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Predictive mapping of abalone fishing grounds using remotely-sensed LiDAR and commercial catch data

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ABSTRACT

Defining the geographic extent of suitable fishing grounds at a scale relevant to resource exploitation for commercial benthic species can be problematic. Bathymetric light detection and ranging (LiDAR) systems provide an opportunity to enhance ecosystem-based fisheries management strategies for coastally distributed benthic fisheries. In this study we define the spatial extent of suitable fishing grounds for the blacklip abalone (*Haliotis rubra*) along 200 linear kilometers of coastal waters for the first time, demonstrating the potential for integration of remotely-sensed data with commercial catch information. Variables representing seafloor structure, generated from airborne bathymetric LiDAR were combined with spatially-explicit fishing event data, to characterize the geographic footprint of the western Victorian abalone fishery, in south-east Australia. A MaxEnt modeling approach determined that bathymetry, rugosity and complexity were the three most important predictors in defining suitable fishing grounds (AUC = 0.89). Suitable fishing grounds predicted by the model showed a good relationship with catch statistics within each sub-zone of the fishery, suggesting that model outputs may be a useful surrogate for potential catch.

1. Introduction

Marine coastal areas are of ecological and economic importance, and management of exploitation by the fishing industry must be aimed at long term sustainability, as well as economic viability (De Freitas and Tagliani, 2009). However, these aims have been jeopardized by anthropogenic effects such as climate change and overexploitation, and effective management responses hampered by a paucity of detailed geospatial information (Jackson et al., 2001; Plagányi et al., 2011). Overharvesting, and in some cases even localized extinction, have been reported for some littoral invertebrates of high commercial relevance, such as the abalone (Stierhoff et al., 2012). It has been suggested that, when aiming to maintain ecosystem health, fisheries models should incorporate biotic and abiotic factors within ecologically meaningful boundaries (Johnson et al., 2012; Pikitch et al., 2004).

A limiting factor for assessing stocks in a benthic fishery is often the accuracy and reliability of descriptions of the geographic extent of suitable fishing grounds, and an understanding of existing links between seafloor characteristics and areas targeted by fishers. This information is pivotal when the target species are sedentary because of associations between species' distribution and seafloor structure (Davies et al., 2008; Galparsoro et al., 2009). Improvement in the availability of high-quality, remotely-sensed data has seen rapid advances in the field of landscape ecology (Simonson et al., 2014). Similarly, considerable advances in technology in the past decade now allow the investigation of seascape complexity and its association with species distributions at finer scales, which may be more relevant to management of coastal fisheries (Brown et al., 2012; Jones, 2006; Pittman et al., 2009; Valle et al., 2011). Collection of data describing fine-scale seafloor structure in coastal waters has been limited because of technical and logistic impediments (Brown et al., 2012; Wilson et al., 2007), particularly in areas where vessel-based sonar systems lose efficiency and face navigation hazards such as shallow reefs and breaking waves (Chust et al., 2010; Costa et al., 2009). These obstacles have often resulted

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in a paucity of detailed bathymetric information in shallow coastal waters. The advent of airborne bathymetric LiDAR (light detection and ranging) systems provides an opportunity to generate information about seafloor complexity across extensive areas in shallow coastal regions (Santos, 2000; Vierling et al., 2008; Zavalas et al., 2014). This also enables integration of detailed seafloor structure with geo-located catch information to delineate shallow-water habitats targeted by the particular fishery (Kuffner et al., 2007).

More than half of the current global wild abalone catch is from Australia (Mayfield et al., 2012). In the state of Victoria, blacklip abalone, *Haliotis rubra* (Leach), is the most valuable commercial fishery, attracting major efforts directed toward achieving sustainability (Gorfine and Dixon, 2000; James et al., 2007). During the past decade, factors such as excessive fishing pressure and an outbreak of abalone viral ganglioneuritis (AVG) disease (Mayfield et al., 2011a; Mayfield, 2010) have dramatically affected Victorian abalone stocks, particularly within the western and central fishing zones. The presence of AVG was first confirmed during 2006 on reefs near Port Fairy, south-west Victoria, resulting in fishery closures to minimize the risk of disease transfer to unaffected stocks (Gorfine et al., 2008). During the lead up to this event, population abundance in the region of the zone west of Portland had been declining which had led to strategic implementation of finer-scale management measures focused on specific reef complexes (Prince et al., 2008). A new system was implemented to spatially monitor commercial diving efforts using global positioning systems (GPS) as part of this strategy (Mayfield et al., 2012). The observed depletion prior to the onset of disease could reasonably have been expected to weaken the resilience of the stock to environmental perturbation (Walker and Salt, 2006).

Management of the abalone fishery is implemented on the basis of zonal levels at broad spatial scales, often spanning 10–100s km of the coastline. This is much coarser than the scale at which abalone fishing activity occur (10–100s m) (Prince et al., 1988; Prince, 2008). Therefore, a particular emphasis has been placed on addressing the dichotomy between the scale of management and the spatial patterns of abalone harvests. One potential solution to this scale mismatch is to integrate geo-located fishing records with newly available measures of seafloor morphology, thereby identifying the boundaries of suitable fishing grounds at a scale that better corresponds with the scale at which fishing occurs. Such data integration could be possible considering the progress made in predictive habitat modeling approaches such as species distribution models (SDMs) that have been widely used to quantify species habitat interactions (Elith and Leathwick, 2009; Phillips et al., 2006), and to predict species distributions in a defined geographic space based on the concept of ecological niche partitioning (Palialexis et al., 2011; Valle et al., 2011). These approaches have recently been applied in marine systems (Jones et al., 2012; Monk et al., 2010; Phillips and Dudík, 2008; Ready et al., 2010), and provide a means to map suitable fishing grounds by integrating representative surrogates of seafloor complexity with catch records (Klemas, 2013; Pierce et al., 2001; Valavanis et al., 2004). Spatially-explicit models may also be used to obtain a better understanding of the key drivers of species distribution in fisheries (Grimm and Railsback, 2012). Given the current vulnerability of abalone stocks within the western fishing zone of Victoria, the main objective of this study was to predict the extent of viable fishing grounds for blacklip abalone. This was achieved by integrating GPS located fishing records and remotely-sensed LiDAR derivatives to identify geophysical determinants of suitable grounds. The study also aimed to quantify the predicted suitable grounds within each abalone fishing sub-zone and to evaluate how well these estimates reflected patterns of reported catch and diver-identified areas of productive reef substrate.

2. Material and methods

2.1. Study area

The study area covered the western abalone fishing zone in southwest Victoria, from the mouth of the Hopkins River in Warrnambool to the western side of Discovery Bay adjacent to the South Australian border (140°56′–142°31′E and 38°06′–38°26′S) (Fig. 1). This region encompasses diverse geographic features along a coastal length of approximately 200 km. The area comprised mosaics of reef and bare sediment with near-shore patchy reef extensions from the intertidal zone to a depth of 20–30 m and offshore reef systems in deeper water. Extensive unconsolidated sandy areas were typically restricted to embayments in the nearshore zone. A number of distinct, partially sediment-filled palaeochannels also occur along the coast, usually in proximity to existing river systems. Diverse algal assemblages can be found on shallow reef systems mostly dominated by fucoid algae, such as *Ecklonia radiata* and *Phyllospora comosa* providing suitable feeding and spawning grounds for several invertebrate and fish species. The abalone fishery within the region is managed through a restricted

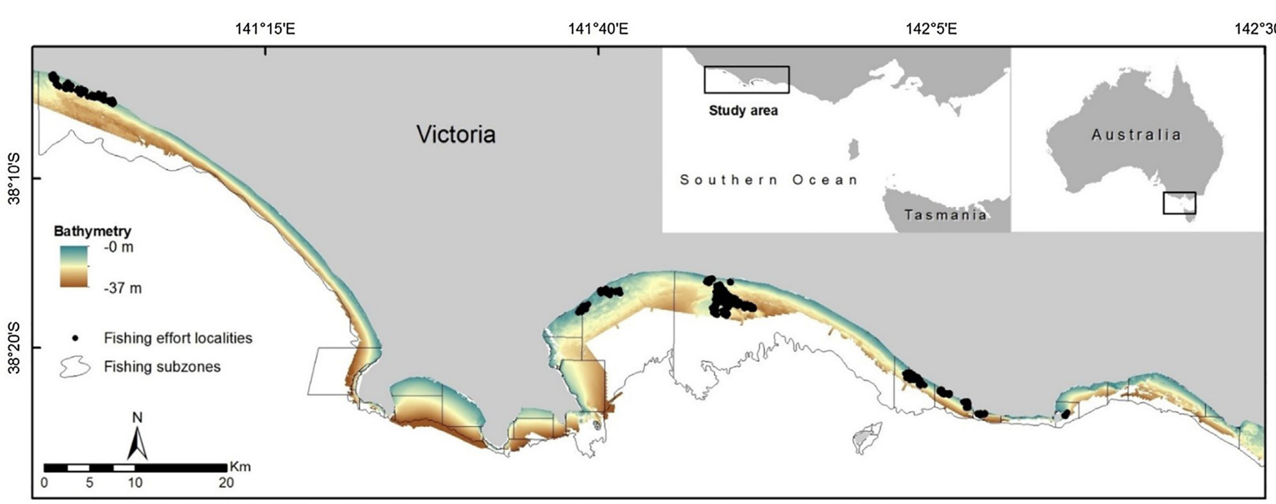

Fig. 1. Map of the study area encompassing the western Victorian abalone fishery management zone, south west Victoria, Australia.