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Are we underestimating elasmobranch abundances on baited remote underwater video systems (BRUVS) using traditional metrics?

C. Samantha Sherman[a,b,*], Andrew Chin[a,c], Michelle R. Heupel[c], Colin A. Simpfendorfer[a]

[a] Centre for Sustainable Tropical Fisheries and Aquaculture, College of Science and Engineering, James Cook University, Queensland 4811, Australia
[b] AIMS@JCU, DB17-063, James Cook University, Townsville, QLD 4811, Australia
[c] Australian Institute of Marine Science, Cape Cleveland, QLD 4810, Australia

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ABSTRACT

Baited remote underwater video systems (BRUVS) are increasingly used to study fish communities, biomass, and animal behaviour. Due to the abundance of BRUVS data, there are many analysis methods. The most commonly used method for analysis of BRUV data is MaxN which refers to the maximum number of individuals observed of a species in a single frame of a video. Here, we present a novel method for BRUVS analysis that involves identifying and counting distinct individuals (MaxIND) to quantify the accuracy of MaxN. Individual oriental bluespotted maskray (*Neotrygon orientalis*) and the bluespotted fantail ray (*Taeniura lymma*) were identified on BRUVS by spot patterns, tail characteristics, and sex at three sites in Malaysian Borneo. We demonstrated that MaxIND gave abundances that were 2.4 and 1.1 times higher than MaxN for *N. orientalis* and *T. lymma*, respectively. These differences between methods were consistent for each species between sites regardless of the presence of marine reserves. However, differences in abundance estimates from MaxN to MaxIND were apparent between species, indicating that correction factors need to be developed on a species basis to better estimate true abundance. While identifying individuals is time consuming, it provides improved accuracy and information about populations. We therefore recommend the use of MaxIND when rare and endangered species are present, in high density populations, and for behavioural analyses.

1. Introduction

Video from Baited Remote Underwater Video Systems (BRUVS) is increasingly being used to assess fish communities and biomass (Cappo et al. 2001; Espinoza et al. 2014; Harvey et al. 2013; White et al. 2013), and animal behaviour (Hill et al. 2014; Watson et al. 2010). BRUVS collect a large amount of data and due to the abundance of data, several methods for analyses have been developed. The most commonly used technique is MaxN (Cappo 2010; Whitmarsh et al. 2016), which is a metric of species local abundance based on the maximum number of individuals observed in a single frame of video (Ebner et al. 2008; Louiseau et al. 2016). Use of MaxN as an estimate of abundance is common because it is relatively simple, fast, and easily comparable to other BRUVS analyses due to its wide use (Cappo 2010; Willis and Babcock 2000). MaxN is the most conservative estimate for total number of individuals from a species observed within a single BRUVS deployment (Whitmarsh et al. 2016) and is designed to eliminate double counting and overestimating abundance. The inability to easily distinguish between individuals of the same species on BRUVS videos means that it is not possible to assume that each appearance represents the arrival of a unique individual. As such, MaxN is likely to underestimate the true abundance of individuals in a single deployment (Kilfoil et al. 2017). Other methods of analysing BRUVS footage include mean count (MeanCount), time in – time out (TITO), and time of first arrival (T1st). MeanCount uses the number of individuals in frame at a given interval (5, 10, 30 s, etc.), to estimate abundance over time of species' presence (Cappo et al. 2011). However, MeanCount may miss individuals that pass quickly in front of the camera. TITO involves notation of the time of entry and exit of each animal included in the study, which is mostly used in behavioural analyses (Schobernd et al. 2014). Finally, T1st refers to the first entry of a species in the video, indicating the distance the animal was to the system and/or the attractiveness of the bait (Campbell et al. 2015). MaxN and MeanCount methods are used to estimate abundance and diversity of species in videos, while TITO allows for behavioural analyses like boldness using the time spent openly in view of the camera (Cappo 2010) and T1st can indicate species with better olfactory abilities based on arrival times to the BRUVS (Bassett and Montgomery 2011).

* Corresponding author at: Centre for Sustainable Tropical Fisheries and Aquaculture, College of Science and Engineering, James Cook University, Queensland 4811, Australia.
E-mail addresses: samantha.sherman@my.jcu.edu.au (C.S. Sherman), andrew.chin@jcu.edu.au (A. Chin), m.heupel@aims.gov.au (M.R. Heupel), colin.simpfendorfer@jcu.edu.au (C.A. Simpfendorfer).

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While studies have compared BRUVS analysis methods to one another (Stobart et al. 2015), few have attempted to identify and count individuals to estimate true abundance (Harasti et al. 2016; Kilfoil et al. 2017). Previous studies have used unique markings to determine movement speed of individuals, but did not attempt to quantify the number of distinct individuals (Campbell et al. 2015; Schobernd et al. 2014). One recent study identified white shark individuals on Stereo-BRUVS, which revealed individuals were not occurring on multiple BRUVS deployed at the same time (Harasti et al. 2016). Identification of unique individuals via static photography has been used to help assess populations. Photo identification of individuals is commonly used in species with unique physical features and applied to a range of taxa including cetaceans (Evans and Hammond 2004; Thompson and Wheeler 2008), birds (Arroyo and Bretagnolle 1999; Williams and Thomson 2015) and reptiles (Bradfield 2004; Reisser et al. 2008). Photo ID has also been used extensively in elasmobranchs. For example, in white sharks (*Carcharodon carcharias*) physical features (dorsal fin markings, injuries, size, etc.) have been used to identify individuals across multiple years (Domeier and Nasby-Lucas 2007; Ryan et al. 2015). In manta rays (*Mobula* spp.) and zebra sharks (*Stegostoma fasciatum*) colour patterns and spots unique to each individual have been used for identification of individuals (Dudgeon et al. 2008; Germanov and Marshall 2014). In BRUVS footage, multiple angles of an individual are often seen enabling detection of distinguishing features making identification of individuals possible in some species.

Surveying batoid (rays, skates, and guitarfish) populations is challenging due to their often cryptic nature and caution around larger animals, including humans (Cappo et al. 2001; Espinoza et al. 2014; Harvey et al. 2013; White et al. 2013). Currently, fishing surveys are the most commonly used method to estimate batoid population abundances and how they change through time. Fisheries sampling bias through targeting desirable species, preferentially fishing in certain areas, gear selectivity, and data limitations mean that catch data may not adequately represent batoid diversity (Graham et al. 2001; Walker and Hislop 1998). However, emerging methodologies such as fishery-independent BRUVS can overcome some of these issues, and are a low impact means of sampling batoid populations (White et al. 2013). As many batoid populations are currently decreasing at a rapid rate globally and are also poorly studied (Dulvy et al. 2014), there is a need for accurate abundance estimates to help inform management and conservation efforts. The aims of this study were to: a) determine if individual batoids could be distinguished in BRUVS footage, and b) examine differences in MaxN compared to results from counts of identified individuals. It was expected that species with unique markings would be able to be distinguished using BRUVS footage and MaxN would significantly underestimate the true abundance.

2. Methods

2.1. Study site

Three sites in Malaysian Borneo (Tunku Abdul Rahman Park (TARP), Tun Sakaran Marine Park (TSMP) and the islands of Mabul and Kapalai (MK)) were sampled with BRUVS. All sites consisted of patchy coral reefs with varying degrees of reef degradation within each site. The TARP (5°59′22.06″N, 116°1′25.28″E), established in 1974, is located 3 km off the coast of Kota Kinabalu and consists of five islands over an area of 49 km^2: Gaya, *Sap*i, Mamutik, Manukan, and Sulug. The TARP is closed to fishing, however many recreational water activities occur in the park such as SCUBA diving, snorkelling, and parasailing. The TSMP (4°38′21.52″N, 118°44′0.13″E) is located 18 km northeast of Semporna and was established in 2004. The TSMP has an area of 101 km^2, and consists of seven islands and one patch reef: Boheydulong, Bodgaya, Sabangkat, Salakan, Maiga, Sibuan, Mantabuan, and Church Reef. The TSMP is restricted to subsistence fishing, however, the enforcement level is low (Sherman pers. obs.). The main activities in the TSMP include scuba diving and snorkelling. Mabul and Kapalai (4°13′49.12″N, 118°39′19.55″E) are located 25 km south of Semporna and consist of an area ~20 km^2. Both islands are open to fishing, however, they are mainly used for SCUBA diving with > 25 operators in the area. Subsistence fishing occurs daily with occasional trawlers operating within 1 km of the islands.

2.2. Sampling

Baited remote underwater video systems (BRUVS) were deployed during daylight hours in a variety of habitats including fore reef, reef crest, reef flat, and lagoon at depths from 1.5 m to 40 m. BRUVS used in this study consisted of aluminium frames that housed a GoPro Hero 4 Silver camera with wide angle view (approx. 170° in air), (1920 × 1080 video format, 30 frames/s) housed in NiMAR housings, and a bait arm that extended 1 m from the camera. The bait arm held a mesh bag containing approximately 1 kg of crushed pilchards (*Sardinella* spp.) or slimy mackerel (*Scomber australiasicus*). BRUVS were manually lowered to the seafloor and recovered using floating rope attached to a surface buoy marking the location. Six BRUVS were deployed at one time with each BRUV left to record video footage throughout a minimum 60 min deployment period. BRUVS were deployed with a minimum of 500 m between each BRUVS, a distance at which it was assumed that batoids would not swim between adjacent cameras within the deployment period. Up to 24 BRUVS were set in a single day through multiple tidal states with fresh bait used for each deployment. During deployments the boat maintained a distance of at least 200 m to reduce any effects of boat noise on animal behaviour.

2.3. Video annotation

All BRUVS footage was watched by two independent, trained annotators using Event Measure software (www.seagis.com v.4.43). Annotators marked the arrival time of every batoid that entered the screen throughout the video. A senior reviewer validated species identification and compared the two reads of each video. If the two reads differed, a third independent annotator was used to determine which of the first two reads was correct. Of 286 videos, 11 required a third reader. In all 11 cases, the third reader's results matched one of the first two annotations, therefore this was deemed the final annotation. This indicated consistent and reliable results from the trained annotators.

2.4. Species

Two batoid species were examined for this study; the oriental bluespotted maskray (*Neotrygon orientalis* Last, White & Séret 2016), and the bluespotted fantail ray (*Taeniura lymma*Forsskål, 1775). These species were selected because they were the two most frequently observed batoids on Malaysian BRUVS.

2.5. Individual identification

To investigate how many different individuals were present, all videos with *N. orientalis* and *T. lymma* were reanalysed. Each time a batoid was within the field of view, the best possible frames were extracted from the video to illustrate key identifying features (Fig. 1). Frames were then compared to differentiate between individuals within each deployment. When individuals were not identifiable (too distant or moving too quickly) they were labelled as "unknown." No studies have been performed to determine the longevity and reliability of re-identification using markings of either species of ray in this study. However, the maximum time in which the rays could be re-identified was 90 min, therefore it was concluded that these features would not change in this time period. No attempt was made to identify individuals across deployments.