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Remote drifted and diver operated stereo–video systems: A comparison from tropical and temperate reef fish assemblages

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ABSTRACT

Underwater visual census methods for sampling reef fish that use scientific divers are common and can be effective in shallow water habitats. There is an ongoing need to develop methods that can sample reef fish assemblages in a similar manner, but at depths that are unsafe or inefficient for scientific divers using conventional SCUBA equipment. This study aimed to assess the limitations and biases associated with a drifted stereo–video system (Drifter) by comparing data collected with a diver operated stereo–video system (stereo–DOVs) at the same locations. The composition, number of species, total abundance and the abundances of dominant reef fishes were compared across the two sampling techniques at three temperate and three tropical reefs. There were no significant differences between the compositions of the assemblage sampled by each technique at either the temperate or tropical reefs. There was significantly higher dispersion in the data collected by the Drifter. This higher dispersion was most likely caused by the combined effects of low vehicle stability, the positioning of the drifter higher in the water column in comparison to the stereo DOVs and the challenges associated with navigating the drifter along narrow and fragmented reefs. The stereo–DOVs sampled more species of fish and more individuals than the Drifter. No significant differences were detected in the abundance of any of the dominant species. The Drifter provides a comparable technique to stereo–DOVs, without the depth and time limitations inherent to that system. The high dispersion of the data, low number of species and lower number of individuals sampled by the Drifter result in a slightly lower statistical power from an equivalent sampling effort when compared to stereo–DOVs. Future developments which will help overcome these differences are discussed.

1. Introduction

Selecting robust and cost effective sampling methods for assessing reef fish assemblages is an important consideration for long-term monitoring programmes (Langlois et al., 2010; Murphy and Jenkins, 2010; Goetze et al., 2015). With the development and implementation of ecosystem-based fisheries management (EBFM) (Fletcher et al., 2005; Smith et al., 2007; Fletcher, 2015), and ecologically sustainable development (Larkin, 1996; Jacquet et al., 2010; Christian et al., 2013; Bellchambers et al., 2014; Rhyne et al., 2014) there is a need for fishery independent sampling techniques that can collect data on the relative abundance and length of individual species, and the composition of fish assemblages at a range of spatial and temporal scales in a repeatable manner (Travers et al., 2010, 2012; Harvey et al., 2012). The limitations and biases associated with each different sampling technique need to be evaluated (Murphy and Jenkins, 2010) to assess their relative suitability in regard to fish assemblages under consideration.

Underwater visual census (UVC) has become the preferred method for non-destructive sampling of shallow water reef fishes (e.g. Newman et al., 1997; Newman and Williams, 2001; Kulbicki et al., 2010), and has been widely modified and adapted (Bortone et al., 1991; Harvey et al., 2001a, 2001b, 2012; Holmes et al., 2013). More recently it has been proposed that video based adaptations of UVC may be a more robust and cost effective means of sampling reef fishes (Harvey et al., 2001a, 2001b, 2004; Pelletier et al., 2011; Holmes et al., 2013; Wartenberg and Booth, 2014). Stereo–video systems have been shown to be an effective tool for surveying fish assemblage structure and diversity, sampling both target and non-target species in fished areas (e.g. Cappo et al., 2001, 2003, 2004, 2006; Harvey et al., 2001a, 2002; Harvey et al., 2007, 2012 Williams et al., 2010; Rosen et al., 2013; Santana-Garcon et al., 2014a; Shedrawi et al., 2014; Goetze et al., 2015; Langlois et al., 2015). Although widely used, stereo–video sampling tools, such as baited remote underwater stereo–video systems (stereo–BRUVs) and diver operated stereo–video systems (stereo–DOVs) have acknowledged biases and limitations (see the above references and Murphy and Jenkins, 2010).

Stereo–BRUVs are limited by the challenge of accurately defining the area covered by a bait plume and the potential inter-specific and intra-specific behaviours of fish in response to the bait, as are other sampling gears such as fish traps (Newman and Williams, 1995, 1996; Travers et al., 2006). While some recent studies have attempted to quantify

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the dispersal of the bait plume (Heagney et al., 2007; Taylor et al., 2013; Rizzari et al., 2014), there is currently no method available that can accurately and cost effectively quantify plume dispersal that also takes into account temporal variability in current and sea conditions and the impact of bathymetry. If bait plume dispersal can be quantified and/or standardised, a further requirement will be to understand and incorporate inter-specific and intra-specific responses of fish to the bait plume. Responses are likely to be unique, not only between species, but also within species due to different swimming speeds and behavioural traits exhibited at different life stages (Cappo et al., 2001). In addition, standardised use of bait quantities and types (e.g. Dorman et al., 2012; Hardinge et al., 2013) is required for repeatable and robust sampling across spatial and temporal scales.

To avoid the possibility of re-counting the same individual fish when they leave and then re-enter the frame of view, only the maximum number of fish of each species seen at the same time on each video (MaxN) is recorded (Cappo et al., 2003; Harvey et al., 2007). The use of MaxN is recognised as being a highly conservative measure of relative abundance with the possibility of hyperstability (Campbell et al., 2015), but it prevents any potential for overly-optimistic or misleading abundance indices from being generated (Cappo et al., 2003, 2006). In contrast, these limitations do not apply to stereo–DOVs, which are often used where density per unit area, or fine-scale habitat association data are required.

The accuracy and precision of counts and length estimates from stereo–DOVs systems have been compared relative to other techniques and their limitations and biases are reported (Harvey et al., 2002, 2010; Murphy and Jenkins, 2010; Watson et al., 2010, 2005; Holmes et al., 2013; Santana-Garcon et al., 2014b; Goetze et al., 2015). The main limitation of stereo–DOVs is their reliance on divers. Sampling using SCUBA divers has depth (Australian Standards limit scientific diving to less than 30 m) and time constraints, and it is also not cost effective to dive below 20 m. The development of electronically controlled closed-circuit rebreathers (eCCR) has the potential to reduce operational complexity and task loading formerly associated with closed circuit rebreathers. This has allowed divers to operate at greater depths and for longer durations (e.g. Pyle et al., 2008; Sieber and Pyle, 2010). The utilisation of such systems remains limited by the high level of training required, their operational complexity relative to open circuit systems, and the amount of pre-and post-dive maintenance required (Sieber and Pyle, 2010).

The presence of SCUBA divers is recognised as a potential source of bias for underwater visual census methods (Watson and Harvey, 2007; Dickens et al., 2011; Lindfield et al., 2014). Stereo–DOVs have also been shown to be less cost-efficient than stereo–BRUVs when sampling fish assemblages in both temperate and tropical locations (Langlois et al., 2010). Despite these limitations, diver based census methods remain popular due to their simplicity, perceived cost effectiveness, and their ability to obtain fine-scale fish-habitat associations and collect density data in terms of individuals per unit area. Further, stereo–DOVs have been shown to effectively sample cryptic species, as well as certain herbivores, when compared to stereo–BRUVs (Watson et al., 2005; Langlois et al., 2010).

A drifted stereo–video (Drifter) system (see McIlwain et al., 2011) has the potential to eliminate the depth and time restrictions associated with divers using stereo–DOVs, without the equipment and infrastructure costs of using Autonomous Underwater Vehicles (AUVs) (Barrett et al., 2010; Seiler et al., 2012), Remotely Operated Vehicles (ROVs) (Trenkel et al., 2004) and manned submersibles (Yoklavich et al., 2007). Some AUVs, ROVs and submersibles use artificial lighting under low light conditions. Artificial lighting has been recognised as a possible source of bias due to avoidance behaviour by mobile species of fish (Stoner et al., 2008; McIlwain et al., 2011; McIntyre et al., 2015).

McIntyre et al. (2015) compared data collected using a towed video system with that collected from a bottom trawl, with approximately equal levels of sampling effort. This balanced comparison allows for an informed discussion of the associated biases and limitations. Without rigorous cross-validation with other sampling techniques, a clear understanding of the limitations and biases of a system cannot be determined (Murphy and Jenkins, 2010; Santana-Garcon et al., 2014b).

The objective of this study was to determine whether a drifted stereo–video system and stereo–DOVs sampled similar fish assemblages and comparable numbers of species and individuals.

2. Methods

2.1. Sampling technique

2.1.1. Location descriptions

Sampling was conducted at one temperate and one tropical location on the West Coast of Western Australia (WA). The temperate samples were collected on Five-Fathom Bank, an extended temperate limestone reef system which runs parallel to the coast (~32°20′21″S 115°37′9″E) south of Perth, WA. The benthic habitat consists of moderate to high relief reef with a variable cover of plate coral, macroalgae and seagrass interspersed with patches of sand at a depth range of 15 m to 25 m. The tropical location was sampled in Lighthouse Bay (21° 47′ 55″S 114° 7′ 3″E), near the northern extent of Ningaloo Reef, WA. Numerous limestone reefs with patchy coral and sponge cover are located within the bay, with study sites in the depth range of 8 m to 12 m.

2.1.2. Description of systems

The stereo–DOVs system used was the same as that described in Watson et al. (2010), with the exception that Sony CX700 cameras were used. The Drifter system used Sony CX12 cameras, mounted on a 0.7 m wide base bar with a convergence of 8°. The base bar was mounted into a towed camera frame and connected to the surface by a coaxial umbilical. A live feed from one camera was supplied to the surface via a coaxial umbilical deployed off the bow of a 4.6 m vessel. This allowed for real time maintenance of height relative to the substrate, improving the consistency of the imagery collected as well as avoiding damage to the system in areas of elevated reef. Both systems did not use lights, reducing the likelihood of behavioural changes in fish (Koslow et al., 1995). In order to maintain comparability with stereo-DOVs transects, drift speed was maintained at approximately 0.3 ms^{-1} using a combination of thrust from the engine and the prevailing wind and current.

2.2. Experimental design

The experimental design consisted of three factors: Technology (two levels: stereo–DOVs and Drifter; fixed), Location (two levels: temperate and tropical; fixed) and Site (three levels: Site 1–3; nested in Location). The Sites were haphazardly sampled. Replication at each of these Sites involved 12 transects for both the stereo–DOVs and the Drifter system, each 25 m long by 5 m wide. Stereo–DOVs transects were measured using a Chainman cotton counter with biodegradable cotton, while Drifter transects were defined ex situ by matching time stamps from the video imagery with GPS tracks recorded by a synchronised GPS. Within each location, Sites were standardised for depth and substrate by using readings from a colour echo-sounder and the skippers' knowledge of the area. The beginning and end of each transect for both techniques were separated by at least 10 m. All sampling occurred between 0800 and 1600 to avoid crepuscular changeover periods (Myers et al., in press).

2.3. Data processing

The software Event Measure (Stereo) was used to identify and measure species and record their abundance (http://www.seagis.com.au). The number of individuals of each species counted along each transect was summed, giving a total abundance per transect. The range in