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# Development and validation of a mid-water baited stereo-video technique for investigating pelagic fish assemblages

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Understanding the abundance, demographics and composition of pelagic fish communities has historically relied on fisheries catch data or destructive fishery-independent methods. Here, we test and validate the use of a pelagic stereo-Baited Remote Underwater Video system (BRUVs) as a non-destructive, fishery-independent approach to study pelagic fish assemblages. We investigated whether differences in the vertical composition of fish assemblages could be detected with pelagic stereo-BRUVs by sampling at different depths in the water column. The effects of soak time and replication on the precision and cost of sampling were explored to allow for the optimization and standardization of future pelagic stereo-BRUVs studies. Pelagic stereo-BRUVs effectively identified 43 fish taxa from 18 different families in the mid-water, 5 and 20 m below the surface, in the Ningaloo Marine Park (Western Australia). The fish assemblages sampled at the two mid-water depths were significantly different demonstrating that this method could be used to investigate the vertical distribution and diel migration patterns of both pelagic and demersal fishes. Precision estimates under different sampling regimes showed that a soak time of 120 min and a sample size of at least 8 replicates per treatment would be optimal for sampling using pelagic stereo-BRUVs in tropical or warm-temperate areas. In order to account for the spatial and temporal variability of the system and to facilitate future comparisons across studies using this method, we encourage maximizing replication given the resources available while standardizing the soak time. Pelagic stereo-BRUVs may provide a useful, non-destructive method to improve our understanding on the ecology and behavior of fishes in pelagic ecosystems.



## 1. Introduction

Pelagic fish are ecologically important to marine ecosystems and are a highly valuable resource, yet little is known about the population status and ecology of many species (Bakun, 1996; Freon et al., 2005). Although our understanding of individual species has improved, our knowledge of the species diversity, abundance and patterns at the community level is still poor (Angel, 1993; Evans et al., 2011; Santos et al., 2013; Worm et al., 2005). Research on pelagic fish presents difficulties for the collection of accurate survey data (Heagney et al., 2007) and often relies exclusively on fisheries catch data (Myers and Worm, 2003; Ward and Myers, 2007).

The use of fishery-dependent data alone has many shortcomings, as it can lead to sampling biases in the size and type of fish it targets. Similarly, it is often not possible to sample destructively within areas that are closed to fishing, thus impeding the assessment of the effects of protection on pelagic fish assemblages (Murphy and Jenkins, 2010). For many pelagic species, the implementation of fishery-independent surveys is inhibited by the high cost of obtaining representative samples from a vast habitat which has high spatial and temporal variability (Bishop, 2006). However, many studies have highlighted the need to further develop fishery-independent methods to assess the ecology and health of pelagic ecosystems (Claudet et al., 2010; Heagney et al., 2007; Ward and Myers, 2005). Murphy and Jenkins (2010) reviewed current and emerging fishery-dependent and independent observational methods used in marine spatial monitoring to obtain population and/or habitat data in order to assess marine biodiversity and population trends. The review highlights the potential of emerging technologies like remote sensing, acoustic cameras and Baited Remote Underwater Video systems (BRUVs), and concludes that a combination of methods would be the most effective way to reduce biases and increase the quality of data.

The use of BRUVs has increased in recent years as it provides a standardized, non-destructive and fishery-independent approach for estimating biodiversity indices and relative abundance measures of a range of marine species (Harvey et al., 2007; Langlois et al., 2010; Stobart et al., 2007; Stoner et al., 2008; Watson et al., 2010; White et al., 2013; Willis and Babcock, 2000). This technique uses bait to attract individuals into the field of view of a camera so that species can be identified and individuals counted (Dorman et al., 2012). When

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stereo-camera pairs are used, precise length and biomass estimates can be obtained (Cappo et al., 2006; Harvey and Shortis, 1995; Harvey et al., 2010). The use of stereo-BRUVs to estimate diversity, relative abundance and size structure of fish communities has been tested and compared to other sampling techniques (Cappo et al., 2004; Ellis and Demartini, 1995; Harvey et al., 2012b; Langlois et al., 2010; Watson et al., 2010). Baited video techniques have proven to be a robust method for assessing fish community structure in deep water (Bailey et al., 2007; Zintzen et al., 2012), estuaries (Gladstone et al., 2012) and tropical or temperate reefs (Langlois et al., 2010; White et al., 2013).

Despite the increase in fishery-independent techniques used to assess demersal fish assemblages, the development and trial of such methodologies to survey pelagic species remain limited. Recent evidence supports the use of stereo-video as a possible tool for pelagic fish monitoring, with the potential to overcome some of the difficulties associated with surveying pelagic ecosystems, if the technique can be suitably adapted, developed and validated. Pelagic fish are often observed during benthic BRUVs deployments (Cappo et al., 2004; Jones et al., 2003), and single-camera mid-water BRUVs have been successfully trialed to survey pelagic ecosystems (Heagney et al., 2007). Moreover, the use of pelagic (or mid-water) stereo-camera pairs would provide accurate length and biomass measurements of pelagic fish (Harvey et al., 2003; Santana-Garcon et al., 2013), as well as, the opportunity to obtain behavioral data to better understand pelagic ecosystems (Santana-Garcon et al., 2013).

One of the biggest challenges when implementing a sampling program for pelagic fish assemblages is the definition of the pelagic community itself. Benthic ecosystems are relatively easy to define by their horizontal distribution and very abrupt boundaries in habitat (i.e. reef to sand) which provide structure to the fish community (Habeeb et al., 2005). In pelagic ecosystems, these physical boundaries are not well defined and there is also the vertical dimension to consider as pelagic fish are distributed throughout the water column at different depths (Gray, 1997; Holling, 1992). Differences in the deployment depth of sampling systems may therefore affect the estimates of abundance and species richness in the pelagic environment (Heagney et al., 2007; Ward and Myers, 2006). This parameter, which potentially affects the sampling ability of BRUVs, is not well understood. Therefore, pelagic stereo-BRUVs should allow for camera systems to be deployed and remain at a predetermined depth using anchored or drifting systems. The deployment of these systems at different mid-water depths could provide a powerful fishery-independent technique to better understand pelagic fish assemblage composition, as well as, the vertical distribution and diel migration patterns of both pelagic and demersal fishes. A fundamental question that needs to be addressed for pelagic stereo-BRUVs to be an effective monitoring and assessment methodology is 'can they detect differences in the vertical composition of pelagic fish assemblages?'

Another challenge with defining the structure of pelagic fish communities is determining the spatial and temporal scales at which they need to be sampled in order to capture the diversity and relative abundance of fishes living within them (Habeeb et al., 2005). For BRUVs that remain stationary, this can be determined by the time that cameras are left recording (soak time) in order to capture the majority of species present in the area. Soak time is known to have a strong influence in the estimates of abundance obtained from fishery-dependent techniques such as longline operations (Ward et al., 2004). For sampling using baited video techniques, there is considerable variation in the soak times used across studies in different environments (Gladstone et al., 2012). Deep water BRUVs use soak times between one and several hours (Bailey et al., 2007; Jones et al., 2003; Zintzen et al., 2011) and studies on reef fish assemblages tend to deploy cameras for 20 to 60 min (Stobart et al., 2007; Watson et al., 2010; Willis and Babcock, 2000). In order to optimize resources and standardize the use of mid-water BRUVs in the pelagic environment, we explore the performance of the method under various sampling regimes (i.e. soak times and number of replicates) and evaluate the associated sampling costs.

Precision has been commonly used to optimize sampling effort in studies involving univariate data (Bartsch et al., 1998; Downing and Downing, 1992; Pringle, 1984). For example, Gladstone et al. (2012) assessed the precision of the species richness and abundance estimates under different soak time regimes to optimize the sampling effort of benthic BRUVs in estuarine environments. The precision of a sampling technique refers to the repeatability of its measurements, the degree to which repeated observations under unchanged conditions lead to the same result (Cochran and Cox, 1957). Precision is an attribute of the sampling procedure and can be assessed relatively easily from characteristics of the sample data (Andrew and Mapstone, 1987). It is usually expressed numerically by measures of imprecision like standard deviation, variance, coefficients of variation and most commonly, as a ratio of the standard error (SE) and the mean (Andrew and Underwood, 1989; Downing and Downing, 1992; Hellmann and Fowler, 1999). Given the resources available, any method should use the sampling effort that yields the greatest precision (Pringle, 1984).

The aims of this study are therefore to understand and validate the use of pelagic stereo-BRUVs as an effective fishery-independent approach to study pelagic fish assemblages. In particular, we describe the design and use of pelagic stereo-BRUVs and present the results of a pilot study in the Ningaloo Marine Park (Western Australia) to test the effects of deployment depth on the ability of this technique to survey pelagic fish in the water column. Furthermore, the effects of soak time and replication on the precision and cost of sampling are explored to allow for the optimization and standardization of future studies. The advantages, limitations and requirements for future development of this emerging sampling technique are also discussed.

## 2. Materials and Methods

### 2.1. Study area

This study was conducted in March 2012 at two locations, Coral Bay and Tantabiddi, in Ningaloo Marine Park (23° 48′ S–21° 48′ S). Ningaloo Reef is a fringing coral reef which stretches for approximately 270 km adjacent to the semi-arid north-west cape of Western Australia. The sites sampled at both locations were 35 m deep and between 1 and 2 km offshore from the reef slope (Fig. 1). Site depth was recorded to the nearest 0.5 m using the depth sounder onboard.

### 2.2. Sampling technique

The pelagic stereo-BRUVs used in this study were designed to be deployed, anchored and to remain at a predetermined depth in the water column. Two Sony CX12 high definition digital cameras were mounted 0.7 m apart on a galvanized steel frame designed for mid-water deployment (Fig. 2). The cameras were converged inwards at 8° to gain a maximum field of view and to allow for fish length measurements to be made (Harvey et al., 2010), although these length measurements are not assessed here. The bait consisted of 800 g of crushed pilchards (*Sardinops sagax*) in a wire mesh basket suspended 1.2 m in front of the cameras. The bait arm acts as a rudder and keeps the camera system facing downstream of the current. The use of ballast and sub-surface floats effectively reduces movement from surface waves and allows for control over deployment depth. The deployment system presented here was developed in collaboration with commercial fishermen and allows for the effective deployment of several camera systems from a wide range of boat types and sizes. These pelagic stereo-BRUVs have been used in depths ranging from 5 to 200 m, but the deployment method presented here can also be adapted to greater depths.

### 2.3. Experimental design

The experimental design consisted of 3 factors: Location (2 levels, random: Coral Bay and Tantabiddi), Site (2 levels, nested