

Herbivore abundance, site fidelity and grazing rates on temperate reefs inside and outside marine reserves



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ABSTRACT

A key objective of marine reserves is to maintain ecological processes important to the functioning of marine ecosystems. Grazing by tropical herbivores contributes to maintaining resilient coral reefs and marine reserves are critical in conserving herbivores and the functional role they provide. Less is known, however, about the effects of marine reserves on herbivorous fish and their role on temperate reefs. This study evaluated the potential for marine reserves to enhance grazing by herbivores on temperate reefs in Jervis Bay Marine Park, Australia. First, the movement patterns of a dominant grazer, luderick *Girella tricuspidata*, were determined using acoustic telemetry to assess the potential effects of marine reserves on *G. tricuspidata*. Second, the size and abundance of *G. tricuspidata* and other grazers (rock blackfish *Girella elevata* and silver drummer *Kyphosus sydneyanus*) was quantified on shallow subtidal reefs inside and outside marine reserves using a diver operated stereo-video system. Finally, grazing rates were quantified inside and outside marine reserves using video cameras. Luderick *G. tricuspidata* exhibited strong site fidelity on shallow subtidal reefs and was significantly larger and more abundant within marine reserves. Rock blackfish *G. elevata* was significantly more abundant in one of four marine reserves, although showed no difference in size between zones. Silver drummer *K. sydneyanus* was significantly larger in marine reserves, although not significantly more abundant. On shallow subtidal reefs, *G. tricuspidata* was the dominant grazer compared to other girellids and kyphosids, accounting for >97% of total algal bites (predominantly on algal turfs). Grazing rates were higher on average within marine reserves (although not significantly higher) and there was a positive correlation between the relative abundance of *G. tricuspidata* and number of algal bites, indicating grazing intensity increased with abundance. The findings in this study demonstrate the clear potential for greater grazing by herbivores within temperate marine reserves. This study also suggests that exploitation of targeted herbivores on temperate reefs is significant and marine reserves can reduce this impact and allow it to be measured via reference areas.

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1. Introduction

Marine reserves are used as a management tool to protect and conserve biodiversity and marine habitats against a range of human impacts including habitat degradation, climate change and overfishing (Ballantine, 2014). While generally not designed solely as a fisheries management tool, the establishment of marine reserves has resulted in significant increases in the size and abundance of targeted species (Roberts et al., 2001; Halpern, 2003; Lester et al., 2009; Edgar et al., 2014). These increases have led to complex changes to marine ecosystems within reserves as the strength of trophic interactions between species are affected,

providing insight into the ecosystem-wide effects of overfishing (Babcock et al., 1999; Edgar and Barrett, 1999; Shears and Babcock, 2003; Edgar et al., 2009). As a result, more research has focussed on the role of marine reserves in maintaining ecological processes essential to ecosystem integrity (Olds et al., 2012) and this is now widely included as key objective of marine park legislation (e.g. South Australian Marine Parks Act, 2007, New South Wales Marine Estate Act, 2014).

The establishment of marine reserves in both temperate and tropical systems has seen several striking examples of a reversal of the effects of overfishing on marine ecosystems. On coral reefs, herbivorous fish play a key ecological role grazing algae, which in turn promotes coral growth and recruitment and helps maintain reef resilience (Hughes et al., 2007). Declines in herbivore populations as a result of overfishing have contributed to phase shifts from coral-dominated reefs to degraded systems where macroalgae dominate (Hughes et al., 2003, 2010; Bellwood et al., 2004). Greater biomass of targeted herbivores and

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increased grazing within marine reserves, however, has been shown to lower macroalgal cover, potentially preventing phase shifts from coral- to algal-dominated systems (Mumby et al., 2006; Harborne et al., 2008; Rasher et al., 2013).

On temperate reefs sea urchins are considered to be the major grazers (Jones and Andrew, 1990) and intense grazing by high densities of sea urchins (due to overharvesting of sea urchin predators i.e. lobsters and predatory fish) has resulted in phase shifts from kelp forests to urchin barrens (Estes et al., 1998; Sala et al., 1998; Babcock et al., 1999; Shears and Babcock, 2002). Shears and Babcock (2003) demonstrated, however, that benthic communities within a New Zealand marine reserve shifted from being dominated by sea urchins and barrens habitat to being dominated by kelp forests, which was attributed to the recovery of populations of lobsters and predatory fish within the reserve.

Compared to coral reefs the ecological importance of fish herbivory on temperate reefs is more contentious. Few species are strictly herbivorous and fish herbivory is generally considered to have a minor impact on algal community structure (Jones and Andrew, 1990; Andrew, 1999), although an increasing number of studies are beginning to challenge this notion (Sala and Boudouresque, 1997; Ojeda and Munoz, 1999; Vergés et al., 2009; Taylor and Schiel, 2010; Bennett et al., 2015). For example, Bennett et al. (2015) showed that herbivores on temperate reefs had significant effects on algal communities and displayed feeding rates comparable to those on global coral reefs. Furthermore, the effects of herbivores on temperate reef algal communities are predicted to increase with the climate-driven range expansion of tropical herbivores onto temperate reefs as waters warm (Verges et al., 2014; Bennett et al., 2015).

On temperate reefs in Australasia species from the closely related families Girellidae and Kyphosidae can form a significant component of the total fish biomass and have been shown to be important grazers (Russell, 1977; Jones, 1988; Kingsford, 2002; Bennett et al., 2015). In south-eastern Australia, the three commonly occurring species are luderick *Girella tricuspidata* (Quoy and Gaimard, 1824), rock blackfish *Girella elevata* (Macleay, 1881) and silver drummer *Kyphosus sydneyanus* (Günther, 1886) (Hutchins and Swainston, 1999). The zebra fish *Girella zebra* (Richardson, 1846) also occurs in southern Australia, although it is relatively uncommon in New South Wales (NSW) (Hutchins and Swainston, 1999). These species are primarily herbivorous, feeding mainly on macroalgae (Russell, 1983; Choat and Clements, 1992; Clements and Choat, 1997; Moran and Clements, 2002; Raubenheimer et al., 2005), and are most abundant in shallow water (Kingsford, 2002). They are also exploited by commercial and recreational fishers in Australia and girellids are amongst the most targeted recreational species caught on reefs in NSW (Lincoln Smith et al., 1989; Kingsford et al., 1991; Kingsford, 2002). For example, *G. tricuspidata*'s current exploitation status in NSW is fully fished (WFRP, 2010a) and the combined commercial and recreational catch in NSW alone is between ~700 and 1000 t annually (Gray et al., 2012). Similarly, *G. elevata* is targeted by recreational fishers and there are concerns that stocks have been significantly depleted by overfishing, however, limited biological or fisheries data exist on which to base reliable assessments (WFRP, 2010b). Silver drummer *K. sydneyanus* is also targeted by fishers in NSW, although not as heavily as both *G. tricuspidata* and *G. elevata* (Kingsford, 2002). Girellids and kyphosids are therefore model species for which to assess the potential effects of fishing on their functional role as grazers on temperate reefs, due to their high level of exploitation. Furthermore, significant fishing effort (e.g. rock fishing, spearfishing and boat fishing) is concentrated in shallow subtidal areas (i.e. 1 to 3 m depth) where these species occur (Lincoln Smith et al., 1989; Kingsford et al., 1991; Smallwood et al., 2006) and any associated impacts would be predicted to be greatest, however, few studies have examined the effects of marine reserves in these areas (Coleman et al., 2013).

Understanding movement patterns is also key to assessing the potential effects of marine reserves on targeted species (Welsh and Bellwood, 2014). Marine reserves can only be effective if they include a significant

part of the home range of targeted species, during at least part of their life cycle (Kramer and Chapman, 1999). Often studies quantifying the size and abundance of targeted species inside and outside marine reserves are done without knowledge of movement patterns in relation to marine reserve design and vice versa. Luderick *G. tricuspidata* is considered to be highly mobile (Kingsford, 2002; Curley et al., 2013) and mark-recapture experiments carried out in NSW have shown that some tagged fish can move distances up to 450 km from their point of release (Thomson, 1959; Gray et al., 2012). It is for this reason that *G. tricuspidata* is considered unlikely to benefit from marine reserves (Kearney, 2007). Despite these relatively large movements, mark-recapture experiments have shown that the majority of tagged *G. tricuspidata* recaptured were caught within the same estuary in which they were released (Thomson, 1959; West, 1993; Gray et al., 2012), in some instances nearly two years later, indicating residency within those estuaries. Initial acoustic tracking data has also demonstrated *G. tricuspidata* exhibit strong site fidelity on shallow subtidal reefs over a three month period (Ferguson et al., 2013). Preliminary data on the movements of *G. elevata* and *K. sydneyanus* also indicates both species display residency on reefs (Stocks et al., 2014; Pillans et al., 2011). Species that exhibit strong site fidelity would be predicted to benefit (through greater size and abundance) from marine reserves which include all or part of their home range if exploitation levels are significant.

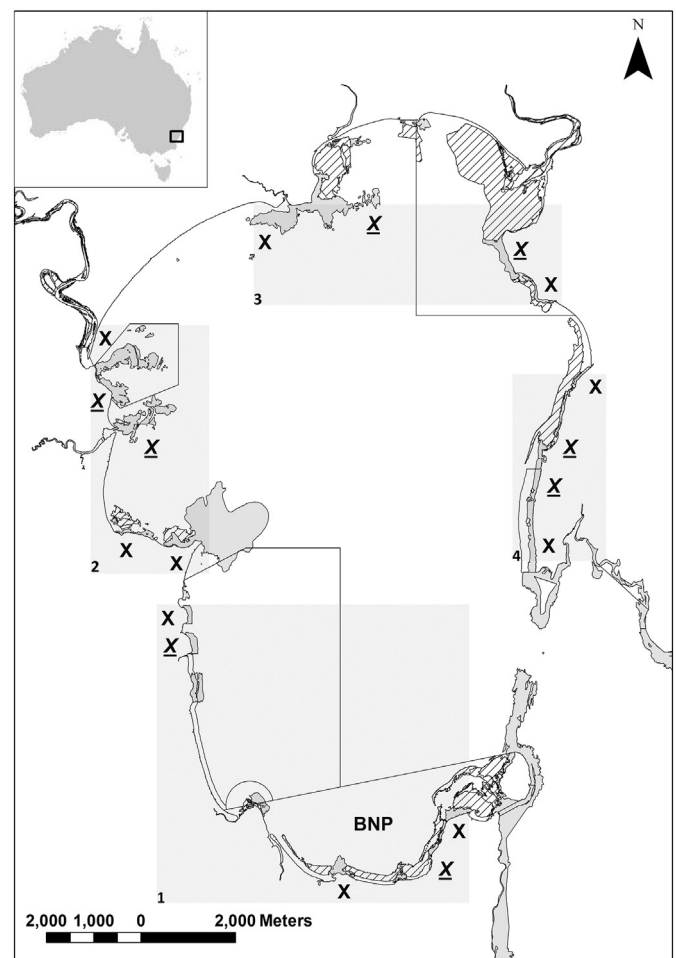


Fig. 1. Map of Jervis Bay, New South Wales, Australia, where the study was conducted. Boxed areas (with the exception of BNP) represent marine reserves. Fish surveys were carried out at a total of 18 sites inside and outside marine reserves (marked with an X). Feeding observations were carried out at a subset of 8 sites (marked with an X). Shaded transparent areas represent Blocks 1–4 (numbered) determined a priori and used in the analyses. Rocky reef (gray) and seagrass (hatch) habitats are shown. An inset map of Australia indicating the study area is also shown.

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