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Rules of attraction: enticing pelagic fish to mid-water remote underwater video systems (RUVS)

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ABSTRACT: Mid-water baited remote underwater video systems (BRUVS) are becoming an increasingly popular tool for examining pelagic fish assemblages in a non-destructive, fisheries independent manner. As the technique is relatively novel, critical methodological questions such as the most appropriate attractant for pelagic fish to mid-water RUVS remain unresolved. In this study, we compared the relative effectiveness of 4 attractant treatments (sight: metallic reflectors, sound: bait fish recordings, scent: pilchards and their combination) on the time of first arrival, total abundance of pelagic fish and the relative abundance of 3 pelagic fish species: *Trachurus novaezelandiae*, *Sarda australis* and *Seriola lalandi.* Recordings were made using mid-water RUVS in the Jervis Bay Marine Park, Australia. RUVS using a combination of all attractants recorded the highest abundances and shortest time of first arrival of pelagic fish. This result was primarily driven by *Trachurus novaezelandiae*. Although not significant, the abundance of *Sarda australis* was also greatest on the RUVS with all attractants. In contrast, the type of attractant had no effect on the abundance of *Seriola lalandi*. Bait, the standard attractant used in BRUVS surveys, was a poor performer for pelagic fish in all instances. We suggest that future studies using this sampling method employ multiple attractants.

KEY WORDS: Acoustics · BRUVS · Coastal ecosystems · Feeding behaviour · Fish behaviour · Fish ecology · Pelagic fish · Sampling · Seascape · Synergism

INTRODUCTION

Patchily distributed taxa present a challenge to adequately census (McDonald 2004, Barnes et al. 2006). Pelagic fish fit this description, as they are fast swimmers capable of avoiding conventional survey equipment, occupy challenging habitats and display high spatial and temporal variation in their patterns of distribution (Edgar & Barrett 1999, Freon & Misund 1999). As a result, ecological knowledge of pelagic fish has historically relied upon fisheries catch data, as well as tagging programs, which are often broad-scale, low in resolution and associated with sampling biases (Gillanders et al. 2001). In the absence of a cost-effective, fisheries independent sampling technique, information on the structure of pelagic fish assemblages over smaller spatial scales (e.g. seascape scales of 1–10 km) remains poorly resolved. Information on the basic ecology of pelagic fish is critical given their ecological importance in marine ecosystems (Freon et al. 2005) and their heavy exploitation by commercial and recreational fishers (Myers & Worm 2003). Therefore, cost-effective, fisheries independent sampling techniques are essential in understanding the ecology of pelagic fish.

Baited remote underwater video systems (BRUVS) have become a popular sampling method in recent

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years, providing robust estimates of demersal fish assemblages comparable to other techniques, in a fisheries independent and non-destructive manner (Murphy & Jenkins 2010, Kelaher et al. 2014, Mallet & Pelletier 2014). Evaluations of BRUVS methodology have focused on optimal length of deployment (Stobart et al. 2007, Gladstone et al. 2012), bait types (Wraith et al. 2013), quantities of bait (Harvey et al. 2007, Hardinge et al. 2013) and the influence of time of day (Birt et al. 2012). The success of BRUVS as a technique to sample demersal fish assemblages has led to the development and application of mid-water BRUVS to survey pelagic fish assemblages (Heagney et al. 2007). Although the mid-water BRUVS technique is in its infancy, studies have evaluated the importance of soak time, replication, current speed and camera depth for assessing pelagic fish, as well as comparing the method to longline surveys (Heagney et al. 2007, SantanaGarcon et al. 2014a, Santana-Garcon et al. 2014c). However, no studies have examined the importance of attractant type on estimates of the diversity and abundance of pelagic fish, with all previous research using an oily bait (tuna oil and/or 100–1000 g of pilchards, *Sardinops sagax*), which is the standard attractant used in BRUVS surveys. Considering the biology of pelagic fish, many of which display schooling behaviour and are piscivorous predators, there may be an alternative attractant or combination of attractants which may provide better estimates of pelagic fish populations. Attractants other than bait, or a suite of attractants may reduce issues currently faced in using mid-water BRUVS, such as zero-inflated datasets and extreme variability in abundance estimates, which create problems for statistical analyses (Santana-Garcon et al. 2014a, Santana-Garcon et al. 2014c). Pelagic fish use vision, chemical senses (smell and taste) and sometimes hearing to locate fish schools, their prey, and fish aggregation devices (FADs) (Banner 1972, Freon & Misund 1999, Dempster & Kingsford 2003, Dempster & Taquet 2004). Therefore, attractants associated with sight and sound stimuli may offer potential alternatives, or complements to bait, thereby providing better estimates of pelagic fish populations.

In this study, we sought to test the effectiveness of 3 attractant types (sight, sound, scent), their combination and an unbaited control on the time of first arrival and the abundance of pelagic fish recorded using mid-water RUVS. We tested the null hypotheses that the time of first arrival, the total abundance of pelagic fish, and the relative abundance of 3 common species — *Trachurus novaezelandiae* (Richardson), *Sarda australis* (Macleay) and *Seriola lalandi* (Valenciennes) — would not differ with the type of attractant used.

MATERIALS AND METHODS

Study site

The study was done in the Jervis Bay Marine Park (JBMP), located ~180 km south of Sydney, New South Wales (NSW), Australia. Jervis Bay is a 102 km^2 marine embayment characterised by 2 peninsulas (Fig. 1) that form coastal habitats with hydrographic conditions similar to those in the open ocean. As a result, pelagic fish are frequently observed close to shore in the open coast habitat of JBMP. The area between Point Perpendicular and the Tubes (see survey area, Fig. 1) in particular is regarded as one of the premier land-based game-fishing locations in NSW and was the focus area in this study (Lynch et al. 2004).

Mid-water RUVS

We constructed 5 identical, single camera midwater RUVS following Heagney et al. (2007) positioned 5 m below the water surface. We used video cameras (Canon HGF10) with wide angle lenses (Raynox HD Pro) and plastic camera housings constructed by SeaGis. All RUVS were fitted with a plastic bait container positioned 1.5 m horizontally from the camera housing. Each RUVS was assigned 1 of 5 treatments (outlined below).

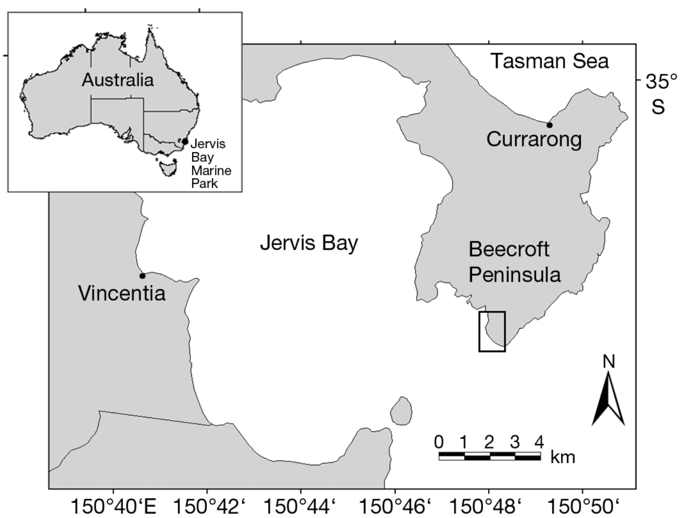

Fig. 1. Survey area (□) within the Jervis Bay Marine Park. Inset map: location of Jervis Bay in Australia

Sampling design and experimental treatments

Each RUVS with its associated treatment was randomly deployed 18× over 10 d between 21 February and 10 April 2013. Video systems were deployed over rocky reef ~20 m in depth, 50 m from the shore and were separated from one another by 400 m to achieve independence (Simpson et al. 2005). Video was recorded for 45 min at each deployment. Previous research has indicated that a 45 min deployment provides representative estimates of pelagic fish at this location (Heagney 2009, but see Santana-Garcon et al. 2014c).

The sight treatment was a spearfishing 'PELAGIC swivel flasher' attached to the RUVS above the camera housing. It consisted of reflective material used by fishers to imitate bait fish.

The sound treatment was a play back of a bait fish recording through an underwater speaker located above the RUVS. The bait fish sound was previously recorded in close proximity to the study area. A combination of white bread and pilchards (*Sardinops sagax*) was used to attract blue mackerel (*Scomber australasicus*) and yellowtail scad (*Trachurus novaezelandiae*), 2 common live bait fish used by fishers targeting larger pelagic fish (Lynch et al. 2004). We recorded the swimming and feeding activities of the 2 species using a hydrophone (High Tech Inc-96-min) and a portable recorder (Zoom H4N). The raw sound files below 20 Hz and above 640 Hz were filtered to remove background interference (Banner 1972). The files were cut to create a 1 min continuous loop in mp3 format. All editing processes were completed in Pro Tools. The edited sound file was played back using an underwater speaker (Lubell UW30) connected to an amplifier (Kentiger) that was powered by a 60 amp 12 volt battery. The amplifier and battery were housed in a 60 l plastic container on the surface of the water. The container was stabilised by surrounding it with an inflated inner tyre tube to ensure that the equipment did not tip and become waterlogged. The speaker was connected to the RUVS, set at a depth of 1.5 m below the water surface and was always positioned <2 m from the RUVS at any time during the deployment.

The scent treatment was 500 g of crushed pilchards (*Sardinops sagax*) placed in the bait container. This is the conventional attractant and quantity used in BRUVS surveys in NSW's marine protected areas (Kelaher et al. 2014). Bait was replenished prior to each mid-water RUVS deployment.

The 'all' treatment consisted of a RUVS with all 3 attractants (sight, sound and scent) attached as previously described. The control treatment consisted of a RUVS with no attractants. To prevent the absence of sound equipment from confounding our experiment, the sight, scent and control RUVS were equipped with identical floating containers of the same weight.

Analysis of video footage

A single experienced observer (M. J. R.) examined the video recordings on a computer screen using VLC media player. All pelagic fish species within the field of view were identified and quantified. The relative abundance of individual species was determined by recording the maximum number of fish (Max *N*) of each species viewed at any one time during the 45 min sample. Total relative abundance was determined by summing Max *N*s for each individual species during the 45 min sample. We also recorded the time of first arrival (t_{1st}) of pelagic fish.

Statistical analysis

We used generalised linear models with a negative binomial distribution to test for differences in the abundance of pelagic fish among the attractant treatments. Analyses were performed in R using the MASS package (R Core Team 2013) following Zuur et al. (2009). No over-dispersion was apparent in models, except for *Seriola lalandi*. Therefore, we did not present statistical analyses for this species. To examine time of first arrival, we used only deployments that detected pelagic fish, and we compared the mean t_{1st} observed on the treatment containing all attractants to the remaining treatments, using a *t*-test performed in R. Prior to analysis, data were examined visually to ensure that the assumption of normality was met (Quinn & Keough 2002).

RESULTS

A total of 2193 pelagic fish were observed, comprising 6 species from 4 families: Carangidae, Scombridae, Istiophoridae and Carcharhinidae. In total, 1412 *Trachurus novaezelandiae*, 669 *Sarda australis*, 108 *Seriola lalandi*, 2 *Makaira indica*, 1 *Seriola rivoliana* and 1 *Carcharhinus* sp. were recorded. *Post-hoc* analysis revealed that the RUVS with all attractants recorded a significantly greater abundance of pelagic fish compared to the RUVS with one or no attractant (Table 1). In all instances, the RUVS with

Table 1. Parameter estimates, SEs and p-values from the *post-hoc* negative binomial model comparing the treatment with all attractants to the control, sight, scent and sound treatments. Significant values in **bold**

Coefficient	Estimate	SE	p
Total pelagic fish abundance			
Control	−3.93	1.04	**<0.001**
Sight	−2.14	1.03	**0.037**
Scent	−4.69	1.06	**<0.001**
Sound	−2.16	1.03	**0.035**
Trachurus novaezelandiae			
Control	−4.86	1.16	**<0.001**
Sight	−7.16	1.50	**<0.001**
Scent	−6.06	1.26	**<0.001**
Sound	−2.47	1.12	**0.028**
Sarda australis			
Control	−3.02	1.60	0.059
Sight	−0.77	1.59	0.631
Scent	−4.12	1.63	**0.012**
Sound	−3.99	1.63	**0.014**

all attractants had >9-fold mean abundance compared to the RUVS with one attractant alone or the control treatment (Fig. 2A). Similarly, the mean time of first arrival of pelagic fish was significantly shorter on the RUVS with all attractants (17 ± 5 min mean ± SE, n = 7) compared to the treatments with one or no attractant (31 ± 3 min, n = 20) (t = 2.215, df = 25, p = 0.036).

Mirroring the pattern in the total abundance of pelagic fish, the RUVS with all attractants recorded a significantly greater abundance of *Trachurus novaezelandiae* compared to the other RUVS (Table 1). The RUVS containing all attractants recorded a mean abundance that was 1 to 2 orders of magnitude higher than those with one or no attractants (Fig. 2B). Similarly, attractants had a significant influence on the relative abundance of *Sarda australis*, with the RUVS containing all attractants recording a significantly greater abundance compared to those with scent and sound (Fig. 2C). There was no significant difference in the abundance of *Sarda australis* recorded on the RUVS with all attractants compared to the sight or control treatments (Fig. 2C, Table 1). Attractants had no clear effect on the abundance of *Seriola lalandi* (Fig. 2D).

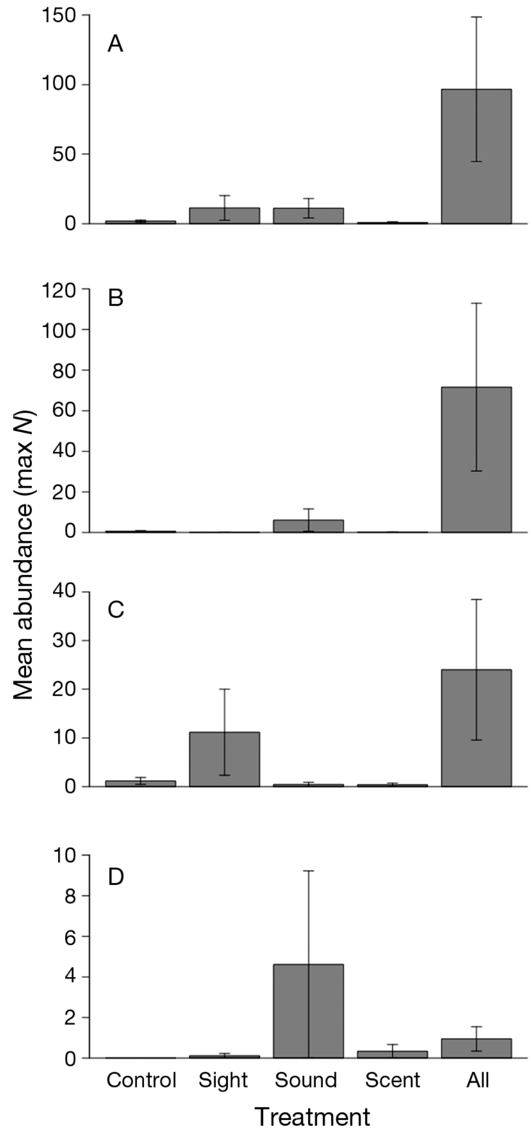

Fig. 2. Relative abundance of (A) pelagic fish (Total Max N), (B) *Trachurus novaezelandiae*, (C) *Sarda australis* and (D) *Seriola lalandi* (mean ± SE; n = 18) estimated by mid-water remote underwater video systems with different attractant treatments

DISCUSSION

We reject our null hypothesis that the time of first arrival and the total abundance of pelagic fish do not differ with the type of attractant used. The total abundance of pelagic fish was markedly greater on the RUVS containing the combination of sight, sound and scent attractants compared to those containing one or no attractant. This result was primarily driven by the small zooplanktivore, *Trachurus novaezelandiae*, which displayed a striking preference for RUVS with all attractants. Similarly, the highest abundance of *Sarda australis* was recorded on the RUVS containing all attractants. In contrast, the attractants had no influence on the abundance of *Seriola lalandi*. This finding was unexpected, considering that ‘flashers' are often used by spearfishers targeting *Seriola lalandi* (pers. obs.). To complement the abundance data, we also demonstrated that the type of attractant or attractants used had an effect on the time of first arrival of pelagic fish. The mid-water RUVS containing all attractants detected pelagic fish in almost half the time of RUVS with one or no attractant. It is noteworthy that in no instances were baited RUVS more effective than unbaited ones.

An array of sensory processes, such as sight, sound or vibrations, scent, touch and magneto-reception have been proposed to explain how pelagic fish detect and remain with floating structures (Dempster & Taquet 2004). In isolation, the sight, sound and scent treatments employed in this study were relatively ineffective. However, when combined, all attractants had a synergistic effect. Synergy is an important phenomenon in ecology, with multiple stressors and stimuli having a pronounced effect on organism fitness (Przeslawski et al. 2005) and behaviour (Raguso & Willis 2005). We encourage further research into the importance of synergistic interactions of multiple stimuli as a method of attracting fish to mid-water and demersal RUVS. Whether the synergistic effect was due to the interaction of all 3 attractants or only a combination of 2 is unknown.

We propose that the mechanism behind the synergistic effect of multiple attractants is the difference in the spatial scale of operation of the different stimuli. In water, sound travels 5× faster, with lower attenuation compared to air, and propagates equally from the source in all directions (Slabbekoorn et al. 2010). Therefore, it is likely that sound is an important stimulus for pelagic fish to interpret their surrounding environment over broad spatial scales. Experiments have shown predatory chondrichthyian behaviour to be significantly influenced by playback of bait fish recordings through underwater speakers (Banner 1972), while research aiming to understand the homing behaviour of pelagic fish to FADs has indicated that sound is likely to be an important sensory cue (Dempster & Kingsford 2003). Recent work has shown that acoustic signals from FADs, primarily from fauna associated with them, are within the sensory range of many fishes (Ghazali et al. 2013).

The scale over which the other attractants (scent and sight) are effective is likely to be less than that of acoustic signals. For example, crushed pilchards may be an effective attractant over scales of up to 200 m (Heagney et al. 2007), while visual stimuli imitating schooling bait fish are effective over scales of up to 50 m (Freon & Misund 1999). We propose that the sound recordings may be attracting pelagic fish over a broad spatial scale (Kingsford et al. 2002) until they detect the bait plume (~200 m) and then visual stimuli (~50 m).

Contrary to expectations, bait alone was a poor attractant of pelagic fish. Since all previous research using mid-water RUVS to survey pelagic fish assemblages have solely used oily baits as an attractant (Heagney et al. 2007, Santana-Garcon et al. 2014a,b,c,d), these studies may have underestimated the abundance of pelagic fish. The use of multiple attractants may also entice pelagic fish closer to mid-water RUVS, which may in turn aid in species identification, abundance estimates and length calculations. However, all previous work has been completed in tropical or warm-temperate waters, particularly coral reef environments harbouring a richer assemblage than the one observed in our study. It remains unclear whether our findings in the temperate zone apply to tropical and warm-temperate systems.

In conclusion, our findings highlight the importance of attractant type when surveying pelagic fish with mid-water RUVS. We demonstrate that multiple attractants associated with sight, sound and scent interact synergistically, recording greater total abundance of pelagic fish, earlier time of first arrival and elevated abundance for some species (*Trachurus novaezelandiae* and *Sarda australis*). We encourage the use of multiple attractants in future studies using mid-water RUVS to sample pelagic fish.

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