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

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Rees, Matthew; Knott, Nathan A.; Fenech, G V.; and Davis, Andrew R., "Rules of attraction: enticing pelagic fish to mid-water remote underwater video systems (RUVS)" (2015). *Faculty of Science, Medicine and Health - Papers: part A*. 3002.
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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.

Disciplines

Medicine and Health Sciences | Social and Behavioral Sciences

Publication Details

Rees, M. J., Knott, N. A., Fenech, G. V. & Davis, A. R. (2015). Rules of attraction: enticing pelagic fish to mid-water remote underwater video systems (RUVS). *Marine Ecology: Progress Series*, 529 213-218.

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

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Running Head: Attractants for pelagic fishes to underwater video systems

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ABSTRACT

Mid-water baited remote underwater video systems (BRUVS) are becoming an increasingly popular tool to examine 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 fishes to mid-water RUVS remain unresolved. In this study we compared the relative effectiveness of four attractant treatments (sight = metallic reflectors, sound = bait fish recordings, scent = pilchards and their combination) on the time of first arrival, total abundance of pelagic fishes and the relative abundance of three pelagic fish species; *Trachurus novaezelandiae*, *Sarda australis* and *Seriola lalandi*. Recordings were made using mid-water RUVS in the Jervis Bay Marine Park, Australia. The total abundance of pelagic fishes observed and their time of first arrival was significantly influenced by the type of attractant employed. RUVS using a combination of all attractants recorded the highest abundances and shortest time of first arrival of pelagic fishes. 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* observed. Surprisingly, bait, the standard attractant used in BRUVS surveys was a poor performer for pelagic fishes in all instances. These outcomes highlight the importance of attractant type when surveying pelagic fishes with RUVS and we suggest that future studies using this sampling method employ multiple attractants.

KEYWORDS

Acoustics, BRUVS, coastal ecosystems, feeding behaviour, fish behaviour, fish ecology, pelagic fish, sampling, seascape, synergism.

INTRODUCTION

Patchily distributed taxa represent a significant 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 fishes historically has relied upon fisheries catch data as well as tagging programs, which are often broad-scale, low in resolution and often associated with a number of sampling biases (Gillanders et al. 2001). In the absence of a cost-effective, fisheries independent sampling technique, information regarding the structure of pelagic fish assemblages over smaller spatial scales (e.g. seascape scales 1-10kms) remains poorly resolved. Information on the basic ecology of pelagic fishes is critical given their ecological importance in marine ecosystems (Freon et al. 2005) and heavy exploitation by commercial and recreational fishers (Myers & Worm 2003). Therefore, cost-effective, fisheries independent sampling techniques are essential to understand the ecology of pelagic fishes over seascape scales and to inform management decisions.

Baited remote underwater video systems (BRUVS) have become a popular sampling method in recent 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). An expanding body of literature

has critically evaluated the BRUVS methodology, examining 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 fishes, as well as comparing the method to scientific longline surveys (Heagney et al. 2007, Santana-Garcon et al. 2014a, Santana-Garcon et al. 2014c). No studies however, have examined the importance of attractant type on estimates of the diversity and abundance of pelagic fishes, with all previous research using an oily bait (tuna oil and/or 100-1000g of pilchards; *Sardinops sagax*), the standard attractant used in BRUVS surveys. Considering the biology of pelagic fishes, many of which display schooling behaviour and are piscivorous predators, there may be an alternate 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 with 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). Previous research has shown pelagic fish to use vision, chemical senses (smell and taste) and sometimes hearing to locate fish schools, their prey and fish aggregation devices (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 three 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 fishes, and the relative abundance of three 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 approximately 180 km south of Sydney, New South Wales, Australia. Jervis Bay is a 102 km² marine embayment characterised by two large peninsulas that protrude from the coastline (Fig. 1). These peninsulas form unique coastal habitats which experience hydrographic conditions similar to the open ocean. As a result, pelagic fishes are frequently observed close to shore in the open coast habitat of JBMP. The area between Point Perpendicular and the Tubes 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 mid-water RUVS following Heagney et al. (2007) with the video cameras positioned 5 m below the surface of the water. We used Canon HGF10 video cameras with Raynox HD Pro wide angle lenses 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 one of five treatments (outlined below).

Sampling design and experimental treatments

Each RUVS with its associated treatment was randomly deployed 18 times over 10 days between 21 February and 10 April, 2013. Video systems were deployed over rocky reef approximately 20 m in depth, 50 m from shore and 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 fishes 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. Spearfishing flashers are reflective material used to imitate bait fish by fishers to attract targeted pelagic fish species. 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*); two known prey species and common live bait used by fishers targeting larger pelagic fish (Lynch et al 2004). We recorded the swimming and feeding activities of the two species using a High Tech Inc-96-min hydrophone and a Zoom H4N portable recorder. The raw sound files were filtered below 20 Hz and above 640 Hz 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. In this study the edited sound file was played back through a Lubell UW30 underwater speaker connected to a Kentiger amplifier powered from 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 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 surface of the water and was always positioned less than 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 MPAs (Kelaher et al. 2014). Bait was replenished prior to each mid-water RUVS deployment. The 'all' treatment consisted of a RUVS with all three attractants (sight, sound and scent) attached as described previously. The control treatment consisted of a RUVS with no attractants. To avoid the absence of sound equipment 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.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. Relative abundance of individual species was determined by recording the maximum number of fish of each species viewed at any one time during the 45 min sample (Max *N*). Total relative abundance was determined by summing Max *N* 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 differences in the abundance of pelagic fishes between the attractant treatments. Analyses were performed in R using the 'MASS' package (R Core Team 2013) following the procedure outline by (Zuur et al. 2009). No over-dispersion was apparent in models with the exception of *Seriola lalandi*. Therefore we do not present statistical analyses for this species. To examine time of first arrival, we only used deployments that detected pelagic fish and compared the mean *t*/st 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 fishes compared to the RUVS with one attractant alone or the control treatment (Table 1). In all instances the RUVS with all attractants had >9-fold mean abundance compared to RUVS with one attractant alone or the control treatment (Fig 2a). Similarly, the mean time of first arrival of pelagic fishes was significantly shorter on the RUVS with all attractants compared to the treatments with one or no attractant ($t = 2.215$, d.f. = 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 1 to 2 orders of magnitude higher than RUVS with single or no attractants (Fig 2b). Similarly, attractant had a significant influence on the relative abundance of *Sarda australis* with the RUVS containing all attractants recording a significantly greater abundance compared to the RUVS 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 treatment (Fig 2c). Attractant had no clear effect on the abundance of *Seriola lalandi* (Fig 2d).

DISCUSSION

Our research provides clear evidence that the attractant or attractants used on mid-water RUVS strongly influences estimates of pelagic fish abundance. Indeed, we reject our null hypothesis that the time of first arrival and total abundance of pelagic fishes do not differ with the type of attractant used. The total abundance of pelagic fishes was markedly greater on the RUVS containing the combination of sight, sound and scent attractants compared to the RUVS containing a single or no attractant. This result was primarily driven by the small zooplanktivore, *Trachurus novaezelandiae*, displaying 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, attractant had no influence on the abundance of *Seriola lalandi* recorded. This finding was unexpected considering that ‘flashers’ are often used by spearfishermen targeting *Seriola lalandi* (Author’s pers. obs.). Complementarily to 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 fishes. The mid-water RUVS containing all attractants detected pelagic fishes in almost half the time of RUVS with a single 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 magno-reception have been proposed to explain how pelagic fishes detect and remain with floating structures (Dempster & Taquet 2004). We found that in isolation the sight, sound and scent treatments employed in this study were relatively ineffective attractants of pelagic fishes. However when combined, we observed a synergistic effect, whereby the estimates recorded on RUVS with all attractants was substantially greater than the additive effect of the RUVS with single attractants. Synergies are an important phenomenon in ecology, where multiple stressors and stimuli have a pronounced effect on organism's 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 for attracting fish to mid-water and demersal RUVS. Whether the synergistic effect was due to the interaction of all 3 attractants or only the combination of 2 is unknown.

We propose that the mechanism behind the synergistic effect of multiple attractants is due to different stimuli operating over a range of spatial scales. In water, sound travels five times 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 fishes to interpret their surrounding environment over broad spatial scales. Experiments have shown predatory chondrichthyan 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 the 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 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 fishes. As all previous research using mid-water RUVS to survey pelagic fish assemblages have used oily baits solely as an attractant (Heagney et al. 2007, Santana-Garcon et al. 2014a, Santana-Garcon et al. 2014b, Santana-Garcon et al. 2014c, Santana-Garcon et al. 2014d), these studies may have underestimated the abundance of pelagic fishes. 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. It is worth noting however, that 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 may apply more generally to tropical and warm-temperate systems.

In conclusion, our findings highlight the importance of attractant type when surveying pelagic fishes with mid-water RUVS. We demonstrate that multiple attractants associated with sight, sound and scent interact synergistically, recording greater total abundance of pelagic fishes, earlier time of first arrival and elevated abundance for some species

(*Trachurus novaezelandiae* and *Sarda australis*). We encourage future studies using mid-water RUVS to sample pelagic fishes to explore the use of multiple attractants.

ACKNOWLEDGEMENTS

We thank Mark Fackerell for assistance with fieldwork, Geoff Hurt and Jim Seager for construction of the mid-water RUVS. This research was supported by the NSW Department of Primary Industries and the Institute for Conservation Biology and Environmental Management, University of Wollongong. We also thank The Nature Conservancy, The Ecological Society of Australia and The Fish Thinkers Research Group (www.fishthinkers.wordpress.com), without their financial support this research would not have been possible. Comments by Ben Gooden and Lachlan Fetterplace improved earlier drafts. This represents contribution no. from the Ecology and Genetics Group, University of Wollongong.

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TABLE CAPTIONS

TABLE. 1: Parameter estimates, standard errors (SE) and p-values from the pots-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
<i>Trachurus novaezelandiae</i>			
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
<i>Sarda australis</i>			
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

TABLE. 1

FIGURE CAPTIONS

FIG. 1: Survey area (indicated by square) within the Jervis Bay Marine Park.

FIG. 2: Relative abundance of (a) pelagic fishes (Total Max N), (b) *Trachurus novaezelandiae*, (c) *Sarda australis* and (d) *Seriola lalandi* (mean $\pm$ SE; $n=18$) estimated by mid-water remote underwater video systems with different attractant treatments.

FIG. 1

FIG. 2