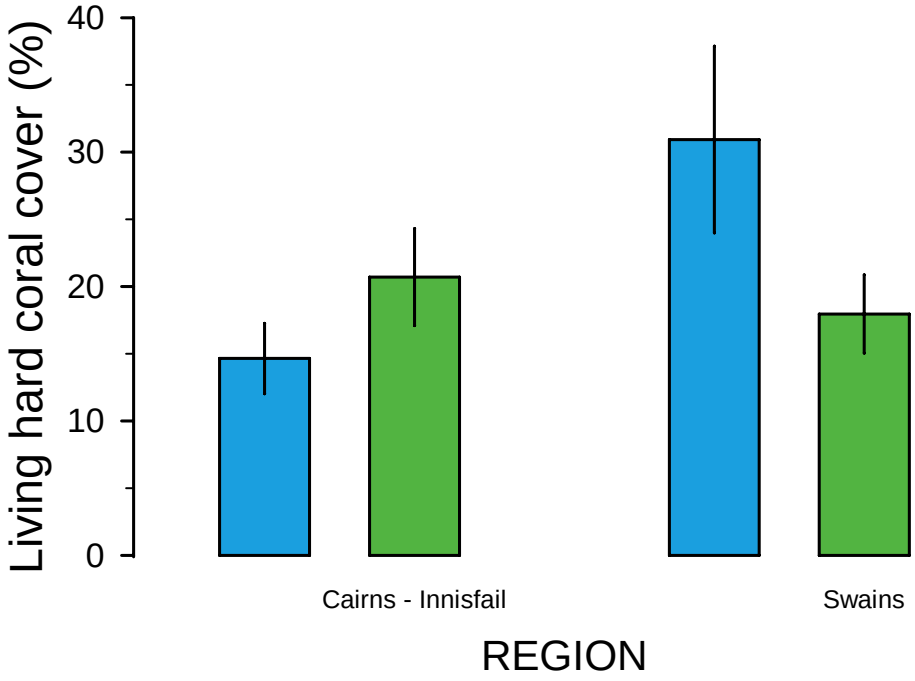

Figure 9: Mean cover of living hard coral on survey reefs in Cairns – Innisfail and Swains regions. Green bars refer to reefs that were rezoned as no-take areas in 2004 having previously been open to fishing; blue bars refer to reefs that were open to fishing prior to 2004 and remained so. Error bars are sample SEs.

Discussion and Conclusions

The new zoning plan for the Great Barrier Reef Marine Park (GBRMP) was implemented on July 1, 2004. These surveys were made 15-24 months after the rezoning, but even at this early stage there was evidence that rezoning is having an effect on target species of fishes. There is a consistent pattern in the results of both sets of surveys showing higher numbers and biomass of target species in no-take zones that were implemented less than two years ago, though differences are not statistically significant in some cases. Data collected from survey sites in the Whitsunday Is prior to the rezoning, and limited data from mid-shelf and offshore reefs from before 2004 show that this is due to an increase in numbers in the no-take areas rather than any consistent decrease in the fished areas. At the same time, some species that are not targeted by fishers do not show consistent changes and there is no systematic relationship between marine park zoning and coral cover in either set of surveys. This suggests that reduced fishing pressure is a likely cause of the higher fish numbers and biomass of target species in no-take areas. These results are thus consistent with a basic expectation of establishing no-take zones: that such zones will reduce fishing mortality and thus increase abundance of species targeted by fishing.

Surveys of fished and no-take areas in the Whitsunday Island group that had been in place for 12-14 years found that mean biomass of *Plectropomus* spp. in no-take protected areas was 4-6 times greater than in neighbouring fished areas (Evans and Russ 2004, Williamson *et al*. 2004). These initial surveys show much smaller differences, but two years is short compared with the potential lifespan of coral trout. Mechanisms that could explain increases in abundance and biomass of target species in the new protected areas in such a short period of time include reduced fishing mortality in the new protected zones, growth of these fish no longer subjected to fishing mortality, apparent successful recruitment into the legal-sized population in the new protected zones, and possibly, immigration of fish into the new protected zones. In terms of growth for example, *Plectropomus* spp. can grow to a range of 30 to 45cm within the first two years of life (Ferreira and Russ 1994). In the next two years *Plectropomus* can range in length from 30cm to 50 cm (Ferreira and Russ 1994).

Given the life histories of the target species, such a change in abundance is surprising in less than two years of closure. However, rapid responses to fishing closures are not unprecedented, both globally and on the GBR. Halpern and Warner (2002) reviewed 112 independent measurements of 80 reserves to show that higher average values of density inside reserves (relative to controls) can reach long-term mean levels within short periods of time (1-3 year). On the GBR both Russ *et al* (1996) and Ayling and Ayling (1994) reported that survivorship of strong recruitment

pulses of coral trout was enhanced in relatively recently closed green zones on mid-shelf reefs off Townsville, and Bramble Reef, respectively. On the other hand, duration of protection required for full recovery of predatory coral reef fish in no-take reserves has been suggested to take decades (Russ and Alcala 2004).

The degree of response should be viewed as the beginning of a recovery process. Both Williamson *et al.* (2004) and Evans and Russ (2004) have reported two to six-fold differences in abundance of coral trout and stripey sea perch between protected and fished areas of near-shore GBR reefs set up in 1987; current differences are much less, but can be expected to increase. The biomass of large predatory fish recorded in these early surveys in the Whitsunday Islands is less than half that reported from no-take reserves protected for 10-20 years in the Philippines (Russ and Alcala 2004). Any substantial assessment of the effects of such a rezoning has to involve repeated surveys to show that the differences between zones are maintained over time. These early results suggest that fish numbers have already increased in no-take zones. The initial surveys have yet to be completed and surveys will need to be repeated over the next decade for a comprehensive assessment of the effects of the rezoning.

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Appendix 1. GPS coordinates of each site surveyed in the Whitsunday Islands in 2003-04 and 2006. 'Zone 1' is the management zone applied to reefs between 1987 and June 2004; 'Zone 2' is the management zone applied to reefs as of July 2004 under the new rezoning plan. 'Blue' and 'Yellow' zones are open to fishing; 'Green' zones are protected.

Initial Survey Date	Survey 2 Date	Island	Zone 1	Zone 2	Site Name	GPS Co-ordinate
30/4/2004	7/3/2006	Whitsunday	Blue	Blue	W8	20°11.102'S; 148°58.921'E
30/4/2004	7/3/2006	Whitsunday	Blue	Blue	W9	20°10.899'S; 148°58.683'E
2/12/2003	8/3/2006	Hayman - East	Yellow	Yellow	HE1	20°03.482'S; 148°54.030'E
2/12/2003	3/3/2006	Hayman - East	Yellow	Yellow	HE2	20°03.216'S; 148°53.940'E
2/12/2003	4/3/2006	Hayman - East	Yellow	Yellow	HE3	20°02.480'S; 148°53.363'E
29/4/2004	3/3/2006	Hook	Yellow	Yellow	HY1	20°03.849'S; 148°54.909'E
29/4/2004	3/3/2006	Hook	Yellow	Yellow	HY2	20°04.101'S; 148°54.369'E
29/4/2004	4/3/2006	Hook	Yellow	Yellow	HY3	20°04.522'S; 148°54.086'E
30/4/2004	6/3/2006	Hook	Blue	Blue	HB7	20°05.532'S; 148°57.317'E
1/12/2003	6/3/2006	Dumbell	Blue	Green	DU1	20°10.326'S; 149°00.415'E
1/12/2003	7/3/2006	Dumbell	Blue	Green	DU2	20°10.538'S; 149°00.553'E
5/12/2003	6/3/2006	Hook	Blue	Green	HG7	20°03.642'S; 148°57.678'E
1/5/2004	4/3/2006	Black	Yellow	Green	BL1	20°04.686'S; 148°53.672'E
1/5/2004	8/3/2006	Black	Yellow	Green	BL2	20°04.693'S; 148°53.693'E
2/5/2004	8/3/2006	Hayman - West	Yellow	Green	HW1	20°02.337'S; 148°52.818'E
2/5/2004	2/3/2006	Hayman - West	Yellow	Green	HW2	20°02.798'S; 148°52.842'E
2/5/2004	2/3/2006	Hayman - West	Yellow	Green	HW3	20°03.039'S; 148°52.708'E
1/5/2004	2/3/2006	Langford	Yellow	Green	L1	20°04.665'S; 148°52.451'E

Appendix 2: Offshore reefs selected for survey.

Region	Reef ID	Reef pair	Open/Closed	Reef	Surveyed
Cairns / Innisfail	15099	1	C	Agincourt Reef No 1	Oct-05
	16019	1	O	St Crispins	Oct-05
	16057	2	C	Hastings Reef	Oct-05
	16064	2	O	Arlington Reef	Oct-05
	16071	3	C	Moore Reef	Nov-05
	16068	3	O	Thetford Reef	Nov-05
	17014	4	C	Hedley Reef	Nov-05
	17016	4	O	McCulloch Reef (No 1)	Dec-05
	17034	5	C	Feather Reef	Dec-05
	17024	5	O	Peart Reef	Dec-05
	17064	6	C	Taylor Reef	Dec-05
	17063	6	O	Farquharson Reef (No 1)	Dec-05
Townsville	18030	7	C	Kelso Reef	Jul-06
	18042	7	O	Roxburgh Reef	*Scheduled Sep 06*
	18076	8	C	Helix Reef	Dec-05
	18032	8	O	Rib Reef	Dec-05
	18031	9	C	Little Kelso Reef	Jul-06
	18043	9	O	Fore And Aft Reef	Jul-06
	18083	10	C	Fork Reef	Jul-06
	18077	10	O	Grub Reef	Jul-06
	18081	11	C	Knife Reef	*Scheduled Sep 06*
	18086	11	O	Chicken Reef	*Scheduled Sep 06*
	18091	12	C	Lynchs Reef	*Scheduled Sep 06*
	18088	12	O	Centipede Reef	*Scheduled Sep 06*
Mackay	20351	13	C	Pompey Reef (No 1)	Jul-06
	21060	13	O	21-060	Jul-06
	20351	14	C	Pompey Reef (No 2)	Jul-06
	21591	14	O	21-591	Mar-06
	20348	15	C	20-348S	May-06
	21062	15	O	21-062S	May-06
	20353	16	C	30-353S	Jul-06
	21064	16	O	21-064	Jul-06
	21139	17	C	21-139	Mar-06
	21187	17	O	21-187	May-06
	20309	18	C	Tern Reef	Jul-06
	21025	18	O	Penrith Island Reef	Jul-06
Swains	21278	19	C	21-278S	Jan-06
	21245	19	O	21-245S	Jan-06
	21584	20	C	Jenkins Reef	Jan-06
	21572	20	O	Small Lagoon Reef	Jan-06
	21588	21	C	Wade Reef	Jan-06
	22102	21	O	Chinaman Reef	Jan-06
	22084	22	C	22-084S	Jan-06
	21550	22	O	21-550S	Jan-06
	21558	23	C	21-558S	Jan-06
	21305	23	O	East Cay Reef	Jan-06
	21296	24	C	21-296	Jan-06
	21302	24	O	21-302	Jan-06
Capricorn - Bunkers	23045	25	C	North Reef (North)	Mar-06
	23048	25	O	Broomfield Reef	Mar-06
	23080	26	C	Hoskyn Islands Reef	May-06
	23079	26	O	Boult Reef	May-06
	23081	27	C	Fairfax Islands Reef	May-06
	23082	27	O	Lady Musgrave Reef	May-06
	23068	28	C	Erskine Island Reef	Mar-06
	23069	28	O	Masthead Island Reef	May-06