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18A Evaluating management success

Measuring and communicating effects of MPAs on deep "shoal" fisheries

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Abstract. Counts by divers have shown a rapid rise in coral trout populations on shallow reefs of the Great Barrier Reef Marine Park closed to fishing in 2004, but the deeper line-fishing grounds (>20m) have been inaccessible to fish biologists until the development of baited remote underwater video stations (BRUVS™). Here we summarise pair-wise comparisons of inter-reef "shoal grounds", closed and open to line-fishing, in terms of abundance and lengths of prized sportfish, bycatch and unfished species. The results of paired "fished-unfished" contrasts all depended on the context of microhabitat type, proximity to fishing ports and species vulnerability to line-fishing. On diffuse, low-relief grounds off Townsville prized target species were actually less abundant in zones closed to fishing. On discrete sunken banks of the Capricorn plateau closed to fishing there were about twice as many prized species, and they were larger than conspecifics on fished banks. A positive effect of closure to fishing around the deep bases of reefs in the Pompeys, Swains and Capricorn-Bunkers was visible only in coral-dominated microhabitats. Reef sharks were consistently more abundant in zones closed to fishing. These differences have been communicated with novel point-and-click, map-based BRUVS footage and data summaries on the "e-Atlas", using Google "Earth" and YouTube. This allows the public to make independent conclusions about the local effects of marine protected areas.

Key words: baited video, MPA, length measurement, multibeam bathymetry, line-fishing, sharks, lutjanids

Introduction

During the extensive community consultation that accompanied the rezoning of the Great Barrier Reef Marine Park (GBRMP) in 2004, anecdotal information emerged about the importance of deep submerged "shoals" and low-relief seabed features as intensified targets for commercial and recreational fishing.

In the reef domain, there was evidence of a shift in the commercial fishery for live coral trout *Plectropomus leopardus* from shallow reef flanks to include deeper waters because of the more valuable red colour of coral trout living at depth. In the inter-reef zone, there was evidence of both increasing commercial catches of lutjanids and a shift in the recreational fishery to deeper "shoals" away from reefs.

Advances in technology (such as affordable, colour echosounders and GPS navigation units) have allowed line-fishers to find and return to small habitat features supporting lutjanid snappers, serranid cods, labrid tuskfish and carangid trevallies. This appears to be a major driver for increased interest in the prized lutjanid red snappers (red emperor *Lutjanus sebae*, large- and small-mouth nannygais *L. malabaricus, L. erythropterus*) by both sectors. Dealing with these shifts in fishing behavior was a challenge for managers of fisheries and the GBRMP because there was almost no information about the distribution and nature of these submerged seabed habitats and their biology (see Mapleston et al. 2006 ; Bridge et al. 2011; Stieglitz 2012).

A four year campaign of research was conducted to describe these unknown seabed features in different regions, develop baseline counts of fish there, and use "pair-wise" comparisons of shoals open and closed to fishing since 2004 to assess differences in fish and shark numbers and sizes.

Only a small subset of these results have been published (see McCook et al. 2010), so this paper summarises the results from different shoal types and outlines a novel method of communicating them visually to the public using the internet.

Material and Methods

The fishing community supplied "GPS marks" to establish spatial, pair-wise comparisons of fished and unfished locations. These grounds were mapped, and baited video techniques were used to find, count and measure fish, sharks, rays and seasnakes (hitherto termed "fish").

Multibeam habitat mapping

Bathymetry was recorded with a RESON Seabat 8101 multibeam echo-sounder. Data were processed with software "SWATHED" (John Hughes Clarke, University of New Brunswick, CA) to produce 3-dimensional digital terrain models with a spatial resolution of 0.5m (see Steiglitz 2012).

Baited Remote Underwater Video Stations (BRUVS™)

The BRUVS consisted of a galvanised steel frame onto which a camera housing, bait arm, ballast weights, ropes and floats were attached (Fig. 1). A Sony MiniDV tape "Handicam" was used to film through an acrylic port within a PVC underwater housing, with the camera tilted downwards at an angle of 10 degrees. A 1.5m flexible bait arm held a plastic mesh bait bag containing 1 kg of crushed pilchards (*Sardinops sagax neopilchardus*) on the seabed. Stereo-BRUVS were also included amongst replicates to enable precise and accurate measurements from video footage.

The AIMS BRUVS2.5.mdb© database provided an interface for standardised identification and quantification of habitat types and fish numbers in the immediate field of view, the capture of images and timing of events, and the comparison of video frames with a library of reference images. "PhotoMeasure"© software from seagis.com.au was used to measure fish.

The percentage cover of abiotic substratum types and biotic habitat types in the field of view was estimated, and the relative abundance of fishes in the 1 hour video record was estimated by *MaxN* - defined as the maximum number of each species visible at any single time on the tape.

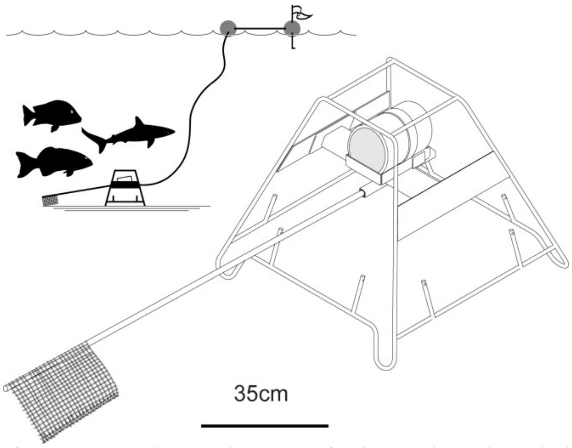

Figure 1: Up to 12 BRUVS were set simultaneously on the seabed to identify and count shoal fishes in paired, "fished-unfished" comparisons. Each replicate produced one hour of footage.

Survey design and analyses

Full description of the spatial and temporal components were given by Speare and Stowar (2008), Stowar et al. (2008), and Cappo et al. (2009a,b, 2010, 2011). Overall, there were 48 "shoal" locations sampled in three major types of habitat. Northern, "diffuse" shoals (n= 3 pairs) close to the fishing port of Townsville had very little topographic relief and sparse epibenthos (Fig. 2A).The southern reef bases (16 pairs) around the Capricorn-Bunker, Pompey and Swains groups of reefs were generally very remote from fishing pressure by recreational day boats. In contrast, the southern banks (2 pairs) included submerged, discrete banks (Fig. 2D) that were readily accessible by day boats. Temporal comparisons were made only on northern shoals and southern banks.

The *MaxN* data were over-dispersed or highly skewed so counts were analysed with a negative-binomial function using a log-link. Response in a given attribute of the fish assemblage was tested for a significant relationship with variation in depth, habitat category, region and zone (see Cappo et al. 2010, 2011 for full results).

Communicating results using YouTube and Google "Earth"

Video highlights, swathe maps and data summaries for each pair of shoals (open /closed) have been delivered via a KML using the "e-Atlas" http://e-atlas.org.au/content/gbr-aims-bruvs

This KML opens "Google Earth", showing the coast, reefs and zoning of the GBRMP and contains layers showing the abundance of 9 major species (red emperor, coral trout, large-mouth nannygai, small-mouth nannygai, venus tuskfish *Choerodon venustus*, red-throat emperor *Lethrinus miniatus*, grey reef shark *Carcharhinus amblyrhynchos*, collared sea bream *Gymnocranius audleyi* and starry triggerfish *Abalistes stellaris*). Each of the 48 shoal locations were displayed as place-markers in the map with an icon shaped to match the actual appearance of each fish species, with a pop-up page that displays summary data (abundance, depth, sampling effort, and species richness), BRUVS video clips and a swathmap of the area.

The same scaling of the icons was used for all layers to allow the user to visually compare the abundance of different species for which they do not know the scientific name. At a cursory glance the user can see, for example, that two of the red snapper species were found mostly in the north, and that coral trout were vastly more abundant in the south. More importantly, they can see the wide variability in numbers between zones.

For this KML a selection of BRUVS footage for all 24 pairs of shoals or reef bases (162 videos from 1102 BRUVS locations) were chosen using count data (*MaxN*) of prized species in an objective database query. In this way we avoided any bias in presentation of the "best" clips from pairs of shoals open and closed to fishing.

Video clips were uploaded to "Youtube" (http://www.youtube.com/user/eAtlasAIMS) with relevant tags. This hosting allows the videos to be discovered through the YouTube and Google video search. Internet surfers unaware of the e-Atlas can, therefore, find the video highlights and follow links back to the e-Atlas for more information.

Results

Full results are available in the series of research reports cited here, which are available for download from the Reef and Rainforest Research Centre Limited website: http://www.rrrc.org.au/mtsrf/

Simple regional comparisons of key species showed that differences between zones were complicated and wholly dependent on the context of seafloor habitat (Fig. 3). Fishermen's "GPS marks" often turned out to be vastly different in terms of seabed topography when mapped and viewed with underwater cameras (Fig. 2). When these differences in habitat were accounted for, a strong consistent, positive effect of closure to fishing was detected in the mean abundances of various species grouped according to their vulnerability to line-fishing (Table 1).

A release from line-fishing mortality would be expected to increase pair-wise differences in fish abundance and fish size through time. The southern banks showed a decline in abundance over two years on the open banks, but there was a coincident increase on only one of the banks closed to fishing (Fig. 4). There was a larger proportion of larger coral trout, red emperor, red-throat emperor and venus tuskfish in the southern banks closed to fishing, above the legal minimum size at first capture. In contrast, two unfished species showed no major displacement amongst modes between zones (Fig. 5).

	Habitat + region + zone	Habitat + depth + zone
Richness	**1.08**	**1.08**
All fish	**1.14**	**1.13**
Unfished	**1.14**	**1.19**
Bycatch	1.05	-
All targets	**1.45**	**1.42**
Prized targets	**1.48**	**1.42**

Table 1: Coefficients of the effect size of closure to fishing on species richness, total fish abundance, and different species categories in two types of model. The first included region of the GBRMP as a factor. Region was a proxy for depth and other covariates, and the second approach did not include it. Prized species are a smaller subset of the fish targeted by line-fishing. Significant effects are highlighted in bold.

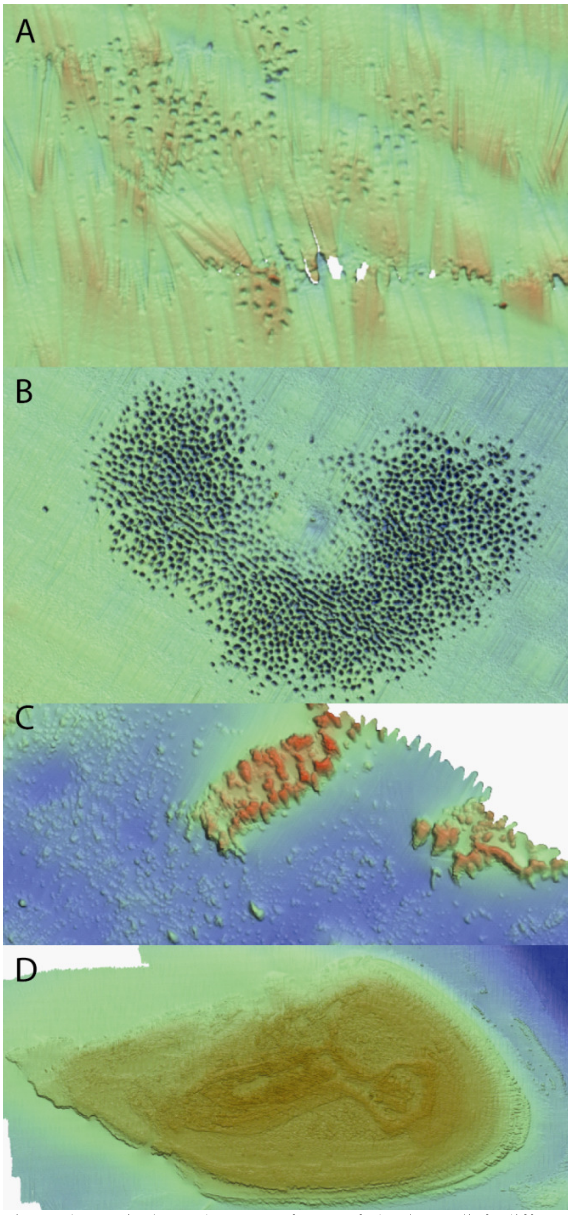

Figure 2: Typical swath maps of one of the low-relief, diffuse, northern shoals (A), the "halo of holes" (sensu Steiglitz 2012) around a wreck (B), the reef base of Green Island (C) and Karamea bank on the Capricorn plateau (D). These maps are not on the same scale, but show the vast differences in "fish holding" habitat.

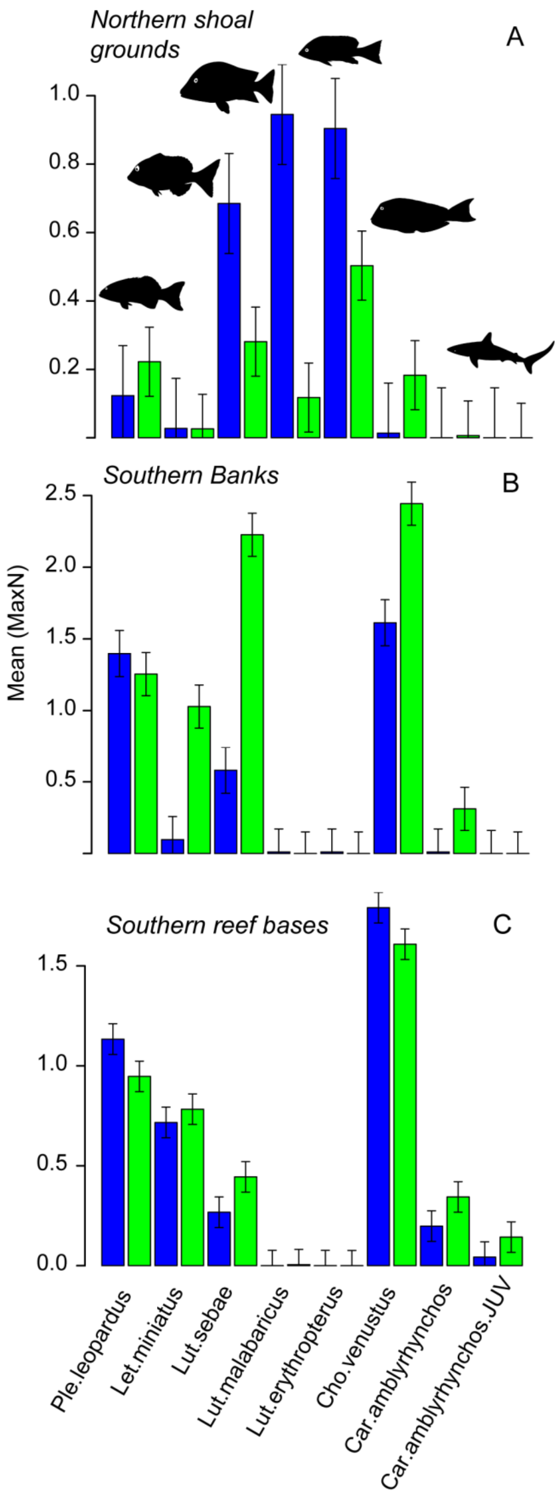

Figure 3: Global mean counts (*MaxN*) of selected species vulnerable to line-fishing on northern diffuse shoals (Townsville, A), distinct submerged banks in 2007 (B, see McCook et al. 2010) and reef bases (C). JUV = Small juvenile grey reef sharks. Green bars were closed, and blue bars were open, to line-fishing since 2004.

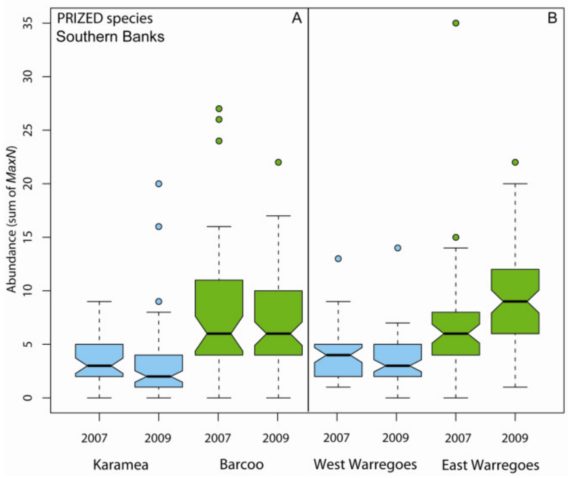

Figure 4: Boxplots of the median counts (sum*MaxN*) and 95% Confidence Intervals for southern banks between two sampling periods in 2007 and 2009. The notches represent 1.5 x (interquartile range of *MaxN*/SQRT(n)). Lack of overlap of notches is strong evidence that medians differ. Green boxes were closed, and blue boxes were open, to line-fishing since 2004.

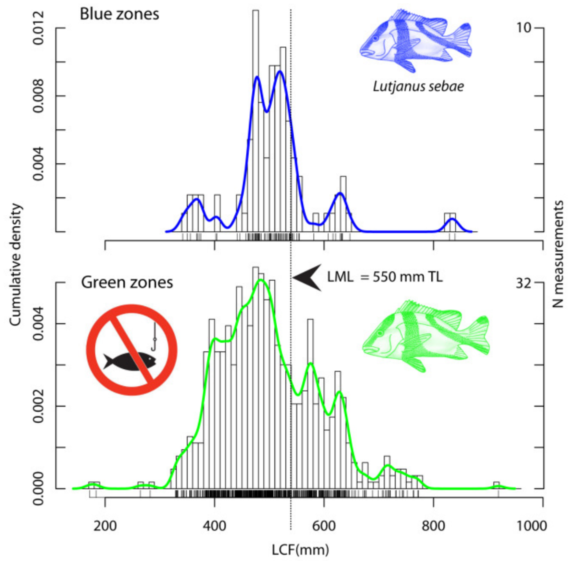

Figure 5: Histogram of stereo-video measurements (southern banks, years pooled) for the red emperor showing the legal size limit at first capture (LML=550 mm). The lines, coloured by zoning status, are empirical cumulative density functions (ECDF) that represent length modes. The rug on the x-axis shows individual measurements. Green zones were closed, and blue zones were open, to line-fishing since 2004.

Discussion

The pool of lutjanids, serranids, labrids and other target species were estimated to be 1.42 times as abundant on shoals closed to fishing in 2004 as they were on fished shoals after depths, substratum type and epibenthic cover were accounted for. The species richness, and abundance of other species groups based on their vulnerability to line-fishing, were either significantly higher in zones closed to fishing or were neutral (bycatch species).

Strong differences amongst regions and habitat types were detected, but they did not affect the overall estimates of the positive effects of zoning on attributes of the fish fauna. For example, the mean number of large-mouth and small-mouth nannygai on Brook shoal off Cardwell (closed to fishing) greatly exceeded the numbers on the nearby shoals open to fishing. Nearby, off Townsville, the difference was in the opposite direction – the mean number of large-mouth and small-mouth nannygai on diffuse shoals open to fishing exceeded the numbers on the diffuse shoals closed to fishing in 2004. One reason for such a difference concerns the transient use of some types of shoal habitat by these mobile, schooling species of lutjanids.

The pairs of discrete, southern banks on the Capricorn plateau were the easiest to compare in context of size, topography, depth and epibenthos. The difference in abundance of target species was about two-fold on banks closed to fishing. The change with increasing time of closure to fishing from 2007 to 2009 was inconsistent, with the gap widening between fished and unfished for one pair but not the other. More, larger, target species were accumulating on southern banks closed to fishing.

The remote southern reef bases were too far offshore for trailer-boats and were accessible only to a small fleet of larger commercial and charter boats. It was not surprising there was no consistent, positive effect of zoning in habitat types other than hard corals. Coral trout, not shoal species, are the major species exploited there, and the knowledge of catch and effort (and poaching) "off reef" is relatively poor.

Despite widespread public debate about MPAs, there has been little evidence of citation or public use of our on-line reports. Our development of the e-Atlas products to visualize spatial differences was intended to encourage the public to view videos and summaries to "make up their own minds" about their local area of interest. There have been over 7000 visits to the e-Atlas site in less than one year, even though it has not been officially launched, and each week there are 75-150 views, and about 35 new viewers.

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