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Does fish behaviour bias abundance and length information collected by baited underwater video?

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ABSTRACT

Baited remote underwater stereo-video systems (stereo-BRUVs) are commonly used to sample fish assemblages across areas of differing fish densities with little consideration of how intraspecific and interspecific behaviours may influence estimates of abundance and body-size distribution. To investigate these potential biases, the current study compared the abundances and body-size distributions of seven target carnivorous species and six lower trophic level non-target species, across sites with high and low densities of large-bodied target species, using Stereo-BRUVs. Samples were collected inside and outside of an area closed to fishing at the Houtman Abrolhos Islands, Western Australia. Densities of large-bodied target species were found to be higher inside the closed fishery area, compared to similar areas outside. The presence of large-bodied target species did not appear to influence the body-size distribution of conspecifics, or the abundance and body-size distribution of small-bodied non-target species throughout the deployments. The abundance of large-bodied target species was found to peak earlier in deployments within the closed area than the areas open to fishing. This difference may be due to the higher relative density with the closed area, which may result in shorter arrival times as fish move towards the baited video, and/or to behavioural differences, as fish within the closed area may approach the baited video more readily. This potential behavioural difference between areas closed and open to fishing has important implications for duration of baited video sampling times, and we suggest that shorter deployments times (< 15 min) are less likely to bias abundance estimates of fishery target species.

1. Introduction

Baited remote underwater stereo-video systems (BRUVs) is a method that is gaining popularity for sampling the abundance and body-size distributions of fish assemblages in marine ecosystems (McLaren et al., 2015). In comparison to alternative methodologies, stereo-BRUVs have been found to survey greater species richness and numbers of individuals than unbaited stationary video systems (Bernard and Götz, 2012; Dorman et al., 2012; Harvey et al., 2007; Watson et al., 2005), stereo-diver operated video transects (Goetze et al., 2011; Watson et al., 2010), and fish traps (Harvey et al., 2012a, 2012b). The greater species richness sampled by BRUVs compared to alternative methods has been attributed to greater diversity of carnivorous species being sampled (Goetze et al., 2011). Unlike unbaited video methods, which passively sample the immediate area, baited video systems actively attract fish, either to the bait itself or to the increased fish activity around the bait (Dorman et al., 2012; Hardinge et al., 2013; Harvey et al., 2007; Watson et al., 2005). A number of factors influence whether fish will respond to bait, including 'fish activity, feeding motivation and the ability to detect, locate and consume baits' (Stoner, 2004). Whilst abiotic conditions such as temperature, light level and current speed have been found to influence fish activity and feeding behaviour (Stoner, 2004), most field studies are designed to standardise these conditions. Fish density, however, a variable of interest in most field surveys, has been found to influence both fish activity and feeding behaviour (Table 1). As a consequence, samples collected by baited methods across density gradients may be influenced by density-dependent species interactions or foraging behaviours (Langlois et al., 2015; Stoner and Ottmar, 2004).

Both ambient density and the increased density of fish gathered at the baited system may affect the data gathered by BRUVs. Whilst ambient density might influence the likelihood of fish detecting bait cues (Shardlow, 1993) and the speed with which fish respond (Stoner and Ottmar, 2004), the concentrated density of fish at the BRUV may bias

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Table 1
Representative studies describing the effect of conspecific or predator density on fish foraging behaviours. The potential effects of these behaviours on fish assemblage metrics collected by baited remote underwater video systems (stereo-BRUVs) and the hypothesised direction of these biases is also described.

Study	Behavioural observations	Metrics potentially biased	Direction of potential bias
Predator density			
McCauley et al. (2010)	Smaller-bodied planktivorous fish (*Chromis margaritifer*) ventured farther from refuges when predators were absent.	Diversity; relative abundance	May be less likely to observe small-bodied herbivorous species in the BRUV field of view when predators are present.
Catano et al. (2016)	Large-bodied herbivorous fish (parrotfish and surgeonfish) observed feeding closest to a predator decoy tended to be 40% smaller than those which fed at a distance. Note similarities with Webster (2004) below.	Length distributions	Size distributions of large-bodied herbivorous fish may be skewed towards smaller individuals when predators are present.
McCauley et al. (2012)	Nocturnal fish may become active during the day in the absence of diurnal predators.	Diversity	Where predatory species are less abundant, nocturnal prey species may be more likely to be sampled.
Conspecific density			
Webster (2004)	Smalled-bodied planktivorous basslets (*Gramma loreto*) frequently feed at the back of feeding aggregations in the presence of large-bodied adult conspecifics. Note similarities with Catano et al. (2016) above.	Length distributions; relative abundance; diversity	At high conspecific densities, size distribution of some species likely to be skewed towards smaller-bodied fish.
Stoner and Ottmar (2004)	Large Pacific halibut (*Hippoglossus stenolepis*) outcompeted smaller conspecifics for bait.	Length Distributions	At high conspecific densities size distributions of predators may be skewed towards larger-bodied fish.
Berriman et al. (2015)	Spiny lobster (*Panulirus interruptus*) exhibited localised predation upon less palatable prey where conspecific density was high.	Diversity; abundance	Localised predator-prey interactions may influence which species are likely to be sampled together under certain conditions.
Shardlow (1993)	Increased propensity of bait strikes was observed at higher conspecific densities of salmon (*Oncorhynchus* spp.), with the 'transferring of information about the availability of food… from salmon near the lure to salmon at farther distances from the lure.' Reviewed by Stoner (2004).	Relative abundance	Facilitatory behaviours may increase the efficiency of bait to attract fish at high densities, with the 'area' sampled by the fishing gear effectively increased by information transfer between fish.
Stoner and Ottmar (2004)	Pacific halibut (*Hippoglossus stenolepis*) responded more slowly to bait cues when alone, than fish in groups (despite standardised feeding histories), and fish in groups had a reduced latency between bait location and attack.	Relative abundance	As above.

samples through predator-prey and size-class interactions (Table 1; Langlois et al., 2015; Willis et al., 2000). A study using stereo-BRUVs on Australia's Great Barrier Reef found small-bodied target fish were displaced by larger-bodied conspecifics after 15 min into a 60-min deployment (Cappo et al., 2009). This shift in size class was suggested to be due to the agonistic behaviour of larger fish towards smaller fish (Cappo et al., 2009). While using a downward facing BRUV system with a small field of view (~1 m^2), Willis et al. (2000) observed aggressive behaviour around the bait by large snapper (*Chrysophrys auratus*) and blue cod (*Parapercis colias*), raising the concern that these behaviours may prevent other fish entering the field of view. Using a similar downward facing system, Dunlop et al. (2015) found that large bodied snapper (*C. auratus*) tended to initiate agonistic behaviours towards smaller bodied conspecifics, often resulting in the smaller bodied fish leaving the field of view. Similarly, the presence of comparatively large, predatory, gummy sharks (*Mustelus antarcticus*) around a horizontally facing BRUV in Batemans Marine Park, New South Wales, was suggested to influence the diversity and abundance of fish sampled by BRUVs (Klages et al., 2014). Furthermore, predator-prey and size-class interactions may be particularly misleading if they are largely dependent upon ambient, rather than the bait-induced density. Some prey/size classes are only predated in areas of high predator/conspecific density, potentially leading to localised interactions (Berriman et al., 2015).

The aim of this study was to investigate the assumption that the behaviour of fish around horizontally oriented stereo-BRUVs does not bias measurements of abundance and size distribution between areas where the densities and mean lengths of targeted and non-targeted fish species differ. To accomplish this aim, we examined how abundance and body-size metrics varied, within and across stereo-BRUVs deployments, between sites closed and open to fishing (where the density of target fish species was known to be greater in the closed area). We predicted that for stereo-BRUVs deployments conducted in an area of higher target species density: (1) small-bodied target species and (2) non-target potential prey species would be displaced in samples by larger bodied target carnivorous species; influencing the body-size distributions sampled. Additionally, following observations on a target species by Cappo et al. (2009) we also predicted that within areas closed to fishing, compared to fished areas, (3) greater abundance and body-size of target species would occur later in the deployment.

2. Methods

2.1. Study site

The Houtman Abrolhos Islands (herein 'Abrolhos') are located 60 km off the mid-west coast of Western Australia in an area of temperate and tropical convergence (28°40′S, 113°45′E; Fig. 1). The archipelago has a north-south orientation parallel to the coastline and consists of 122 islands arranged as a single island to the north (North Island) and three successive island 'groups' to the south (Wallabi, Easter and Pelsaert). This study was conducted in June 2010 inside and outside an area closed to fishing at the Easter Group (Fig. 1). This closed area was established in 1994 and was therefore 16 years old at the time (2010) the data we used in this study was collected. Initial studies of the Targeted Fishery Closures at the Houtman Abrolhos Islands reported that targeted species were significantly more abundant and larger in areas closed to fishing (Watson et al., 2007; 2009). More recently, studies by Bornt et al. (2015) and Santana-Garcon et al. (2014) found only significant differences for fish length, but no consistent effects of protection on the relative abundance of target species.

2.2. Sampling design and equipment

The experimental design included three sites within an area closed to fishing, and three sites within an area open to fishing (Fig. 1). Five replicate stereo-BRUVs deployments were conducted between the hours of 08:00 and 16:00 at each site, with each deployment left to sample on the seafloor for 60 min. Replicate stereo-BRUVs were deployed a minimum of 250 m apart to reduce bait plume overlap and the