



## Accounting for habitat structural complexity improves the assessment of performance in no-take marine reserves

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### ABSTRACT

Seascape variability may confound assessments on the effectiveness of no-take marine reserves (NTMRs) in conserving biodiversity. In most cases baseline data are lacking, resulting in evaluations of NTMR effectiveness being Control Impact (CI) assessments. Even with independent replicate areas among management zones, this approach can make it difficult to detect zone effects if seascape attributes, such as habitat structural complexity varies among experimental areas. To determine the importance of structural complexity in evaluations of NTMR effectiveness we performed assessments on the abundance of a targeted fish, yellowtail kingfish (*Seriola lalandi*), in the Lord Howe Island Marine Park (LHIMP). We compared assessments which did and did not account for structural complexity, quantified using high resolution multibeam bathymetry. Despite almost 3 times more *S. lalandi* in NTMRs, the traditional CI assessment explained only 3% of the variation in the abundance of *S. lalandi* and revealed no clear effect of protection. Incorporating structural complexity into the assessment increased the deviance explained to 65% and uncovered an important interaction between zone and structural complexity. Greater abundances of *S. lalandi* were detected in NTMRs compared to fished zones but only on highly complex reefs. By accounting for structural complexity, we demonstrate that the precision and accuracy of NTMR assessments can be improved, leading to a better understanding of ecological change in response to this conservation strategy. Consequently, where marine park zones vary greatly in structural complexity, we strongly advocate for quantifying and accounting for such variability in assessments of NTMR performance.

### 1. Introduction

Highlighted as an effective strategy to address a number of human pressures that contribute to changes in marine ecosystems, no-take marine reserves (NTMRs) have increased steadily on a global scale in the last two decades (Halpern et al., 2010; Costello and Ballantine, 2015). To evaluate whether this form of spatial management is providing beneficial conservation outcomes, it is essential that no-take marine reserves are accurately assessed (McCook et al., 2010). Robust assessments of ecological change related to marine reserve zoning rely upon sampling designs capable of teasing apart the effects of protection. This entails disentangling specific ecological attributes from underlying temporal and spatial variability (Garcia-Charton and Perez-Ruzafa, 1999; Garcia-Charton et al., 2000). If natural variability is not accounted for assessments of no-take marine reserve effectiveness may be confounded, potentially leading to misleading conclusions (Claudet and

Guidetti, 2010). A popular approach to date has been Before After Control Impact (BACI) experimental designs, which allow zone effects to be separated from underlying natural variability (Underwood, 1992). This methodology however, requires sampling multiple times prior to NTMR establishment which rarely occurs (Halpern and Warner, 2003). Instead, most studies use a Control Impact (CI) approach where biological assemblages within protected areas (preferably replicated areas) are compared to those in adjacent, or nearby, partially protected or unprotected areas (Lester et al., 2009; Sciberras et al., 2013; Miller and Russ, 2014). Differences observed in biological assemblages among management zones are then inferred as evidence of a reserve effect.

A potential issue for CI studies testing no-take marine reserve effectiveness is that they may be confounded by seascape variability (Claudet and Guidetti, 2010; Huntington et al., 2010; Osenberg et al., 2011). For example, in coral reef environments numerous studies have demonstrated habitat structural complexity as an important driver of

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the diversity and abundance of fishes (Friedlander and Parrish, 1998; Almany, 2004; Gratwicke and Speight, 2005). Previous research has demonstrated that coral reef habitats of greater structural complexity generally harbour a greater diversity and biomass of fishes compared to reefs of low structural complexity. This relationship is likely to be a result of structurally complex habitats providing increased abiotic variability, niches and resources (Bell et al., 1991; Friedlander and Parrish, 1998). Therefore, if structural complexity varies among management zones and is not accounted for in CI assessments on marine reserve effectiveness, there is a risk that incorrect conclusions may be drawn from such assessments (Young et al., 2016).

A possible solution to this issue is to include a measure of structural complexity as a co-variate in statistical tests of no-take marine reserve effectiveness, thereby improving the accuracy and precision of the assessment (Claudet and Guidetti, 2010). In the past however, this has been problematic due to the difficulties and costs associated with collecting seascape data over the broad spatial scales that NTMRs and multi-use marine protected areas (MPAs) encompass. Recent advances in remote-sensing technologies now allow seafloor habitats to be mapped in high resolution over a range of spatial scales (Mellin et al., 2009; Brown et al., 2011). Consequently, marine ecologists have employed this technology to explore relationships between remotely-sensed seascape measures, such as structural complexity and biological assemblages in both coral and temperate rocky reef environments (Kuffner et al., 2007; Purkis et al., 2008; Pittman et al., 2009; Rees et al., 2014; Ferrari et al., 2017). As strong relationships between remotely-sensed measures and biological assemblages have been observed, habitat mapping has become increasingly used in guiding the design of zones within MPAs (Pittman and Brown, 2011; Rees et al., 2014). Despite the applicability of this technology, the use of remote-sensing to account for potential seascape confounding in CI assessments is still in its infancy. This is most likely a result of the relatively high costs and limited availability of this technology throughout many regions of the world. However, as remote-sensing technologies become more cost effective and readily available (Mellin et al., 2009; Brown et al., 2011; Ierodiaconou et al., 2011), the application of this approach to aid no-take marine reserve assessments is likely to become more feasible.

In this study, we tested the effectiveness of no-take marine reserves in the Lord Howe Island Marine Park (LHIMP) with and without accounting for underlying differences in structural complexity. The LHIMP is located 610 km off the east coast of Australia in the subtropical region of the South Pacific Ocean. For many reasons the LHIMP provides an ideal system to test marine reserve performance while accounting for differences in structural complexity. First, Lord Howe Island and its surrounding waters have significant biological value, comprising the world's southernmost coral reef and a diversity of both tropical and temperate taxa that includes a suite of endemic species (Edgar et al., 2010). Consequently, Lord Howe Island received World Heritage Listing in 1982 (Environment Australia, 2000). Second, the LHIMP is positioned in the subtropics; a region prone to the effects of climate change, and the marine park's remoteness makes it vulnerable to ongoing and increasing anthropogenic pressures (Edgar et al., 2010). Therefore, it is critical that conservation efforts are adequately and accurately assessed. Finally, the Lord Howe Island shelf has been extensively mapped with high resolution sonar (~5 m resolution) to understand the distribution and structure of shelf habitats, particularly relict coral reefs formed 7000 to 9000 years ago (Woodroffe et al., 2010). As a result, quantification of structural complexity across the majority of the LHIMP shelf habitat is possible.

To determine the importance of accounting for structural

complexity in CI assessments of no-take marine reserves, we performed two tests on the effectiveness of the LHIMP. The first, a traditional CI assessment and the second, a series of CI assessments including a measure of structural complexity. Both tests compared the effect of NTMR protection on the abundance of yellowtail kingfish (*Seriola lalandi*), a heavily exploited species of bony fish in the LHIMP (Figueira and Hunt, 2012). We predicted that remotely-sensed structural complexity and reserve protection would influence the abundance of *S. lalandi*. Consequently, we predicted that the model including structural complexity would explain more of the variation in *S. lalandi* abundance, therefore leading to a more accurate and precise assessment of NTMR effectiveness on this targeted species compared to the model excluding structural complexity.

## 2. Materials and methods

The Lord Howe Island Marine Park is a 3470 km<sup>2</sup> multi-use marine park located 610 km off NSW, Australia, at latitude 31°50'S. The marine park contains two separate shelf areas adjacent to Lord Howe Island and Balls Pyramid, which are separated by a 4–8 km wide trench reaching depths of approximately 500 m. The marine park covers the State waters (proclaimed in 1999) and Commonwealth waters (proclaimed in 2000) which surround Lord Howe Island and Balls Pyramid. State waters are from the mean high water mark to 3 nautical miles (nm) surrounding the islands while Commonwealth waters extend from 3 nm to 12 nm offshore. The study was undertaken on the Lord Howe Island and Balls Pyramid shelves between depths of 25–50 m. At this depth, 2 different management zones are present within federal and state waters. Zones are either, sanctuary zones which are strictly no-take marine reserves (referred to as NTMRs in this study) that prohibit extractive activities, or habitat protection zones which are partially protected areas allowing some forms of fishing, such as charter boat operations and recreational line fishing (referred to as fished zones in this study) (Fig. 1). Spearfishing and commercial fishing in the park is prohibited.

The abundance of yellowtail kingfish; *Seriola lalandi*, was surveyed using baited remote underwater video systems (BRUVS) constructed by SeaGIS Pty Ltd. with Canon HG21 video cameras. This species was chosen as they are the most common species targeted by fishers in the park. Catch by weight of *S. lalandi* based on landings by charter operators has ranged from 16,904 kg to 24,313 kg per year between 2006 and 2011 (Figueira and Hunt, 2012). Depredation of hooked and released individuals by the abundant galapagos whalers; *Carcharhinus galapagensis* is a common occurrence in the LHIMP, therefore fishing mortality is likely to be greater than reported (Figueira and Hunt, 2012). Although *S. lalandi* inhabit both demersal, mid-water and pelagic environments (Heagney et al., 2007; Rees et al., 2015), the majority of charter boat fishing effort for *S. lalandi* occurs on or closely associated with seafloor habitats (NSW DPI unpublished data). This includes the Lord Howe Island and Balls Pyramid shelf; the habitat assessed in this study (Figueira and Hunt, 2012). In response to their high catch rates on the LHIMP shelf, *S. lalandi* are likely to show a positive response to the cessation of fishing (Claudet et al., 2010). In addition, the abundance and distribution of *S. lalandi* is likely to be influenced by structural complexity at the scale explored in this study. Reefs of high structural complexity are potentially optimal habitat for *S. lalandi* within the LHIMP, providing increased prey such as baitfish and macroinvertebrates as well as favourable abiotic conditions such as variability in current movements. Previous research has demonstrated increased catches of *S. lalandi* in areas of high structural complexity compared to areas of relatively low structural complexity (Hobday and

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