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Remotely operated vehicles as alternatives to snorkellers for video-based marine research

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Abstract

Capabilities of remotely operated vehicles (ROVs) have increased substantially in the last decade, and mini-ROV designs are now able to conduct visual research frequently conducted by snorkellers or divers in shallow marine environments. There are logistical, financial and experimental benefits of using mini-ROVs over snorkellers or divers, yet the adoption of mini-ROVs for common shallow underwater research tasks has not been widespread. To assess the capabilities of mini-ROVs to sample fish communities we compared the results produced by a mini-ROV to that of snorkellers for performing two of the most common marine video-based research activities (1) underwater visual fish census and (2) observing and tracking fish behaviour. Results of both activities suggested that the fish community observed by the mini-ROV was not distinguishable to that observed by the snorkellers, however, the mini-ROV detected significantly more fish (39% higher abundance) and greater diversity (24% higher). When tracking butterflyfish behaviour, video obtained from the mini-mini-ROV was as efficient as a snorkeller at finding and tracking individuals. Video from the mini-ROV produced comparable responses snorkellers with hand-held GoPros, although over the course of tracks the response between the two methods differed, with a decrease in refuge time for snorkeller video and an increase in tailbeat rate for the mini-ROV video. Our study shows that video obtained from mini-ROVs can be used for research in shallow marine environments when direct manipulations are not required. We predict the research capabilities of mini-ROVs to increase substantially in the coming years, which should cement the use of this tool for research across all marine environments.

Introduction

Assessments of fish diversity, abundance and in-situ behaviours form the backbone of many long-term monitoring programs. Perhaps the most pervasive activity performed by scientists in marine environments is the underwater visual census, an ecological approach aimed at quantifying diversity, abundance and/or benthic cover of various organisms (Davis et al., 2015; Edgar et al., 2017; Wong et al., 2018). A Google Scholar search using the terms "underwater visual survey" and "underwater visual census" yielded a total of 1090 search results since 2014. Underwater visual surveys usually consist of a diver or snorkeller swimming in a straight line over a standardised distance and/or time and either recording data on a slate or videoing for post-field analysis (Bacheler et al., 2017; Mallet and Pelletier, 2014). In-situ visual observations of fish behaviour form the basis of many ecological studies and, like underwater visual censuses, is a common methodology (Bos et al., 2017; Kruse et al., 2016; Leal et al., 2015).

Historically, videos were not recorded during underwater visual censuses or behavioural monitoring, as this could add difficulties associated with the management of big data, video resolution was limited, and the approach requires additional time to process outside the field (Tessier et al., 2005). Snorkellers or SCUBA divers are also more flexible (since surveys are conducted in real time) and can give estimates of size classes of fishes and record co-variates that are not possible with video recordings. However, video-based fish surveys and behavioural monitoring are increasingly commonplace (Mallet and Pelletier, 2014) due to the ability to preserve data over time, the increase in resolution of low-cost waterproof cameras, the benefits of stereo-footage that allow precise length measurements, and the growing possibility of automatic fish identification using machine learning approaches (Shortis et al., 2016; Wäldchen and Mäder, 2018; Yulianto et al., 2015). Research also suggests that video-based censuses may be optimal for fish surveys in some circumstances (Wartenberg and Booth, 2015). For both visual and video-based methods, however, interactions between divers and focal species can create biases in the data. These concerns are particularly relevant for more cryptic species that hide or alter their behaviour in the presence of divers (Dearden et al., 2010; Lindfield et al., 2014; Lopes Jr, 2017; Pais and Cabral, 2017). Adopting new methods that reduce these biases for video-based underwater visual censuses and behavioural monitoring would benefit researchers by increasing the accuracy of studies.

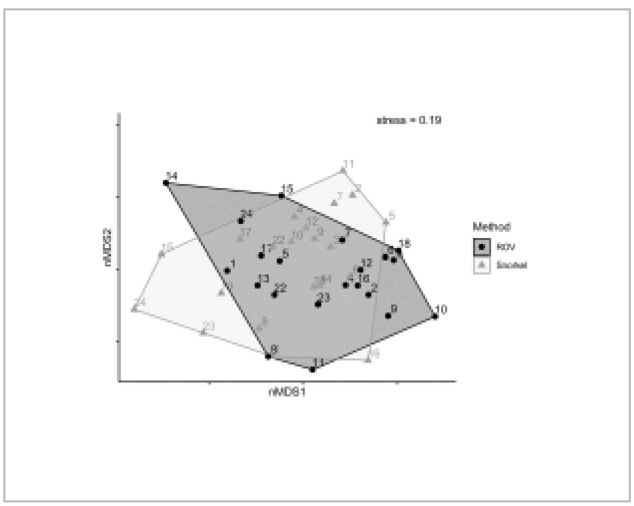
Underwater Remotely Operated Vehicles (ROVs) were originally utilised to allow the exploration or surveying of marine environments that were too dangerous for human exploration, such as deep oceans (below 100 m down to 10 km), archaeological wrecks, and hydrothermal vents (Whitcomb, 2000). These machines form the backbone of deep sea research, and new remote-sensing technologies such as hyperspectral imaging have only increased their capabilities (Johnsen et al., 2016). ROVs have typically been viewed as awkward, multi-million dollar pieces of equipment ranging in sizes up to 310-ton underwater mining ROVs with substantial logistical support requirements (Bogue, 2015; McLean et al., 2017). Recently, however, with the miniaturisation of electronics, incorporation of aerial drone stabilisation hardware, increases in the resolution and quality of video feeds, and the potential for virtual reality interfaces (García et al., 2017), ROVs now have comparable abilities to human researchers in shallower areas, while still maintaining the advantage of access to greater depths (Sward et al., 2019; Vedachalam et al., 2015). Where repetitive or spatially widespread tasks are necessary, the automation capabilities of ROVs already show potential at scales that would be impossible using diving or snorkelling (Hagman, 2015). The automation of fieldwork and ease of access to environments provided by ROVs offer significant benefits to research, and the explosion of the use of aerial drones for marine science provides a guideline for the potential benefits of ROVs for marine research (Joyce et al., 2018; Raoult and Gaston, 2018; Raoult et al., 2018).

Small and economical 'mini-ROVs' have expedited the development of novel ecological approaches in shallow waters such as behavioural observations of released sharks (Raoult et al., 2019) and wild Loggerhead sea turtles (Smolowitz et al., 2015). Mini-ROVs are compact units weighing under 30 kg, <1 m in length (Sward et al., 2019) and are more affordable than larger units. Research with mini-ROVs such as the one used by Smolowitz et al. (2015) would not be possible with human divers due to the need for numerous repetitive, rapid dives and the remoteness of the environment. Mini-ROVs have also been shown to be as effective as divers when studying marine benthos in environments >30 m (Boavida et al., 2016) and have been used to replace divers in mesophotic zones where diving can be difficult (Consoli et al., 2016; Etnoyer et al., 2010; Goldstein et al., 2016; Torquato et al., 2017).

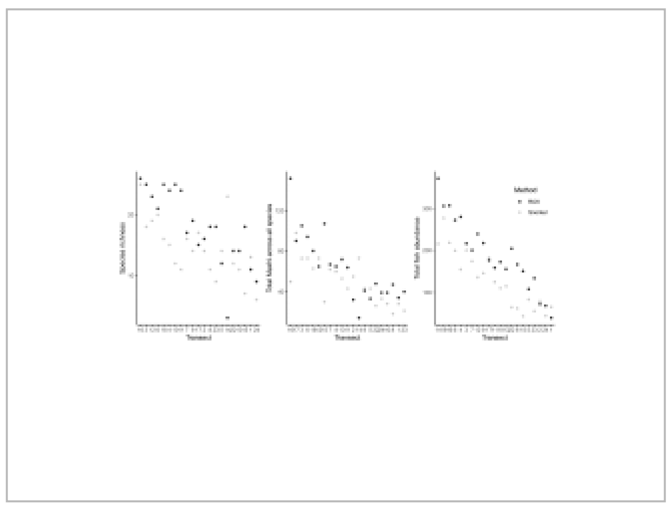
There is an increasing overlap in capabilities between mini-ROVs and snorkellers/divers (Table 1), but to date the inferred effectiveness of mini-ROVs in relation to divers (e.g. Goldstein et al., 2016; Sward et al., 2019) has primarily been tested at depths greater than those where recreational diving and snorkelling and most underwater visual censuses occur (>30 m). The two studies that have directly compared divers and mini-ROVs for such research in shallow environments (<30 m) (Carpenter and Shull, 2011; Pita et al., 2014) recommended additional research with ROVs despite detecting higher abundance and diversity of fishes with divers than with ROVs. These studies were done using last-generation ROVs (Bleeper Evo ROV from Praesentis (Barcelona, Spain), VideoRay Pro 3 XE GTO ROV by VideoRay) that lacked full high-definition video, were unstable in currents, and were difficult to pilot due to a lack of self-stabilising software and hardware. Latest generation mini-ROVs have improved on all these limitations through the of drone-based hardware (IMU (inertial measurement unit) and full HD video) and software interfaces. Revisiting the effectiveness of modern mini-ROVs and comparing them to snorkellers may help researchers determine whether the latest generation of ROVs offer an improvement over previous versions for research in shallow marine environments.

Our study directly compares the effectiveness of mini-ROVs against common snorkelling methods in conducting two of the most common ecological protocols in aquatic environments: underwater visual censuses and observing and tracking behaviour. Fishes were used as mobile focal species in the censuses and butterflyfishes were used for tracking behaviour because of their close and complex associations with reef habitat. Shallow reef was chosen as an ideal assessment habitat because censuses here are commonly done on snorkel, the habitat contains a high diversity and abundance of fishes, and the reef structure within the habitat is spatially complex. All analyses were done from video footage rather than in situ to ensure direct comparisons between video capture platforms and to reduce biases that could result from observers spending time looking directly at a fish. We predicted that footage from a mini-ROV would produce data of similar or higher quality than those produced by snorkellers with hand-held video cameras due to the more stable video recording platform on the mini-ROV.

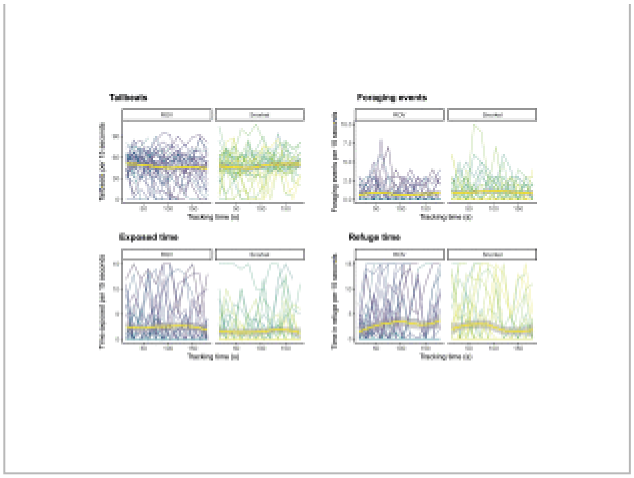
Figures



Non-metric multidimensional scaling plot using Bray-Curtis dissimilarity comparing the communities of fishes from one area observed in transects conducted from a Remote Operated Vehicle (mini-ROV, gre...



Species richness, total MaxN (cumulative conservative estimate of abundance of each species), and total fish abundance across 24 transects assessed concurrently by underwater visual surveys conducted ...



Observed behaviours of butterflyfishes tracked for 3min across the sand flat of Heron Island lagoon under snorkel and with an underwater Remote Operated Vehicle (mini-ROV). Each coloured line represen...

Section snippets

Study area

All fieldwork was conducted on the shallow reef flat on the southern side of Heron Island (23° 25′ S, 151° 55′ E) within the scientific research zone, approximately 80 km northeast of Gladstone on the Great Barrier Reef, Australia. This shallow reef flat is typical of those found at similar latitudes on the outer Great Barrier Reef (Williamson et al., 2017), containing isolated bommies and supporting diverse coral and invertebrate species interspersed with sand (Raoult et al., 2016). Sampling...

Underwater visual census

There was no significant difference between the mini-ROV inbuilt camera and mini-ROV attached GoPro for total abundance counts of fish ($F^{1,19}=0.078$, $p=.78$) and species richness counts of fish ($F^{1,19}=0.916$, $p=.35$) in the transects. This allowed footage from either source to be used interchangeably, and on-board footage was only used in the three instances where the mini-ROV-based GoPro footage was not available.

Across the 24 transects we counted a total of 6765 fishes across 100...

Discussion

Our research shows that mini-ROVs are an effective method for conducting shallow water ecological research typically reserved for snorkellers and may, in some cases, be superior to traditional approaches. In our study significantly greater numbers of fish and higher species richness were measured by the mini-ROV than by snorkellers in video-based underwater visual censuses. The mini-ROV was just as capable at tracking fish behaviour, although fish appeared to respond differently to the two…

Conclusions and future considerations

The use of mini-ROVs for research in marine environments expands opportunities to perform research activities generally reserved for marine research in high-risk areas. For example, snorkelling and diving in high-energy environments, enclosed environments (caves, under sea ice) or deeper waters is generally avoided, but mini-ROVs can readily be used in these areas with low risk to the equipment and the users. One of the reasons mesophotic reef ecosystems are relatively poorly studied is because …

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

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