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Assessment of spatial fishing closures on beach clams

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ABSTRACT

Spatial fishing closures are typically implemented for conservation and fisheries benefits, but the effects of such initiatives are often not tested. This study examined whether the densities and size compositions of beach clams differed between commercially fished and non-fished zones on beaches. Sampling of clams was stratified across two habitats (swash and dry sand) on two commercially fished beaches, before and during (early and late) the 6-month harvesting period. Two beaches that had no commercial fishing were also sampled the same way and acted as external controls. Differences in densities, but not size compositions, of clams were evident between zones on the commercially fished and control beaches, but they were mostly apparent only across short (day and week) periods before, early and late harvesting, and thus were most likely pulse responses of clams to stochastic, non-fishing related events that acted independently across the different zones on each beach. The potential movements of clams along and across beaches as well as current restrictions on commercial fishing probably dampened detection of longer-term fishing-related impacts and demographic differences in clams between commercially fished and non-fished zones. Direct fishing-related impacts on clams may only be discernable in the immediate vicinity of, and persist for a short period following, an actual fishing event on a beach. Nevertheless, the zones closed to commercial fishing may provide valuable protection to a portion of clams on each beach and alleviate beach-wide harvesting impacts. The broader value of these closed fishing zones requires knowledge of the impacts of fishing on other beach organisms and ecosystem functioning. Further experimentation that tests other aspects of management arrangements of beach clams may help determine their global applicability for sustainable harvesting, and contribute to the overall conservation management of sandy beach ecosystems.

1. Introduction

Spatial closures to fishing are increasingly being incorporated into conservation and fisheries management strategies as a means to provide protection to wild populations of aquatic organisms from human exploitation (Lubchenco et al., 2003; Botsford et al., 2009; Lester et al., 2009). The most notable examples of such measures are no-take marine protected areas and reserves, which compared to openly fished areas have in many instances been shown to enhance the densities and sizes of organisms as well as aquatic biodiversity (Lester et al., 2009; Sciberras et al., 2013). Much of this evidence has been based on work done on fishes and invertebrates inhabiting shallow coastal rocky reefs (Barrett et al., 2007; Di Franco et al., 2009; Edgar and Barrett, 2012; Guidetti et al., 2014). Few studies have examined the effects of such management initiatives on the fauna inhabiting beaches.

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Sandy beaches are the most common type of shoreline bordering the world's oceans and among the most dynamic, but threatened, habitats worldwide (McLachlan and Brown, 2006; Schlacher et al., 2008; Defeo et al., 2009). Ocean beaches are culturally valuable and of high socio-economic importance as they provide extensive ecosystem services to humans (Schlacher et al., 2008; Defeo et al., 2009). Even so, many such beaches support diverse assemblages of benthic invertebrates and other fauna (McLachlan and Brown, 2006; Defeo and McLachlan, 2013). Beach clams (burrowing bivalve molluscs) often dominate the macrofaunal biomass of shallow subtidal and intertidal zones and contribute greatly to the ecology of high-energy ocean beach ecosystems in tropical and temperate regions (McLachlan et al., 1996; Defeo and McLachlan, 2013). Beach clams are also widely harvested for human consumption and bait (McLachlan et al., 1996; Defeo, 2003), but like many exploited benthic invertebrates (Anderson et al., 2011) population declines have been observed in several species (McLachlan et al., 1996; Defeo, 2003; Ortega et al., 2012). Various management initiatives to conserve beach clam populations have been implemented, including closed areas and times to harvesting, and quotas (Castilla and Defeo, 2001; Defeo, 2003). Rarely, however, has the success of such strategies been evaluated in an experimental manner (Walters and Holling, 1990; Underwood, 1995), thus limiting their global applicability for sustainable resource management.

The beach clam *Donax deltoides* supports significant fisheries throughout eastern and southern Australia, but in recent years there have been notable declines in population levels across its distribution, the causes of which have not been fully identified (Ferguson and Ward, 2014; Gray et al., 2014). In response to these declines and to appease social conflicts between commercial harvesters and other beach user groups, some east Australian beaches were zoned into fished and non-fished sections to commercial beach clam harvesting in 2010. Further to this, a six-month temporal closure to commercial harvesting was implemented across beaches in 2012 along with the introduction of a minimum shell length (SL) of 45 mm and a 40 kg per-day trip limit. Across all beaches, recreational and indigenous fishers are permitted to catch clams year round, but since 2010 they have not been permitted to remove clams from beaches due to toxin concerns and they can only be retained and used in-situ as bait. The presumed current total harvest from these two sectors is therefore considered low and may be <5% the total annual commercial harvest (Murray-Jones and Steffe, 2000). The harvesting of clams by all sectors is restricted to digging by hand. The impacts of these management arrangements on beach clams and in particular the potential value of the spatial closures to commercial fishing have not been assessed, and are the subject of investigation here.

The overall goal of this study was to evaluate the potential effects of within-beach spatial closures to commercial harvesting on beach clams. This was done by quantitatively sampling clams across two habitats in the commercially fished and non-fished zones on two beaches, before, early and late harvesting. This was done to specifically test the hypothesis that changes in the densities and size compositions of clams from before to during harvesting would differ between the commercially fished and non-fished zones on beaches. Because the potential impacts of commercial harvesting of clams may not be limited to just the fished zones on beaches but also the non-fished zones, two delineated zones across two non-commercially fished beaches were also sampled in the same way and acted as external controls, thus providing a before versus after, control versus impact (BACI) type assessment. The results are discussed in terms of management strategy evaluation and sandy beach ecology and conservation.

2. Methods

2.1. Experimental design and sampling

The two commercially fished study beaches were South Ballina (−28.95, 153.51; 30 km long) and Stockton (−32.80, 151.88; 32 km), with the northern 5 and 3 km of each beach, respectively, being closed to commercial fishing. The sampling of the commercially fished zone on each beach was limited to a 6 km section where commercial fishing effort is most concentrated, and immediately abutted the non-fished zone. A total of 6 commercial fishers reported harvesting clams on each beach throughout the study period. The two non-commercially fished control beaches were Sandon (−29.64, 153.32; 7.3 km) and Illaroo (−29.72, 153.30; 9.2 km) and each of these beaches was split into two zones (north and south) of similar size to simulate the management zoning of the commercially fished beaches. All beaches are characteristically fronted by bar and rip systems and exposed to a wide range of ocean conditions (Short, 2007).

Sampling of clams was stratified temporally across three distinct periods, before and during the six-month austral winter–spring (1 June to 30 November) commercial harvesting season for clams in 2013. This was 3 years after the spatial fishing closures, and 1 year after the six-month temporal fishing closure and the size and trip limit restrictions were implemented. The length of each sampling period and the interval between consecutive sampling periods was six weeks. The 'Before' sampling was in April/May when all beaches were totally closed to commercial clam harvesting, the 'Early' harvesting in July/August and 'Late' harvesting in October/November, with sampling beginning 6 and 18 weeks, respectively, after the commencement of the harvesting season. In each of these three periods, sampling was further stratified across two randomly selected days in each of three randomly selected weeks to account for short-term variability in clam densities (Gray, 2016).

Sampling was also stratified spatially across two habitats, the swash zone and the dry sand belt typically located 10–30 m above the swash zone at low tide. To account for small-scale spatial variability (Gray, 2016), on each sampling day, four locations in the swash zone and another four locations in the dry sand clam belt were selected at random within each commercially fished and non-fished zone on each commercially fished beach, and in each simulated zone on each control