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Fin spotting: efficacy of manual and video-based visual assessments of reef fish swimming behaviour

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ABSTRACT

Here we report on the efficacy of manual and video-based underwater visual census (UVC) for recording the swimming behaviour of fishes within complex coral reef habitats. Focusing upon four common fish species from the Great Barrier Reef (*Acanthurus nigrofuscus*, *Chaetodon lunulatus*, *Siganus doliatus* and *Sufflamen chrysopterus*), we compared manual recordings by divers against post-field analysis of underwater video of the same species in the ability to detect the different fin types used by fishes while they foraged over the reef. Both video and manual UVC methods detected similar trends in the number of fins and the proportional use of each fin type by reef fishes engaged in different activities (e.g., travelling, searching, feeding). While estimates of fin use from the two methods were largely within 15% of each other, video UVC tended to record higher proportions of fin use within each species due to a better detection of rare and/or rapid fin movements. Such differences were most extreme for the balistiform-swimming *S. chrysopterus*, where video detected a significantly higher proportion of fins used by this species. Notably, the sampling effort required to improve precision and gain sufficient independent replicates was much higher for video-based versus manual UVC. Our findings reflect the relative strengths of each UVC method for studies of fish behavioural ecology in the wild, with the various benefits of each method likely to align with different research questions and fish species of interest, within the logistical constraints of funding and field safety.

1. Introduction

Underwater visual census (UVC) provides a non-invasive method for exploring the biology and ecology of marine organisms. Since Brock (1954) used UVC to measure the density of reef fishes, UVC has underpinned a wealth of field-based research in temperate and tropical reef systems, with early studies largely using UVC to assess patterns of species abundance and distribution (e.g., Edgar et al., 2004; Sale and Douglas, 1981; Samoilys and Carlos, 2000). Quantitative UVC methods have also been applied to behavioural observations of fish habitat-use and foraging in the wild (e.g., Bellwood and Choat, 1990; Fulton and Bellwood, 2002; Nunes et al., 2013). While these examples have shown manual UVC can be an effective and inexpensive method for collecting independent replicates, a key limitation of manual UVC has been logistical safety for human observers (e.g., diving times/depths, water temperatures and currents; Sale and Douglas, 1981; Pelletier et al., 2011). Other limitations, such as observer bias (Bellwood and Alcala, 1988; Dickens et al., 2011; Edgar et al., 2004; Kulbicki, 1998; Pelletier et al., 2011; Williams et al., 2006) and under-representation of some taxa such as small-bodied cryptic species (Ackerman and Bellwood, 2000; Lincoln-Smith, 1989; Williams et al., 2006), have prompted the exploration of other visual survey techniques.

Over the past decade underwater video cameras have become increasingly popular for observing fishes (e.g., Fox and Bellwood, 2008; Noble et al., 2014; Pelletier et al., 2011). Video-based UVC has some major benefits over manual UVC by minimizing observer bias and allowing for underwater surveys in areas considered dangerous to human observers (Cappo et al., 2003; Ebner and Morgan, 2013; Murphy and Jenkins, 2010; Pelletier et al., 2011). Indeed, some of the best assessments of observer effects upon estimates of fish ecology have been revealed with video versus manual UVC comparisons (e.g., Fox and Bellwood, 2008; Harvey et al., 2001; Longo and Floeter, 2012). However, when the video camera is operated by a diver (often called Diver Operated Video, DOV), rather than remotely placed in the aquatic environment, similar observer effects can apply to both video and manual UVC (Davis et al., 2014; Holmes et al., 2013). An overarching advantage of video UVC is the ability to replay footage at various speeds for analysis (Ebner and Morgan, 2013), although this post-survey “reading” of video footage often requires a substantial time commitment (Holmes et al., 2013; Pelletier et al., 2011). Nonetheless, recent advances in underwater video technology and affordability have

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provided researchers with many choices of method for conducting UVC-based studies of marine organisms.

Studies of coral reef fish feeding and swimming behaviour in the field have often used either underwater video or manual UVC methods to provide key insights (e.g., Fulton and Bellwood, 2002; Longo and Floeter, 2012; Noble et al., 2014). In this study we aimed to determine the relative efficacy of manual surveys conducted by divers *in situ* (manual UVC) versus post-field analysis of underwater digital video (video UVC) in quantifying the fin use behaviours of fishes as they foraged over a coral reef. We specifically aimed to compare the efficacy of manual and video UVC techniques for recording: (1) the average number of fin types being used by fishes and (2) the proportional use of different fin types by fishes engaged in a range of daily activities (e.g., travelling, searching, feeding). The effect of different levels of sampling effort upon precision was also explored, which we used in concert with the literature to synthesize the benefits and limitations of each UVC method in the context of fish behavioural ecology.

2. Material and Methods

2.1. Field surveys

Underwater censuses of fish swimming behaviour were conducted during three weeks in September 2011 at two sites (North Point and Bird Islets) around Lizard Island (14°40'S, 145°28'E), northern Great Barrier Reef, Queensland, Australia. The four study species, *Acanthurus nigrofuscus*, *Chaetodon lunulatus*, *Siganus doliatus* and *Sufflamen chrysopterus*, were chosen for their abundance (Randall et al., 1997), similar style of active benthic foraging, and because they encompassed four common forms of locomotion (labriform, chaetodontiform, subcarangiform and balistiform, respectively) recorded for coral reef fishes (Fulton, 2007). Working along the leeward side of each reef site, three observers on SCUBA swam non-overlapping paths over the reef while taking manual or video-based recordings of swimming behaviour by each of the target species. Alternating visits were made to each site across a range of similar weather conditions (mean wind velocity $\pm$ s.d. $= 24.8 \pm 4.8$ knots from a mean southeast compass direction of 132 ± 7.4, derived from Lizard Island weather station managed by Australian Institute of Marine Science). Fin use was defined as the full extension and/or movement of a fin type, with the exception of *S. chrysopterus* whose dorsal and anal fins were always extended, so use was defined as movement via undulation for this species. All observations were taken at a minimum distance of 5 m from the target individual when weather conditions afforded horizontal underwater visibility greater than 8 m, which minimized disturbance of the observed individual while allowing the divers to clearly see their swimming activity (Pink and Fulton, 2014). This basic method was used for both manual and video UVC. Approximately 80% of field time (~17 days) was needed to collect manual observations, while just 20% of field time (~4 days) was needed to collect the raw video footage.

Manual UVC involved recording the following whenever an individual of the four target species was encountered in front of the diver: the fish species, estimated total length (TL, to nearest cm), type of activity (travelling, chasing, station-holding, searching or feeding, following Pink and Fulton 2014), and the fin types being used in the three seconds following first observation (pectoral, pelvic, caudal, dorsal, anal, following Fulton 2007). Initial training by the experienced team member (C.J.F.) ensured that all divers were consistent in their recording of these variables (i.e., consistent detection of different types of fin use by all three observers for all four target species). A minimum of 120 replicate observations of each activity type for each fish species was recorded within an approximately equal area (~8000 m^2) of shallow-water habitat at each site.

Video UVC involved the diver locating a target individual and then using a video camera (Sony HDR-XR150E or Canon HFM300) in an underwater housing to record high-definition (1080p) digital video of the target individual for a total of 60 s (30 replicates per species). An additional set of video recordings of 180 s duration (12 replicates per species; North Point only) were taken to explore the consequences of video duration for the precision of swimming observations (see Section 2.2 below). At the conclusion of filming, the species name and estimated TL (to nearest cm) were manually recorded on a slate along with the video file name. If an individual disappeared from view (e.g. under a coral), the diver waited approximately 10 s for it to reappear and continue recording until 60 s of clear footage was obtained; otherwise the recording was terminated and discarded. At the end of each day, the digital video files were downloaded and viewed to ensure that the target individual was in focus for the full observation period. Detailed analysis of the digital videos was conducted back in the laboratory over a 12-week period. Files were converted from.mts to.mpg format using Any Video Converter (Version 3.2.7) and then viewed with Elecard MPEG Player (version 5.7.1). Each video was viewed at half speed to record the start and finish time for each activity type (to nearest 0.1 s), along with the fin types being used during that activity. Where fin use changed during a single activity type, the time of change and fin use was recorded as separate events for the same activity type.

2.2. Data analysis

Manual and video UVC estimates of fin use were compared in three ways. Firstly, we compared estimates obtained via manual and video UVC for the average number of fins being used by each fish species engaged in each type of activity at the two sites. To align levels of replication across methods for this comparison, we used 30 independent observations per activity and site for each method. For manual UVC values, this required selecting 30 observations for each combination of site, species and activity using a random number generator to choose from the total pool of 120 replicates. For the videos, a single observation lasting 3 second duration (i.e. to match manual UVC method) was chosen at a random point (again using a random number generator) in each video sequence (total $n = 30$). The total number of different fin types utilized by the fish within the 3 second period of observation (from both manual and video UVC) was the dependent variable in the analyses. After testing for the assumptions of normality and homoscedascity, a three-way MANOVA, with method, site and species as fixed factors, and four types of activity as variables (chasing had to be excluded due to very few video-based observations of this activity), was used to compare recorded number of fins used. Significant interaction terms revealed by MANOVA were explored with three-way ANOVAs for each species, with method, site and activity as fixed factors.

Secondly, estimates of proportional use of each fin type by species while they were engaged in each activity were compared across the two UVC techniques. For video UVC, this required taking the average proportion of time a fin was used per activity type during each individual video observation, and averaging this across the 30 replicate videos for each species. For manual UVC, the average proportion of individuals using each fin type per activity was calculated for each species from the total pool of manual UVC recordings. Estimates of proportional fin use based on manual UVC were then subtracted from the proportional fin use recorded via video UVC in order to provide a measure of difference between the two methods for each activity type and species, at each site. This difference data was then analysed using a generalized linear mixed model (GLMM) with a binomial distribution for each activity and species, with method and site as fixed factors and the fin types as response variables. The error term was set as the individual fish to account for non-independence in the data obtained via the video technique, so all observations from the manual data had unique numbers whereas observations from each individual video had the same identifying number. If the individual error term was less than the standard error in the