Marine and Tropical Sciences Research Facility

The influence of zoning (closure to fishing) on fish communities of the deep shoals and reef bases of the southern Great Barrier Reef Marine Park

Part 2 - Development of protocols to improve accuracy in baited video techniques used to detect effects of zoning

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Australian Government
Department of the Environment, Water, Heritage and the Arts

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Australian Institute of Marine Science

Reef & Rainforest Research Centre

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Supported by the Australian Government's
Marine and Tropical Sciences Research Facility
Project 4.8.2 Influence of the Great Barrier Reef Zoning Plan
on inshore habitats and biodiversity, of which
fish and corals are indicators: Reefs and shoals

ISBN 9781921359378

This report should be cited as:
Cappo, M., De'ath, G., Stowar, M., Johansson, C. and Doherty, P. (2009) *The influence of zoning (closure to fishing) on fish communities of the deep shoals and reef bases of the southern Great Barrier Reef Marine Park. Part 2 – Development of protocols to improve accuracy in baited video techniques used to detect effects of zoning*. Report to the Marine and Tropical Sciences Research Facility. Reef and Rainforest Research Centre Limited, Cairns (40pp.).

Published by the Reef and Rainforest Research Centre on behalf of the Australian Government's Marine and Tropical Sciences Research Facility.

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This report is available for download from the
Reef and Rainforest Research Centre Limited website:
http://www.rrrc.org.au/publications/research_reports.html

Report first completed June 2009
Published by RRRC October 2009
RRRC thanks Suzanne Long (RRRC) and Peter Speare (AIMS) for use of images on cover artwork.

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Acronyms and Abbreviations

AIMS ..... Australian Institute of Marine Science
BRUVS ..... Baited remote underwater video station
GBRMP ..... Great Barrier Reef Marine Park
GBRMPA ..... Great Barrier Reef Marine Park Authority
GBRWHA ..... Great Barrier Reef World Heritage Area
GPS ..... Global Positioning System
MPA ..... Marine Protected Area
MTSRF ..... Marine and Tropical Sciences Research Facility
NTMRs ..... No-take Marine Reserves
RAP ..... Representative Area Program (2004)
RRRC ..... Reef and Rainforest Research Centre Limited
SBRUVS ..... Stereo baited remote underwater video station
SCUBA ..... Self-Contained Underwater Breathing Apparatus
UVC ..... Underwater Visual Census

Acknowledgements

The authors wish to acknowledge Gavin Ericson (AIMS Data Centre) and Dr James Seager (www.SeaGis.com.au) for constructing an interface between the BRUVS tape reading software and the 'PhotoMeasure' stereo-video software. We thank Liz Howlett for formatting this report and Dr Ed Cripps for useful discussions on length frequency distributions.

Executive Summary

Baited video techniques (BRUVS) are a useful, non-destructive approach to measure the effects of zoning in marine parks. The use of stereo pairs allows extremely accurate and precise fish measurments.

However, the technique is so novel that it lacks protocols in data collection. It can therefore be argued that bias introduced by the performance of various tape readers could reduce the 'signal-to-noise' ratio in comparing diversity, abundance and fish lengths between zones with the BRUVS technique.

By repeating readings in a robust sampling design, we demonstrated remarkable consistency amongst three readers and two readings in counting highly-prized red emperor, coral trout and red-throat emperor in the field of view of the BRUVS. Almost all the variation in those species could be attributed to the tapes.

However, three minor sources of error emerged across the entire suite of 257 species recorded in the test. Firstly, a 'new' reader added the sightings of a considerable number of the same, small taxa multiple times as 'new species' whereas the other readers did identify them only once to species level. This inflated the richness (but not the abundance) recorded by the 'new' reader.

Secondly, there were obvious differences amongst readers in distinguishing species with very similar appearance. Species pairs in the genera *Cantheschenia*, *Heniochus, Naso, Acanthurus*, *Pseudolabrus, Parapercis* and *Pomacentrus* were notable sources of variation in identification.

Finally, we found that the 'new' and 'veteran' readers were inadvertently switching choices in identification, rather than missing sightings, between readings for some of these 'difficult' species pairs. In contrast, the 'experienced' reader showed remarkable consistency.

These three errors accounted for, at most, only one-third of the variation due to the differences amongst tapes. At this level they would not affect the signal-to-noise ratio for any of the 'target', 'bycatch' and 'unfished' groups of fish in assessing effects of zoning.

We recommended the best protocols to assure the quality of BRUVS data collection would:

- Organise the 'experienced' reader to process the first few tapes in the collection of replicates for a sampling site, then allow 'new' readers to complete the remaining tapes by referring to, and learning from, the names and images stored for that site;
- Pool 'difficult' species groups by the level (e.g. genus) to which they can be identified confidently by the team of readers;
- Classify the counts of *MaxN* into the five categories of abundance to overcome the 'saturation' when large numbers of fish (>50) obscure the field of view.

We developed a 'rule' and a protocol for allocating measurement effort that maximised opportunities for measurement of the full range of fish sizes in the field of view of stereo-video BRUVS. Smaller individuals were arriving earlier than larger conspecifics in the case of coral trout, red emperor and perhaps Venus tuskfish. There were clear differences between southern 'shoals' open and closed to fishing in the shape of length frequency plots. These could not be immediately attributed to removals by fishing in the absence of temporal data to quantify shoal-specific differences in recruitment and growth.

Introduction

In the past decade, baited remote underwater video techniques have become a popular tool to detect effects of Marine Protected Areas (MPAs) on fish diversity and relative abundance (e.g. Watson *et al*. 2007, 2009; Willis and Babcock 2000; Denny *et al*. 2004). They offer a non-destructive, deep water alternative to underwater visual census (UVC) that removes the need for specialist observers in the field with the provision of permanent tape records (see Cappo *et al.* 2003, 2007 for reviews).

Early research focused on the dynamics of appearance of fishes in the field of view to develop estimates of density and relative abundance (e.g. Ellis and DeMartini 1995). The most popular estimators of relative abundance concerned the time elapsed before first sighting (TFS) and the maximum number sighted at one time (*MaxN*). Meanwhile a small number of studies have documented the biases of the baited video approach in assessing relative abundance by comparing it with hook and line (Willis *et al*. 2000), UVC (Watson *et al.* 2005), seine netting (Stoner *et al.* 2008) or trawling (Cappo *et al.* 2004) in the same habitats.

Despite the growing use of the technique, there has been no accounting for differences amongst readers, or other errors, in the processes of acquiring data on diversity and abundance from the video tapes. Extremely accurate and precise measurements of vertebrates are now also possible when video cameras are used in stereo pairs (Harvey *et al.* 2001, 2002, 2003), yet there are no published protocols on when to measure fish within a tape, or how many measurements to make to test for differences amongst locations.

To date, the most common technique used to analyse the footage is to interrogate the video for abundance and biodiversity, record the *MaxN* for each species (Watson *et al*. 2005) and perform length measurements at *MaxN* (Harvey *et al*. 2003; Watson and Harvey 2007; Watson *et al.* 2009). We speculated that this technique could avoid smaller individuals that might visit the field of view before their larger conspecifics.

Both single and stereo-video techniques have been used in Years 1 and 2 of MTSRF Project 4.8.2 examining the influence of zoning (closure to fishing) on fish communities of the deep shoals and reef bases of the Great Barrier Reef Marine Park (GBRMP) (see Stowar *et al.* 2008). Differences in both relative abundance (*MaxN*) and length compositions of fishes were documented between shoals opened and closed to fishing. Verification and validation of those results requires an examination of possible sources of error due to the tape interrogator and tape interrogation method.

Therefore the current study aimed to:

- Test the quality of estimates of relative abundance and fish identifications amongst observers, and amongst different readings by the same observer;
- Compare length compositions obtained by different measurement protocols for the same stereo-video tapes; and
- Synthesise these results to recommend optimum methods of tape interrogation in surveys using baited video techniques.

Materials and methods

Sources of variation amongst tape readings

Sixteen tapes (*tapeid*) were selected to represent the range in diversity and abundance found in complex habitats on submerged shoals of the southern GBRMP (Figure 1, Table 1). These tapes had earlier been included in the analyses reported by Stowar *et al*. (2008).

The tapes were read twice by three readers of different levels of experience in tape interrogation for inter-reefal faunas. The readers were classified as 'new', 'experienced' and 'veteran'. Both the 'new' and 'experienced' readers had prior experience with some of the tapes. They had contributed to the collection of data for Stowar *et al*. (2008). The 'veteran' reader had wide experience in identifying the deeper faunas of reef bases and shoals, and had set up the original reference image library, but had not previously seen the tapes.

Tape interrogations were made under the standards imposed by the BRUVS2.1.mdb software (AIMS 2006, BRUVS2.1.mdb©) interface to record the identity of each species and the maximum count of each species in the field of view (*MaxN*) using the existing reference image library from Stowar *et al.* (2008). The timing of arrival and accumulation of *MaxN* was also recorded in the database.

Fish abundances and species richness were analysed using univariate and multivariate statistical approaches with the R statistical package (R Development Core Team 2005). The *MaxN* data were highly skewed by counts made when shoals of pelagic fish passed the field of view, so data were either used in raw form, transformed by 4^{th} root, or classified in five categories as 0(*MaxN*=0),1(1),2(2-5),3(6-19),4(*MaxN* >20).

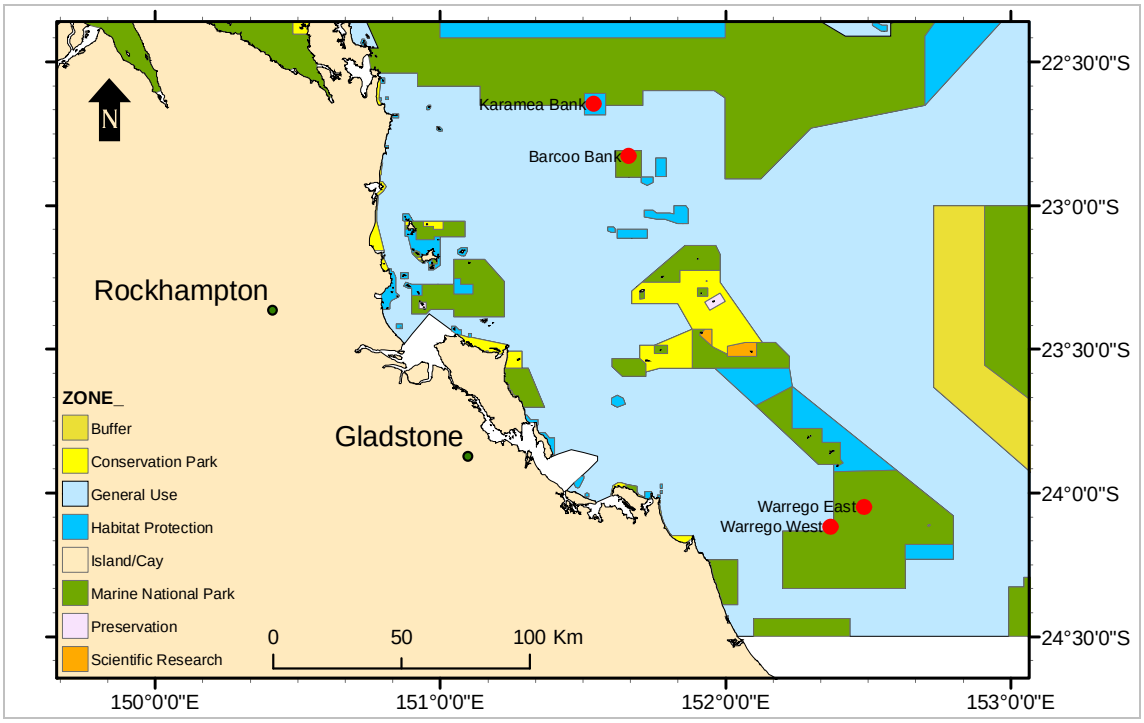

Figure 1: Location of the four submerged shoals in the southern Great Barrier Reef, showing the 2004 GBRMPA zones (redrawn from Stowar *et al.* 2008).

Table 1: Mean species richness and abundance (*MaxN*) amongst three readers and repeated readings from sixteen tapes collected from 'green' shoals (g) closed to fishing (BB= Barcoo Bank; EW = Eastern Warregoes).

tapeid	richness	abundance
RAPBBgC-3	31.83	96.17
RAPBBgC-5	15.5	80.67
RAPBBgC-6	19.17	55.33
RAPBBgD-2	26.33	96.67
RAPBBgF-1	23.83	56.17
RAPBBgF-2	26.17	162.33
RAPBBgF-5	16.5	50.5
RAPBBgF-6	10.67	21
RAPEWgC-4	37.67	176.33
RAPEWgD-15	36	66
RAPEWgD-4	15.67	59.17
RAPEWgE-2	15.17	51.83
RAPEWgE-4	26.33	64
RAPEWgE-5	36.17	96.17
RAPEWgG-2	22	82.67
RAPEWgH-1	43.17	627.83

Univariate and multivariate analyses were conducted on four data sets. One contained all 257 fish species sighted on tapes, and the second, third and fourth were subsets of species considered to be the 'target' (*n*=40), 'bycatch' (*n*=27) and 'not caught' (*n*=194) in line fisheries (see below and Appendix 1). This enabled comparison of the tape reading biases for both large, conspicuous and small, obscure species.

Univariate and multivariate analyses

The univariate analyses assessed differences in species richness and abundances between the tapes (*tapeid*), *readers* and *readings* using generalised linear models with a quasipoisson link function and variance proportional to the mean. 'Bubble plots' were constructed to visualise the variation by *tapeid*, *reader* and *reading* amongst counts of species occurring on at least twenty tape reading occasions. The main effects of these three factors were examined for each of these species individually using generalised linear models with a quasipoisson link function and variance proportional to the mean.

Species composition was represented by species occurrence (presence/absence), 4^{th} root *MaxN*, or five categories of *MaxN*, in various ordinations. The multivariate analyses used partial redundancy analysis (**rda**) to determine the relationships between species composition, and biplots were used to illustrate all results. Permutation tests were used to assess the significance of the relationships. The analyses were done for the overall dataset and the three subsets based on species vulnerability to line fishing. The redundancy models were fitted hierarchally. The order of inclusion of terms was (1) *tapeid*, (2) *reader* and *reading*, and their interaction. Thus each effect was adjusted for previously included terms.

Target status of species

For the purposes of assessing the possible direct and indirect effects of fishing on 'shoal' communities, fish species have been categorised by Stowar *et al*. (2008) into four sets depending on the likelihood they would be caught and retained by line fishers. Three sub-sets were recognised for the purposes of the tape reading comparisons presented here:

i. *TARGET – "Sought-after species"*. These included the most desirable demersal and pelagic species, based on their landed catch and size, as well as their reef dwelling habits. This was a pooling of categories (i) and (ii) of Stowar *et al.* (2008).
ii. *BYCATCH – "All species considered likely to be caught by line fishers including by-catch"*. Comprised the 'undersized' juveniles of fishes in (i) as well as the undesirable fishes and sharks caught by line fishers.
iii. *NOT CAUGHT – "Species considered unlikely to be caught by line fishers"*. This list included all species unlikely to take a hook because of their dietary preferences (e.g. herbivores such as scarid parrotfishes) or small size (e.g. pomacentrid damselfishes and chaetodontid butterflyfishes).

Comparison of stereo-video measurement techniques

Sampling with stereo video cameras was performed on two pairs of 'green' and 'blue' shoals off Gladstone and Port Clinton in 2007 (see Stowar *et al.* 2008). Each pair consisted of one shoal open to fishing and one shoal closed to fishing [Karamea and Barcoo Banks and West and East Warregoes] (Figure 1). A total number of 22 replicates per zone were sampled, but failure of some tapes reduced the useful footage to 18 (green) and 20 (blue).

Red emperor (*Lutjanus sebae*), coral trout (*Plectropomus leopardus*) and Venus tuskfish (*Choerodon venustus*) were measured as primary 'target' species on the tapes. The collared sea bream (*Gymnocranius audleyi*) and starry triggerfish (*Abalistes stellatus*) were chosen as unfished 'controls'.

Underwater stereo-video rigs were described in Stowar *et al.* (2008). Rigs were calibrated prior to field trips by analysing footage of a labelled cube using the software "Cal"^{TM} (www.SeaGis.com.au). The footage from each replicate was interrogated using BRUVS2.1.mdb to record times where species appeared (T_{arr}) and where *MaxN* occurred (T_{MaxN}). These events were used to drive the stereo-video measurement software to points of interest on .avi files. Length measurements from caudal fork to snout tip (LCF) were performed using "PhotoMeasure" ^{TM} (www.SeaGis.com.au).

Development of a 'rule' for applying measurement effort

There are no published protocols to measure fish on tapes, but it is well known that *MaxN* is a conservative estimator of abundance (Willis and Babcock 2000; Cappo *et al*. 2004). We wished to weight the measurement effort on a given tape by the likelihood that different individuals may pass through the field of view over the course of the set, but not be distinguished visually, and that this number is likely to be higher for species with a high *MaxN* and a long time during which they can be seen passing in and out of the field of view. For example, twenty sightings of a single red emperor throughout a tape was recorded only as *MaxN*=1, yet it is plausible that there may have been up to twenty different red emperor present.

Therefore, the number of measurements [*Me*] to take from each tape for each species was derived by considering the time of first arrival of a species and the time elapsed before the maximum number of fish was sighted.

$Me = MaxN \times (T_{elapsed}/60 + SQRT(MaxN)/2)$ Eq. (1)

*$T_{elapsed}$ = [Time at which *MaxN* occurred minus time of first arrival (T_{arr})] in minutes, on a sixty minute tape.

Stereo measurement techniques

Other laboratories navigate within a tape to make stereo-measurements around the time when *MaxN* occurs (pers. comm. Drs E. Harvey and D. Watson, University of Western Australia), under the working assumption that this will avoid repeated measurements of the same individual and maximise measurement opportunities. However, Johansson and others (2008) showed that this approach can be flawed when large numbers of fish occlude the field of view. In an extreme case, the presence of over forty large red emperor at one time resulted in only three useful measurements around the time of *MaxN*.

Instead, the two techniques tested here both included the time around the sighting of *MaxN*, and both had measurement effort (*Me*) positively weighted by the size of *MaxN* (see Eq. 1 above). The techniques differed in the allocation of *Me* and in the need for measurement when the species was first seen (*Tarr*).

Technique 1: For *MaxN*=1, and for *Me*<=*MaxN*, this technique stepped immediately to the T_{MaxN} to commence measurement. If Me>MaxN, this technique rewound the .avi file and began measuring at T_{arr} with application of a one minute 'stepping increment' between T_{arr} and the end of the tape to reach the required number of measurements (*Me*) from Eq. (1).

Technique 2: The revision of the BRUVS2.1.mdb© tape reading interface allowed the recognition and storage of times of accumulation of *k* multiple *MaxN.* This allowed the measurer to commence reading at T_{arr} (= $T_{MaxNi=1}$) and step to each $Max_{N\ i....k}$ to make measurements. The stepping process continues until T_{MaxNk} was reached, or until the fish was no longer sighted (in the case that $Me > \sum MaxN_{i...k}$).

Results

Sources of variation amongst tape readings

Fish diversity and abundance, all species

The fish fauna on the sixteen tapes included an extremely diverse range of families, size classes and functional groups likely to be encountered when surveying reef bases or submerged, inter-reef 'hard ground' with BRUVS. These included large, apex predators such as carcharhinid sharks, carangid trevallies and scombrid spanish mackerels, reef-dwelling carnivores (Serranidae, Lethrinidae and Lutjanidae), scarid and acanthurid herbivores, planktivores, small reef-associated fishes, and sea snakes (Table 1, Appendix 1).

At first glance there were three obvious differences amongst readers, but the consistency of readers for the most common species was good. Firstly, the 'new' reader added the sightings of many taxa as new to the database without species identifications, to the level of genus or sometimes only family. Undoubtedly the other readers recorded those species as well, but did identify them to species level. Therefore overall differences amongst readers in species identifications would not be visible in terms of species richness alone.

Secondly, there were obvious differences in distinguishing species with very similar appearance. The species pairs *Cantheschenia grandisquamis* and *C. dumerilii*, *Heniochus acuminatus* and *H. diphreutes, Naso brevirostris* and *N. annulatus*, *Pseudolabrus guentheri* and *Cirrhilabrus punctatus, Parapercis clathrata* and *P. xanthozona* were notable sources of variation in identification. Finally, some large species, such as *Pristipomoides multidens* and *Scolopsis monogramma*, were sighted less by the 'new' reader, but perusal of Appendix 1 cannot show if this was a true negative, or a mis-identification as some other taxa.

Comparisons in ANOVA of the F-ratios for species richness and overall species abundance showed that the greatest source of variation could be attributed to the differences amongst tapes, but there were significant differences amongst some readers and some minor interactions attributable to individual tapes (Table 2, Table 3).

Table 2: Results of an ANOVA examining main effects and interactions of the sources of variation in recording species richness in tape readings.

source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
tapeid	15	8207.4	547.2	267.2	< 0.0001
reader	2	246.9	123.5	60.3	< 0.0001
reading	1	3.8	3.8	1.8	0.185
reader:reading	2	18.9	9.4	4.6	0.017
tapeid:reader	30	268.1	8.9	4.4	< 0.0001
tapeid:reading	15	38.4	2.6	1.25	0.291
Residuals	30	61.4	2.0		

Table 3: Results of an ANOVA examining main effects and interactions of the sources of variation in assessing raw species abundance (*MaxN*) in tape readings.

source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
tapeid	15	1822191	121479	28.82	< 0.0001
reader	2	46724	23362	5.54	0.008
reading	1	11245	11245	2.66	0.112
reader:reading	2	5326	2663	0.63	0.538
tapeid:reader	30	403612	13454	3.19	0.001
tapeid:reading	15	160556	10704	2.53	0.014
Residuals	30	126449	4215		

A significant source of variation amongst readers was due to the 'new' reader over-estimating richness on average (by about 3.8 species) and under-estimating abundance on average (Figure 2). The 'veteran' reader also showed slightly higher records of species richness (by about 1.2 species) than the 'experienced' reader, but a remarkable agreement in records of fish numbers. Paired *t*-tests for the 'veteran' and 'new' readers showed a very similar pattern, with significant differences in both richness (Richness; t=3.71, p=0.00082, mean difference= 2.62 species) and transformed abundance (Abundance; t=2.48, p=0.0187, mean difference= 0.163 species).

Perusal of the major dimensions of ordinations of the entire dataset of 257 species provided easier comprehension of these sources of variation. Transformation of the abundance data by 4^{th} root (Figue 3) and conversion into five categories (Figure 4) showed the same pattern of wide separation of one tape (RAPEWgH_1) from the others and a greater 'distance' amongst *tapeids* than amongst combinations of *reader* and *reading*.

Put simply, the over-riding effect was due to the differences amongst tapes, and the magnitude of the (minor) interactions between all effects appeared to be related somewhat to the diversity and abundance of vertebrates on each tape. In this regard, RAPEWgH_1 had a very high diversity and abundance (~43 species, 628 individuals). The duplicate readings within readers most often formed close pairs in the ordinations, showing that the reading occasion had less influence than the reader.

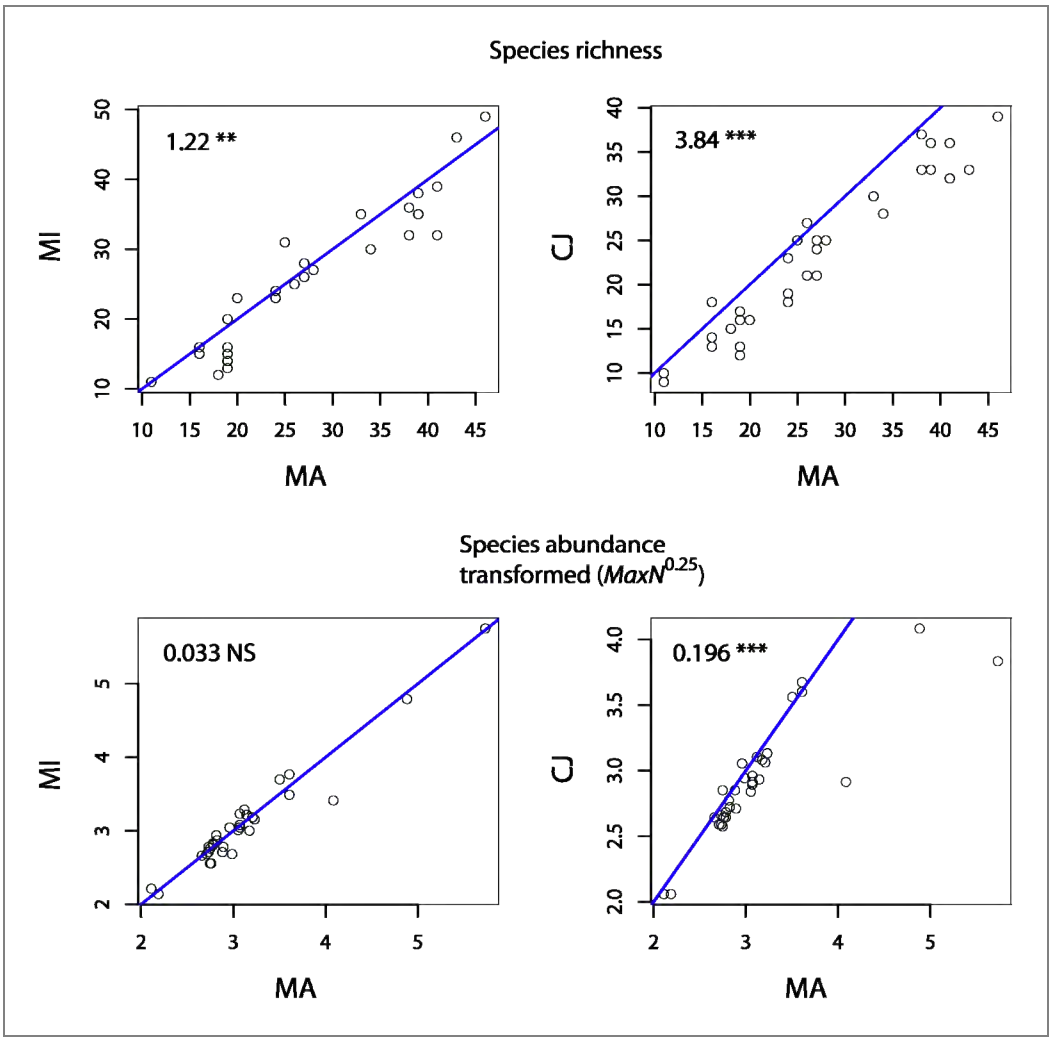

Figure 2: Comparison of species richness and abundance between the 'experienced' reader and the 'new' and 'veteran' readers. Inset numbers are the results of paired t-tests, showing significance of differences from the model x=y and estimation of the mean difference. NS = not significant, ***p< 0.001 **p< 0.01 *p< 0.05.

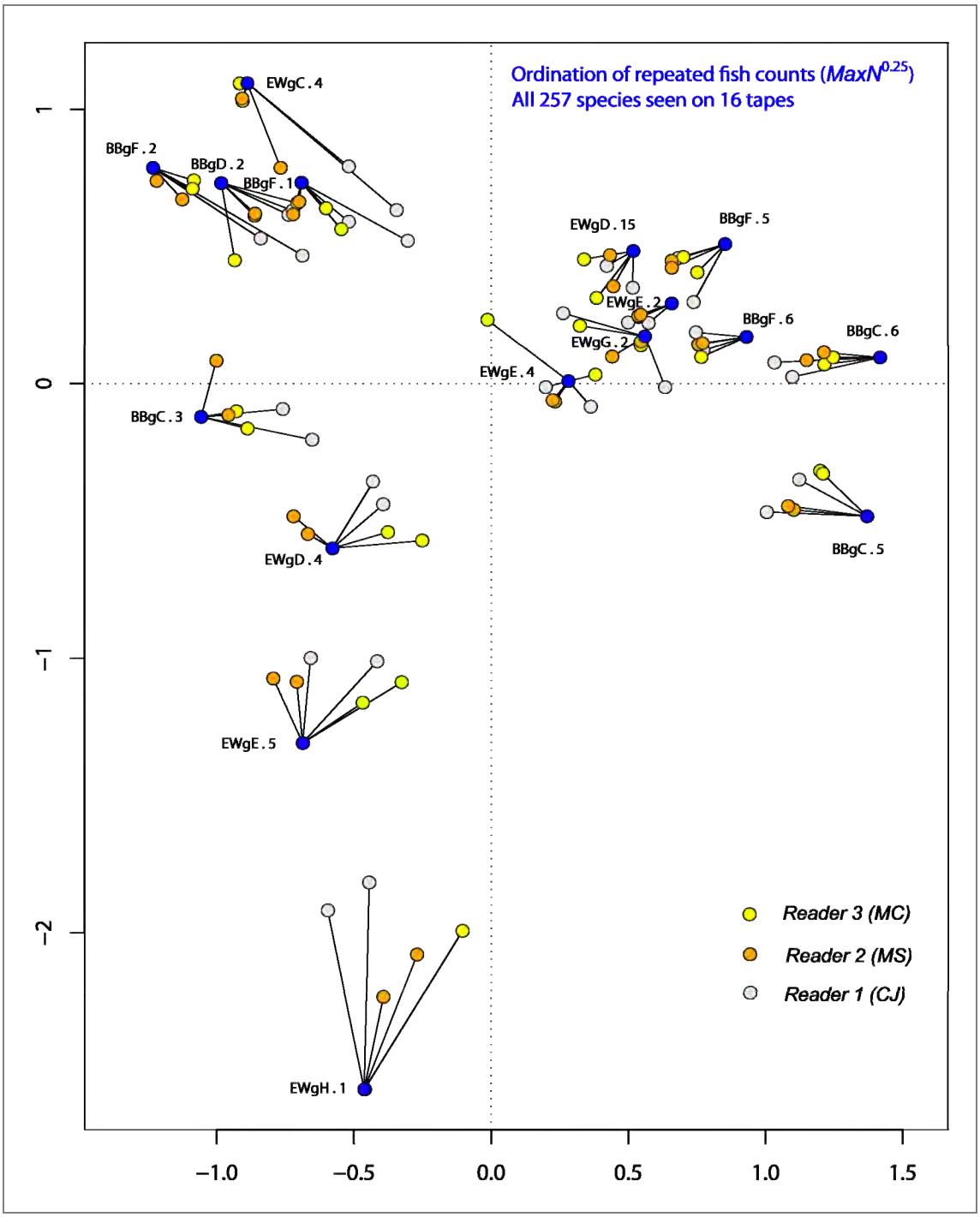

Figure 3: The first two dimensions of an ordination of transformed abundance of all 257 species ($MaxN^{0.25}$) in the main effects model *abundance~tapeid*. The blue symbols represent centroids of the linear constraints (*tapeid*). The grey, orange and yellow symbols show the weighted averages for the first and second readings by the three readers.

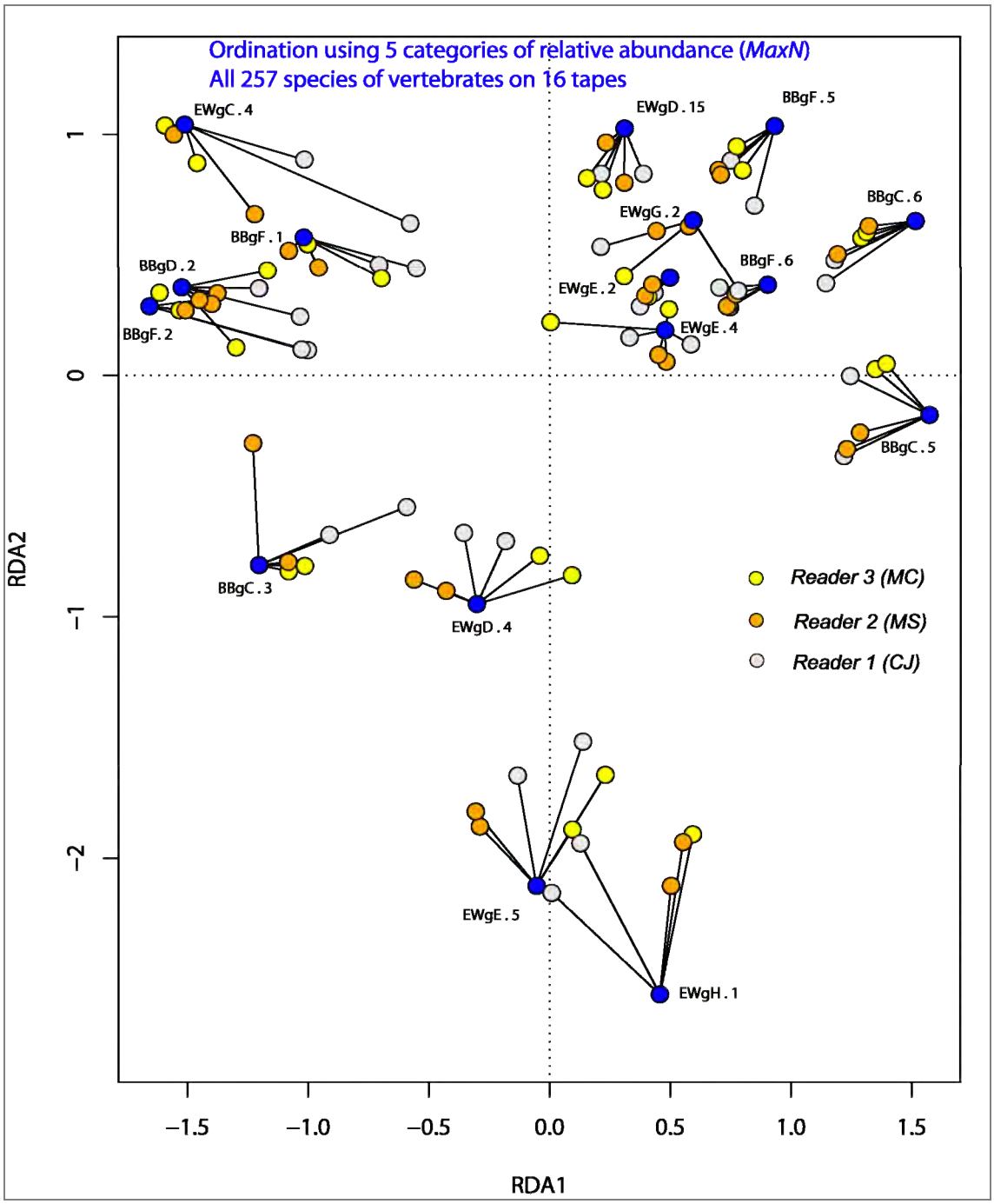

Figure 4: The first two dimensions of an ordination of five categories of abundance of all 257 species in the main effects model *abundance~tapeid*. All other conventions follow Figure 3.

Permutation tests (Tables 4-6) showed the over-riding source of variation in the ordination of transformed abundance data (Figure 3) was the *tapeid*. This accounted for about 2.5 times the variation due to sum of the other effects. The second most important source was the interaction between tapeid and reader, with some tapes (such as RAPEWgH_1) being more 'difficult' to read.

Table 4: Permutation test for the rda in Figure 3 under the direct model; $MaxN_{i=1...257}^{0.25}$ ~ *tapeid.*

source	Df	Var	F	N.Perm	Pr(>F)
Model	15	18.75	13.82	199	0.005
Residual	80	7.6			

Table 5: Permutation test for the main effects model; $MaxN_{i=1...257}^{0.25}$ ~ *tapeid + reader + reading.* Terms added sequentially (first to last).

source	Df	Var	F	N.Perm	Pr(>F)
tapeid	15	18.75	13.82	99	0.01
reader	2	0.54	3.00	99	0.01
reading	1	0.05	0.63	99	0.91
Residual	77	6.96			

Table 6: Permutation test for the model of main effects and all interactions; $MaxN_{i=1...257}^{0.25}$ ~ *tapeid + reader + reading + (tapeid * reader * reading).* Terms added sequentially (first to last).

source	Df	Var	F	N.Perm	Pr(>F)
tapeid	15	18.75	20.98	99	0.01
reader	2	0.54	4.56	99	0.01
reading	1	0.05	0.96	99	0.48
reader:reading	2	0.14	1.16	99	0.28
tapeid:reader	30	4.16	2.32	99	0.01
tapeid:reading	15	0.88	0.98	99	0.60
Residual	30	1.78			

Classification of the raw abundance data by five abundance categories (Figure 4) allowed a slightly clearer definition of effects. Permutation tests (Tables 7-9) showed the the *tapeid* accounted for about three times the variation due to sum of the other effects. The second most important source was the interaction between *tapeid* and *reader* for diverse, 'difficult' tapes where fish were abundant.

Table 7: Permutation test for the rda in Figure 4 under the direct model; five abundance categories ($MaxN_{i=1...257}$) ~ *tapeid*.

source	Df	Var	F	N.Perm	Pr(>F)
Model	15	38.80	15.14	199	0.005
Residual	78	13.33			

Table 8: Permutation test for the main effects model; five abundance categories ($MaxN_{i=1...257}^{0.25}$) ~ *tapeid + reader + reading.* Terms added sequentially (first to last).

source	Df	Var	F	N.Perm	Pr(>F)
tapeid	15	38.80	16.14	99	0.01
reader	2	0.89	2.78	99	0.01
reading	1	0.09	0.62	99	
Residual	77	12.34			

Table 9: Permutation test for the model of main effects and all interactions; five abundance categories ($MaxN_{i=1...257}^{0.25}$) ~ *tapeid + reader + reading + (tapeid * reader * reading).* Terms added sequentially (first to last).

source	Df	Var	F	N.Perm	Pr(>F)
tapeid	15	38.8	23.77	99	0.01
reader	2	0.89	4.09	99	0.01
reading	1	0.1	0.91	99	0.52
reader:reading	2	0.25	1.16	99	0.28
tapeid:reader	30	7.23	2.21	99	0.01
tapeid:reading	15	1.6	0.97	99	0.55
Residual	30	3.26			

Specific differences in identifications and counts

The ordinations and associated permutation tests indicated only about one-third of the variation was due to the effects of *readers* and their interactions with *tapeid*. It was surmised that this was due to the presence of 'difficult' tapes where diversity was high and there were numerous fish visiting the field of view.

A complementary explanation was that the interactions between tape *readers* and tapes was due to the presence of species pairs that were difficult to separate. The ANOVA results presented in Tables 10 and 11 showed that this was indeed the case. The magnitude of the difference between the *F*-ratios among the main effects showed the main source of variation for each species, and there were notable cases where an effect of reader was apparent.

The species pairs *Heniochus acuminatus* / *H. diphreutes*, and *Pterocaesio marri* / *P. trilineata* showed as much difference between *readers* as they did amongst *tapeids*. These fish were easily confused with each other and occur abundantly on BRUVS set on deep, topographically complex 'hard ground'. The lack of an effect of *reading* showed one or more of the *readers* were consistently mis-identifying *H. acuminatus*. There was an effect of *reading* for the very abundant, schooling *Pterocaesio marri*, indicating the one or more *readers* were not being consistent in their identification of this species.

The major 'target' species (snappers, emperors and coral trouts) were counted and identified consistently, with most of the variation due to the *tapeid*. The 'bycatch' showed a similar pattern, with the exception of *Lutjanus adetii* / *L. vitta* where there was evidence that some *reader*(s) changed their identification between *readings* for some tapes. Both of these 'hussar' species have a dusky mid-line stripe and can be confused when they occur together in schools. The large grouper *Epinephelus undulatostriatus* (Maori cod) also showed an effect of *reader* and *reading*. This large fish may have been confused with *E. coioides* or *E. fasciatus*, rather than being 'missed' in the field of view.

The same analysis with abundance classified into five categories (Table 11) reduced the influence of schooling, abundant species somewhat. The significant *F*-ratios persisted with consistency of identification of some species in the genera *Scarus, Naso,* and *Sufflamen*.

The bubble plots in Figures 5 and 6 illustrate the inconsistencies, and show that both the 'new' and 'veteran' readers were the most inconsistent between readings. The complete lack of sightings on one reading or another by these readers could be matched by the appearance of a record for another similar species in Figures 5 and 6. This showed that readers were inadvertently switching choices in identification, rather than missing sightings, between readings. In contrast, the 'experienced' reader showed remarkable consistency.

Table 10: Results of ANOVA (***F*** ratios) for the main effects examining variation in raw, untransformed counts (*MaxN*) of the 35 most prevalent species on 96 tape reading occasions (16 tapes(*tapeid*) X 3 readers X 2 readings). These 35 species occurred on at least twenty percent of tape reading occasions. Significant ($p<0.05$) effects are highlighted in bold.

species	*tapeid*	*reader*	*reading*
Choerodon venustus	**20.86**	**12.45**	0.02
Gymnocranius audleyi	**78.14**	**4.96**	0.03
Plectropomus leopardus	**157.06**	**6.66**	0.46
Sufflamen fraenatum	**61.38**	**5.11**	**4.21**
Lethrinus miniatus	**55.55**	0.02	0.16
Chaetodontoplus meredithi	**64.77**	**3.9**	0
Lethrinus ravus	**67.87**	2.52	2.5
Aipysurus laevis	**13.76**	**5.53**	0.31
Lutjanus sebae	**570.94**	**7.08**	1.33
Abalistes stellatus	**287.01**	**4.22**	0.46
Naso tonganus	**97.57**	**6.7**	4.21
Chromis nitida	**40.32**	**7.05**	0.01
Lutjanus adetii	**179.14**	3.08	**9.79**
Siganus argenteus	**92.26**	1.08	0.94
Pomacentrus australis	**31.57**	**5.87**	0.01
Scolopsis monogramma	**21.4**	2.52	0.46
Parupeneus heptacanthus	**62.12**	0.27	2.48
Cirrhilabrus punctatus	**115.05**	1.63	**4.33**
Pomacentrus nagasakiensis	**9.02**	0.45	0
Heniochus acuminatus	**28.38**	**31.04**	0.06
Naso brevirostris	**105.6**	2.67	**6.52**
Scarus schlegeli	**21.99**	1.49	**5.23**
Labroides dimidiatus	**11.68**	3.02	0.44
Epinephelus undulatostriatus	**99.16**	**12.89**	1.89
Epinephelus fasciatus	**80.95**	2.46	2.97
Lethrinus nebulosus	**49.86**	**13.1**	1.91
Carangoides fulvoguttatus	**68.34**	**6.34**	**4.5**
Coradion altivelis	**24.6**	0.34	0.45
Pentapodus nagasakiensis	**21.14**	2.96	0.65
Lutjanus vitta	**136.65**	**18.58**	0.45
Chaetodon rainfordi	**80.76**	**4.69**	0.39
Pterocaesio marri	**18.93**	**20.75**	**25.04**
Epinephelus areolatus	**193.99**	**4.57**	0
Leptojulis cyanopleura	**13.97**	0.54	0.55
Echeneis naucrates	**29.96**	0.41	0

Table 11: Results of ANOVA (***F*** ratios) for the main effects examining variation in categorised counts of the 35 most prevalent species on 96 tape reading occasions (16 tapes(*tapeid*) X 3 readers X 2 readings). These 35 species occurred on at least twenty percent of tape reading occasions. The five categories of *MaxN* were 0, 1, 2(2-5), 3(6-19), and 4(*MaxN* >20). Significant ($p<0.05$) effects are highlighted in bold.

species	*tapeid*	*reader*	*reading*
Choerodon venustus	**11.54**	**4**	0.85
Gymnocranius audleyi	**35.17**	1.51	0
Plectropomus leopardus	**131.09**	**7.84**	0
Sufflamen fraenatum	**61.38**	**5.11**	**4.21**
Lethrinus miniatus	**34.83**	0.2	0.2
Chaetodontoplus meredithi	**64.77**	**3.9**	0
Lethrinus ravus	**32.83**	1.39	0.05
Aipysurus laevis	**13.76**	**5.53**	0.31
Lutjanus sebae	**> 10^{12}**	0	0
Abalistes stellatus	**1176.96**	2.81	2.79
Naso tonganus	**198.55**	1.8	**4.01**
Chromis nitida	**31.65**	0.53	1.11
Lutjanus adetii	**76.74**	0.05	0.05
Siganus argenteus	**73.24**	**6.33**	0.43
Pomacentrus australis	**20.91**	**3.25**	0.51
Scolopsis monogramma	**21.4**	2.52	0.46
Parupeneus heptacanthus	**48.75**	0	0.41
Cirrhilabrus punctatus	**21.98**	**6.1**	0.25
Pomacentrus nagasakiensis	**15.1**	1.99	0.77
Heniochus acuminatus	**24.35**	**24.48**	0.1
Naso brevirostris	**70.14**	**5.6**	**6.27**
Scarus schlegeli	**21.99**	1.49	**5.23**
Labroides dimidiatus	**11.68**	3.02	0.44
Epinephelus undulatostriatus	**99.16**	**12.89**	1.89
Epinephelus fasciatus	**101.12**	**5.54**	**7.19**
Lethrinus nebulosus	**36.14**	**6.47**	1.15
Carangoides fulvoguttatus	**75.26**	**4.12**	2.39
Coradion altivelis	**22.8**	0.39	0.13
Pentapodus nagasakiensis	**12.34**	0.78	0.08
Lutjanus vitta	**146.82**	**8.92**	**10.66**
Chaetodon rainfordi	**80.76**	**4.69**	0.39
Pterocaesio marri	**28.57**	1.23	0.65
Epinephelus areolatus	**159.17**	**5.53**	0
Leptojulis cyanopleura	**23.6**	0.5	0.65
Echeneis naucrates	**29.96**	0.41	0

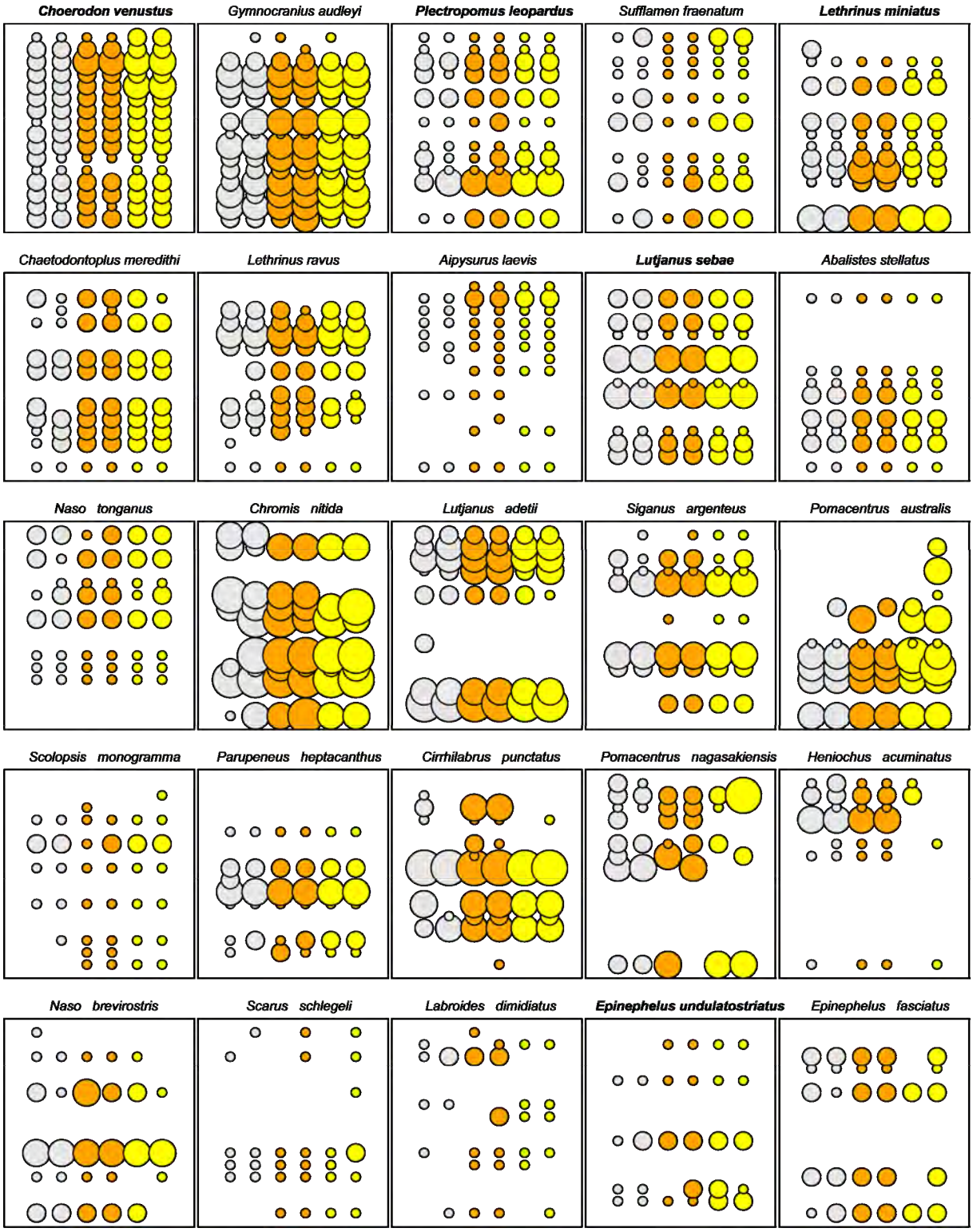

Figure 5: The differences in abundance recorded amongst tapes (horizontal rows in each panel), readers ('new' = Grey, 'experienced' = Orange, 'veteran' = Yellow), and readings (1, 2) for the most prevalent 25 species. The bubbles are scaled by the fish abundance in 5 categories. 'Target' species of economic importance are highlighted in bold.

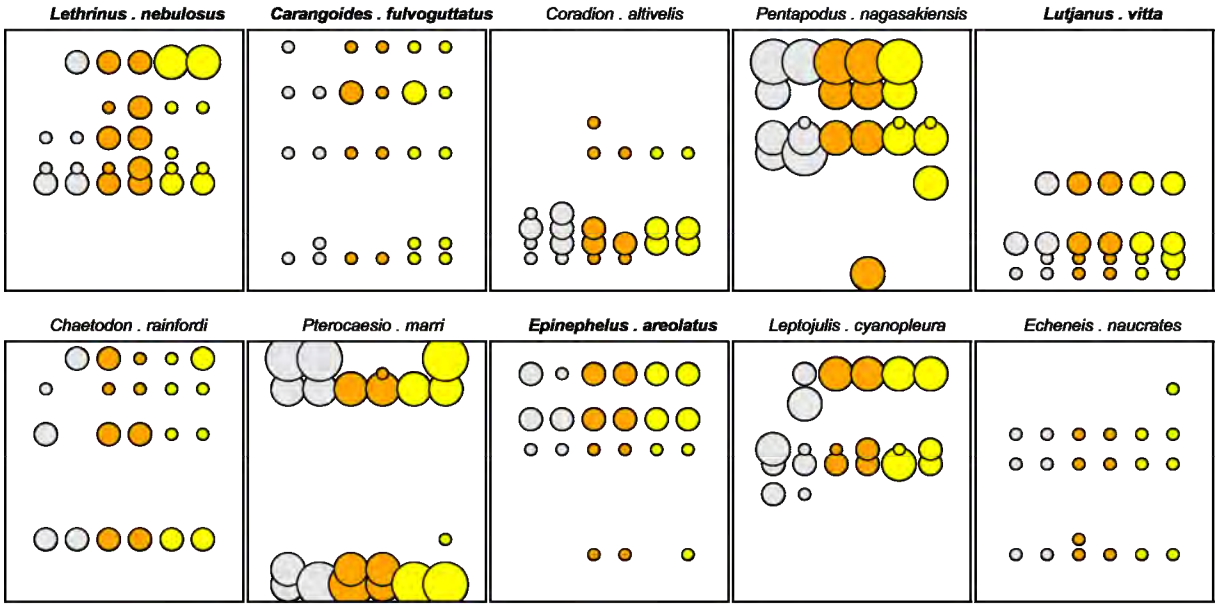

Figure 6: The differences in abundance recorded amongst tapes (horizontal rows in each panel), readers ('new' = Grey, 'experienced' = Orange, 'veteran' = Yellow), and readings (1, 2) for species ranked 26-35 in occurrence. The bubbles are scaled by the fish abundance in five categories. 'Target' species of economic importance are highlighted in bold.

Comparison of length compositions from stereo-video measurement techniques

Apart from the tedium of stepping forward across every one-minute increment for T1, here were no obvious differences in either the efficiency or length measurements of either technique (Table 1).

It was clear, however, that the smallest red emperor (*L. sebae*), coral trout (*P. leopardus*) and Venus tuskfish (*C. venustus*) were measured earlier in the tape, within the first fifteen minutes of the stereo-BRUVS settling on the seabed (Table 13, Figure 7). This implies an imperative to measure immediately after the time of first arrival (T_{arr}) as well as T_{MaxN}.

Table 12: Summaries of the mean and quantiles in the *N* measurements of the five species divided by zoning (closed to fishing – G(green); open to fishing – b(blue)) and measurement technique (T1 and T2).

species	Tchnq	Zone	Min.	2nd Qu.	Mean	Median	3rd Qu.	Max.	*N*
P. leopardus	T1	b	294.6	377.2	447.6	432.9	502.1	650.9	39
	T2	b	270.9	377.4	448.1	436.5	532.6	665.5	44
	T1	G	201.9	305.2	415.8	420.8	485.3	710.6	42
	T2	G	197.8	313.3	408	413.6	478.5	641.4	42
L. sebae	T1	b	350.2	469.8	518.4	483	617.3	839.1	20
	T2	b	355.6	462.2	508	479.9	581.3	828.9	17
	T1	G	171.6	409	503.5	485.4	573.7	918.5	125
	T2	G	183.4	420.4	496.2	489.8	559	743.1	102
C.venustus	T1	b	220.6	267.2	298.7	293.3	320.6	411.1	33
	T2	b	132.4	281.3	295.1	295.9	319	405.5	30
	T1	G	207.7	297.7	328.6	325.8	356	462.4	85
	T2	G	158	281.9	312.9	316.3	350.1	446.1	76
A. stellatus	T1	b	205.3	293.6	319.9	308.2	330.2	444	21
	T2	b	205.2	289.7	315.7	312.4	331.2	436.4	20
	T1	G	195.1	297	325.7	323.3	359.2	454.2	27
	T2	G	175.8	256.1	327.6	336.5	375.9	460.7	24
G. audleyi	T1	b	195.1	247.3	260.7	260	277.3	317	82
	T2	b	186.7	250.8	261.9	263.3	278.5	322.2	76
	T1	G	185.1	244	260.7	259.3	276.2	320	154
	T2	G	182	248.1	264.4	263.8	280.9	325	167

Table 13: Results of *t*-tests for the model *length~epoch*. The two levels of epoch were 'A' (measurements made within fifteen minutes of the strereo-BRUVS settling on the seabed) and 'B' (measurements made after that time).

source	Df	Mean(A)	Mean(B)	t	p	95%CI.difference
P. leopardus	165	327.8	458.8	-7.2	< 0.0001	-166.9 , -95.2
L.sebae	262	296.7	505.2	-3.8	< 0.0001	-316.3, -100.7
C. venustus	222	301.6	321.5	-2.5	0.013	-35.5, -4.2
A. stellatus	90	307.8	325.1	-0.88	0.38	-56.1, + 21.5
G. audleyi	477	262.9	261.9	0.38	0.70	-4.0, + 5.9

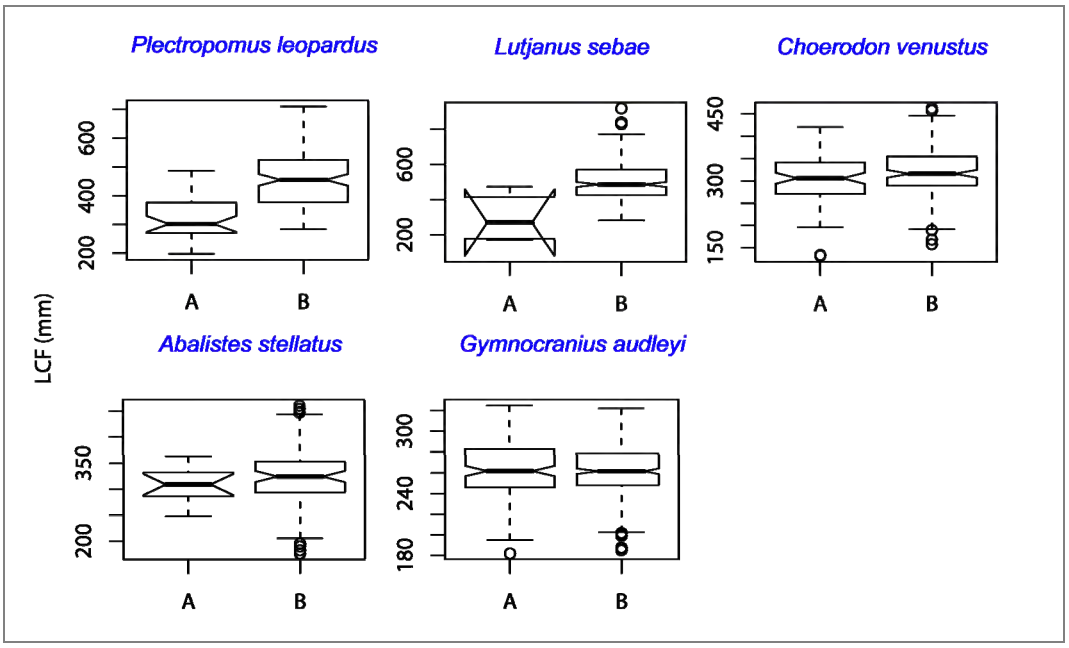

Figure 7: Boxplots showing the median and 95% Confidence Intervals for the model *length~epoch*. The notches represent 1.5 x (interquartile range of lengths/SQRT(*n*)). The two levels of epoch were 'A' (measurements made within fifteen minutes of the strereo-BRUVS settling on the seabed) and 'B' (measurements made after that time). If the notches of A and B do not overlap this is 'strong evidence' that the two medians differ for a species, independent of any assumptions about normality of data distributions or equivalence of variances.

Length-frequency distributions

It was impossible to either avoid repeated measurements of the same individual fish, or to distinguish individuals on the basis of measurement times, lengths and associated errors. Instead the shapes of the length compositions in Figures 7-12 can be compared between zones to detect differences. The number, location and shapes of the length modes gave us confidence that stereo-video measurements were a useful tool to examine effects or removal by fishing and other influences.

There were clear differences in the shape of the length compositions for the coral trout and Venus tuskfish (Figure 8, Figure 10). There were six clear length modes for coral trout that agree well with knowledge of length-at-age (Begg *et al*. 2005). There was a larger proportion of larger coral trout in the shoals closed to fishing, and the Venus tuskfish in green zones were both larger and in higher proportions at lengths above the legal minimum size at first capture. The length modes were in similar positions between zones for the red emperor, but much fewer fish were available for measurements in the shoals open to fishing. The 'blue' zones had six times less measurements than the 'green' zones for red emperor (Table 12) and were represented by fewer (four), sharper modes in the blue zones than the seven modes visible in the green zones.

In contrast, the 'non-target' starry triggerfish and collared sea bream showed no major displacement amongst modes between zones, perhaps with the exception that triggerfish were larger, on average, in the green zones.

The differences in length compositions of 'target' species cannot be immediately attributed to removals by line-fishing, because there may have been natural variability amongst zones in recruitment and fish growth. These natural influences may be density-dependent.

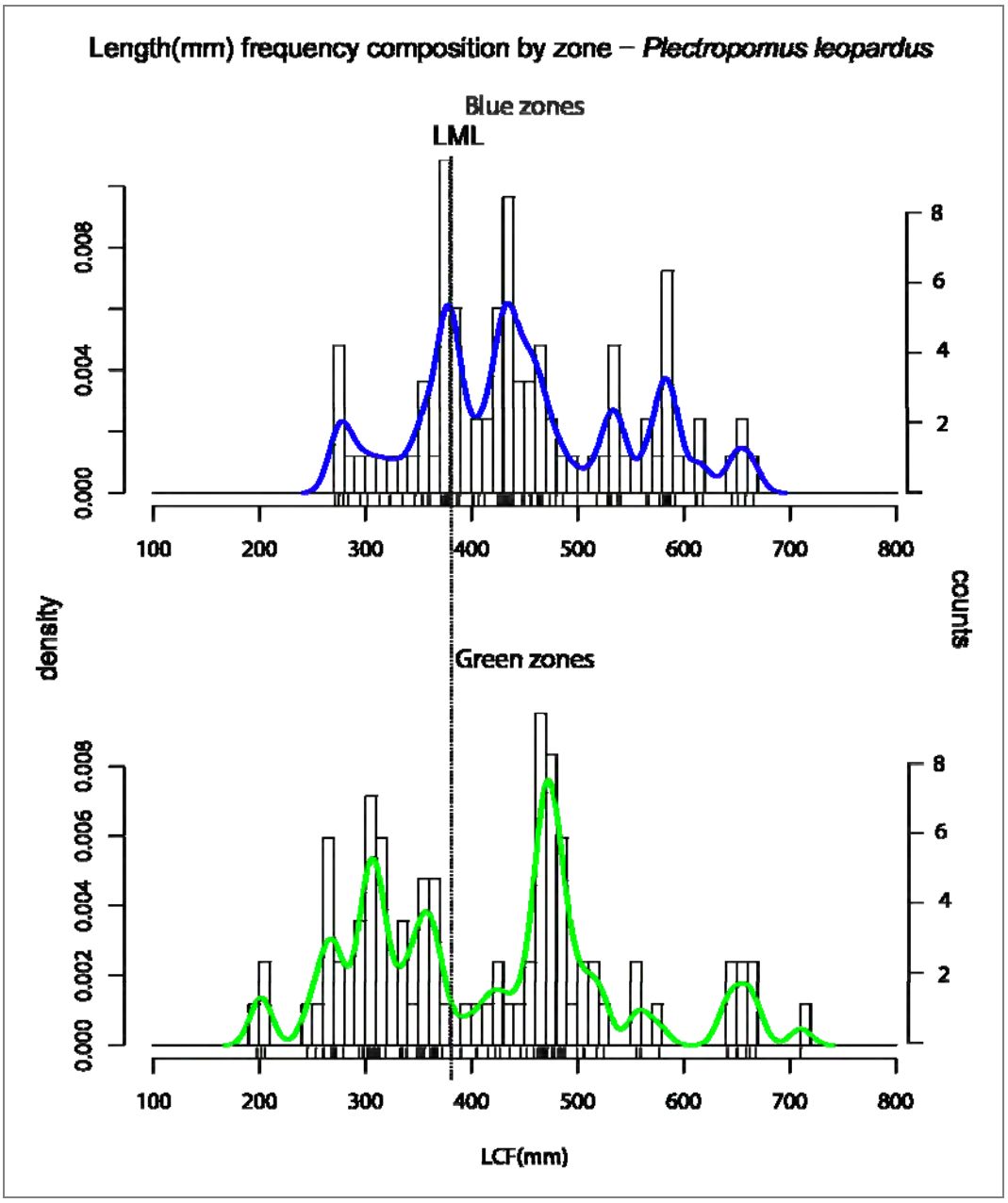

Figure 8: Histogram of stereo-video measurements (both techniques pooled) for the coral trout *Plectropomus leopardus* showing the legal size limit at first capture (LML). The lines, coloured by zoning status, are empirical cumulative density functions (ECDF) that represent length modes. The rug on the x-axis shows individual measurements.

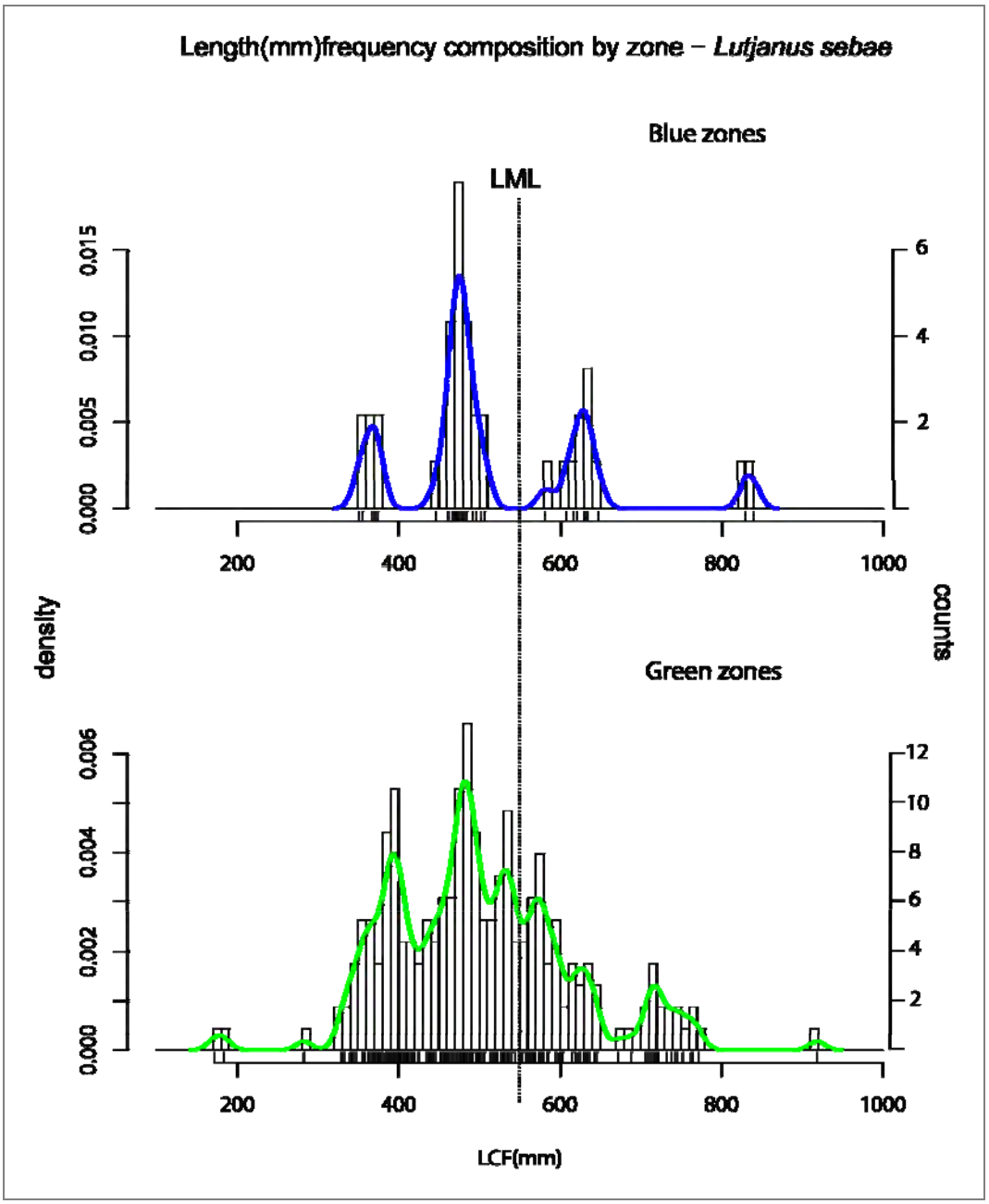

Figure 9: Histogram of stereo-video measurements (both techniques pooled) for the red emperor *Lutjanus sebae* showing the legal size limit at first capture (LML=550 mm). All other conventions follow Figure 8.

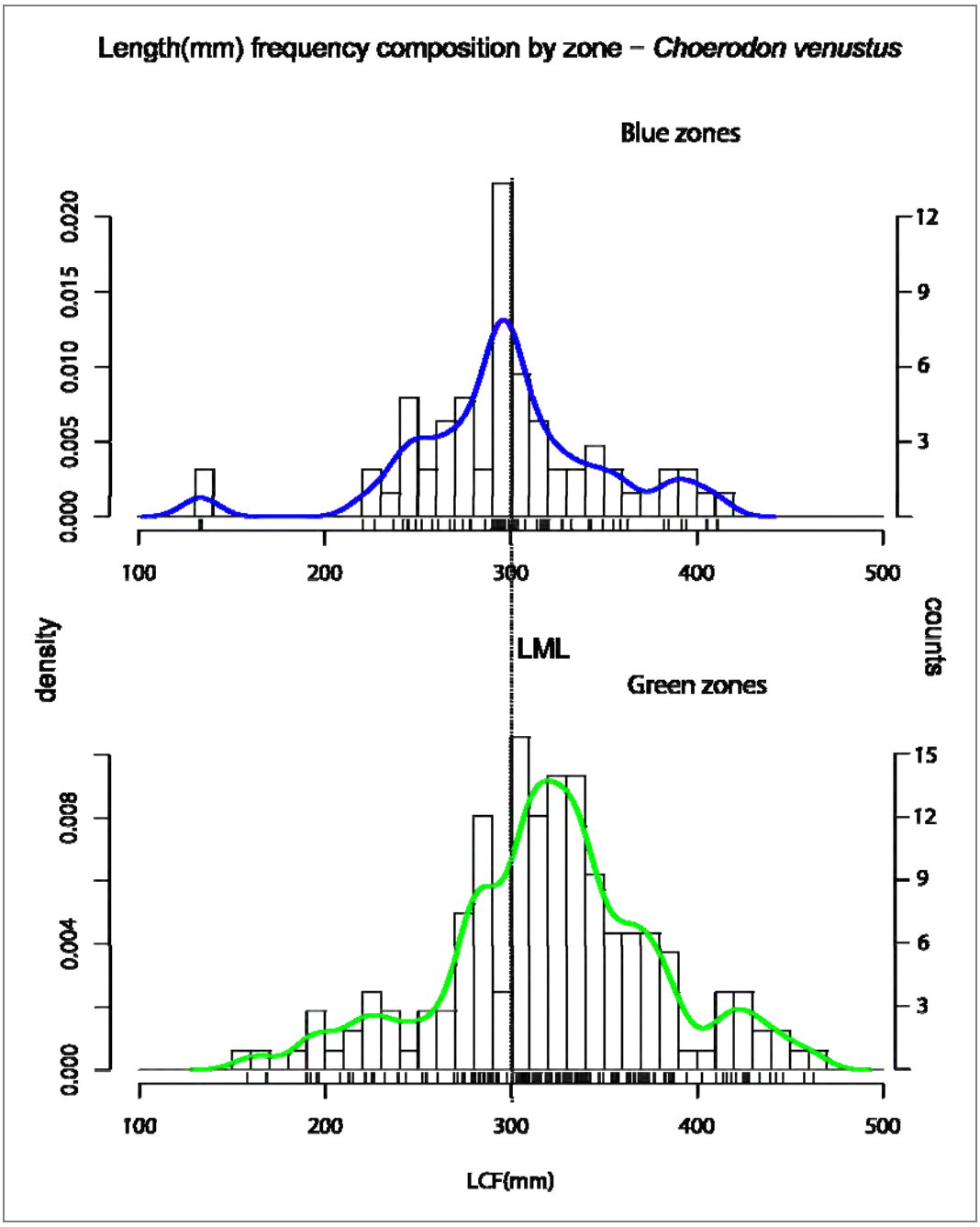

Figure 10: Histogram of stereo-video measurements (both techniques pooled) for the Venus tuskfish *Choerodon venustus* showing the legal size limit at first capture (LML=300 mm). All other conventions follow Figure 7.

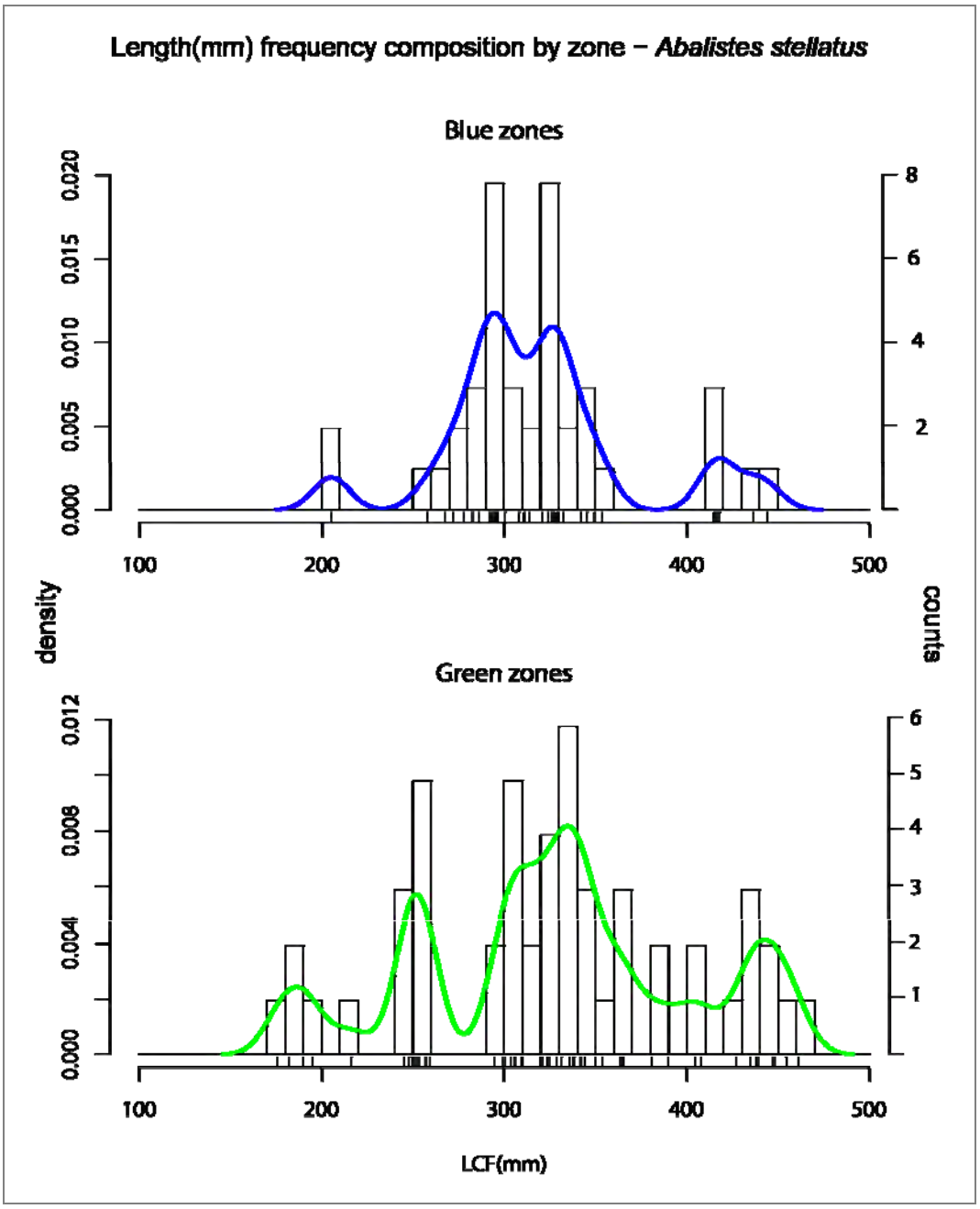

Figure 11: Histogram of stereo-video measurements (both techniques pooled) for the starry triggerfish (*Abalistes stellatus*). There is no legal size limit at first capture for this species, which is treated with extreme disdain by fishermen if caught. All other conventions follow Figure 7.

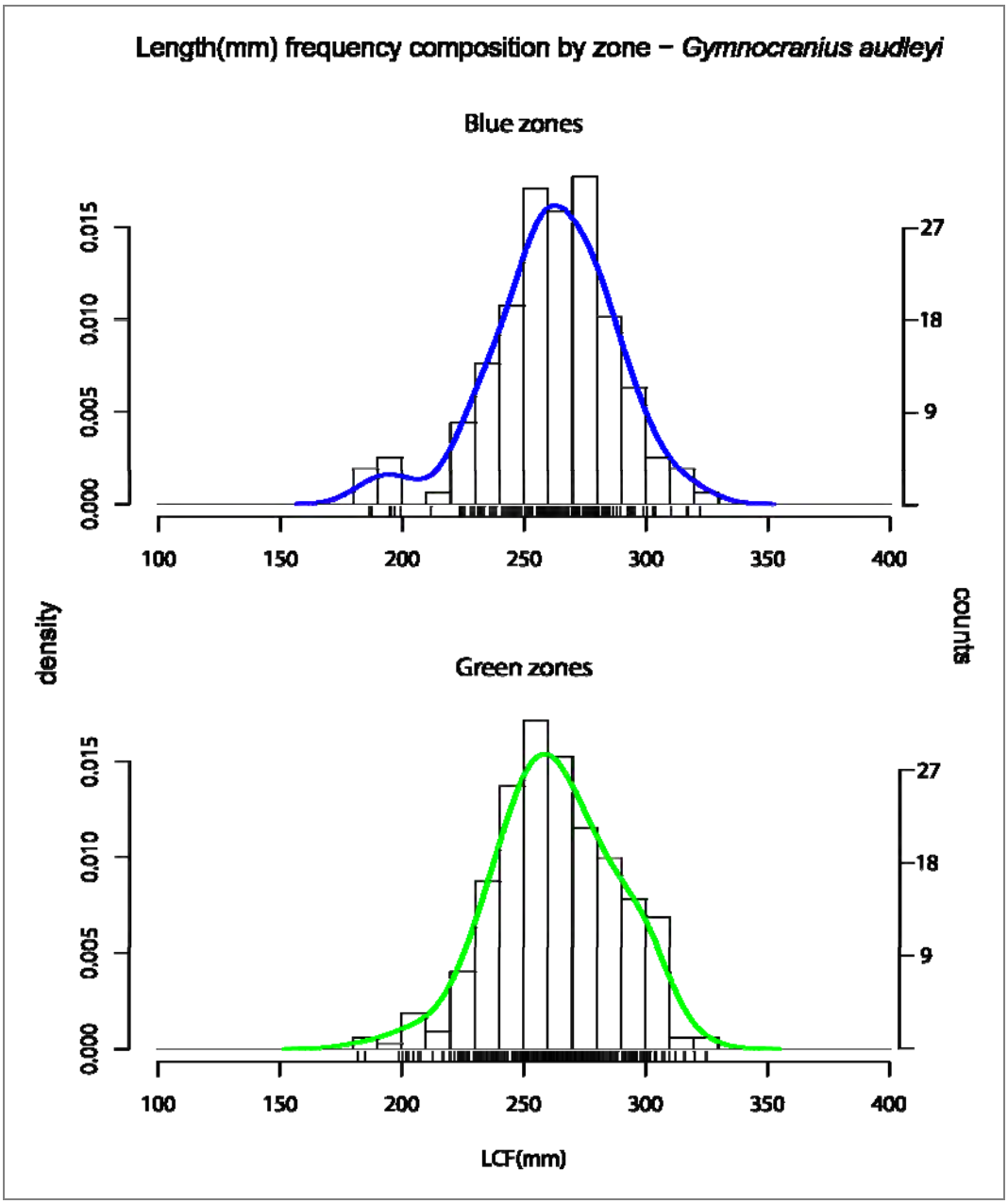

Figure 12: Histogram of stereo-video measurements (both techniques pooled) for the collared sea bream (*Gymnocranius audleyi*). There is no legal size limit at first capture listed specifically for this species, which is not a favoured target, but an LML of 250mm applies to unspecified 'sweetlips and emperors' in the GBRMP. All other conventions follow Figure 8.

Discussion

The previous comparison by Stowar *et al.* (2008) showed strong evidence that the abundance of the species prized most by recreational and commercial line fishers were, on average, approximately two times greater on the southern shoals closed to fishing (green zones) relative to those open to fishing (blue). While the responses to zoning of the 'target' species varied in magnitude, they all showed increases. Five of these species – red emperor (*Lutjanus sebae*), red-throat emperor (*Lethrinus miniatus*), Venus tuskfish (*Choerodon venustus*), spangled emperor (*Lethrinus nebulosus*) and golden spot hogfish (*Bodianus perditio*) showed statistically significant increases ($p<0.05$). The consistency of the response of these target fishes both individually and when aggregated strongly suggested an effect of zoning.

That study also found varying differences in the abundance of species not caught by line-fishing in alignment with the zoning of the shoals. As the analyses showed no obvious trend with respect to fishing, functional groups or habitats, this result was thought to reflect natural variability in species abundance rather than the effect of zoning on these species.

However, it might also be argued that errors introduced by the performance of various tape readers in that study could have reduced the 'signal-to-noise' ratio in comparing zones with the BRUVS technique.

In this report, we have re-analysed some of these southern shoals tapes within a robust sampling design to detect the effects of readers and readings in comparison with the differences amongst the tapes.

We demonstrated remarkable consistency amongst readers and readings in counting highly-prized red emperor, coral trout and red-throat emperor in the field of view of the BRUVS. Almost all the variation in those species could be attributed to the tapes.

However, some minor biases were evident across the entire suite of 257 species recorded in the test. Firstly, a 'new' reader added the sightings of a considerable number of small taxa (such as wrasses and damselfish) as 'new to the database' without species identifications, whereas the other readers did identify them to species level. This inflated the richness (but not the abundance) recorded by the new reader by about three species, on average.

Secondly, there were obvious differences amongst readers in distinguishing species with very similar appearance. The species pairs *Cantheschenia grandisquamis* and *C.dumerilii*, *Heniochus acuminatus* and *H. diphreutes, Naso brevirostris* and *N. annulatus*, *Pseudolabrus guentheri* and *Cirrhilabrus punctatus, Parapercis clathrata* and *P. xanthozona, Pterocaesio marri* and *P. trilineata* were notable sources of variation in identification.

Finally, we found that the 'new' and 'veteran' readers were inadvertently switching choices in identification, rather than missing sightings, between readings for some of these 'difficult' species. In contrast, the 'experienced' reader showed remarkable consistency.

The use of five categories of abundance, rather than transformed counts, in analyses could not overcome the errors caused by mis-identifications but it did reduce the impact of under-estimation of numbers of schooling species (such as *Pterocaesio* spp) by the 'new' reader'.

Recommendations for quality assurance of tape reading

A 'reference image' collection was maintained as part of the tape reading protocol, and we recommend frequent communication and calibration amongst readers attempting to add new records and images to this database. However, standardisation of identification of a number of genera will undoubtedly prove very difficult to attain. The imagery of these taxa is often poor and they are inherently very similar. They include both large and small species.

The best way to allow such communication and calibration is by organising the tape reading to make the 'experienced' reader process the first few tapes in the collection of replicates for a sampling site, then allow 'new' readers to complete the remaining tapes by referring to the names and images stored for that site. The practice of assigning unfamiliar tape readers to read the complete suite of replicates in any one strata of a sampling design should be avoided.

The life stages of a significant number of the scarid parrotfish are large, but very difficult to identify on BRUVS imagery. Similar problems exist with the large fish in the acanthurid complexes *Acanthurus blochii/grammoptilus, A. nigricauda/nigroris, A. dussumieri/ xanthopterus/mata,* and *Naso brevirostris/annulatus*. The very small damselfish in the *Pomacentrus nagasakiensis/australis/brachialis* group and the small wrasses in the genera *Pseudolabrus, Pseudocoris*, and *Halichoeres* may never be properly counted in the field of view.

These species groups should be pooled in analyses of abundance by the level to which they can be confidently identified.

There were a number of taxa that were exceptionally abundant in the field of view because they formed schools, or were gregarious in their activity around the bait canister. These include the planktivorous fusiliers *Pterocaesio* and *Caesio*, the gregarious hussars *Lutjanus adetii* and *L. vitta* and the small, ubiquitous *Pentapodus nagasakiensis* and *P. aureofasciatus*. The classification of counts of *MaxN* into the five categories of abundance specified in this report would overcome the problems in analyses caused by differences amongst readers in counting such large numbers of fish. It would also aid in overcoming the effect of 'saturation' when large numbers of fish obscure the field of view.

Recommended revision of stereo-measurement protocols

The two techniques developed here both benefited from the development of a 'rule' for allocation of measurement effort based on both the maximum number of fish sighted for a species and the amount of time that species was sighted on a tape. This standard estimation of measurement effort will overcome the problems caused by 'saturation' of the field of view at the time of *MaxN*, and improve the measurement opprtunities for the indistinguishable visits of separate individuals that do not raise *MaxN*.

The significant differences in size of fish between the first fifteen minutes of the tape and the remainder implies an imperative that fish must be measured from the time of first appearance on the tape, regardless of their abundance. It is plausible that small fish will be shy of, or displaced by, larger conspecifics in the field of view. This effect was evident in our analyses of coral trout, red emperor and Venus tuskfish.

There were no discernible differences in the lengths recorded by the two techniques tested here, but the tedium of navigating amongst different parts of the stereo files can best be overcome by using the second technique. This involved stepping forward for new measurements to each new region of the tape where *MaxN* was known to increase. This

does cause repeated measurement of the same fish, but also includes as many of the 'new individuals' as possible.

Our preliminary conclusions were that there was a larger proportion of larger coral trout in the shoals closed to fishing, and the Venus tuskfish in green zones were both larger and in higher proportions at lengths above the legal minimum size at first capture. A compelling account of the same effect for *Plectropomus* and *Choerodon* in the Abrolhos Islands of Western Australia was reported by Watson *et al.* (2007, 2009) using stereo-video measurements. The length modes were in similar positions between zones for the red emperor, but much fewer fish were available for measurements in the shoals open to fishing. In contrast, the 'control species' starry triggerfish and collared sea bream showed no major displacement amongst modes between zones – perhaps with the exception that triggerfish were larger, on average, in the green zones.

The differences in length compositions of 'target' species cannot be immediately attributed to removals by line-fishing, because there may have been natural variability amongst zones in both recruitment and fish growth. Profound differences amongst regions in some demographic and reproductive parameters have been found for *Lethrinus miniatus* and *Plectropomus leopardus* in the GBRMP, irrespective of zoning status (Williams *et al.* 2007; Adams *et al.* 2000). These natural influences may be density-dependent – especially for coral trout, which are suspected to prey on their juvenile conspecifics at high adult densities (Begg *et al.* 2005).

We recommend that stereo-video techniques will be a powerful tool to detect effects of zoning in the GBRMP on the major target species, especially if they are repeated through time to account for recruitment and growth in analysis of length modes. Effects of zoning will manifest in the shape of length compositions at both juvenile and adult ends, as well as the height of peaks and proportion of individuals above the legal minimum size at first capture.

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Appendix

Appendix 1: Number of tape readings on which each of 257 taxa were recorded by the 'new' (N), 'experienced' (E) and 'veteran' (V) tape readers.

species	N	E	V
Choerodon venustus	32	31	32
Gymnocranius audleyi	27	28	27
Plectropomus leopardus	21	22	22
Sufflamen fraenatum	17	20	20
Lethrinus miniatus	19	18	20
Chaetodontoplus meredithi	18	19	18
Lethrinus ravus	18	20	17
Aipysurus laevis	14	21	19
Lutjanus sebae	18	18	18
Abalistes stellatus	16	16	16
Naso tonganus	15	16	16
Chromis nitida	16	16	14
Lutjanus adetii	15	14	14
Siganus argenteus	11	14	16
Pomacentrus australis	11	12	16
Scolopsis monogramma	9	15	13
Parupeneus heptacanthus	12	12	12
Cirrhilabrus punctatus	9	16	8
Pomacentrus nagasakiensis	14	11	8
Heniochus acuminatus	11	14	4
Naso brevirostris	11	10	7
Scarus schlegeli	8	10	10
Labroides dimidiatus	7	11	10
Epinephelus undulatostriatus	8	9	10
Epinephelus fasciatus	10	10	7
Lethrinus nebulosus	7	10	9
Carangoides fulvoguttatus	8	8	10
Coradion altivelis	8	8	6
Pentapodus nagasakiensis	8	7	7
Lutjanus vitta	6	8	8
Chaetodon rainfordi	5	8	8
Pterocaesio marri	8	7	6
Epinephelus areolatus	6	8	7
Leptojulis cyanopleura	8	6	6
Echeneis naucrates	6	7	7
Scomberomorus queenslandicus	4	9	5
Chaetodon kleinii	6	6	6
Parupeneus cyclostomus	6	6	6
Lutjanus carponotatus	6	6	6
Carcharhinus albimarginatus	6	6	6
Carcharhinus amblyrhynchos	5	6	5
Acanthurus olivaceus	5	6	4

species	N	E	V
Choerodon schoenleinii	5	5	5
Chaetodon melannotus	4	6	5
Lethrinus rubrioperculatus	3	6	6
Thalassoma lunare	5	5	4
Argyrops spinifer	3	5	6
Lethrinus genivittatus	6	4	4
Symphorus nematophorus	2	6	6
Naso unicornis	1	8	4
Naso lituratus	4	4	5
Pseudolabrus guentheri	0	2	11
Chaetodontoplus duboulayi	3	6	4
Cantherhines dumerilii	0	12	0
Acanthurus xanthopterus	4	6	2
Parapercis xanthozona	0	7	5
Chaetodon auriga	4	4	4
Pentapodus paradiseus	4	4	4
Pseudocaranx dentex	4	4	4
Diploprion bifasciatum	4	4	4
Galeocerdo cuvier	4	4	4
Hydrophis ornatus	4	3	4
Prionurus microlepidotus	3	4	4
Heniochus diphreutes	2	0	9
Scolopsis bilineata	3	4	4
Chaetodon speculum	2	4	4
Zebrasoma scopas	3	4	2
Scarus flavipectoralis	2	5	2
Chaetodon lunulatus	2	4	3
Chaetodon trifascialis	2	4	3
Pentapodus aureofasciatus	0	6	3
Balistidae sp.1	0	8	0
Sufflamen chrysopterum	2	0	6
Nemipterus furcosus	0	4	4
Lutjanus bohar	0	4	4
Seriola dumerili	1	4	3
Labridae sp.	1	6	0
Acanthurus sp.	6	1	0
Cantheschenia grandisquamis	0	0	7
Acanthurus grammoptilus	0	0	7
Chaetodon plebeius	1	3	3
Coradion chrysozonus	0	3	4
Gnathanodon speciosus	3	2	2
Seriola lalandi	2	2	3
Variola louti	0	2	5

species	N	E	V
Saurida sp	0	4	2
Aluterus scriptus	2	2	2
Siganus puellus	3	2	1
Bodianus diana	2	2	2
Bodianus perditio	2	2	2
sp. sp.	6	0	0
Dascyllus trimaculatus	2	2	2
Chaetodon flavirostris	2	2	2
Pomacanthus sexstriatus	2	2	2
Pagrus auratus	2	2	2
Pterocaesio trilineata	0	1	5
Lutjanus quinquelineatus	2	2	2
Selaroides leptolepis	0	3	3
Rachycentron canadum	2	2	2
Cromileptes altivelis	2	2	2
Gymnothorax javanicus	4	0	2
Taeniura meyeni	2	2	2
Rhynchobatus djiddensis	2	2	2
Triaenodon obesus	2	2	2
Nebrius ferrugineus	2	2	2
Siganus vulpinus	2	2	1
Naso annulatus	0	1	4
Aspidontus taeniatus	1	4	0
Parapercis clathrata	5	0	0
Choerodon graphicus	2	2	1
Cheilodactylus vestitus	2	2	1
Pomacentrus amboinensis	3	0	2
Forcipiger longirostris	1	2	2
Chaetodon unimaculatus	1	2	2
Chaetodon pelewensis	1	2	2
Centropyge vroliki	1	2	2
Kyphosus vaigiensis	2	2	1
Pristipomoides multidens	0	1	4
Cephalopholis miniata	2	3	0
Variola albimarginata	3	2	0
Epinephelus rivulatus	1	0	4
Pterocaesio sp.	0	4	0
Lethrinus sp.	4	0	0
Siganus punctatus	0	4	0
Acanthurus albipectoralis	0	2	2
Coris pictoides	1	3	0
Oxycheilinus bimaculatus	0	2	2
Bodianus mesothorax	1	2	1
Pomacentrus brachialis	0	0	4
Pomacanthus imperator	1	3	0
Upeneus filifer	0	2	2
Gymnocranius euanus	2	2	0
Lethrinus atkinsoni	2	0	2

species	N	E	V
Gymnocranius grandoculis	0	0	4
Plectorhinchus picus	0	2	2
Nemipterus theodorei	0	2	2
Aprion virescens	2	0	2
Lutjanus argentimaculatus	0	2	2
Cirrhitichthys sp.1	0	3	0
Gymnothorax sp.	0	3	0
Gymnosarda unicolor	1	2	0
Sarda orientalis	0	0	3
Acanthurus mata	0	0	3
Acanthurus dussumieri	0	2	1
Scarus ghobban	0	2	1
Thalassoma lutescens	0	0	3
Hologymnosus doliatus	0	3	0
Coris aygula	1	2	0
Oxycheilinus digrammus	0	1	2
Choerodon vitta	0	1	2
Cirrhitichthys aprinus	1	0	2
Amblyglyphidodon aureus	0	3	0
Acanthochromis polyacanthus	0	2	1
Centropyge tibicen	2	1	0
Diagramma pictum	0	2	1
Cephalopholis sonnerati	0	0	3
Cephalopholis boenak	0	2	1
sp blue body yellow c-fin	2	0	0
Variola sp.	1	1	0
Labridae sp.8	0	2	0
sp red front dark back	2	0	0
seasnake sp.	2	0	0
Scarus sp.	0	2	0
Pomacentrus sp.	1	1	0
Halichoeres sp.	0	2	0
Cephalopholis sp.	2	0	0
Sufflamen bursa	0	0	2
Grammatorcynus bicarinatus	0	0	2
Siganus doliatus	0	0	2
Siganus corallinus	1	0	1
Ctenochaetus striatus	0	0	2
Meiacanthus atrodorsalis	2	0	0
Scarus forsteni	0	0	2
Halichoeres zeylonicus	0	0	2
Halichoeres scapularis	2	0	0
Halichoeres prosopeion	2	0	0
Choerodon fasciatus	2	0	0
Pomacentrus coelestis	0	2	0
Chrysiptera flavipinnis	0	2	0
Amphiprion ocellaris	2	0	0
Chaetodon oxycephalus	2	0	0

species	N	E	V
Chaetodon lineolatus	1	0	1
Lethrinus laticaudis	0	1	1
Plectorhinchus flavomaculatus	2	0	0
Symphorichthys spilurus	2	0	0
Lutjanus erythropterus	2	0	0
Carangoides gymnostethus	0	2	0
Oxycercichthys veliferus	0	0	2
Epinephelus coioides	0	2	0
Saurida gracilis	2	0	0
sp.*dark*	1	0	0
sp. *grey*	1	0	0
Halichoeres small_dull	0	0	1
sp. *too small to see*	1	0	0
seasnake banded	1	0	0
Cirrhilabrus black/yellow	1	0	0
Labridae black/white	1	0	0
Labridae spSmallGreen	1	0	0
unknown sp.	0	0	1
Platax sp.	0	1	0
seasnake dappled	1	0	0
unknown sp.13	0	0	1
Lutjanus sp.	1	0	0
Pseudochromis sp.	0	0	1
Pentapodus sp.	0	1	0
Chromis sp.	1	0	0
Carangoides sp.	1	0	0
Arothron nigropunctatus	1	0	0
Melichthys vidua	1	0	0
Cantherhines pardalis	0	0	1
Amanses scopas	1	0	0
Aluterus monoceros	0	0	1
Grammatorcynus bilineatus	0	0	1
Paracanthurus hepatus	1	0	0
Naso brachycentron	0	0	1
Acanthurus nigroris	0	0	1
Acanthurus blochii	0	0	1
Acanthurus bariene	0	0	1
Acanthurus auranticavus	1	0	0
Chlorurus sordidus	1	0	0
Scarus oviceps	0	1	0
Chlorurus bleekeri	1	0	0
Cetoscarus bicolor	1	0	0
Cirrhilabrus randalli	1	0	0
Labroides bicolor	1	0	0
Halichoeres margaritaceus	0	0	1
Coris batuensis	1	0	0
Coris dorsomacula	0	0	1
Cheilinus chlorourus	0	0	1

species	N	E	V
Bodianus axillaris	0	1	0
Cheilinus trilobatus	1	0	0
Pomacentrus moluccensis	1	0	0
Pomacentrus imitator	1	0	0
Chrysiptera cyanea	0	0	1
Chromis xanthura	0	0	1
Chromis retrofasciata	0	0	1
Chaetodon rafflesii	1	0	0
Centropyge bicolor	0	1	0
Platax orbicularis	0	0	1
Kyphosus sydneyanus	0	0	1
Parupeneus pleurostigma	1	0	0
Scolopsis margaritifer	1	0	0
Pristipomoides filamentosus	0	1	0
Elagatis bipinnulata	1	0	0
Atule mate	1	0	0
Plectropomus maculatus	0	1	0
Saurida undosquamis	0	0	1
Gymnothorax flavimarginatus	0	0	1
Gymnothorax pseudothyrsoideus	0	0	1

Further Information

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