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.

KEY WORDS: 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. unpubl.). 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, BRUV 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 bait such as pilchards *Sardinops* spp. proving more effective at catching a greater abundance of fish than white-fleshed bait 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 & DeMartini (1995) attached a squid to the outside of the bait container filled with mackerel, and Stobart et al. (2007) combined sardines with an effervescent bait pellet, while Lowry et al. (2012) used vegetable meal and added tuna oil as an attractant. Recent work by Dorman et al. (2012) comparing 3 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 comparisons among studies, it remains unclear whether bait type influences the assemblages that are observed, particularly among temperate reef fishes.

The aim of the present study was to compare a number of commonly used metrics relating to reef fish assemblages recorded at BRUVS on the presentation of 3 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 & Babcock 2000, Cappo et al. 2004, Watson et al. 2005, Heagney et al. 2007). Abalone viscera, hereafter referred to as 'abalone', were 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 & Babcock 2000), the primary focus of many studies has been determination of the fish assemblage (e.g. Malcolm et al. 2007, Langlois et al. 2010). We sought to test the influence of 3 types of bait on 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 3 coastal reefs over 2 yr.

MATERIALS AND 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 (Fig. 1). We deployed BRUVS on 3 shallow subtidal rocky reefs within the bay: Callala Reef (35° 05′ S, 150° 43′ E), Huskisson Reef (35° 20′ S, 150° 40′ E) and Plantation Point (35° 04′ S, 150° 41′ E). Each of these reefs provided >1 km of continuous subtidal rocky reef to a depth of around 15 m, and they were widely separated. We targeted the reef and sand interface with a depth sounder (Simrad) to maximise the number of
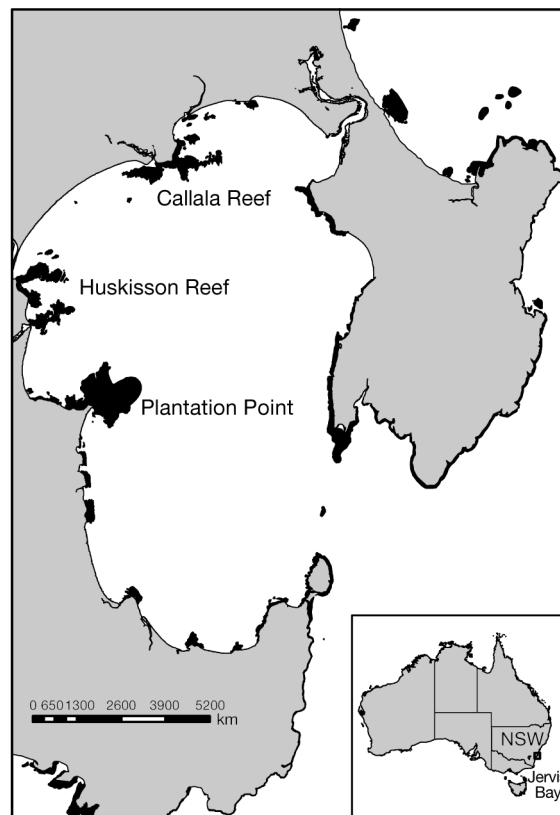

Fig. 1. The 3 study locations within Jervis Bay, 180 km south of Sydney, New South Wales (NSW), Australia. Subtidal rocky reef is denoted in black

fish species recorded, while minimising the likelihood of entanglement of the equipment on the reef. All recordings were made between 3 and 10 m depth.

Sampling design

We sampled in the early Austral winter, June 2005 and again in June 2006. Sampling was restricted to daylight hours (08:00 to 16:00 h) to avoid confounding influences from crepuscular or nocturnal feeding species. We established a 3-factor orthogonal sampling design: bait type (fixed, 3 levels), location (random, 3 levels) and year (fixed, 2 levels). We assert that considering 2 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, 12 samples were taken at each location comprising 4 replicate samples for each of the 3 bait types: pilchard, abalone and urchin. Each location was sampled in 1 d, with the order of bait deployment randomised. Replicate BRUVS deployment sites within locations were selected haphazardly with a GPS used to record position. A minimum of 200 m was maintained between samples, and with the low flow rates experienced by these shallow reefs within Jervis Bay (<1.5 cm s^{-1}; Holloway 1995) and the modest levels of bait used (200 g deployment^{-1}), 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, New South Wales, Australia; 34° 22′ S, 150° 56′ E) at 1 to 3 m depth and then frozen. Baits were thawed the day before use. Pilchard and abalone were chopped into 5 cm cubes, while urchins were cut open at the Aristotle's Lantern and placed in perforated plastic bags to retain their contents. For each BRUV deployment, 200 g of fresh bait was placed in a hard plastic cylindrical bait bag (30 cm × 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 centre 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 television screen, and we did not use specialised software for video analyses. Observation began once the BRUV had settled on the bottom and continued for 30 min. 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 2 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 et al. (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 & Babcock (2000) reported that t$1st$ was an accurate time-based index of relative abundance for blue cod *Parapercis colias*.

Feeding guilds

We assigned all of the fishes observed to 6 feeding guilds based on their feeding habits and functional morphology (Appendix 1). 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) alga/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 5 of the 6 feeding guilds and for the exploited snapper *Pagrus auratus*. No other commercially or recreationally exploited species was sufficiently abundant to warrant close scrutiny. Dependent variables were tested using 3-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 comparisons.

After ANOVA, we employed the pooling procedures recommended by Winer (1971), removing the bait × location interaction and thereby increasing the power of our bait comparisons. We present pooled data in the ANOVA tables (Table 1). 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 (PERM-ANOVA) (PRIMER software, Plymouth Marine Laboratories) using the same design as the ANOVA. We also examined those taxa contributing to the dissimilaries we observed with similarity percentage (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 2 yr of sampling: 35 species from 23 families in 2005 and 40 species from 26 families in 2006 (Appendix 1). 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 spe-

Table 1. Three-factor mixed model ANOVA for fish assemblages recorded with baited remote underwater video. 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 (B, fixed with 3 levels), location (L, random with 3 levels) and year 2005 and 2006 (Y, fixed with 2 levels), n = 4. Significant differences at α = 0.05 are indicated by **bold** type. 1-Pooled data: data stemming from pooling procedures recommended by Winer (1971), see text for details; NS: not significant

| Source	df	*F* versus	Species richness			Total Max *N*			T*1st* (arrival)		
			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 × L	30.68	8.15	0.104	8.48	7.10	0.117	10.65	0.32	0.631
B × L	2	1-Pooled data	10.72	1.35	0.263	1.39	1.28	0.287	69.43	1.08	0.376
B × Y	2	B × L × Y	6.22	1.23	0.383	0.27	0.94	0.463	3.22	0.07	0.929
L × Y	4	1-Pooled data	3.76	0.47	0.625	1.19	1.10	0.339	33.79	0.52	0.594
B × L × 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)		
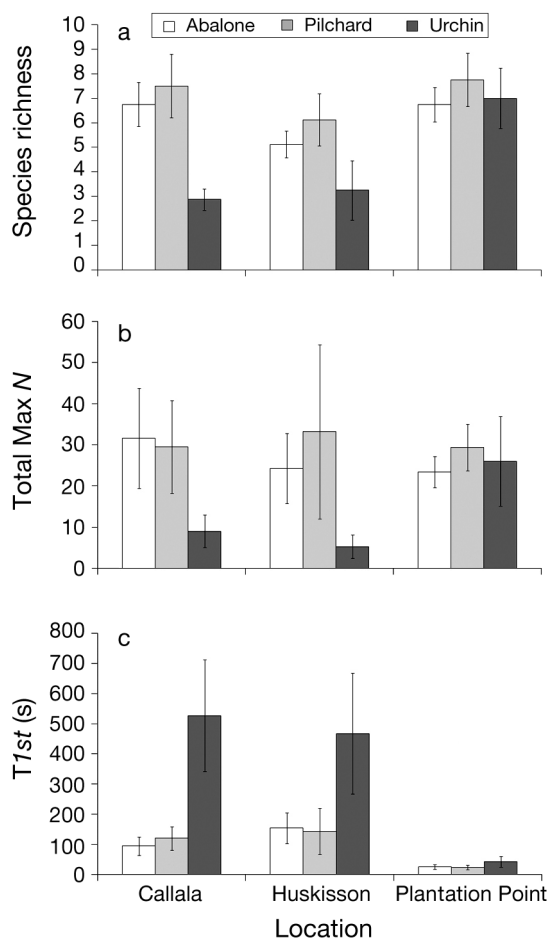
Fig. 2. (a) Species richness, (b) relative abundance (Total Max *N*) and (c) time of first arrival (T*1st*) for fishes recorded by baited remote underwater video in the presence of 3 types of bait (abalone, pilchard and urchin). Data are means (±SE) at 3 locations and are pooled over years (2005 and 2006, n = 8 after pooling)

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 3 locations, in each case exceeding 83%. There was considerable overlap in the species that contributed to these dissimilarity 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. 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 spe-

cies 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 2 locations, with mean t*1st* exceeding 500 s (Table 1, Fig. 2c, SNK; abalone = pilchard < urchin).

Table 2. Three-factor mixed model PERMANOVA for fish assemblages recorded with baited remote underwater video. Factors are the same as those listed in Table 1, n = 4. Significant differences at α = 0.05 are indicated by **bold** type

Source	df	Untransformed			Presence/absence		
		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 × L	4	3905.4	1.188	0.186	3518.7	1.3463	0.105
B × Y	2	2930.2	0.838	0.626	1785.8	0.7455	0.65
L × Y	2	2954.1	0.898	0.608	1479.4	0.5660	0.901
B × L × Y	4	3496.3	1.063	0.371	2395.4	0.9165	0.618
Residual	54	3287.9			2613.6		
Total	71						

cies richness for the invertebrate carnivore guild nor for alga/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

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

| Common name	Scientific name	Untransformed data			Transformed data		
		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
Yellowtail scad	*Trachurus novaezelandiae*	4	2	2			
Silver sweep	*Scorpis lineolata*		5	5			
Crimson-banded wrasse	*Notolabrus gymnogenis*						5
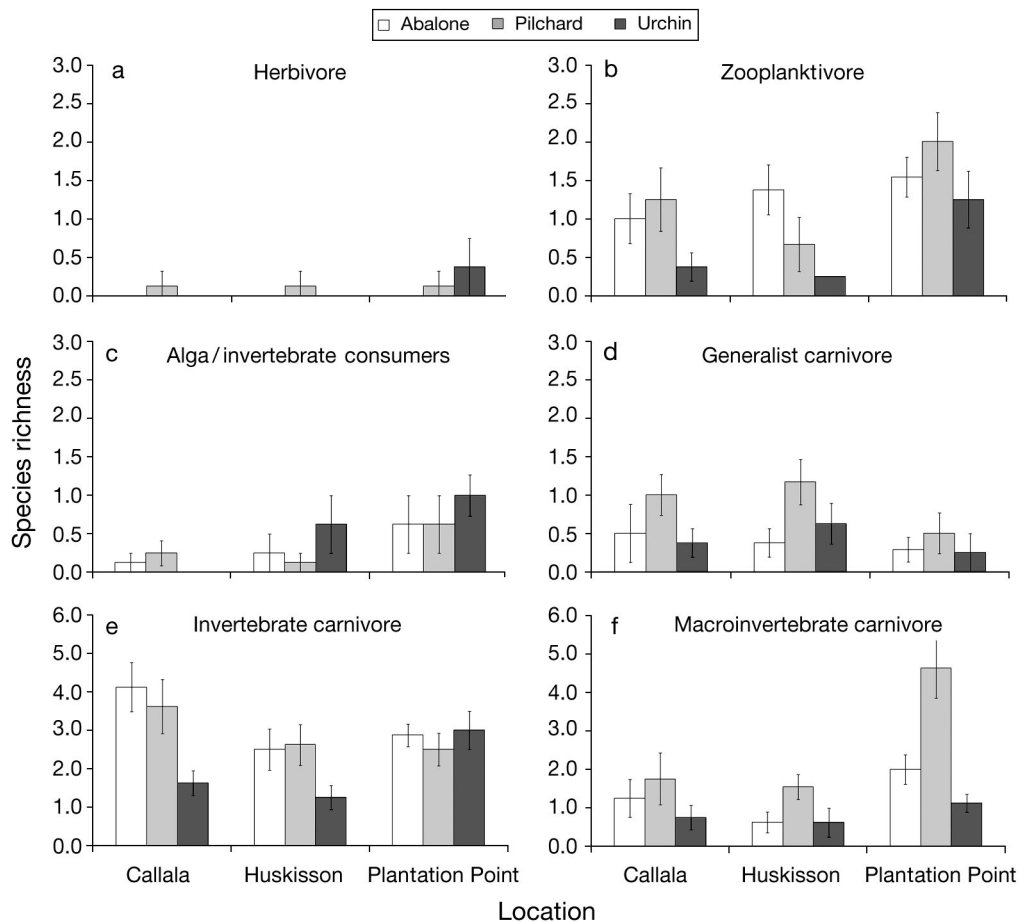
Fig. 3. Mean (±SE) species richness for 6 feeding guilds (see Appendix 1) of fishes (a to f) in the presence of 3 types of bait (abalone, pilchard and urchin) at 3 locations. Data are pooled over years (2005 and 2006, n = 8 after pooling)

Table 4. Three-factor mixed model ANOVAs for feeding guilds within fish assemblages recorded with baited remote underwater video testing for (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. NS: not significant, untrans.: untransformed

Source	df	Zooplanktivore			Alga/ invertebr. consumers			Invertebrate carnivore			Macroinvertebrate carnivore			Generalist carnivore		
		MS	F	p	MS	F	p	MS	F	p	MS	F	p	MS	F	p
(a) Species richness																
Bait	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**
Location	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
Year	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 × 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 × 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 × 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 × L × 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, untrans.			Cochrans C (NS): 0.212, untrans.			Cochrans C (NS): 0.138, untrans.			Cochrans C (NS): 0.163, untrans.			Cochrans C (NS): 0.215, untrans.		
(b) Total Max N																
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 × 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 × 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 × 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 × L × 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, untrans.			Cochrans C (NS): 0.162, $\sqrt{(x + 1)}$			Cochrans C (NS): 0.271, untrans.		

these fishes (Figs. 3b & 4b). The herbivore guild was only regularly observed at the 3 locations when we used pilchard bait, and, although we present these data (Figs. 3a & 4a), we did not deem them 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), for which 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 alga/invertebrate consumer guilds (Table 4, Fig. 4c,f).

Effects on targeted taxa—*Pagrus auratus*

The effect of bait on patterns of abundance for snapper *Pagrus 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 3-way interaction (p = 0.059; Table 5).

DISCUSSION

Our research provides clear evidence that bait type has the potential to bias samples from 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 to those fishes consuming macroinvertebrates and zooplankton. Notably, pilchards were the only bait to consistently attract herbivores
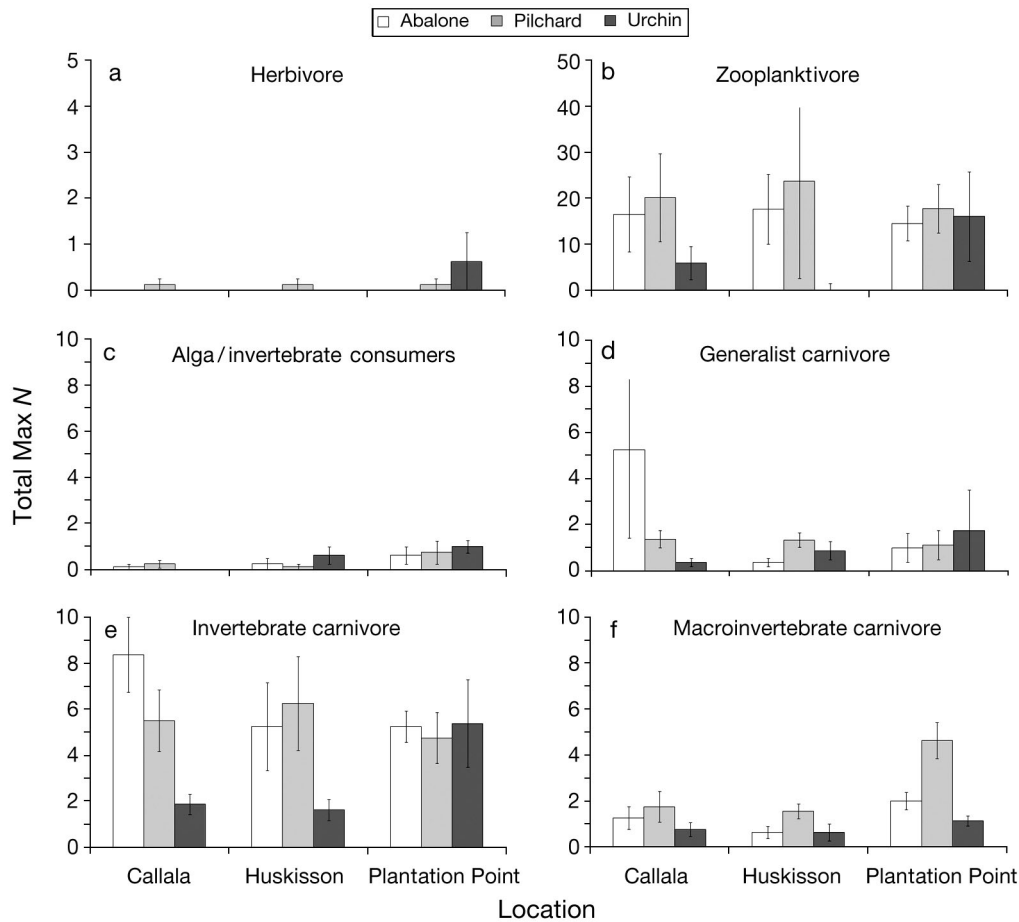
Fig. 4. Mean (±SE) relative abundance (Total Max N) for 6 feeding guilds of fishes (a to f) in the presence of 3 types of bait (abalone, pilchard and urchin) at 3 locations. Data are pooled over years (2005 and 2006, n = 8 after pooling)

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 pattern was 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, 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 s) irrespective of bait type at Plantation Point. These outcomes further underscore the importance of assessing pattern at multiple locations; if we had 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 support the assertion of Colton & Swearer (2010),
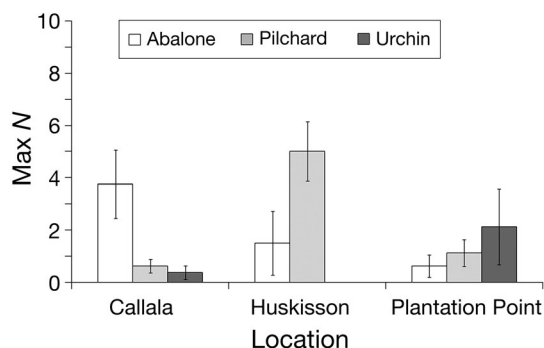
Fig. 5. *Pagrus auratus*. Mean (±SE) relative abundance (Max *N*) for snapper in the presence of 3 types of bait (abalone, pilchard and urchin) at 3 locations. Data are pooled over years (2005 and 2006, n = 8 after pooling)

Table 5. *Pagrus auratus*. Three-factor mixed model ANOVA for relative abundance (Max *N*) of snapper recorded with baited remote underwater video. Factors are the same as those listed in Table 1, n = 4. NS: not significant

Source	df	MS	*F*	p
Bait	2	0.028	0.04	0.960
Location	2	0.778	2.19	0.122
Year	1	1.467	1.74	0.318
B × L	2	0.680	1.91	0.121
B × Y	2	0.023	0.03	0.974
L × Y	4	0.845	2.38	0.102
B × L × Y	4	0.865	2.44	0.059
Residual	54	0.355		
Total	71			
		Cochrans *C* (NS): 0.2368, $\sqrt{(x+1)}$		

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 that it was generally unattractive to fishes or that the bait plume dispersion at our study locations was poor. Although Jervis Bay is a large embayment, currents in the upper reaches of the bay are particularly weak, rarely exceeding 1.5 cm s^{-1} (Holloway 1995). It is possible that urchin bait would perform better in more exposed environments, where they might generate a better plume. Heagney et al. (2007) were faced with a similar dilemma at their mid-water BRUVS. 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 fish assemblages represents a significant challenge in BRUVS 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 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 100 g (Heagney et al. 2007) and 1000 g being 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 standardise BRUV methodologies (e.g. Stobart et al. 2007), but 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 New South Wales, Australia, is a positive step in this direction.

An additional consideration in relation to bait use in BRUVS studies is the environmental impact 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 5000 km of southern Australia in the mid-1990s and were attributed to a herpesvirus, perhaps newly introduced into these waters (Whittington et al. 1997). The risks associated with bait for BRUVS needs to be 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 (e.g. Willis & 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. 2003). Nevertheless the limitations of this technique need to be established, combined with

efforts to standardise BRUVS methodology and reduce bias. Taken together our data provide 2 clear outcomes. Oily types of bait, such as pilchards, were most effective at attracting fishes—particularly carnivorous species. As most existing studies have predominantly used pilchards as bait, our data suggest 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 at multiple locations.

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Appendix 1. Membership of the 6 feeding guilds used in our analysis

Species	Common name	Species	Common name
Herbivore		**Generalist carnivore (continued)**	
Aplodactylus lophodon	Rock cale	*Squatina australis*	Angelshark
Kyphosus sydneyanus	Silver drummer	*Trygonoptera testacea*	Common stingaree
Odax cyanomelas	Herring cale	*Aptychotrema rostrata*	Bank's shovelnose ray
Zooplanktivore		*Trygonorrhina fasciata*	Fiddler ray
Atypichthys strigatus	Mado	**Invertebrate carnivore**	
Pseudocaranx dentex	Silver trevally	*Acanthopagrus australis*	Yellowfin bream
Schuettea scalaripinnis	Ladder-finned pomfret	*Bathygobius krefftii*	Krefts goby
Scorpis lineolata	Silver sweep	*Centropogon australis*	Eastern fortescue
Trachurus novaezelandiae	Yellowtail scad	*Enoplosus armatus*	Old wife
Alga/invertebrate consumers		*Eupetrichthys angustipes*	Snakeskin wrasse
Anoplocapros inermis	Eastern smooth boxfish	*Hypoplectrodes maccullochi*	Half-banded seaperch
Cheilodactylus fuscus	Red morwong	*Nelusetta ayraudi*	Chinaman leatherjacket
Cheilodactylus vestitus	Magpie morwong	*Ophthalmolepis lineolatus*	Maori wrasse
Chelmonops truncatus	Eastern talma	*Pagrus auratus*	Snapper
Eubalichthys mosaicus	Mosaic leatherjacket	*Parapercis ramsayi*	Spotted grubfish
Meuschenia flavolineata	Yellow-striped leatherjacket	*Pictilabrus laticlavius*	Senator wrasse
Meuschenia freycineti	Six spine leatherjacket	*Platycephalus caeruleopunctatus*	Eastern blue-spotted flathead
Meuschenia venusta	Stars and stripes leatherjacket	*Suezichthys gracilis*	Gracilis wrasse
Nemadactylus douglasii	Blue morwong	*Tetractenos hamiltoni*	Common toadfish
Parma microlepis	White ear	*Torquigener pleurogramma*	Banded toadfish
Parascyllium ferrugineum	Rusty catshark	*Upeneichthys vlamingii*	Blue-spotted goatfish
Generalist carnivore		**Macroinvertebrate carnivore**	
Dasyatis brevicaudata	Smooth stingray	*Achoerodus viridis*	Blue groper
Dinolestes lewini	Long-finned pike	*Heterodontus portusjacksoni*	Port Jackson shark
Hypoplectrodes nigroruber	Black-banded seaperch	*Latris lineata*	Trumpeter
Parupeneus spilurus	Blackspot goatfish	*Myliobatis australis*	Eagle ray
		Notolabrus gymnogenis	Crimson-banded wrasse