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Final Report

Effects of marine park zoning on coral reefs of the Capricorn-Bunker Group

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Australian Government

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Report on surveys in October 2015

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Cover photographs: AIMS LTMP

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ACRONYMS

AIMS	Australian Institute of Marine Science
COTS	Crown-of-thorns starfish
GBR	Great Barrier Reef
GBRMP	Great Barrier Reef Marine Park
GBRMPA	Great Barrier Reef Marine Park Authority
GBRWHA	Great Barrier Reef World Heritage Area
HPD	Highest Probability Density
JCU	James Cook University
LTMP	Long-term Monitoring Program
MPA	Marine Protected Area
TL	Total length

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SUMMARY

Here we report findings from the AIMS surveys of the effects of marine park zoning on communities of fishes and corals on Capricorn-Bunker Reefs in October 2015. Four pairs of matched reefs were surveyed; one reef in each pair is open to fishing while the other was zoned no-take in 2004. The abundance and biomass of the primary target of reef line fishery, coral trout, were higher on no-take reefs in the Capricorn-Bunker region. However there were no consistent differences in the numbers of herbivorous fishes, in cover of live hard coral or the abundance of juvenile hard corals. These results concur with the overall findings of these surveys on the GBR since 2006 (Emslie et al., 2015): protection from fishing has a clear effect on target species, but few indirect effects on other components of the reef community.

1.0 INTRODUCTION

The establishment of marine protected areas (MPAs) where fishing is not permitted is the most commonly advocated measure for conservation of biodiversity in coastal areas. There is clear evidence that no-take MPAs are associated with increased populations and size of individuals of fishery target species within the protected areas (Bohnsack 1993, Halpern and Warner 2002, Halpern 2003) with increasingly convincing evidence for spill-over of adults and recruits into the surrounding unprotected habitats (Abesamis and Russ 2005, Harrison et al. 2012,). In some circumstances, the establishment of MPAs has led to broader ecosystem effects: herbivorous fishes are exploited in many parts of the world, so establishment of MPAs can lead to higher coral cover in the reserves (Mumby and Harborne 2010), because the increase in herbivore numbers inside reserves can cause more successful coral recruitment resulting in higher coral cover within reserves. Outbreaks of crown-of-thorns starfish (*Acanthaster planci*) (COTS) are a major cause of coral mortality on the GBR (Osborne et al 2011) and between 1993and 2004, outbreaks were less frequent on reefs in the GBRWHA where fishing was prohibited (Sweatman 2008).

In 2004, following an extensive consultation process, the Great Barrier Reef Marine Park (GBRMP) was rezoned to align the multiple use zonation of the marine park with C.A.R. (Comprehensive, Adequate, Representative) principles of conservation planning (Fernandes et al. 2005). This included the objective of including 20% of each of the many identified bio-regions in no-take zones, leading to a substantial increase in the area of the marine park that was closed to fishing. Beginning in late 2005, AIMS has been monitoring the changes in communities on midshelf and outer shelf reefs that can be attributed to rezoning in alternate years. The major findings from the first 10 years of surveys of both nearshore and offshore reefs were published recently in Emslie et al. (2015). This report presents some results from the most recent surveys of selected Capricorn-Bunker reefs.

2.0 METHODS

2.1 Selection of study reefs

The general study of the effects of the Great Barrier Reef Marine Park Zoning Plan 2003 (GBRMPA 2004) on offshore reefs is based on surveys of pairs of reefs that were selected because they were similar in size, distance from shore, wave exposure, and underwater topography. Prior to 2004, both reefs in each pair were open to fishing, but one reef was closed to fishing when the new zoning was implemented in July 2004. The reef pairs were distributed in 5 clusters: 6 pairs each in the Cairns-Innisfail, Townsville, Mackay and Swains regions and 4 pairs in the Capricorn-Bunker region (Fig 1). This report concerns the surveys of the four pairs of reefs in the Capricorn-Bunker Group (Fig. 2) made 2 - 17 October 2015.

Following the colour coding on the Marine Park Authority's zoning maps, reefs that are closed to fishing will be referred to as "green reefs" while reefs that are open to fishing will be referred to as "blue reefs".

2.2 Sampling methods

The standard AIMS Long-term Monitoring Program (LTMP) methods were used to survey reef communities. Three sites, each consisting of 5 x 50m transects at 6-10 m depth were established on the NE face of each survey reef. Larger reef fishes were surveyed using underwater visual census on transects that are 5m wide. Both the number and total length (T.L. cm) of coral trout and secondary target species seen on belt transects were recorded, but only counts were recorded for other reef fishes that were not targeted by fishing (including all species from the Acanthuridae, Labridae (*Hemigymnus* spp, tribe Scarinae), Chaetodontidae, Siganidae). Smaller, site-attached damselfishes were counted on transects that were 1m wide (see Standard Operating Procedure 2).

Benthic organisms were surveyed from photo-transects in the same locations as the fish surveys. The organisms beneath five points on each of 40 frames from each transect were classified into one of 80 categories. These data were used to calculate percent cover (see Standard Operating Procedure 10). Juvenile corals (<5cm diam.) were counted on in a 0.34 x 5.0m area at the start of each transect. Agents of coral mortality such as crown-of-thorns starfish (*A. planci*), *Drupella* spp., and coral diseases were also surveyed on the same transects. Coral disease was recorded as the number of infected colonies (see Standard Operating Procedure 9).

Commercial and recreational fishers within the GBRMP primarily target all species of *Plectropomus* and *Variola* (family Serranidae), hereafter referred to as "coral trout". On the GBR, fishers using hook and line will retain all species of coral trout that are above the minimum legal size (38cm T.L.), so density and size estimates for all these species were pooled. We also looked for effects of zoning on mobile herbivorous fishes that are not taken by fishers in any numbers.

Benthic data (hard coral, soft coral and algae) were converted to per cent cover. Estimates of the density of juvenile coral colonies were corrected to density per m^2 of suitable substrate. Areas of sand or sediment and areas that are already occupied by corals or macro-algae or other macro invertebrates were not available for coral recruits to colonise. All reef fish data were standardised by converting raw counts to densities 1000 m^{-2}. Biomass of coral trout (kg 1,000 m^{-2}) was calculated from estimated fish lengths (T.L. cm) using published length-weight relationships (Kulbicki 2005, Froese and Pauly 2014).

Reef pairs have been sampled in alternate years (even-numbered) 2006-2016. Note that this survey is the first of five survey trips planned for the year.

2.3 Statistical methods

The spatial and temporal variation in the effects of implementation of zoning on the density and abundance of coral tout were estimated using Bayesian hierarchical linear mixed models (Gelman and Hill, 2007) via JAGS (Plummer, 2012) and the R2jags (Yu-Sung and Masanao, 2012) package in R (R Development Core Team 2011). The model included the fixed effects of Management Zone (Green or Blue) and Survey Year, as well as their interactions. Density and biomass of coral trout were modelled using a negative binomial distribution.

Since this is a report on just one of five regions to be surveyed in the program, these preliminary results for other variables are simply presented graphically, by reef pair.

Figure 1: Map of the central and southern Great Barrier Reef showing the five clusters of paired study reefs (orange areas) that comprise the survey design for the entire project. Reefs range from the Cairns-Innisfail region in the north to the Capricorn-Bunker reefs in the south. Grey circles show the locations of inshore study areas surveyed by staff of JCU in a complementary program. The surveys reported here only concern the southern Capricorn-Bunker region.

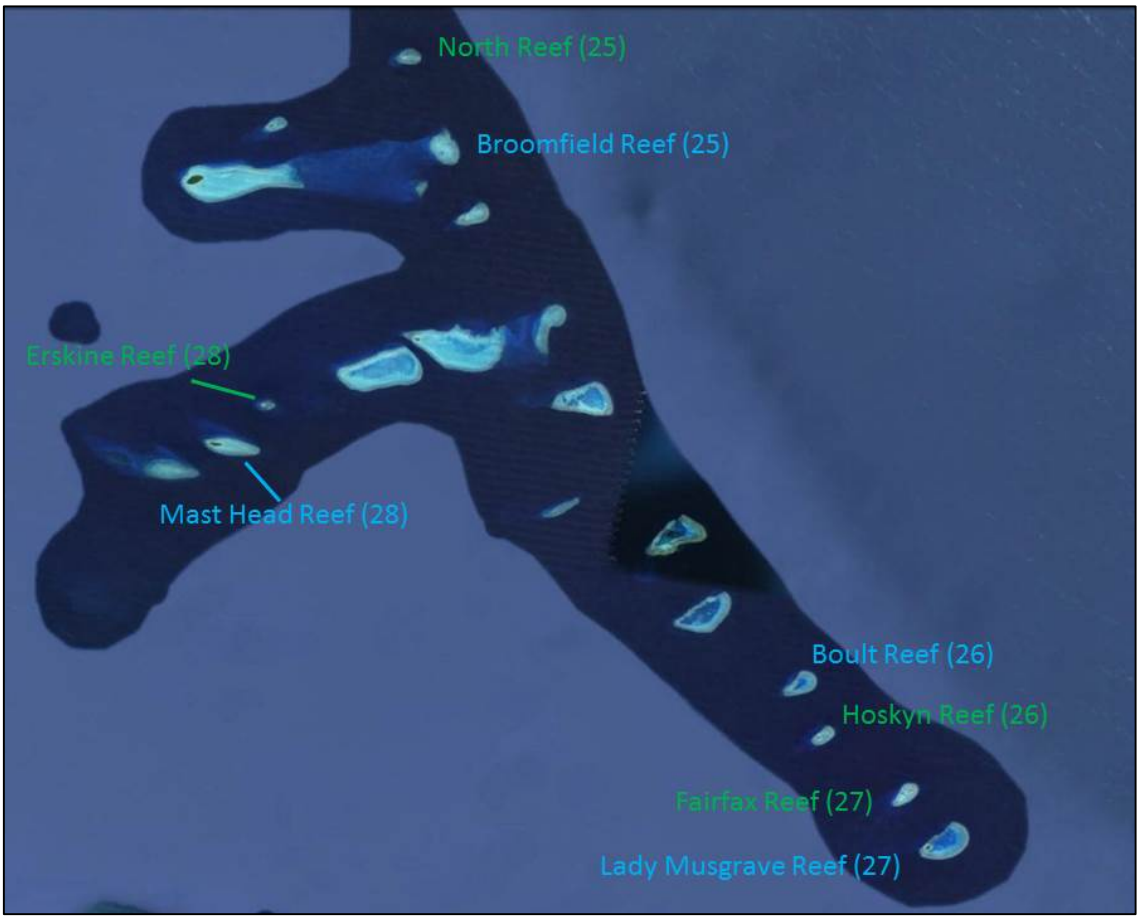

Figure 2: Annotated Google Earth image of the Capricorn-Bunker reefs. Survey reefs are named and the colour of the text labels shows the post-2004 zoning (green – no-take reefs, blue – reefs that bare open to fishing). Numbers in parentheses denote the reef pair that each survey reef belongs to**.**

3.0 RESULTS

3.1 Effects on exploited species: coral trout

While the objective of rezoning the GBRMP was to better protect biodiversity of the GBR, the principal management intervention was to control fishing activity, so the primary effects of rezoning should be evident in differences in the population characteristics of species that are affected by fishing. The most important reef-associated species in fisheries of the GBR is the coral trout, which refers to six species in the genera *Plectropomus* and *Variola.* On exposed outer shelf reefs, the main species is *Plectropomus leopardus* with a much smaller proportion of *P. laevis*.

Over the 12 years of surveys of the matched pairs of Capricorn-Bunker Reefs, the average number of coral trout has varied from year to year and the extent of the difference between blue and green reefs in each reef-pair has also varied, but general no-take, green reefs have had more individuals (Fig. 3) and a greater biomass of coral trout than the fished blue reefs (Fig. 4). This conforms to the general finding over the first 10 years since rezoning (Emslie et al. 2015).

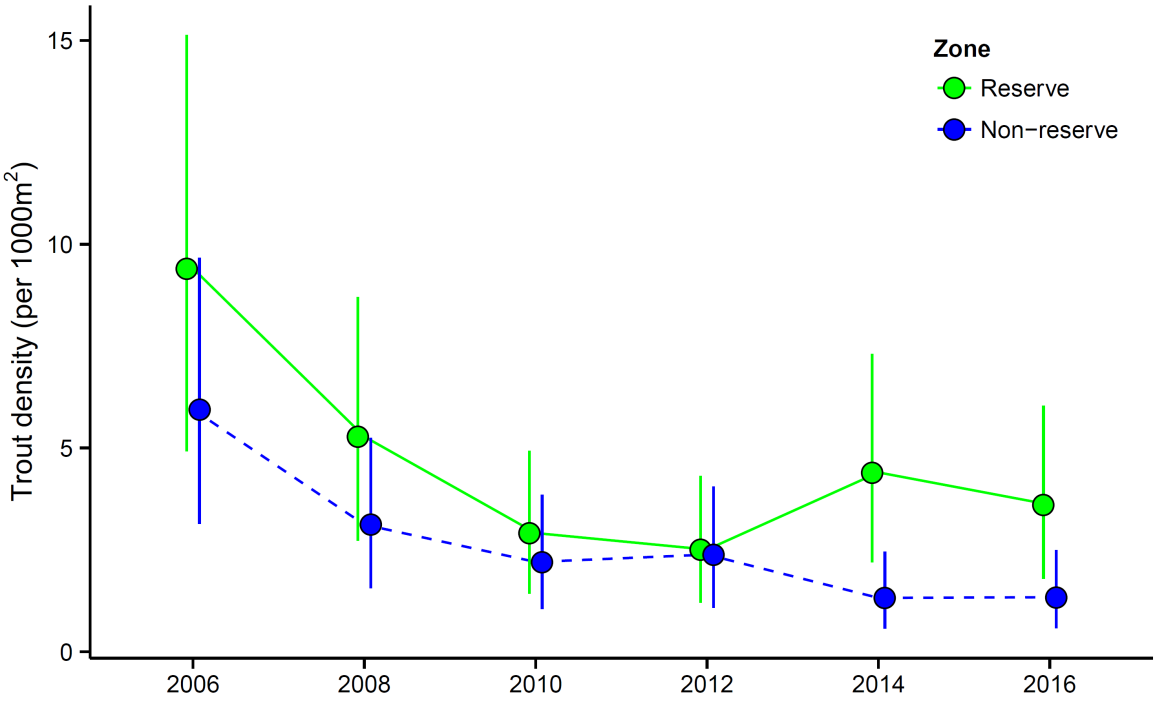

Figure 3: Abundance of coral trout (Plectropomus spp) on blue (fished) and green (no-take) offshore reefs in the Capricorn-Bunker region for the 2006-2016 reporting years. Error bars are 95% limits of Highest Probability Density (HPD).

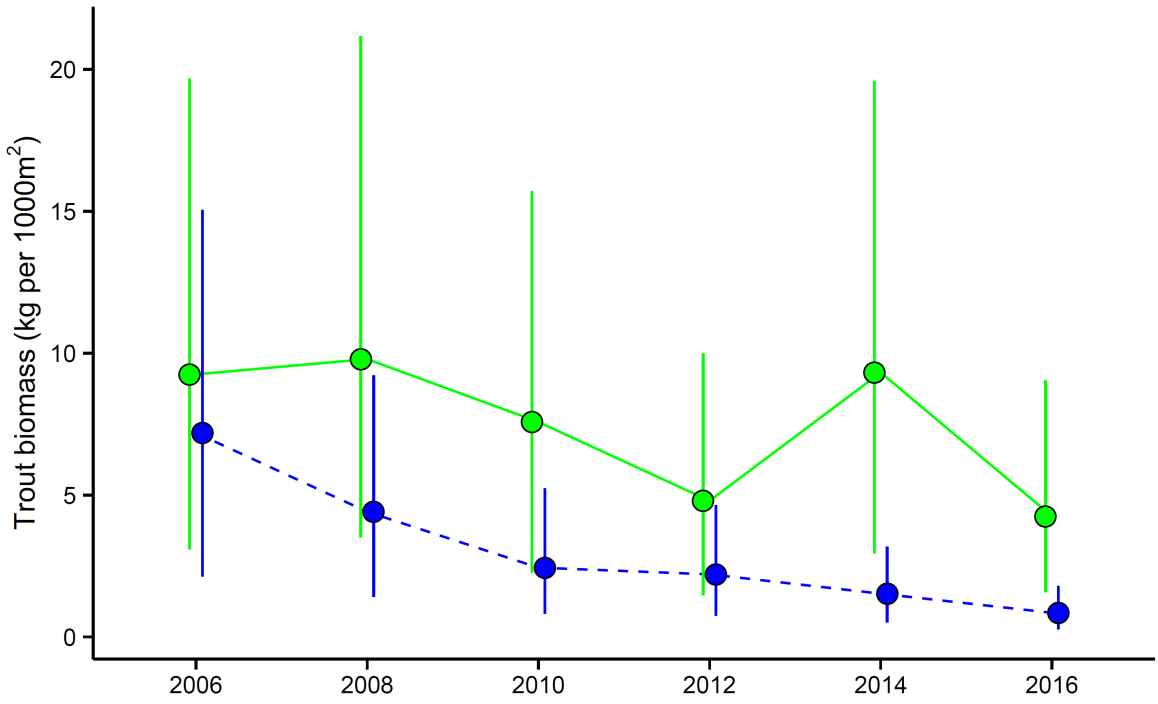

Figure 4: Median biomass of coral trout (*Plectropomus* spp) on blue (fished) and green (no-take) offshore reefs in the Capricorn-Bunker region for the 2006-2016 reporting years. Error bars are 95% limits of Highest Probability Density (HPD).

3.2 Effects on other species of fishes: herbivorous fishes

Herbivorous fishes are considered to have an important ecological function in promoting ecological resilience by inhibiting the growth of macroalgae and so favouring coral recruitment. The surveys in 2015 found variation in the numbers of mobile herbivorous fishes on the matched pairs of survey reefs in the Capricorn-Bunker region. The relative abundance of herbivorous fishes on blue and green reefs varied among the reef pairs, and has also varied over time within each pair. This suggests that protection from fishing has not had a strong effect on populations of mobile herbivorous reef fishes on southern reefs of the GBR.

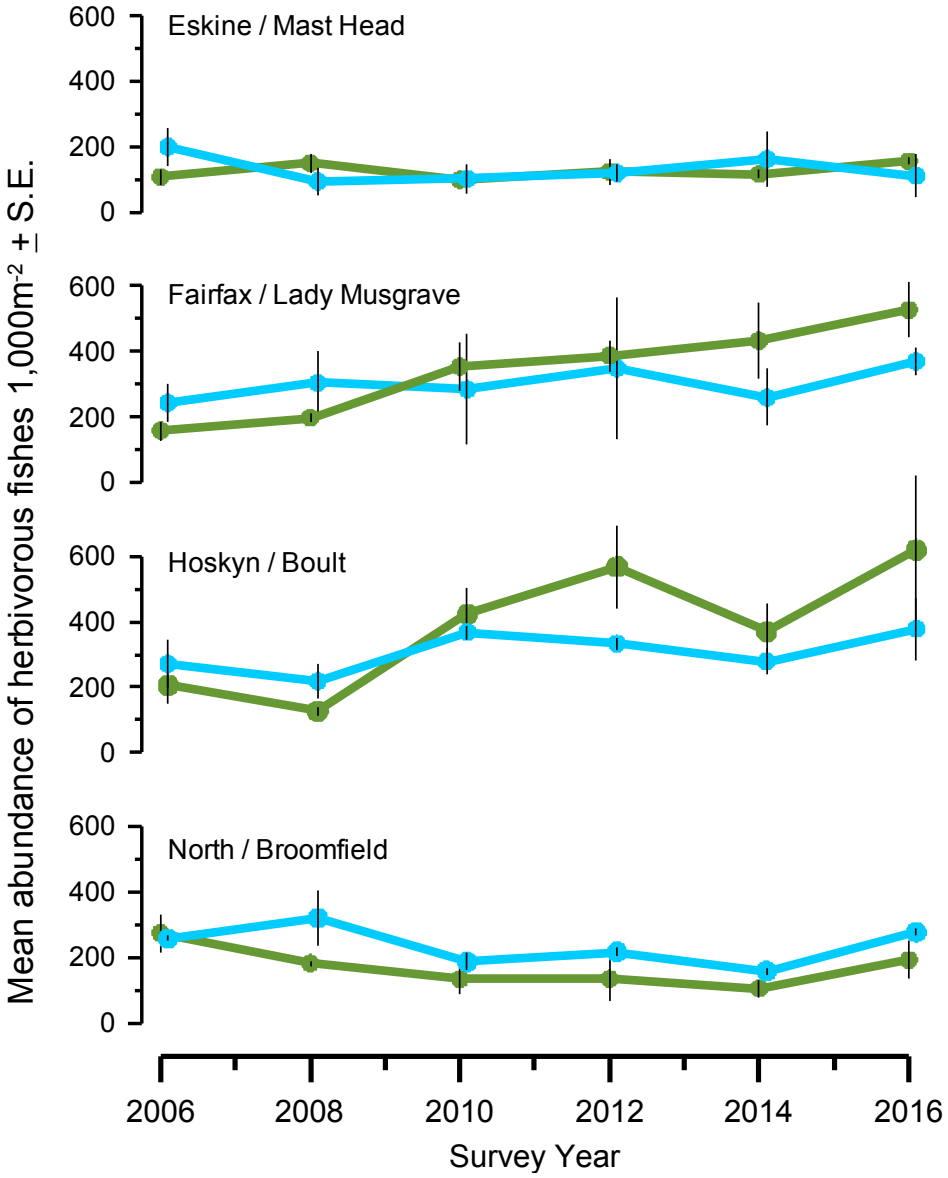

Figure 5: Abundance of mobile herbivorous reef fishes on matched pairs of offshore blue (fished) and green (no-take) reefs in the Capricorn-Bunker region of the GBR Marine Park, 2006-16.

3.3 Effects of zoning on coral cover

Some studies in the Caribbean have found that coral cover was higher in long-established marine protected areas (Mumby & Harborne 2010). This was not the case on offshore reefs of the southern GBR. Coral cover on most Capricorn-Bunker reefs dropped between 2008 and 2010 (Fig. 6), due to sub-cyclonic storms and Tropical Cyclone Hamish (March 2009), though there was little change in cover on Erskine and Mast Head Reefs. Coral cover has increased subsequently and that trend continued in the most recent surveys. The trajectories of coral cover have been similar on the reefs in each matched pair and the reefs in each zoning category have shown no consistent differences in coral cover.

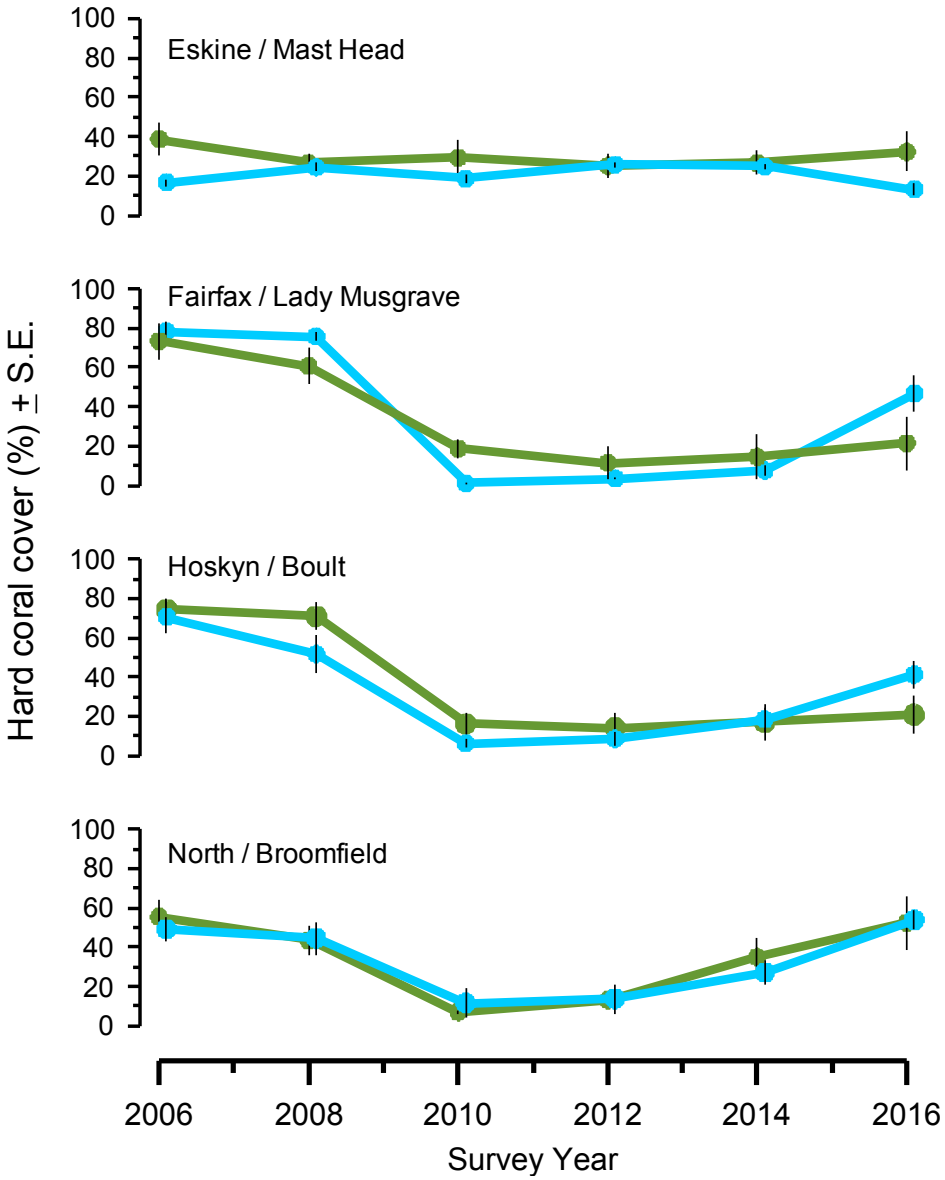

Figure 6: Percent cover of hard coral cover on matched pairs of offshore blue (fished) and green (no-take) in the Capricorn-Bunker region of the GBR Marine Park, 2006-16.

3.4 Effects of zoning on coral recruitment

One mechanism that might lead to increased coral cover on green reefs is through higher rates of coral recruitment, because grazing by herbivorous fishes suppresses algal growth and creates favourable conditions for corals to settle and grow. The lack of a difference in herbivore numbers between Capricorn-Bunker reefs in zones (Fig. 3) makes this unlikely. As expected, the numbers of juvenile corals on The Capricorn-Bunker reefs has increased in recent years (Fig. 5), but there is no consistent difference that can be attributed to zoning.

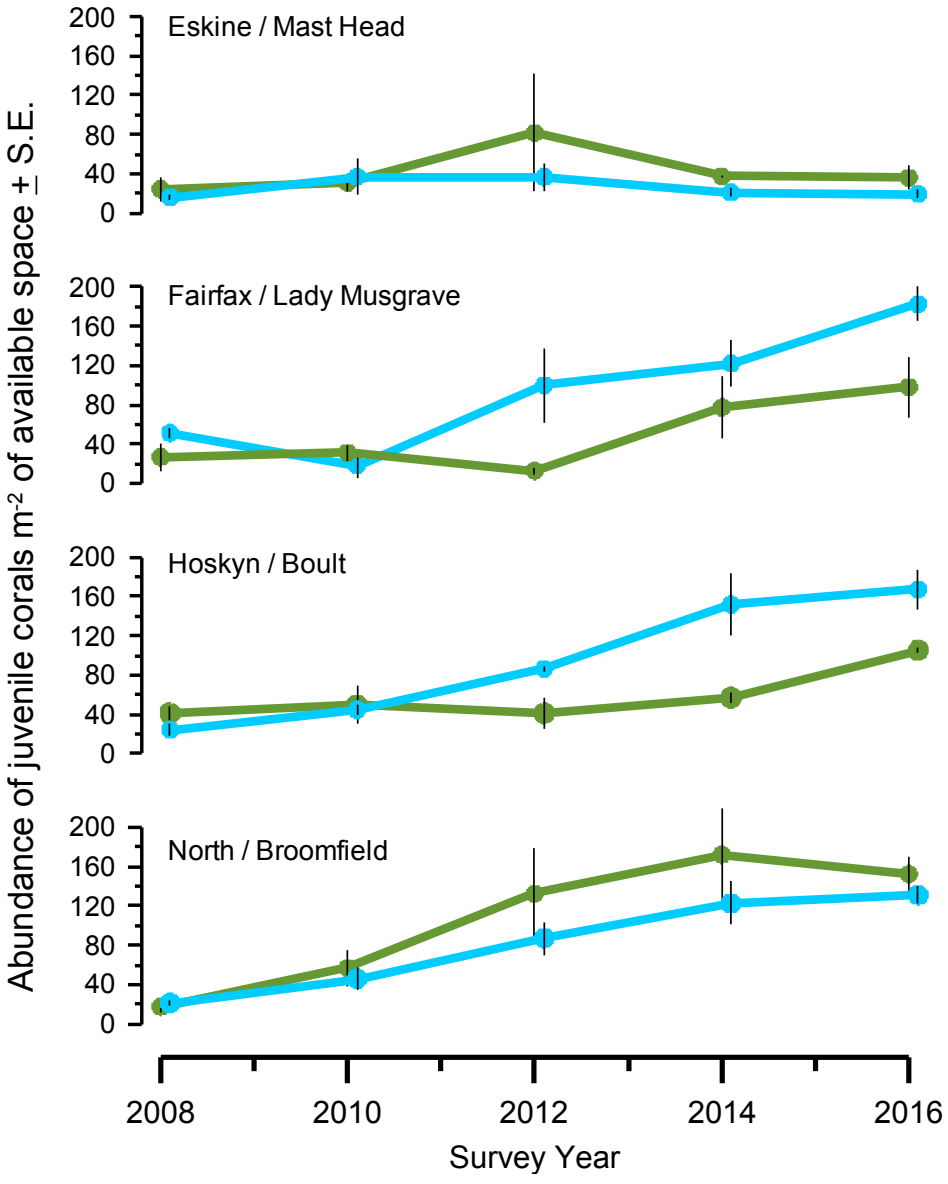

Figure 7: Average counts of juvenile corals (per m^2 of substrate available for settlement) on matched pairs of offshore blue (fished) and green (no-take) reefs the Capricorn & Bunker Groups in the southern GBR Marine Park, 2008-16.

3.5 Crown-of-thorns starfish on Capricorn-Bunker reefs

Small numbers of the crown-of-thorns starfish (COTS) have been recorded intermittently on Capricorn-Bunker reefs since surveys began in the 1980s, notably at Lady Musgrave Is Reef. These were usually large individuals and numbers appeared to be stable and low and no outbreaks were recorded. Starfish numbers increased after 2008, and in 2012-14 there was an active outbreak (an average of >1.0 COTS per manta tow) at Fairfax Reef, and numbers at Lady Musgrave Reef reached Incipient Outbreak levels (>0.22 COTS per tow). The timing of the appearance of the outbreak at Fairfax Reef suggests that it is a primary outbreak that arose by recruitment from non-outbreaking populations, making it the first well-documented example (Miller et al. 2015). Low numbers of starfish have also been seen at Boult Reef since 2006. Surveys in 2015 found that the former outbreaks had subsided, there were only small numbers of starfish (below outbreak densities) at all three reefs. No starfish were recorded at other Capricorn-Bunker reefs. These observations do not demonstrate any consistent effect of zoning; Fairfax Reef, which has had the highest starfish densities in recent years, was rezoned as a no-take zone in 2004, while Boult and Lady Musgrave Reefs are open to fishing.

4.0 DISCUSSION

The findings of the most recent surveys of reefs in the Capricorn-Bunker region correspond to the findings of the recently published summary of the effects of rezoning on reefs of the GBR (Emslie et al. 2015), in that there is clear evidence that no-take zoning has a positive effect on numbers and on size (and hence biomass) of target fish species. Similarly, indirect, ecosystem effects of zoning are not evident: there are no consistent differences between green and blue reefs in hard coral cover, in the density of juvenile coral colonies, or in the numbers of mobile herbivorous reef fishes.

There may be several underlying reasons. First, Australia is an advanced economy, fishing is highly regulated and fishers target relatively few high-value, top carnivores. This contrasts with the situation on many coral reefs that are located in the developing countries with expanding coastal populations that depend on local reefs for food. Fishing is much more indiscriminant in such places, removing all top carnivores as well as many fishes in other trophic levels. The consequences of these different scales of fishing for ecosystems will be quite different. Secondly, a largescale study of fish communities in MPAs globally (Edgar et al. 2014) concluded that the greatest conservation benefits were evident in marine reserves with five characteristics: **N**o-take zoning, effective **E**nforcement, and were **O**ld, **L**arge an **I**solated (so-called "NEOLI" attributes). The criterion for "old" was >10 years, so protected areas established under the current zoning plan for the GBRMP have only recently attained "old" status.

Thirdly, the period since the re-zoning has been unusual among recent decades in seeing a great number of large tropical storms that have caused wide-scale destruction of reef habitats. Acute destruction by cyclones is unaffected by zoning, and has been similar on both blue and green offshore reefs. Major disturbances caused by cyclones may well have swamped some more subtle and long-term indirect effects of zoning on reef ecosystems.

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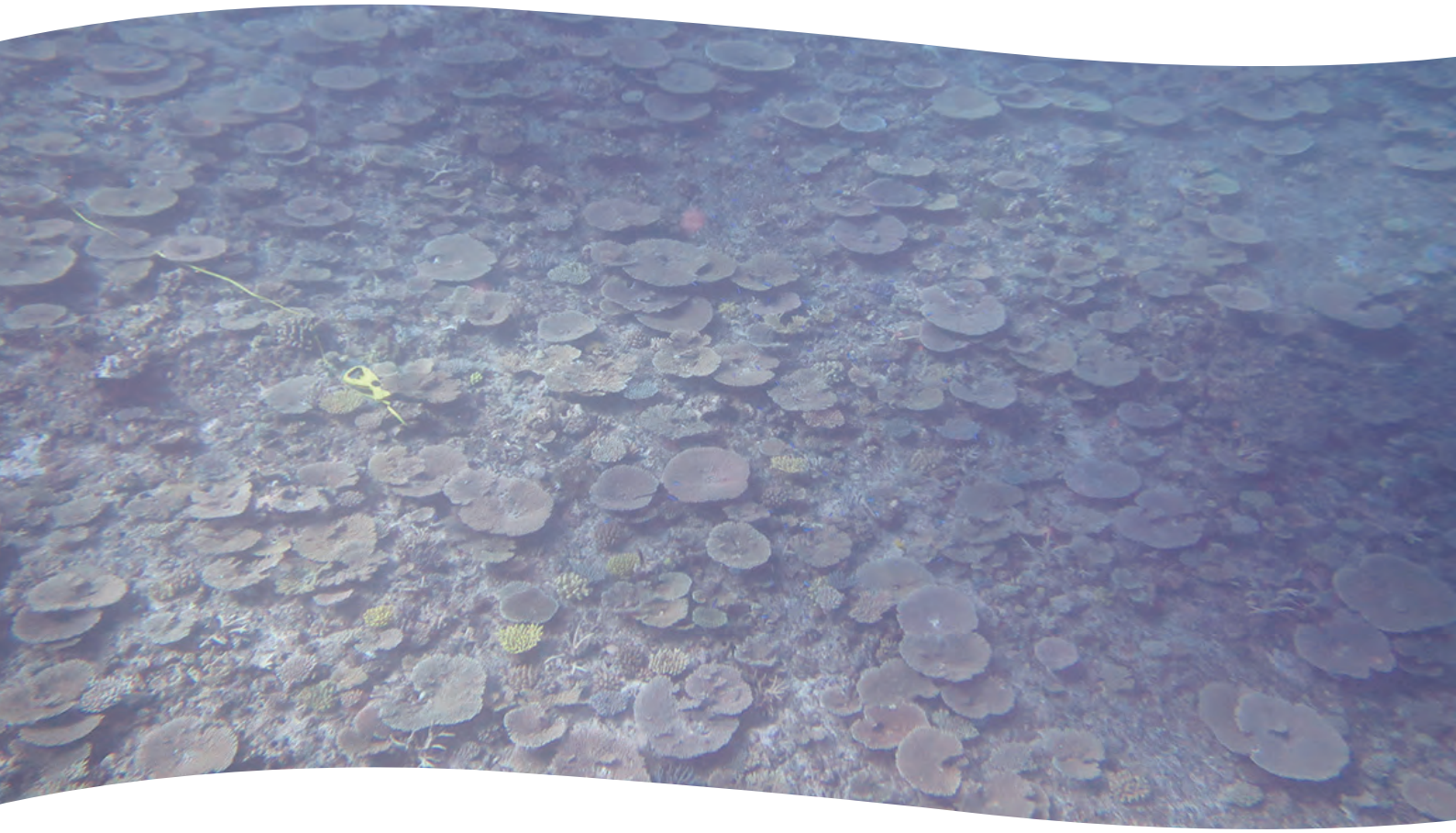

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