

RESEARCH NOTE

EFFECTS OF *PINNA* CLAMS ON BENTHIC MACROFAUNA AND THE
POSSIBLE IMPLICATIONS OF THEIR REMOVAL FROM SEAGRASS
ECOSYSTEMS

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Seagrasses are widely distributed throughout the world's oceans and are among the most productive and economically important of all 'ecosystem engineers'. They provide habitat structure to coastlines that would otherwise consist of bare sand, and deliver many important ecosystem services, such as shoreline stabilization (Bos *et al.*, 2007), nutrient cycling (worth US\$19,000 ha⁻¹ year⁻¹; Costanza *et al.*, 1997), habitat provision (for fish, bird and invertebrate species; Heck, Hays & Orth, 2003; Hughes *et al.*, 2009) and carbon sequestration (Macreadie *et al.*, 2013; McLeod *et al.*, 2011). Within seagrass ecosystems, there are also other organisms that provide different habitat structure, but there have been few empirical tests of whether these additional habitat-providing organisms are effectively redundant because of the habitat provided by the seagrass, or whether they provide unique and ecologically-significant ecosystem services not offered by seagrasses.

Pinna clams—also known as 'razor clams', 'razor fish', 'razor shells' and 'pen shells' (Fig. 1A)—are habitat-forming bivalves that occur within seagrass meadows in many of the world's oceans. In Lake Macquarie (New South Wales), Australia's largest coastal lake, local residents and recreational users of the Lake have called for eradication of *Pinna* clams from seagrass meadows, because of the hazard they pose to swimmers. Their broad posterior margins are razor-sharp—hence the name 'razor'—and, throughout the summer, a considerable number of swimmers require hospitalization after standing on the clams'. Although *Pinna* clams have always resided within the Lake, there have been anecdotal reports of a 'population boom'. The Lake Macquarie City Council is therefore considering a *Pinna* clam removal programme, which would see the clams physically removed from popular swimming areas.

The species of *Pinna* clam residing within Lake Macquarie remains uncertain at the time of this publication. Previous studies on *Pinna* clams within the Lake (e.g. Burns & Smith, 2011), and elsewhere around Australia (e.g. Butler, 1987; Beer & Southgate, 2006), have referred to the clam as *Pinna bicolor* based on Rosewater (1961), who suggested that the species had a wide Indo-Pacific distribution. However, a recent worldwide revision of the family Pinnidae (Schultz & Huber, 2013)

suggests that *P. bicolor* is actually limited to the Indian Ocean and that the species located within Lake Macquarie is likely to be *P. madida*, although further confirmation of this classification is needed. We therefore refer to *Pinna* clams within Lake Macquarie as *Pinna* sp.

The goal of this study was to assess the potential importance of *Pinna* sp. in Lake Macquarie for the seagrass community (i.e. benthic macrofauna) and/or the seagrass itself. Our primary interest was whether removal of *Pinna* sp. is likely to negatively impact the seagrass ecosystem within which they live, i.e. would eradication of *Pinna* sp. from seagrass meadows within the Lake have a major impact on the seagrass community? To address this question, we performed a series of surveys and manipulative experiments, the details of which can be found in the Supplementary Material. In brief, these involved: (1) a survey of site-to-site variability in *Pinna* sp. densities and sizes; (2) a survey of organic matter content and infaunal macroinvertebrates associated with natural *Pinna* sp. populations compared with seagrass and bare sand; and (3) a manipulative experiment to parse out the relative importance of *Pinna* sp. clams versus seagrass in providing habitat for benthic macrofauna. In the context of our results, as well as other published work, we then consider the implications of *Pinna* sp. removals on the future viability of the *Pinna* sp. populations within the Lake, keeping in mind that *Pinna* sp. clams are long-lived (up to 18 years) and make relatively limited investment towards reproduction (Butler, 1987; Butler, Vicente & de Gaulejac, 1993).

In our lake-wide assessment at 10 different sites (Fig. 2), we found that *Pinna* sp. densities varied from 0 to 1.93 individuals m⁻², with a mean of 0.44 ± 0.25 (SE) individuals m⁻² (Supplementary Material, Table S1). At the highest *Pinna* sp. density site, Point Wolstoncroft, most (92%) of *Pinna* sp. individuals were in the 126–250 mm size range (Supplementary Material, Table S1), which corresponds with an age class of c. 7–24 months (Idris *et al.*, 2012).

In a follow-up survey of Point Wolstoncroft, we found no association between *Pinna* sp. presence and infaunal abundance ($F_{1,16} = 1.39$, $P = 0.25$; Fig. 3B) or richness ($F_{1,16} = 0.16$, $P =$

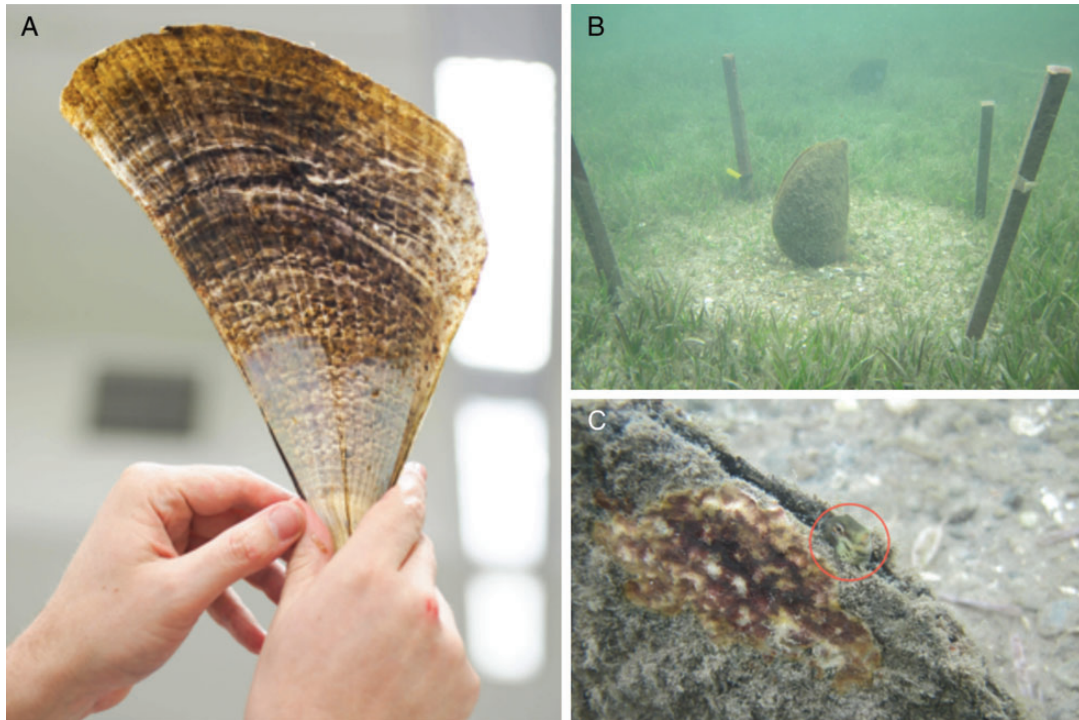


Figure 1. **A.** One valve (inside view) of a cleaned *Pinna* sp. shell taken from Lake Macquarie (NSW, Australia). **B.** An experimental plot showing a transplanted *Pinna* sp. with surrounding seagrass removed. **C.** A goby (*Parablennius intermedius*) peering out of a nonliving *Pinna* sp. shell.

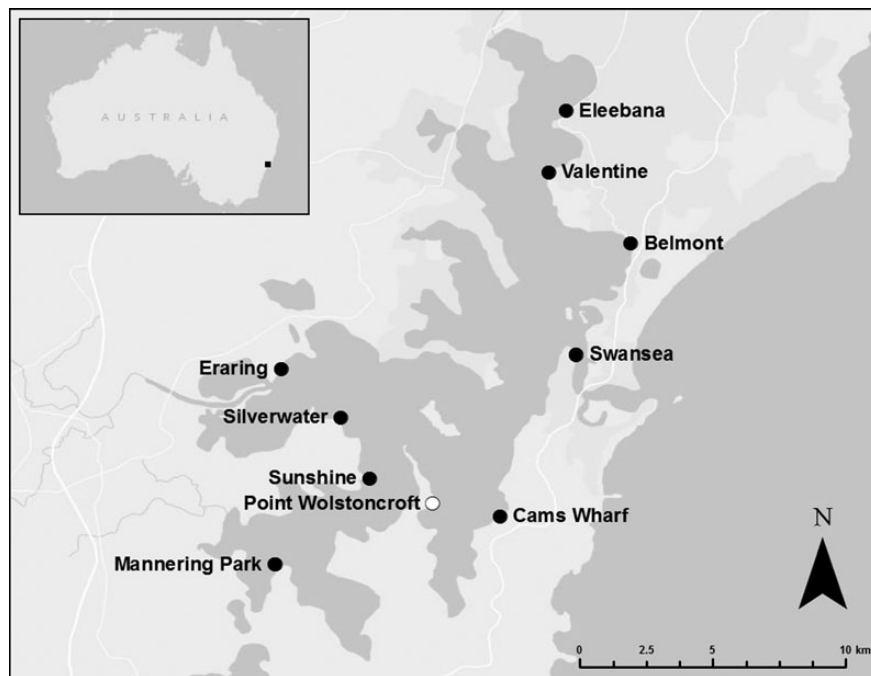


Figure 2. Diagram of study site showing the 10 locations where *Pinna* sp. populations were surveyed (density and length). Point Wolstoncroft was also used for the manipulative experiment.

0.69; Fig. 3A). Whereas there were marginal effects of seagrass presence on the number of infaunal taxa (seagrass $F_{1,16} = 4.00$, $P = 0.06$), the number of infauna was higher in the presence of

seagrass than in its absence (Fig. 3A). The total abundance of infaunal individuals was also higher in the presence of seagrass ($F_{1,16} = 6.38$, $P = 0.02$; Fig. 3B). There were no interactions

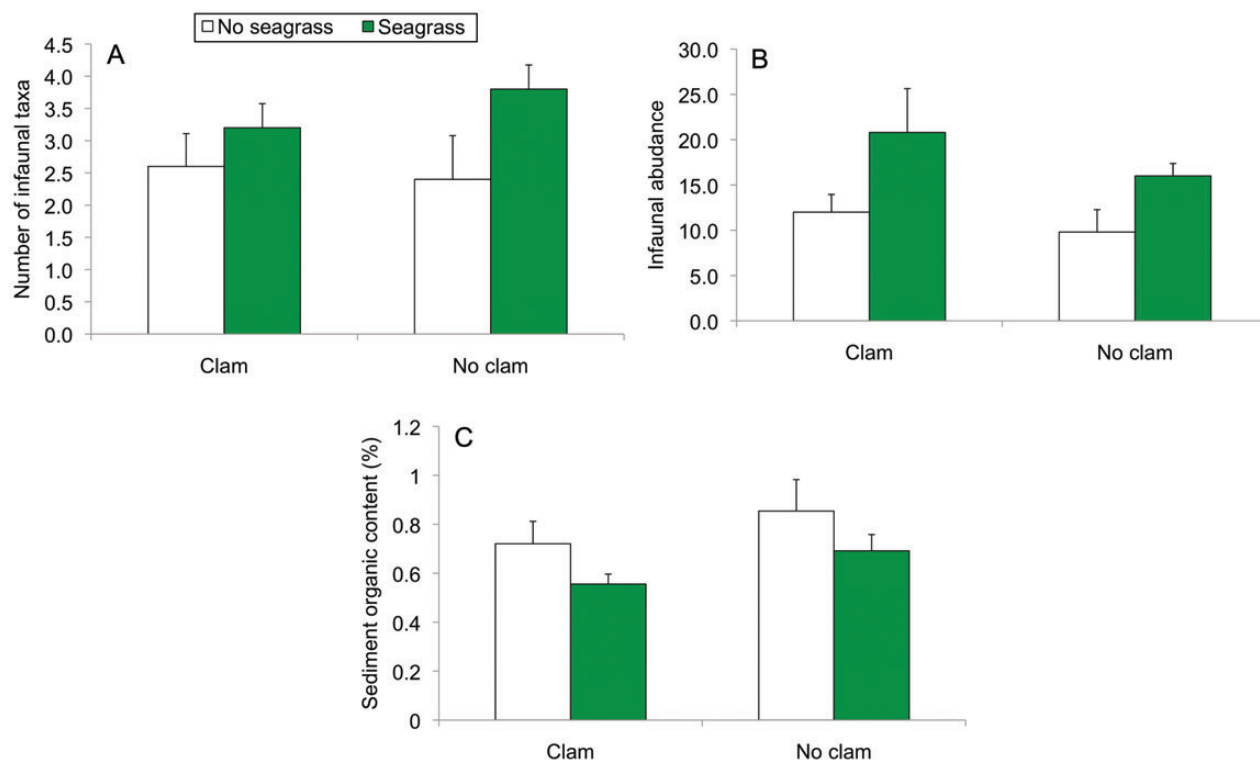


Figure 3. Survey data showing: the number of infaunal taxa (A), the abundance of infauna (B) and the percentage sediment organic content (C) in sediment cores taken from natural assemblages with seagrass and *Pinna* present, seagrass present with no *Pinna*, no seagrass with *Pinna* present, and no seagrass or *Pinna* present.

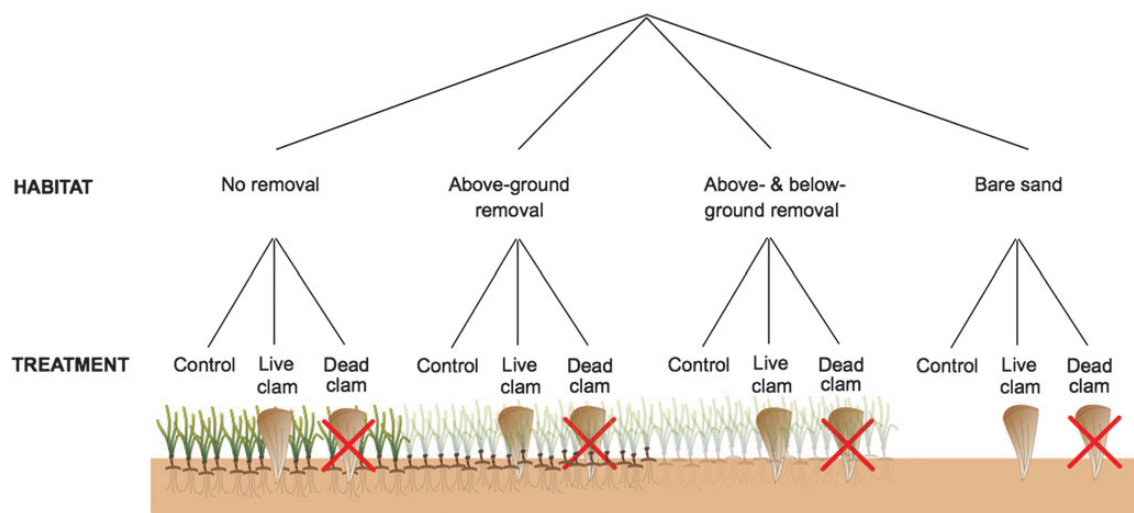


Figure 4. Experimental design showing the four habitat types (no removal of seagrass; above-ground seagrass removal; above- and below-ground removal of seagrass; and bare sand), each was containing three treatments (controls—i.e. no clam; live clam and dead clam—i.e. empty shell) within a plot that was 1 × 1 m. There were five replicates ($n = 5$) of each treatment, which were sampled through time.

between *Pinna* sp. presence and seagrass presence. Both seagrass presence ($F_{1,16} = 3.43$, $P = 0.08$) and *Pinna* sp. presence ($F_{1,16} = 2.34$, $P = 0.14$) had marginal effects on sediment organic content in natural assemblages (Fig. 3C). Organic content was lower in the presence of seagrass than in bare sediments and was also slightly lower in the presence of *Pinna* sp. than in its absence (Fig. 3C).

At this same site, we conducted a manipulative, fully-crossed factorial experiment (Fig. 4), whereby we manipulated the presence and absence of *Pinna* sp. and seagrass cover (no removal, above-ground cover removal, total removal) and monitored the response (via changes in abundance and species richness) of benthic macro invertebrates and fish (assessed via visual census) at three points in time (after 1 week, 2 months and 5 months).

Pinna sp. treatment did not have independent or interactive effects on the abundance of associated species (Fig. 5B). Of the 16 fish species observed, the horned blenny (*Parablennius intermedius*) was the only species found to be affected by *Pinna* sp. treatment; this species was found to be significantly more abundant in dead clam shells ($F_{2,144} = 6.26$; $P < 0.001$; Fig. 1C), regardless of the habitat type in which these shells were situated. Similarly, Munguia (2007) found that dead pen shells (*Atrina rigida*) provide shelter for egg-laying fishes that did not appear to be offered by the surrounding seagrass.

Seagrass cover was highest in the no-removal treatments, intermediate in the above-ground-removal treatments and lowest in the complete-removal treatments (seagrass treatment $F_{2,108} = 233.82$, $P < 0.001$; Fig. 5A). The number of associated benthic macroinvertebrate species varied by sampling date when all treatments were pooled ($F_{3,144} = 3.06$, $P = 0.03$; Fig. 6), but there was no effect of seagrass treatment ($F_{2,144} = 1.99$, $P = 0.14$) or *Pinna* sp. treatment when sampling times were pooled ($F_{2,144} = 2.15$, $P = 0.12$). The total abundance of

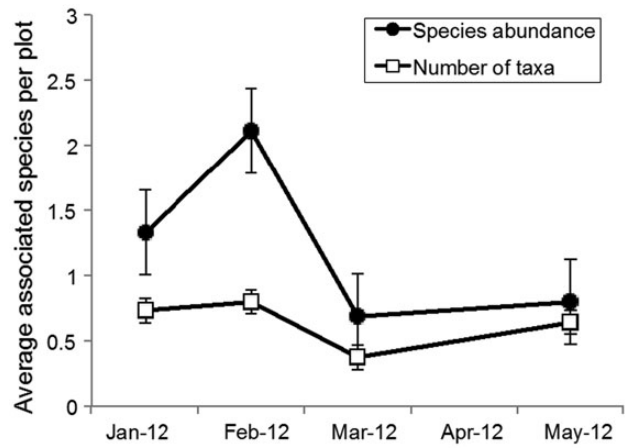


Figure 6. Average abundance and number of taxa at each sampling time.

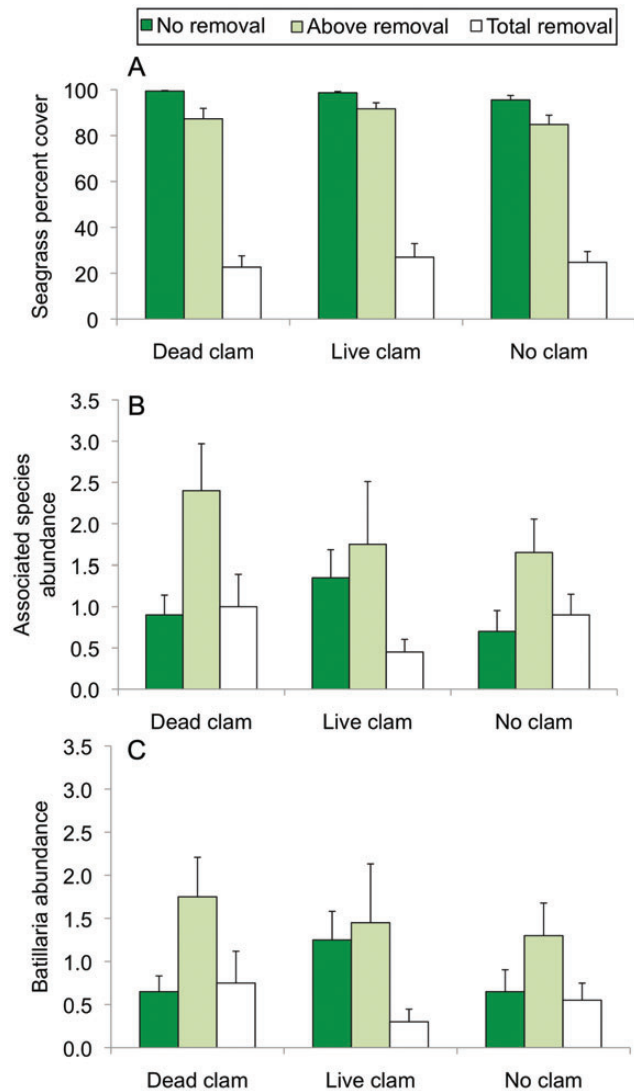


Figure 5. The effects of seagrass removal (no removal vs above-ground removal vs above- and below-ground removal) and *Pinna* treatment (live *Pinna*, dead *Pinna*, or no *Pinna*) on seagrass percent cover (A), associated species abundance (B) and *Batillaria australis* abundance (C).

associated benthic macroinvertebrate species (monitored via visual censuses, see Supplementary Material) in our experimental plots also varied by sampling date ($F_{3,144} = 5.89$, $P < 0.001$; Fig. 6). In addition, there was a significant effect of seagrass treatment ($F_{2,144} = 7.04$, $P = 0.001$; Fig. 5B), with highest abundances in the above-ground removal treatment, regardless of *Pinna* treatment (Fig. 5B). This effect was largely due to the response of the common gastropod species, *Batillaria australis* (seagrass treatment $F_{2,144} = 5.87$, $P = 0.003$) which had greatest abundance in the seagrass above-ground removal treatment (Fig. 5C).

Overall, this study suggests there are very small effects of *Pinna* sp. on local associated fauna that are not offered by seagrass meadows alone. The only substantial effect observed was that the presence of dead *Pinna* sp. shells significantly increased the abundance of horned blennies. This demonstrates, from an ecological point of view, that *Pinna* sp. clams are not functionally redundant in terms of facilitating biodiversity when seagrass is present. However, is the positive effect that these clams have on a single, nonthreatened fish species enough to outweigh proposed council actions to remove razor clams from popular swimming areas? This is a complex issue. With regards to the possible impacts on associated fauna, it is our opinion that removal of razor clams is unlikely to lead to any major impacts on horned blenny populations within Lake Macquarie. We should also point out that *Pinna* sp. probably support epiphytic communities (which we did not quantify) not found within seagrass (Munguia, 2007; Munguia & Miller, 2008).

That said, the main concern of removals could be the impacts on *Pinna* sp. populations themselves. *Pinna* sp. occur as metapopulations, with irregular dispersal (Burns & Smith, 2011). After settlement, growth of *Pinna* sp. recruits is rapid; they reach *c.* 260 mm in length during the first 2 years, which corresponds with the time of highest predation risk, and then grow about 35 mm per year thereafter (Butler & Brewster, 1979). This life-history strategy makes *Pinna* sp. dependent on the 'storage effect', whereby maintenance of populations is 'stored' in the adult population as a result of their long adult life (Butler *et al.*, 1993). This means that populations are only stable if the longevity of adult populations is maintained, and that increases in adult mortality can cause localized population collapses (Katsanevakis, 2009). Localized removal of *Pinna* sp. could have serious detrimental consequences for persistence of the species within Lake Macquarie, especially given that their abundance was found to be highly variable among sites within the Lake.

Further work is needed to identify possible 'source' and 'sink' populations, which could be achieved through analysis of the genetic structure of populations, combined with hydrodynamic modelling to assess connectivity among populations.

SUPPLEMENTARY MATERIAL

Supplementary Material is available at *Journal of Molluscan Studies*.

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