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Reef vision: A citizen science program for monitoring the fish faunas of artificial reefs

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ABSTRACT

There has been a marked increase in the number of artificial reefs being deployed around the world, many of which are designed to increase catches of recreationally-targeted fish species. As artificial reef deployments should be accompanied by clear and measurable goals and thus subsequent environmental impact monitoring and performance evaluation, there is a need to develop cost-effective monitoring programs. This study provides proof of concept for a citizen science approach to monitoring the fish faunas of artificial reefs (Reef Vision). Recreational fishers were recruited to collect video samples using Baited Remote Underwater Video systems and submit the resultant footage for analysis and interpretation by professional scientists. Reef Vision volunteers were able to collect enough data of sufficient quality to monitor the Bunbury and Dunsborough artificial reefs in Geographe Bay, south-western Australia. Data were extracted from the footage and used in robust univariate and multivariate analyses, which determined that a soak time of 45 min was sufficient to capture ≥ 95% of the number of species, abundance, diversity and composition of the fish fauna. The potential for these data to detect differences in the characteristics of the fish fauna between reefs and seasons was also investigated and confirmed. With the continuing deployment of artificial reefs around the world, the use of similar cost-effective citizen science monitoring approaches can help determine the effectiveness of these structures in achieving their aims and goals and provide valuable data for researchers, managers and decision makers. Projects such as Reef Vision can also benefit volunteers and communities by enhancing social values, creating ownership over research projects and fostering stewardship of aquatic resources.

1. Introduction

Artificial reefs are widely deployed around the world and are increasingly becoming a part of the seascape in coastal environments, including in Australia (Diplock, 2010; Fabi et al., 2015). The term 'artificial reef' is variously used (Seaman and Jensen et al., 2000), however, most usage falls within the broad definition of Sutton and Bushnell (2007), i.e. “one or more objects of natural or human origin deployed purposefully on the seafloor to influence physical, biological or socioeconomic processes related to living marine resources". One of the most common applications is as a tool in fisheries management to improve fishing (Seaman, 2007; Fabi et al., 2015; Becker et al., 2017) and, in regions such as Australia and the United States of America, particularly recreational fishing (Seaman and Jensen et al., 2000; Lowry et al., 2014). These installations are popular with recreational fishers as they can enhance fishing experiences and catch rates by providing access to target species and, in the longer term, stimulate *in situ* production, thereby increasing total fish stocks (Bohnsack, 1989; Brickhill et al., 2005; Cresson et al., 2014; Smith et al., 2016).

The artificial reefs used in fisheries enhancement in developed countries are now typically purpose-built, rather than constructed from materials-of-opportunity (Diplock, 2010; Lowry et al., 2014), ideally with considerable planning directed towards ensuring that the reef design, configuration and location is suited to the designated purpose (Diplock, 2010; Fabi et al., 2015). Post deployment of the structures, it is crucial to assess the extent to which a reef is achieving the intended purpose (Seaman and Jensen et al., 2000; dos Santos and Zalmon, 2015; Becker et al., 2017), and to determine the type and magnitude of any environmental impacts (Department of Fisheries, 2012; Department of the Environment, 2016; International Maritime Organization, 2016). Without such an assessment, there is a risk of repeatedly reusing suboptimal or even undesirable reef materials and designs, and incurring large costs in the process (Diplock, 2010). For example, the size, configuration and location of a reef is known to influence the density,

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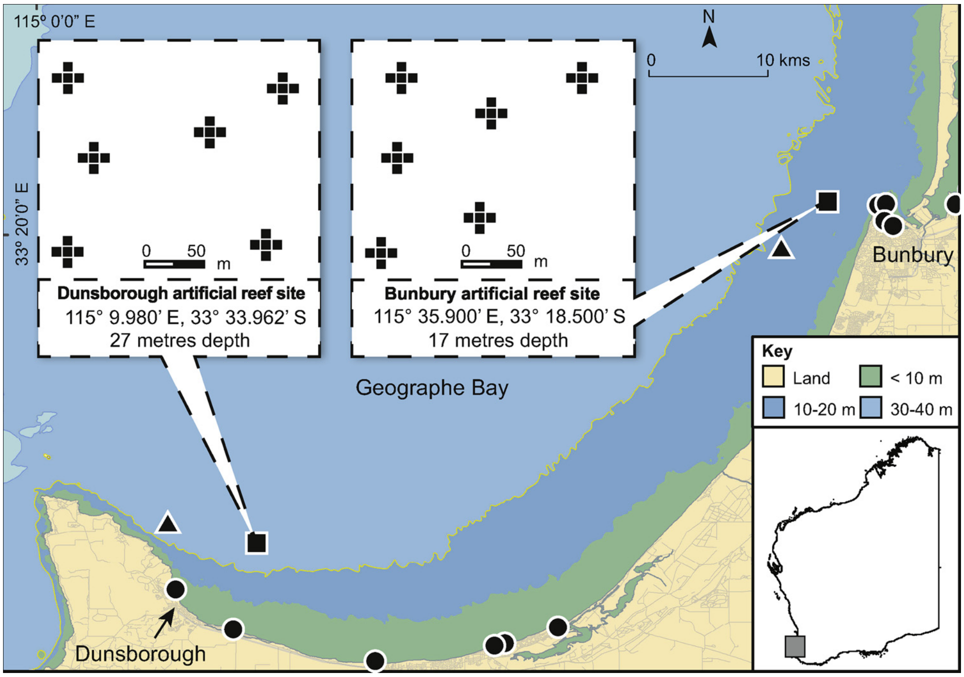

Fig. 1. Map showing the location of the Bunbury and Dunsborough artificial reefs in Geographe Bay and the configuration of their 30 concrete FishBox modules into six clusters. Grey square on inset denotes the location of Geographe Bay in Western Australia. ■, purpose-built concrete reef; ▲ sunken ship artificial reef; ●, boat ramp. Map modified from the Department of Primary Industries and Regional Development.

biomass, and composition of the fish fauna and the long-term productivity of a reef, as well as fishing effort (Bohnsack et al., 1991; Jordan et al., 2005; Fabi et al., 2015). However, how these interactions manifest is still poorly understood (Diplock, 2010; Lowry et al., 2014). Information on the spatial and temporal variability of the fish fauna on an artificial reef can be used to put in place actions that maximize returns from the fish resources on the reef (dos Santos and Zalmon, 2015), to understand ecosystem-level responses of fishes to the reef (Scott et al., 2015) and to integrate the reef into a broader management framework (Lowry et al., 2014; Fabi et al., 2015). Thus, long-term monitoring of the fish assemblages associated with artificial reefs for fisheries enhancement is essential (dos Santos and Zalmon, 2015; Becker et al., 2017). This requirement can, however, add considerable costs to an artificial reef project (Fabi et al., 2015).

The financial costs of monitoring the fish faunas of an artificial reef could potentially be reduced by involving citizen scientists. Citizen science describes an approach where members of the public, usually non-experts or non-professionals, participate in scientific research or monitoring on a voluntary basis (Chase and Levine, 2016; McKinley et al., 2017). This approach has been applied in a variety of settings (Dickinson et al., 2012; Cigliano et al., 2015; Follett and Strezov, 2015; McKinley et al., 2017) and is being increasingly used in natural resource monitoring (Boakes et al., 2016; Chase and Levine, 2016). Although the use of citizen science in marine research and monitoring has recently started to gain traction (e.g. Fairclough et al., 2014; Thiel et al., 2014; Anderson et al., 2017), Cigliano et al. (2015) have pointed out that there is considerable potential to expand in this area. Citizen science monitoring can be a cost-effective method of data collection, whilst also increasing stakeholder engagement and buy-in (Dickinson et al., 2010; Fairclough et al., 2014; Aceves-Bueno et al., 2015; McKinley et al., 2017). However, if the program is poorly designed and managed, it can result in unsystematic data collection, leading to uncertainty about the efficacy of the data (Dickinson et al., 2010; Boakes et al., 2016). It is also important to consider the 'hidden costs' of administering citizen science programs, such as the recruiting, training and retaining volunteers (Thiel et al., 2014; McKinley et al., 2017). Ultimately, the costs and benefits of using citizen science in natural resource monitoring are context dependent (see Chase and Levine, 2016; McKinley et al., 2017). Success or failure will depend on the outcome of the interactions between a range of key variables, such as the type and goals of the monitoring, the tasks and levels of responsibility given to the member of the public and how the project is administered (Chase and Levine, 2016).

The overall objective of this study was to provide a proof of concept of a citizen scientist program (called Reef Vision), where recreational fishers used Baited Remote Underwater Video systems (BRUVs) to monitor the fish fauna of two artificial reefs. These purpose-built reefs were recently deployed in a marine embayment (Geographe Bay) on the south-western coast of Australia, with the aim of enhancing recreational fishing opportunities and experiences. A BRUV monitoring method was chosen because it is cost-effective (Cappo et al., 2003); relatively robust to user skills and bias (Thompson and Mapstone, 1997); unaffected by depth and time limitations unlike, for example, diver surveys (Willis et al., 2000); actively attracts fish to the camera, thereby increasing the chances of observing more fish (Stobart et al., 2015); and has been successfully used by scientists to study the fish fauna of artificial reefs elsewhere (e.g. Folpp et al., 2013; Scott et al., 2015; Becker et al., 2017). BRUVs also provide a permanent record of the data, which means that fish identifications and counts can be done later and checked for accuracy by qualified scientists, thus removing a potential source of error from the data set (Cappo et al., 2003; Whitmarsh et al., 2017).

The specific aims of the study were to (i) elucidate whether sufficient quantities of video footage could be collected to constitute an effective monitoring regime; (ii) determine quantitatively the duration of a video that needs to be examined before there is no significant change in the characteristics of the fish fauna; and (iii) investigate whether data of sufficient quality can be extracted from the video footage to enable robust univariate and multivariate analysis of any spatial and/or temporal changes in the characteristics of the fish fauna.

2. Materials and methods

2.1. Study site

Citizen scientists monitored two artificial reefs in Geographe Bay, a shallow, open embayment in south-western Australia (Fig. 1). This region experiences a Mediterranean climate, with hot dry summers and cool wet winters (Gentilli, 1971; Belda et al., 2014). Geographe Bay is well flushed with ocean water and the salinity is around full strength