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Research paper

Visual versus video methods for estimating reef fish biomass

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ABSTRACT

Estimates of fish biomass collated at the community level are reliable indicators of fish and ecosystem health. Data to calculate fish biomass is routinely collected using either underwater visual census (UVC) or stereo diver operated video (DOV), although the compatibility of UVC and DOV based estimates are yet to be assessed. Accordingly, we calculated and compared community level measures of coral reef fish biomass at Ningaloo reef (Western Australia) using both UVC and DOV. The UVC based biomass estimates were 788 kg/Ha, which was ~50% greater than those from DOV (500 kg/Ha). Differences between the methods were primarily due to DOV measuring the length of only ~40% of fish detected by video, preventing fish specific weight calculations for all fish encountered. When the size of unmeasured fish was assumed to be the median value of fish measured by DOV, revised DOV+ estimates of community biomass (778 kg/Ha) were similar to those from UVC. However, even when unmeasured fish were included in DOV calculations, biomass of some families (serranids) were still higher when using UVC. Conversely, DOV adjusted estimates of pomacentrid biomass were higher than those from UVC, due to DOV measuring fewer small bodied fish (< 3 cm), thus having a larger median size for the high number of unmeasured pomacentrids compared to UVC. Our results suggest that community measures of fish biomass from DOV and UVC are broadly comparable once weights of unmeasured fish are incorporated into DOV estimates. This may increase the spatial and temporal scales at which fish biomass can be monitored, although compatibility of data will depend on the composition and size distribution of the fish assemblages.

1. Introduction

Community level measures of fish biomass combine abundance and size information on both fisheries target and non-target species providing a holistic assessment of fish assemblage condition relative to natural and anthropogenic pressures (Nash et al., 2016). This community level measure is a particularly useful indicator of fishing pressure (Nash and Graham, 2016), and can be used to identify ecological thresholds for ecosystem based management of fisheries (McClanahan et al., 2011), drivers of ecosystem health (Cinner et al., 2016) and assess the recovery potential of fish functions (MacNeil et al., 2015). Comparing biomass at different trophic levels can also improve understanding of trophodynamics and how fishing effects this process (Trebilco et al., 2013).

Estimates of coral reef fish abundance and body size are commonly collected using underwater visual census (UVC), providing a rapid, cost effective and fisheries-independent method for monitoring fish communities (Murphy and Jenkins, 2010). Underwater video is however an increasingly popular method for recording fish abundance in temperate and tropical locations around the globe (Mallet and Pelletier 2014). A major advantage of video techniques is that images can be stored indefinitely and repeatedly scrutinised to identify taxa, verify findings, or garner new information (Bennett et al., 2016; Wilson et al., 2009). The use of stereo cameras or laser measurement also facilitates accurate length and depth measures of fish (Harvey et al., 2002) that may be combined with species-specific length weight and abundance data to calculate community biomass.

Previous comparisons of fish data collected by UVC and video techniques have focussed on differences in numeric abundance and diversity (Bortone et al., 1991; Goetze et al., 2015; Greene and Alevizon, 1989; Pelletier et al., 2011; Tessier et al., 2005) and size estimates of a few taxa or models, that are often carried out in aquaria (Harvey et al., 2004, 2002; Holmes et al., 2013). There have been comparisons of different video techniques to assess the size structure

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and biomass of fish communities using baited and diver operated video (Langlois et al., 2010; Watson et al., 2010), though this has not been extended to compare measures of the ecologically important indicator, community biomass, using widely employed UVC methods under field conditions. Moreover, differences in size estimates between methods are likely to change with respect to distance that fish were observed, fish size and environmental conditions (Edgar et al., 2004; Harvey et al., 2004; Letessier et al., 2013). This suggests that methodological differences in size estimates equated from previous studies are not directly transferrable to differences in community biomass equated from data collected under field conditions.

Comparisons between UVC and video techniques have found the two methods produce comparable estimates of numeric abundance for some taxa (Bortone et al., 1991; Tessier et al., 2005), yet the abundance of cryptic species may be underestimated by video, particularly in structurally complex and highly diverse systems like coral reefs (Holmes et al., 2013; Pelletier et al., 2011). Furthermore, videos are typically unable to estimate the length of all fish observed during filming (Goetze et al., 2017; Watson et al., 2010) as the entire body may not be captured, be partially obscured by other objects in the video, or be recorded at an angle that prevents accurate measurement (Harasti and Malcolm, 2013; Harvey et al., 2010). The size of observed but unmeasured fish may be estimated from similar taxa whose size was accurately measured (Andradi-Brown et al., 2016; Lindfield et al., 2014), though the compatibility of fish community biomass estimates from video and UVC remains equivocal.

Here we test whether measures of community level biomass are comparable when measured using video versus UVC techniques across a broad range of species and environmental conditions. We compared fish community biomass estimates from UVC and stereo-Diver Operated Video (DOV) assessments of fish species, size, and abundance from the same coral reef sites within the Ningaloo Marine Park, Western Australia to determine if estimates from the two methods were similar. We considered how variations in structural complexity and fishing pressure among sites at Ningaloo may influence estimates of community biomass using DOV and UVC. We also examined size distributions of fish data captured from the two methods and assessed which families contributed the most to any differences between the methods.

2. Methods

This study was carried out in the Ningaloo Marine Park, located on the western coast of Australia. The park was gazetted in 1987 with the aim of conserving marine biodiversity on Australia's longest fringing reef and facilitating ecologically sustainable research, education, recreational and commercial activities (CALM and MPRA, 2005). Accordingly, the 263 343 Ha of the park has been zoned into different management areas which cater to a range of human activities. Approximately a third of the park is zoned as no-take marine sanctuaries, though this is divided into 18 sanctuary zones that vary in size (8–44 752 Ha) and purpose. The park is visited by > 200,000 people each year, many of whom undertake recreational fishing, from the beach, small vessels or chartered boats (Smallwood et al., 2013; Smallwood and Beckley, 2012). The fish most commonly caught by recreational fishers are from the families Lethrinidae, Serranidae, Lutjanidae and Scombridae (Ryan et al., 2015).

To assess compatibility of fish biomass estimates using different methods DOV and UVC surveys were conducted at eight sites in the northern part of the Ningaloo marine park in April/May 2016. All sites were on shallow (2–4 m) coral reefs within a lagoon, protected from oceanic swells by a fringing reef, although these sites differed slightly in structural complexity and fishing management (Table 1). Four of the sites were within different no-take sanctuary zones and four were in adjacent areas where fishing is permitted. The influence of zoning on fish biomass at Ningaloo is however equivocal with some studies finding greater biomass and larger fish in no-take zones (Fitzpatrick et al., 2015; Westera et al., 2003), whilst other studies have failed to demonstrate any major differences in targeted fish biomass between zones (Wilson et al., 2012). Nonetheless spatial differences in fishing and habitat are a potentially important source of variation in fish biomass and were therefore considered in our sampling design.

Table 1
Characteristics of survey sites.

Site	Management	Depth (m)	Complexity ± SE
Mandu	NTA	2.1	0.9 ± 0.2
Mandu F	Fished	1.5	1.8 ± 0.2
Mangrove Bay	NTA	1.5	2.2 ± 0.2
Mangrove Bay F	Fished	2.5	1.0 ± 0.0
Osprey	NTA	2.2	1.0 ± 0.0
Osprey F	Fished	2.0	1.9 ± 0.2
Tantabiddi	NTA	2.9	2.0 ± 0.1
Tantabiddi F	Fished	3.6	3.2 ± 0.2

NTA, No Take Area. Complexity measured on a scale of 0–5, where sites that score 0 have no vertical relief and 5 represents numerous caves, overhangs and exceptional complexity, as described in Polunin and Roberts (1993).

At each site, fish size and abundance was estimated along six 50 m transects using both UVC and stereo-DOV. This is the same level of replication and transect length used by the state government's monitoring program for assessing the condition of fish assemblages in the Ningaloo park (Holmes et al., 2013). Three of the six transects were initially surveyed using UVC for all large (TL > 8 cm), non-cryptic, diurnal fish, other than pomacentrids, within a 5 m wide transect. A second diver swam with the diver recording large fish, simultaneously estimating the size and abundance of all pomacentrids (including < 8 cm TL) within a 2 m wide transect. The narrower transect was used for pomacentrids to increase precision estimates of smaller bodied fish density (Cheal and Thompson, 1997; Sale and Sharp, 1983). The other three transects were initially surveyed using stereo-DOV. The DOV transects were swum at a consistent swimming pace of around 0.5 m/s and at a height of no more than 1 m above the substrate. The stereo-DOV cameras faced directly ahead and avoided sudden sideway movements as per Holmes et al. (2013). Once DOV transects were completed the same transects were surveyed by UVC at a similar pace, while the three transects initially assessed using UVC were surveyed using DOV. Consequently, the time between surveys using the two methods and disturbance from DOV and UVC was similar.

The DOV unit consisted of two high definition Sony HG21 digital video cameras inside underwater housings mounted 0.7 m apart on a neutrally buoyant metal base bar and angled inward at 8° (Harvey and Shortis, 1996). A bar with a synchronising diode was attached to the centre of the base bar so that the diode was in the field of view of both cameras, allowing frames from the two cameras to be synchronised.

Video footage collected by DOV was analysed using the program EventMeasure Stereo v3.54 (SeaGIS Pty Ltd). The stereo component of the program was used to simultaneously record fish identification (to the highest possible taxonomic level) and total length (TL mm) measurements. As with UVC, fish from the family Pomacentridae were recorded on a transect of 2 m width and non-pomacentrids with a TL greater than 8 cm were recorded on a 5 m transect width. All records were limited to within 7 m of the cameras, which was also the approximate extent of underwater visibility.

As reef structure may obscure fish and contribute to differences in biomass estimates between the methods, structural complexity of each transect was evaluated. We used a visual 0–5 complexity measure, whereby transects with low structural complexity and no vertical relief scored 0, while at the other extreme those with numerous caves, overhangs and exceptional complexity scored 5 (Polunin and Roberts, 1993). The method has proved valuable in capturing variation in reef fish abundance, biomass and diversity in other studies (Darling et al., 2017; Wilson et al., 2007)