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Bait type affects fish assemblages and feeding guilds observed at baited remote underwater video stations

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Abstract

Baited remote underwater video stations (BRUVS) are increasingly being used to examine assemblages of fishes, yet critical methodological questions related to sampling limitations and bias, such as the influence of bait type, remain poorly understood. At multiple locations, we examined the hypothesis that diversity and abundance in temperate reef fish assemblages were independent of bait type. We used 3 bait types (abalone viscera, pilchards and crushed urchin) and quantified commonly used metrics for the fish assemblage, including species richness, time of first arrival and relative abundance on 3 shallow rocky reefs in southeastern Australia over 2 yr. We distinguished the following 6 feeding guilds: herbivore, zooplanktivore, alga/invertebrate consumers, invertebrate carnivore, macroinvertebrate carnivore and generalist carnivore. The response of fishes was dependent on bait type, with urchin bait performing particularly poorly. Although we did not detect statistical differences between the performance of pilchards and abalone viscera as bait, pilchards produced more consistent outcomes. Importantly, we also observed strong spatial effects. In general, bait type had a marked effect on species richness, but little influence on relative abundance. Overall we conclude that oily bait such as pilchards, which have been widely used in most studies, yield the most consistent outcomes. Consequently, bait type and spatial variation in fish assemblages needs to be considered in sampling designs to assess the limitations of BRUVS.

Keywords

assemblages, stations, fish, guilds, affects, type, bait, observed, baited, remote, underwater, feeding, video

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Does bait type affect fish assemblages and feeding guilds observed at baited remote underwater video stations?

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Abstract: Baited Remote Underwater Video Stations (BRUVS) are increasingly being used to examine assemblages of fishes, yet critical methodological questions related to sampling limitations and bias, such as the influence of bait type, remain poorly understood. At multiple locations, we examined the hypothesis that diversity and abundance in temperate reef fish assemblages were independent of bait type. We used three bait types (abalone viscera, pilchards and crushed urchin) and quantified commonly used metrics for the fish assemblage including species richness, time of first arrival and relative abundance on three shallow rocky reefs in southeastern Australia over 2 years. We distinguished the following six feeding guilds: herbivore, zooplanktivore, algae/invertebrate consumers, invertebrate carnivore, macroinvertebrate carnivore and generalist carnivore. The response of fishes was dependent on bait type with urchin bait performing particularly poorly. Although we did not detect statistical differences between the performance of pilchards and abalone viscera as bait, pilchards produced more consistent outcomes. Importantly, we also observed strong spatial effects. In general, bait type had a marked effect on species richness, but little influence on relative abundance. Overall we conclude that oily baits, such as pilchards, which have been widely used in most studies, yield the most consistent outcomes. Consequently, bait type and spatial variation in fish assemblages needs to be considered in sampling designs to assess the limitations of BRUVS.

Keywords: Subtidal fish assemblages, BRUVS, Temperate rocky reefs, Feeding Guilds, Jervis Bay Marine Park

Introduction

Baited remote underwater video stations (BRUVS) are increasingly being employed to estimate the diversity and abundance of fish (e.g. Cappo & Brown 1996, Willis & Babcock 2000, Murphy & Jenkins 2010, Heagney et al. *in press*). As BRUVS are a non-destructive sampling tool they are often a standard monitoring technique within marine protected areas (Babcock et al. 1999, Cappo et al. 2003, Willis et al. 2003). In Australia, BRUVS monitoring programs have now been established in all marine parks in New South Wales, the Great Barrier Reef Marine Park in Queensland, and Ningaloo Marine Park in Western Australia (Westera et al. 2003, Cappo et al. 2004, Malcolm et al. 2007).

Assemblages of reef fish species, a common target of BRUVS studies, comprise a variety of trophic levels and feeding guilds. The effectiveness of bait has been well documented in trapping studies (Wolf & Chislett 1974, Munro 1983, Whitelaw et al. 1991), with oily baitfish such as pilchards (*Sardinops* spp.) proving more effective at catching a greater abundance of fish than white-fleshed baits such as *Lethrinus choerorhynchus* (Whitelaw et al. 1991) or octopus (High 1980). It seems likely then that the type of bait used may influence the fish that are attracted to BRUVS, particularly among different feeding guilds, and add an additional source of variability (Dorman et al. 2012). Most BRUVS studies have used oily fish, such as mackerel, bonito tuna or pilchards as bait (e.g. Babcock et al. 1999, Westera et al. 2003, Cappo et al. 2004, Watson et al. 2005, Brooks et al. 2011, Bond et al. 2012), although there have been some exceptions. For example, Ellis and DeMartini (1995) attached a squid to the outside of the bait container filled with mackerel, and Stobart and co-workers (2007) combined sardines with an effervescent bait pellet, while Lowry and co-workers (2012) used vegetable meal and added tuna oil as an attractant. Recent work by Dorman et al (2012) comparing three bait types on BRUVS outcomes concluded that different baits do indeed sample different components of coral reef fish assemblages. Despite the range of bait types being used and the potential to confound comparison among studies, it remains unclear whether bait type influences the assemblages that are observed, particularly among temperate reef fishes.

Our aim was to compare a number of commonly used metrics relating to reef fish assemblages recorded at BRUVS on the presentation of three different bait types: pilchards, abalone viscera (*Haliotis* spp.) and crushed sea urchin (*Centrostephanus rodgersii*). We used pilchards as they are a common bait for shallow BRUVS studies within Australian and New Zealand waters (Willis and Babcock 2000; Cappo et al. 2004; Watson et al. 2005; Heagney et al. 2007). Abalone viscera, hereafter referred to as "abalone", was chosen as they are an important trophic component of Australian temperate rocky reefs (Barrett et al. 2009) as are urchins. Urchins were also chosen based on the observation that numerous reef fish are attracted when they are cracked open by divers.

While some BRUVS studies have targeted specific species such as snapper (Willis and Babcock 2000), many studies have as their primary questions determination of the fish assemblage (e.g. Malcolm et al.

2007, Langlois et al. 2010). We sought to test the influence of three baits to observations of the entire assemblage as well as their attraction to fishes belonging to distinct trophic groups. We also examined the effects of bait on attraction of the commercially and recreationally exploited Sparid, *Pagrus auratus*. Finally, to determine the generality of our outcomes, a key feature of monitoring programs, we examined spatial and temporal variation in our sampling design, with replication across three coastal reefs over two years.

Methods

Study Site

Jervis Bay is a 102 km^2 marine embayment, which forms the major part of the multiple-use Jervis Bay Marine Park (JBMP) located approximately 180 km south of Sydney, New South Wales, Australia (Figure 1). We deployed BRUVS on three shallow subtidal rocky reefs within the Bay: Callala Reef (35^{o}05'S, 150^{o}43'E), Huskisson Reef (35^{o}20'S,150^{o}40'E), and Plantation Point (35^{o}04'S, 150^{o}41'E). Each of these reefs provided more than 1km of continuous subtidal rocky reef to a depth of around 15m and were widely separated. We targeted the reef and sand interface with a depth sounder (Simrad) to maximise the number of fish species recorded while minimising the likelihood of entanglement of the equipment on the reef. All recordings were made between 3 and 10m depth.

Sampling Design

We sampled in the early Austral winter, June 2005 and again in June 2006. Sampling was restricted to daylight hours (8am – 4pm) to avoid confounding influences from crepuscular or nocturnal feeding species. We established a three-factor orthogonal sampling design: bait type (fixed, 3 levels), location (random, 3 levels), and year (fixed, 2 levels). We assert that considering two consecutive years as a random factor would overstate the generality of our findings as they do not represent a random draw from a large number of potential years. In each year, twelve samples were taken at each location comprising four replicate samples for each of the three bait types: pilchard, abalone, and urchin. Each location was sampled in one day, with the order of bait deployment randomized. Replicate BRUVS deployment sites within locations were selected haphazardly with a GPS used to record position. A minimum of 200m was maintained between samples and with the low flow rates experienced by these shallow reefs within Jervis Bay (<1.5 cm/s, Holloway 1995) and the modest levels of bait used (200 grams per deployment) we contend that this ensured their independence.

Bait and BRUV deployment

Pilchard and abalone baits were purchased frozen. Urchins were hand collected at Bellambi Harbour (near Wollongong, NSW, 34°22'S, 150°56'E) at 1-3 m depth and then frozen. Baits were thawed the day before use. Pilchard and abalone were chopped into 5cm cubes, while urchins were cut open at the Aristotle's Lantern and placed in perforated plastic bags to retain their contents. For each BRUVS deployment, 200 grams of fresh bait was placed in a hard plastic cylindrical bait bag (30 cm x 8 cm diameter with a mesh size of 5 mm). We sought to use similar amounts of each bait type and given the large size of the urchins this restricted us to 200 g of each bait; this is more than some researchers have used at BRUVS (e.g. Heagney et al. 2007). Digital video cameras (Canon MV750i with WA-30.5 wide angle lens) were housed within high-pressure PVC (polyvinyl chloride) pipe with flat acrylic end-ports. The camera housings were bolted within the center of galvanized steel frames to view the 1.5 m long bait arm and substratum in a horizontal orientation.

Analysis of video footage

Video footage from each deployment was examined in the laboratory on a TV screen and we did not use specialist software for video analsysis. Observation began once the BRUV had settled on the bottom and continued for 30 minutes. Species accumulation curves indicate that this is sufficient time to provide a representative sample of the fauna (Wraith & Davis 2007). All species within the field of view to a maximum distance of 2 m behind the bait bag were identified and recorded thereby minimising bias associated with variable underwater visibility at our study locations. We recorded two additional metrics from the tapes; the time of first arrival (t*1st*) for all species, and the maximum number of each individual species viewed at any one time (Max *N*) as used by Cappo and co-workers (2003). We then summed this latter metric to give Total Max *N* for each sample (tape). Previous studies have shown that Max *N* is correlated with fish abundance (Willis et al. 2000), and Willis and Babcock (2000) reported that *t1st* was an accurate time-based index of relative abundance for blue cod (*Parapercis colias*).

Feeding Guilds

We assigned all of the fishes observed to six feeding guilds based on their feeding habits and functional morphology (Appendix). We based these functional groupings on those developed by Harvey et al. (2007) and derived information from 'FishBase' (Froese & Pauly 2006), and local fish identification guides (Coleman 1980; Kuiter 2000). We classified the groups on the basis of the predominance of prey type using the above sources into (1) Herbivores, (2) Zooplanktivores, or (3) Invertebrate carnivores. Further groupings were recognised based on a mixture of prey types into (4) Algae / Invertebrate consumers. We assigned carnivores to groups based on the size and range of items eaten including (5) Macroinvertebrate carnivores, such as large rays, consuming cephalopods, molluscs and crustaceans. Finally, (6) Generalist carnivores were classified on the basis of a wide range of fishes and invertebrates taken from the benthos or water column. 'Piscivores', a relatively small group in our samples were combined with the latter guild.

Statistical Analyses

We analysed data for the entire assemblage, for five of the six feeding guilds and for the exploited Snapper, *Pagrus auratus*. No other commercially or recreationally exploited species was sufficiently abundance to warrant close scrutiny. Dependent variables were tested using three-factor ANOVA (GMAV 5 software, University of Sydney). We did not detect an effect of year in the univariate analyses and elected to pool across years in presenting the data. Prior to analysis, data were examined visually to assess the assumption of normality while Cochran's C test was used to ensure that the variances were homogeneous. Data were transformed if significant heterogeneity was detected. We used Student-Newman Keuls (SNK) tests for *post-hoc* comparison.

After ANOVA, we employed the pooling procedures recommended by Winer (1971), removing the Bait x Location interaction and thereby increasing the power of our bait comparisons. We present pooled data in the ANOVA tables. A camera malfunction at Huskisson rendered our design unbalanced with a pilchard bait replicate missing in 2005. We generated a mean from other pilchard bait counts at this location during 2005 and entered this into the cell. We removed a degree of freedom from the denominator for each F test as recommended by Zar (1999 p. 248) and recalculated the P value. We do not present recalculated P values as they represent little more than rounding error and did not change our interpretation of the data.

We also undertook multivariate comparisons of the effect of bait on the entire assemblage. We generated a dissimilarity matrix based on Bray-Curtis distances and then tested hypotheses with a 3 factor permutational multivariate analysis of variance (PERMANOVA) (PRIMER software, Plymouth Marine Laboratories) using the same design as the ANOVA analysis. We also examined those taxa contributing to the dissimilaries we observed with SIMPER. We contrasted outcomes for the untransformed data set with a presence/absence transformation; we could then interpret outcomes for the overall data set with outcomes for species composition alone.

Results

A total of 47 species from 30 families were recorded over the two years of sampling: 35 species from 23 families in 2005 and 40 species from 26 families in 2006 (Appendix). In total, 32 species from 21 families were recorded on presentation of abalone bait, 36 species from 26 families using pilchard bait, and 33 species from 22 families using urchin bait.

Effects on the assemblage

Bait had a significant effect on the fish assemblage with lower species richness observed with urchin bait than other baits (Table 1, SNK; abalone=pilchard>urchin). At Callala and Huskisson this was apparent as a 40% to 60% reduction in the species richness observed (Fig. 2a). We also detected a significant difference among locations for species richness (Table 1, SNK; Plantation Point>Callala=Huskisson).

Bait type also affected relative fish abundance, as measured by Total Max *N* (Table 1, SNK; abalone=pilchard>urchin), with abundance strikingly lower at Callala and Huskisson in the presence of urchin bait (Fig 2b). Urchin bait also proved relatively ineffective in attracting fishes at these two locations with mean ‘time of first arrival’ (*t1st*) exceeding 500 seconds (Table 1, Fig. 2c, SNK; abalone=pilchard<urchin). Time of first arrival also varied significantly among locations (Table 1, SNK; Callala=Huskisson>Plantation Point).

Unlike the univariate measures, our multivariate examination of the data did not detect a significant influence of bait on the assemblage irrespective of whether the data were transformed (presence/absence) or untransformed. Our multivariate analysis did, however, reveal significant differences among locations (Table 2). Pairwise *post-hoc* comparisons confirmed that the fish assemblages at Callala differed from those at Huskisson and Plantation Point. A SIMPER analysis revealed marked dissimilarity among the three locations, in each case exceeding 83%. There was considerable overlap in the species that contributed to these dissimilarities measures at each location. The highly abundant planktivorous Mado, *Atypichthys strigatus* was the top ranked contributor to the dissimilarities at all locations for the untransformed data set. While maori wrasse, *Ophthalmolepis lineolatus*, and Port Jackson sharks, *Heterodontus portusjacksoni*, were key drivers of pattern for the transformed data set (Table 3).

Effects on feeding guilds

Species richness for several feeding guilds was strongly influenced by bait type (Fig. 3, Table 4), being notably elevated among carnivorous guilds (macroinvertebrate carnivores and generalist carnivores, Fig 3d, f) in the presence of pilchard and abalone bait. Pilchard bait proved to be more attractive to these guilds than abalone, but the differences were not significant (SNK; pilchard=abalone>urchin). We did not detect any effects of bait on species richness for the invertebrate carnivore guild nor algae/invertebrate consumers. A significant difference between locations was apparent for the macroinvertebrate carnivore guild (Fig. 3f, Table 4, SNK; Plantation Point>Huskisson=Callala). Unexpectedly, the species richness of zooplankton consumers was significantly elevated in the presence of pilchards and abalone, as was the abundance of these fishes (Fig. 3b, Fig. 4b). The herbivore guild was only regularly observed at the three locations when we used pilchard bait and, although we present these data (Fig. 3a, Fig. 4a), we deemed them not sufficiently normal to justify an analysis.

Bait type had little impact on the abundance of fishes within most feeding guilds, with the exception of the zooplankton feeding guild (Fig. 4b) where we recorded significantly lower relative abundance in the presence of urchin bait (SNK; pilchard=abalone>urchin). We were also reticent to reject the null hypothesis that bait did not affect the abundance of macroinvertebrate carnivores (P=0.057). We detected differences among locations for the macroinvertebrate carnivore and algae invertebrate consumer guilds (Table 4, Fig. 4c, f).

Effects on targetted taxa – Pagrus auratus

The effect of bait on patterns of abundance for snapper, *P. auratus*, was difficult to interpret, with considerable variation apparent in our abundance estimates with different baits at each location (Fig 5).

More snapper were associated with abalone bait at Callala, whereas abundance was highest with pilchards at Huskisson and urchins at Plantation Point. We were reticent to reject the null hypothesis relating to the three-way interaction (*P*=0.059, Table 5).

Discussion

Our research provides clear evidence that bait type has the potential to bias samples from Baited Remote Underwater Video Stations (BRUVS). Pilchard and abalone bait consistently maximised the diversity (species richness) and abundance of fishes we observed while urchin bait performed poorly. Fishes were also slow to respond (time of first arrival) to urchin bait, particularly at our Callala and Huskisson locations. Bait type affected the diversity we observed in feeding guilds; pilchards proved to be particularly attractive bait to our generalist carnivore guild and those fishes consuming macroinvertebrates and zooplankton. Notably, pilchards were the only bait to consistently attract herbivores at all of our sample locations. Bait type did not affect the abundance of fishes we observed in any of the feeding guilds with the exception of its attractiveness to consumers of zooplankton and, once again, urchins performed poorly.

The other key finding from our research was the important role that location played when comparing univariate and multivariate metrics of fish diversity and abundance. We repeatedly detected significant effects of location. Plantation Point stood out in this regard; it showed consistency for all of our univariate measures (Species richness, Max *N* and t*1st*) irrespective of bait type and this was pattern not apparent at the other locations. We contend that at locations where the abundances of fishes are lower (Callala and Huskisson) or perhaps bait plumes are less well dispersed, then inadequacies in the attractiveness of the bait will become increasingly apparent. For example, time of first arrival (t*1st*) at Callala and Huskisson was 3 to 5 fold longer in response to crushed-urchins relative to other baits, while t*1st* was extremely rapid (<60 seconds) irrespective of bait type at Plantation Point. These outcomes further underscore the importance of assessing pattern at multiple locations, as had we focused solely on Plantation Point in this study we would not have detected differences among baits.

Feeding guilds, particularly the carnivorous ones, were significantly less speciose in the presence of urchin bait, but we failed to detect any differences in the abundance of carnivorous species in response to bait. Similarly, the abundance of the snapper *Pagrus auratus* showed no clear pattern with bait type. BRUV appears to be highly effective in estimating the abundance of carnivores and planktivores (Stobart et al. 2007), but ineffective in estimating herbivore abundance (Colton & Swearer 2010). Our data supports their assertion, with herbivores poorly represented as a feeding guild and then only appearing consistently in the presence of pilchard bait. In contrast, Harvey et al. (2007) did not detect differences in the feeding groups attracted to their baited units in a similar but Western Australian temperate reef system.

It remains unclear whether the poor responses we obtained with urchin bait reflected it being generally unattractive to fishes or poor bait plume dispersion at our study locations. Although Jervis Bay is a large embayment, currents in the in the upper reaches of the Bay are particularly weak, rarely exceeding 1.5 cm/second (Holloway 1995). It is possible that urchin bait will perform better in more exposed environments where they might generate a better plume. Heagney and co-workers (2007) were faced with a similar dilemma at their mid-water BRUV stations. Assemblages of pelagic fishes at Lord Howe Island differed with current speed, but as this was confounded with the dispersion of the bait plume it was not possible to determine which of these variables was responsible for the patterns they observed. Developing a clearer understanding of the dispersion of bait plumes and how this impacts on fish assemblages represents a significant challenge in BRUV studies (Priede et al. 1991), but one that is deserving of attention.

The recent proliferation of BRUVS studies has also seen an increase in the types of bait used. Most studies have relied on oily bait-fish such as pilchards (*Sardinops* spp.) (e.g. Babcock et al. 1999, Cappo et al. 2004) or sardines (Stobart et al. 2007), while scombrids (bonito tuna) have been used as bait to assess shark populations (Brooks et al. 2011). Other workers have added tuna oil as an additional attractant (e.g. Heagney et al. 2007, Lowry et al 2012). Quantities of bait also show considerable variation across studies with between 100g (Heagney et al. 2007) and 1000g used (Harvey et al. 2007) for each deployment. Although, this may allow effective comparison of the factors of interest within a study it complicates contrasts among studies. A number of workers have sought to standarise BRUV methodologies (e.g. Stobart et al 2007), and this will continue to present a challenge to researchers in the field. The adoption of standard techniques across broad geographic areas as seen for Marine Parks in the State of NSW Australia is a positive step in this direction.

An additional consideration in relation to bait use in BRUV studies is the environmental impacts associated with using wild caught fishes (Brooks et al. 2011). Further, some baits may increase the risk of introducing disease. For example, large die-offs of pilchards (*Sardinops sagax neopilchardus*) were observed across 5000km of southern Australia in the mid 1990's and were attributed to a herpesvirus, perhaps newly introduced into these waters (Whittington et al. 1997). The risks associated with BRUVS bait needs to weighed against the routine use of pilchards as bait by recreational fishers. The recent use of vegetable meal (falafel) with the addition of tuna oil (Lowry et al. 2012) side steps the issue of disease introduction, but further impedes standardisation of BRUVS methodologies.

BRUVS can offer significant advantages over other fish sampling methods (Murphy & Jenkins 2010), particularly in marine protected areas (eg Willis and Babcock 2000). The use of bait ensures that BRUVS are less prone than other survey methods to zero counts that lead to results with low statistical power (Cappo et al. 2002). Nevertheless the limitations of this technique need to established, combined with efforts to standardize BRUVS methodology and reduce bias. Taken together our data provide two clear outcomes. Oily bait such as pilchards were most effective at attracting fishes – particularly carnivorous species. As most existing studies have used pilchards predominantly as bait, our data suggests that this practice should continue. Pilchards have the additional advantage of being readily available. Finally, to ensure generality it is important to consider the impacts of spatial variation in fish diversity and abundance. Hence if we are to further develop the utility of this technique, then the limitations and biases associated with BRUVS need to be assessed in multiple locations.

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Figure Captions

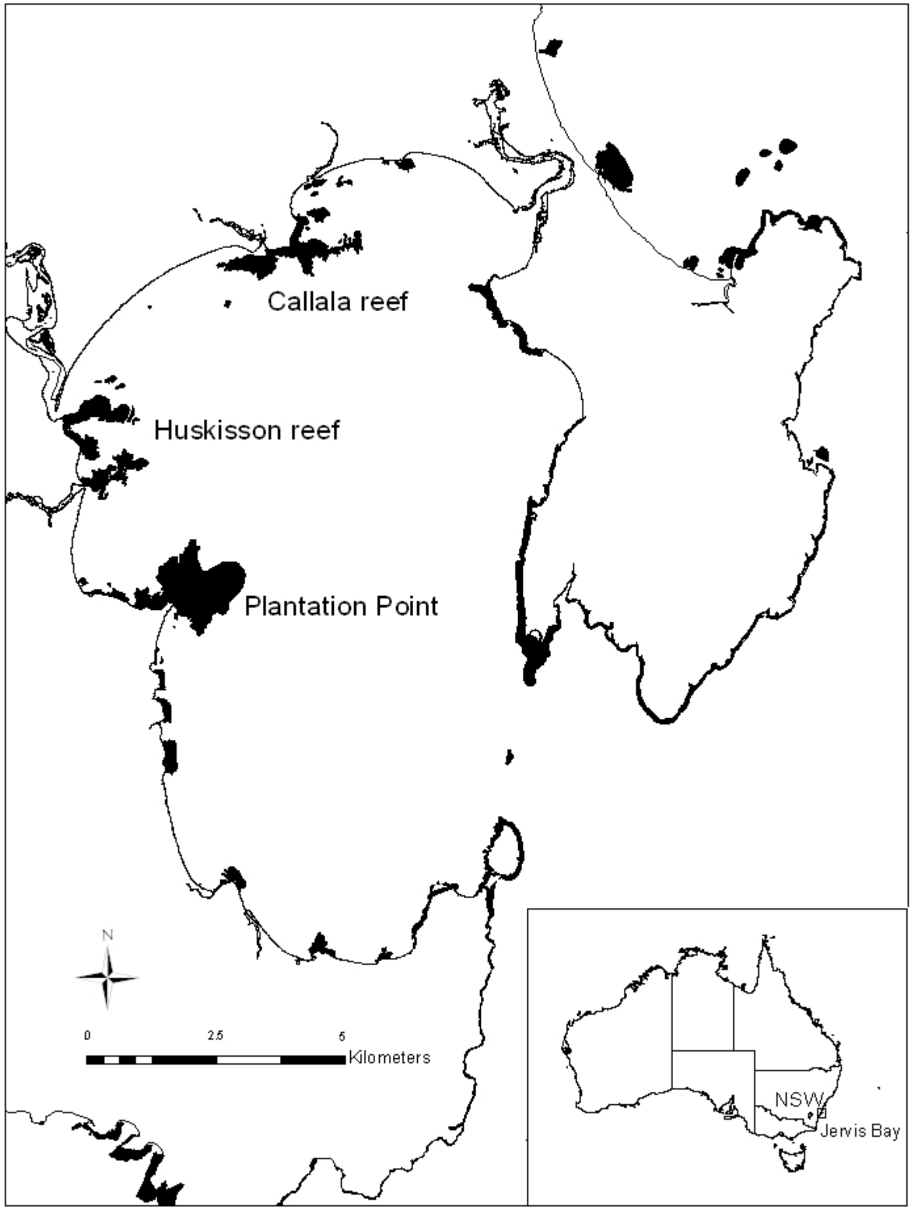
Figure 1. The three study locations within Jervis Bay, 180km south of Sydney. Subtidal rocky reef is denoted in black.

Figure 2. (a) Species richness (b) relative abundance (Total Max *N*) and (c) time of first arrival (T*1st*) for fishes recorded by BRUV in the presence of three baits (abalone, pilchard and urchin). Data are means (± SE) at three locations (Callala, Huskisson, and Plantation Point) and are pooled over years (2005 and 2006, n=8 after pooling).

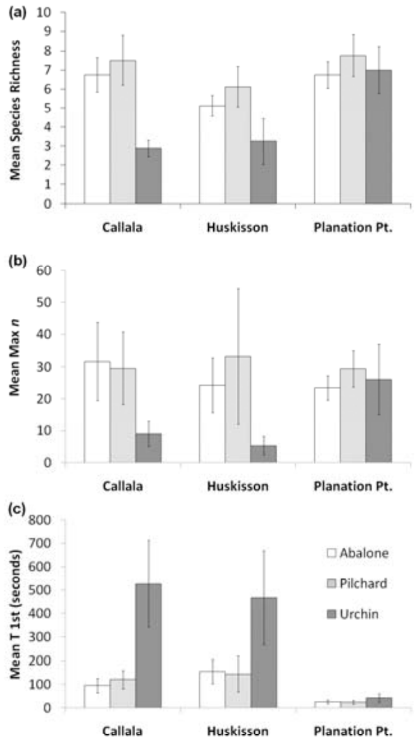
Figure 3. Mean (± SE) species richness for six feeding guilds (see Appendix) of fishes (a-f) in the presence of three baits (pilchard, abalone and urchin) at three locations (Callala , Huskisson , and Plantation Point). Data are pooled over years (2005 and 2006, n=8 after pooling).

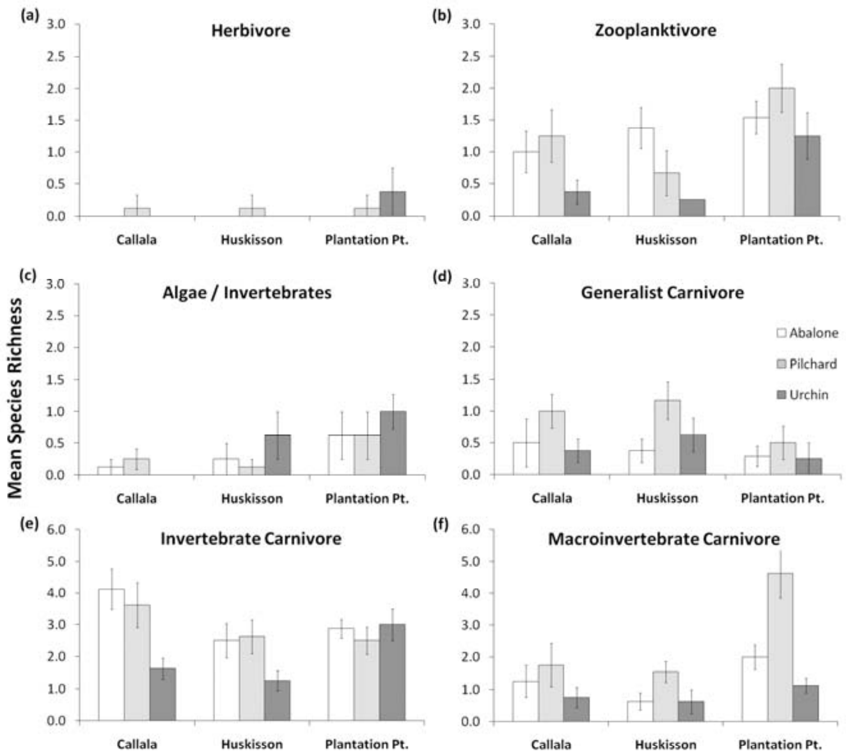
Figure 4. Mean (± SE) relative abundance (Total Max *N*) for six feeding guilds of fishes (a-f) in the presence of three baits (pilchard, abalone and urchin) at three locations (Callala , Huskisson , and Plantation Point). Data are pooled over years (2005 and 2006, n=8 after pooling).

Figure 5. Mean (± SE) relative abundance (Total Max *N*) for snapper (*Pagrus auratus*) in the presence of three baits (pilchard, abalone and urchin) at three locations (Callala , Huskisson , and Plantation Point). Data are pooled over years (2005 and 2006, n=8 after pooling).

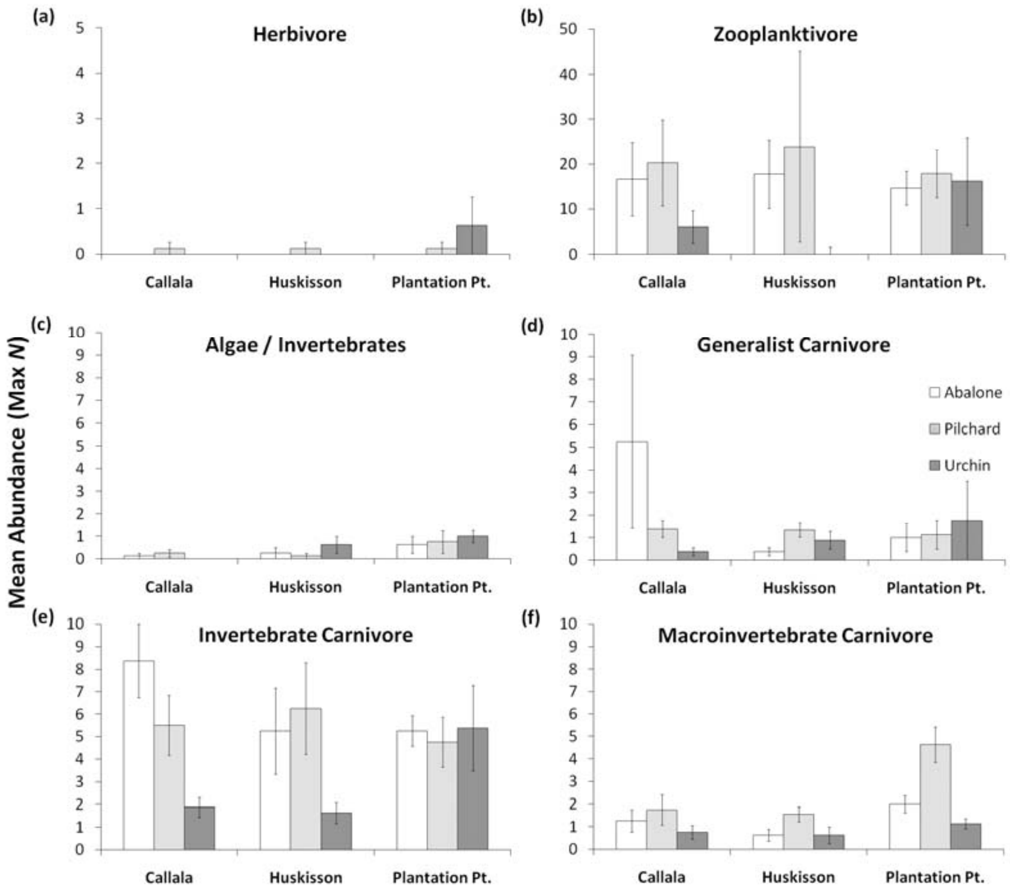


Callala reef
Huskisson reef
Plantation Point
N
0
2.5
5
Kilometers
NSW
Jervis Bay


(a)
Mean Species Richness
10
9
8
7
6
5
4
3
2
1
0
Callala
Huskisson
Planation Pt.
(b)
Mean Max n
60
50
40
30
20
10
0
Callala
Huskisson
Planation Pt.
(c)
Mean T 1st (seconds)
800
700
600
500
400
300
200
100
0
Abalone
Pilchard
Urchin
Callala
Huskisson
Planation Pt.



(a)
Herbivore
(b)
Zooplanktivore
(c)
Algae / Invertebrates
(d)
Generalist Carnivore
(e)
Invertebrate Carnivore
(f)
Macroinvertebrate Carnivore
Mean Species Richness
Abalone
Pilchard
Urchin
Callala
Huskisson
Plantation Pt.



(a)
Herbivore
(b)
Zooplanktivore
(c)
Algae / Invertebrates
(d)
Generalist Carnivore
(e)
Invertebrate Carnivore
(f)
Macroinvertebrate Carnivore
Mean Abundance (Max N)
Abalone
Pilchard
Urchin
Callala
Huskisson
Plantation Pt.

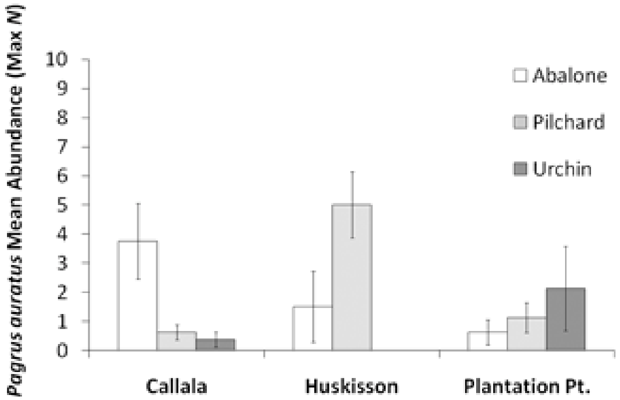

Pagrus auratus Mean Abundance (Max N)
10
9
8
7
6
5
4
3
2
1
0
Abalone
Pilchard
Urchin
Callala
Huskisson
Plantation Pt.

Table 1. Three-factor mixed model ANOVA for fish assemblages recorded with Baited Remote Underwater Video (BRUV). Three dependent variables are reported: Species richness, relative abundance (Total Max *N*), and time for first species to arrive (T*1st*) in seconds. Factors were Bait type (fixed with 3 levels), Location (random with 3 levels) and Year 2005 & 2006 (fixed with 2 levels) n=4. Significant differences at α = 0.05 are indicated by **bold** type.

			Species Richness			**Abundance** (Max *N*)			**T 1st (arrival)**		
Source	**df**	**F versus**	**MS**	**F**	**p**	**MS**	**F**	**p**	**MS**	**F**	**p**
Bait	2	1-POOLED DATA	47.06	5.92	**0.005**	6.22	5.74	**0.005**	287.56	4.46	**0.016**
Location	2	1-POOLED DATA	33.35	4.20	**0.019**	1.87	1.73	0.187	498.29	7.59	**0.001**
Year	1	Y x L	30.68	8.15	0.104	8.48	7.10	0.117	10.65	0.32	0.631
B x L	2	1-POOLED DATA	10.72	1.35	0.263	1.39	1.28	0.287	69.43	1.08	0.376
B x Y	2	B x L x Y	6.22	1.23	0.383	0.27	0.94	0.463	3.22	0.07	0.929
L x Y	4	1-POOLED DATA	3.76	0.47	0.625	1.19	1.10	0.339	33.79	0.52	0.594
B x L x Y	4	1-POOLED DATA	5.06	0.64	0.639	0.283	0.26	0.902	43.42	0.67	0.613
Residual	54										
Total	71										
1-POOLED DATA	58										
			Cochrans C (NS): 0.1646 untransformed			Cochrans C (NS): 0.1870 Ln(x+1)			Cochrans C (NS): 0.2383 SQRT(x+1)		

Table 2. Three-factor mixed model PERMANOVA for fish assemblages recorded with Baited Remote Underwater Video (BRUV). Factors are the same as those listed in Table 1, n=4. Significant differences at α = 0.05 are indicated by **bold** type.

		Untransformed			Presence / Absence		
Source	df	MS	Pseudo F	P (perm)	MS	Pseudo F	P (perm)
Bait	2	4627.9	1.185	0.318	3517.4	0.9996	0.462
Location	2	8574.5	2.608	**0.001**	9941.3	3.8037	**0.001**
Year	1	8890.7	3.010	0.166	5030.9	3.4007	0.098
B x L	4	3905.4	1.188	0.186	3518.7	1.3463	0.105
B x Y	2	2930.2	0.838	0.626	1785.8	0.7455	0.65
L x Y	2	2954.1	0.898	0.608	1479.4	0.5660	0.901
B x L x Y	4	3496.3	1.063	0.371	2395.4	0.9165	0.618
Residual	54	3287.9			2613.6		
Total	71						

Table 3. Fish species ranked in order of importance (1 high to 5 low) which contributed to the dissimilarities among locations as determined using SIMPER for the untransformed and transformed (presence/absence) datasets. C: Callala; H: Huskisson; PP: Plantation Point.

	Untransformed data			Transformed data		
Fish species	**Locations**					
	C-H	**C-PP**	**H-PP**	**C-H**	**C-PP**	**H-PP**
Mado, Atypichthys strigatus	1	1	1	5	3	3
Port Jackson Shark, Heterodontus portusjacksoni	5			1	4	4
Snapper, *Pagrus auratus*	2	3	4	3	5	
Maori Wrasse, Ophthalmolepis lineolatus		4	3		1	1
Blue-spotted Goatfish, Upeneichthys vlamingii	3			2		
Fiddler Ray, Trygonorrhina fasciata				4		
Senator Wrasse, Pictilabrus laticlavius					2	2
Yellow Tail Scad, Trachurus novaezelandiae	4	2	2			
Silver Sweep, Scorpis lineolata		5	5			
Crimson Banded Wrasse, *Notolabrus gymnogenis*						5

Table 4. Three-factor mixed model ANOVAs for feeding guilds within fish assemblages recorded with Baited Remote Underwater Video testing (A) species richness and (B) relative abundance (Total Max *N*). Factors are the same as those listed in Table 1, n=4. Significant differences at α = 0.05 are indicated by **bold** type.

A) Species Richness		**Zooplanktivore**			**Algae / Invertebrates**			**Invertebrate carnivore**			**Macroinvertebrate carnivore**			**Generalist carnivore**		
Source	df	MS	F	p	MS	F	p	MS	F	p	MS	F	p	MS	F	p
B	2	4.034	5.24	**0.008**	0.347	1.00	0.444	9.764	2.08	0.241	3.042	20.86	**0.008**	1.895	8.74	**0.035**
L	2	4.493	5.84	**0.005**	2.431	4.65	**0.014**	6.222	3.13	0.052	3.167	5.85	**0.005**	0.909	1.57	0.218
Y	1	7.347	15.71	0.058	1.125	3.86	0.189	0.347	0.15	0.740	4.014	10.32	0.085	0.303	4.00	0.184
B x L	2	0.634	0.82	0.515	0.347	0.66	0.620	4.701	2.37	0.064	0.146	0.27	0.897	0.217	0.37	0.826
B x Y	2	0.443	1.07	0.424	1.042	1.79	0.279	1.264	0.63	0.577	0.681	5.76	0.066	0.228	0.76	0.525
L x Y	4	0.468	0.61	0.548	0.292	0.56	0.576	2.389	1.20	0.308	0.389	0.72	0.492	0.076	0.13	0.878
B x L x Y	4	0.414	0.54	0.709	0.583	1.12	0.359	1.993	1.00	0.414	0.118	0.22	0.927	0.300	0.52	0.723
Residual	54	0.780			0.523			1.986			0.542			0.580		
Total	71															
		Cochrans C (NS): 0.143 untransformed			Cochrans C (NS): 0.212 untransformed			Cochrans C (NS): 0.138 untransformed			Cochrans C (NS): 0.163 untransformed			Cochrans C (NS): 0.215 untransformed		

B) Abundance (Total Max *N*)		**Zooplanktivore**			**Algae / Invertebrates**			**Invertebrate carnivore**			**Macroinvertebrate carnivore**			**Generalist carnivore**		
Source	df	MS	F	p	MS	F	p	MS	F	p	MS	F	p	MS	F	p
B	2	8.920	12.27	**0.020**	0.047	0.91	0.474	2.746	3.88	0.116	1.624	6.38	0.057	0.588	1.91	0.262
L	2	4.501	2.30	0.110	0.365	5.04	**0.010**	0.684	1.59	0.214	1.579	11.08	**<0.001**	0.156	0.26	0.773
Y	1	27.663	8.94	0.096	0.138	3.65	0.196	0.092	0.15	0.733	0.749	6.56	0.125	0.391	1.65	0.328
B x L	2	0.727	0.37	0.828	0.052	0.71	0.589	0.709	1.64	0.177	0.255	1.79	0.145	0.308	0.51	0.729
B x Y	2	1.025	4.88	0.085	0.150	1.82	0.274	0.075	0.07	0.930	0.059	1.57	0.314	0.065	0.23	0.804
L x Y	4	3.093	1.58	0.215	0.038	0.52	0.596	0.598	1.38	0.259	0.114	0.80	0.454	0.237	0.39	0.678
B x L x Y	4	0.210	0.11	0.979	0.082	1.14	0.349	1.011	2.34	0.066	0.038	0.26	0.900	0.283	0.47	0.7594
Residual	54	1.954			0.072			0.432			0.143			0.605		
Total	71															
		Cochrans C (NS): 0.173 Ln(x+1)			Cochrans C (NS): 0.260 SQRT(x+1)			Cochrans C (NS): 0.225 untransformed			Cochrans C (NS): 0.162 SQRT(x+1)			Cochrans C (NS): 0.271 untransformed		

Table 5. Three-factor mixed model ANOVA for relative abundance (Max *N*) of snapper *Pagrus auratus* recorded with Baited Remote Underwater Video. Factors are the same as those listed in Table 1, n=4.

Abundance (Max *N*)	**Snapper, *Pagrus auratus***			
Source	df	MS	F	p
B	2	0.028	0.04	0.960
L	2	0.778	2.19	0.122
Y	1	1.467	1.74	0.318
B x L	2	0.680	1.91	0.121
B x Y	2	0.023	0.03	0.974
L x Y	4	0.845	2.38	0.102
B x L x Y	4	0.865	2.44	0.059
Residual	54	0.355		
Total	71			
		Cochrans C (NS): 0.2368 SQRT(x+1)		

Appendix. Membership of the six feeding guilds used in our analysis.

Diet Classification	***Species***	**Common Name**
Herbivore	*Aplodactylus lophodon*	Rock Cale
	Kyphosus sydneyanus	Silver Drummer
	Odax cyanomelas	Herring Cale
Zooplanktivore	*Atypichthys strigatus*	Mado
	Pseudocaranx dentex	Silver Trevally
	Schuettea scalaripinnis	Ladder-finned Pomfret
	Scorpis lineolata	Silver Sweep
	Trachurus novaezelandiae	Yellowtail Scad
Invertebrate Carnivore	*Acanthopagrus australis*	Yellowfin Bream
	Bathygobius krefftii	Krefts Goby
	Centropogon australis	Eastern Fortescue
	Enoplosus armatus	Old Wife
	Eupetrichthys angustipes	Snakeskin Wrasse
	Hypoplectrodes maccullochi	Half-banded Seaperch
	Nelusetta ayraudi	Chinaman Leatherjacket
	Ophthalmolepis lineolatus	Maori Wrasse
	Pagrus auratus	Snapper
	Parapercis ramsayi	Spotted Grubfish
	Pictilabrus laticlavius	Senator Wrasse
	Platycephalus caeruleopunctatus	Eastern Blue-spotted Flathead
	Suezichthys gracilis	Gracilis Wrasse
	Tetractenos hamiltoni	Common Toadfish
	Torquigener pleurogramma	Banded Toadfish
	Upeneichthys vlamingii	Blue-spotted Goatfish
Algae / Invertebrates	*Anoplocapros inermis*	Eastern Smooth Boxfish
	Cheilodactylus fuscus	Red Morwong
	Cheilodactylus vestitus	Magpie Morwong
	Chelmonops truncatus	Eastern Talma
	Eubalichthys mosaicus	Mosaic Leatherjacket
	Meuschenia flavolineata	Yellow-striped Leatherjacket
	Meuschenia freycineti	Six Spine Leatherjacket
	Meuschenia venusta	Stars and Stripes Leatherjacket
	Nemadactylus douglasii	Blue Morwong
	Parma microlepis	White Ear
Generalist Carnivore	*Dasyatis brevicaudata*	Smooth Stingray
	Dinolestes lewini	Long-finned Pike
	Hypoplectrodes nigroruber	Black-banded Seaperch
	Parupeneus spilurus	Blackspot Goatfish
	Squatina australis	Angelshark
	Trygonoptera testacea	Common Stingaree
	Aptychotrema rostrata	Bank's Shovelnose Ray
	Trygonorrhina fasciata	Fiddler Ray

5 Appendix (continued)

Diet Classification	***Species***	**Common Name**
Macroinvertebrate Carnivore	*Achoerodus viridis*	Blue Groper
	Heterodontus portusjacksoni	Port Jackson Shark
	Latris lineata	Trumpeter
	Myliobatis australis	Eagle Ray
	Notolabrus gymnogenis	Crimson-banded Wrasse
	Parascyllium ferrugineum	Rusty Catshark