Sydney Harbour

A systematic review of the science 2014

Sydney Institute of Marine Science Technical Report

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Cover Photo | Mike Banert *North Head*
The light was changing every minute. I climbed over some huge rocks to get into a great position to take some surfing shots, when suddenly this huge cloud covered up the sun. Suddenly the beautiful light illuminating the waves the surfers were riding was gone. I looked to my left and noticed the light here. Quickly, I grabbed my stuff and setup this shot … only got one frame, because soon after this the light here was also gone.

Design: Luke Hedge and Marian Kyte

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within the bed. Experiments in Sydney Harbour have shown that this leads to a decrease in abundances of encrusting algae, sponges and colonial ascidians and an increase in covers of turfing algae (Kennelly, 1987). Another important process shaping kelp forests is grazing (Dayton, 1985; Steneck et al.,2002). Grazing by fish influenced covers of some understory species in *Ecklonia* beds in the Harbour (Kennelly, 1991). Conversely, herbivory by mesograzers in the kelp beds of Sydney Harbour do not seem to affect their host *Sargassum* sp. (Poore et. al., 2009).

Knowledge Gaps

There are obvious differences in physical properties between estuarine and coastal systems (e.g. salinity, wave-exposure, nutrient loading). Despite this, no studies have determined whether these differences influence ecological patterns and processes in subtidal reef habitats in the harbour compared to those on the open coast or nearby estuaries such as Botany Bay. This is important, as the same types of subtidal reef habitats; kelp beds, turfs and barrens, occur in the harbour and on the open coast. There is still little understanding on whether these habitats support similar species and whether the processes that influence them are similar.

In contrast to kelp beds, urchin barrens in Sydney Harbour have not been studied. This is despite them being the second most abundant habitat type within subtidal reef environs. On the open coast, barrens are generally dominated by the sea-urchin *Centrostephanus* spp., the turbinid snails *Turbo turquatus* and *Astralium tentoriiforme* and several species of limpets, such as *Patelloida alticostata*, *P. mufria* and *Cellana tramoserica* (Fletcher, 1987; Underwood et al., 1991; Underwood and Kennelly, 1990). Grazing of the substratum by urchins and limpets keep covers of foliose algae low (< 10 %) and dominated by encrusting coralline algae (> 80 %) (Fletcher, 1987; Andrew and Underwood 1989; Andrew 1993).

Rocky Intertidal Shores

Sydney Harbour's natural shoreline is dominated by horizontal, or gently sloping sandstone platforms. Natural intertidal shores, however, are rare and fragmented. Breakwalls and other artificial surfaces cover around 50 % of the harbour shoreline.

Approx. 127 taxa are dispersed along the rocky shoreline.

Lower shorelines are dominated by foliose algae and tubiculous polychaetes.

Sydney Rock Oysters *Saccostrea glomerata* dominate the mid-shoreline, with barnacles, limpets and encrusting algae species.

Most studies on rocky shores have compared natural reef to artificial structures. Little consideration has been given to differences between estuaries, or between Sydney Harbour and the outer coast.

right: The ubiquitous gastropod snail *Austrocochlea porcata* (Adams, 1851) can be found on many rock platforms in Sydney Harbour. The ecology of the species has been heavily investigated by Sydney based scientists since the early 1980's.

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above: The islands of Sydney Harbour are dominated by intertidal rocky reefs. Clark Island, below, is the site of early biological exploration, and students from the University of New South Wales still visit the island to study the ecology of rocky shores.

General Introduction and Context

Rocky shores lie between the low and high water marks that fringe entire countries, coasts and estuaries (Menge and Branch, 2001). The importance of these areas for the advancement of conceptual and experimental ecology cannot be overstated. This has occurred because the animals that live in this habitat, the ambient environmental conditions, and the habitat itself can be easily accessed and manipulated. Key theories regarding predation (Underwood and Jernakoff, 1981), disturbance and competition (Menge, 1976; Menge and Sutherland, 1987) and recruitment (Caffey, 1985), among many others, have all been explored on the rocky shore found between the low and high water mark, especially around Cape Banks in Botany Bay (Underwood and Chapman, 2007). Many of the methods and statistical techniques developed in this system have now been adapted to other systems throughout the world (Underwood and Chapman, 2007).

The community composition on the rocky shoreline is determined by a combination of biotic and abiotic factors. Wave exposure, for example, can vary dramatically at sites along a coastline, within an estuary or even within a small embayment. Wave exposure is often greatest at the tips of headlands, with energy levels far greater than what you would find in sheltered bays This distribution in wave energy can dramatically alter the invertebrate communities in these areas (Menge and Branch, 2001). It is, however, the vertical zonation of animals up a shoreline that is most noticeable in this environment. Colman's (1933) seminal work on the British coast at the beginning of last century, led many ecologists to believe that animals in this system simply 'clumped' according the amount of time they were emerged from water. This early work analysed emersion times down a rocky shore in the intertidal zone and correlated this zonation with species abundance and composition. These beliefs were a dominant paradigm up until the 1970's. It was not until Underwood (1978) refuted the work of Colman (1933) that cracks in this long-standing belief in 'zonation' appeared. Using more robust statistical techniques, Underwood (1978) showed species do not clump according to emersion times on British shores and hence showed no evidence for intertidal zonation. The very noticeable differences in assemblages vertically up a shoreline *can* be non-random, more accurately, are generally driven by a combination of biotic and abiotic functions that vary over scales from 10s of m to hundreds of km.

The factors that promote species abundance patterns on rocky shores are varied and differ in both space and time. Grazing, for instance, can remove early stages of development of macro-algae, which can create space used for settlement by sessile species (Underwood et al.,1983). Similarly, competition is one of the major factors controlling the abundance and distribution of intertidal-dwelling gastropods. Intra- and inter-specific interactions are responsible for the co-existence of the limpets *Cellana tramoserica* and *Siphonaria denticulata* at mid-tidal levels on the NSW rocky shores (Creese and Underwood, 1982). Although *C. tramoserica* is competitively superior, it is unable to exclude the siphonarian limpets from an area of the shore due to strong intra-specific competition (Creese and Underwood, 1982). Other species of grazing gastropods also inhabit the same areas and compete for similar resources, leading to complex interactions (Underwood, 1978).

Rocky Shores in Sydney Harbour

In Sydney Harbour, intertidal shores are usually horizontal and/or gently-sloped sandstone platforms (Bulleri et al., 2005; Cole et al., 2007; Cole, 2009), which are very similar to most shores in NSW. They have relatively little exposure to waves and have a tidal range of about 1.5 m (Cole, 2009). There are, however, some fully vertical natural rocky shores about 15–20 m long (e.g. Chapman, 2003; Bulleri, 2005; Bulleri et al., 2005). Similarly, intertidal boulder fields, although not particularly common in Sydney Harbour, support a great diversity of organisms living on or under the boulders (Chapman, 2002, 2003).

Chapman (2003), in a comprehensive study of sea-walls and natural shores in Sydney Harbour, found a total of 127 taxa dispersed along the shoreline. There was great spatial variability in the diversity of species at the different heights of the shore and from place to place, which is consistent with other studies done on sheltered and wave-exposed shores on the open coast (Chapman and Underwood, 1998). The low part of the shores in Sydney Harbour can be characterised by large covers of foliose algae, the tubiculous polychaete *Galeolaria gemineoa* and/or the ascidian *Pyura praeputialis*, while the mid-shore assemblages are generally dominated by the presence of the Sydney Rock Oyster *Saccostrea glomerata*, limpets, barnacles and encrusting algae (Chapman, 2003; Goodsell, 2009). For a list of the many species found on natural shores in the harbour, see Bulleri (2005). Many of the species listed above form important biogenic habitats such as oyster, worm or algal beds (Coleman, 2002; Cole et al., 2007; Cole, 2009; Matias et al., 2010). The distribution of these habitat-forming organisms on intertidal shores in Sydney is naturally patchy, forming mosaics on and around the shoreline (Cole et al., 2007). Such habitats support a great diversity of additional organisms (Bruno and Bertness, 2001).

Naturally occurring rocky shores in Sydney Harbour are, however, extremely fragmented (Goodsell et al. 2007, Goodsell 2009), with most of the natural coast replaced by sea-walls (see Habitat Modification). This may be one of the reasons few studies have been done on intertidal shores in the Harbour. These studies are needed to understand the ecological processes occurring on these systems and, consequently, determine and manage possible impacts on these shores.

Knowledge Gaps

Although rocky intertidal assemblages in NSW and the processes occurring in these systems have been extensively studied throughout the years (Rocky shores- General Introduction and Context), very little is known about these systems inside Sydney Harbour. Much like subtidal reefs, the processes that act on these communities on the open coast may differ greatly than those that are experienced by estuarine rocky shore communities.

The great majority of research articles on Sydney Harbour compared assemblages on natural shores to those on adjacent seawalls (Chapman and Bulleri, 2003; Chapman, 2003; Bulleri et al., 2004, 2005) or studied the effects of the fragmentation caused by these interspersed artificial structures on natural shores (Goodsell et al., 2007; Goodsell, 2009). A few studies have also assessed the effects of matrix and/or complexity of foundation species on communities, using artificial structures such as pot scourers (Cole et al., 2007; Cole, 2009) and artificial grass (Matias et al., 2010) placed on natural shores. These studies are further discussed in the Habitat Modification section of this report. Only one study evaluated the distribution and abundance of algae on an intertidal natural shore in Sydney Harbour (Coleman, 2002). Although sampling was done inside and outside of the Harbour, results showed that most of the variability in the composition of algal turfs occurred at the smallest spatial scale with little differences between the estuary and open coast (Coleman, 2002). Despite significant research on the effects of artificial structures in the Sydney Harbour (see also Habitat Modification), further studies on ecological patterns and processes on natural shores in the Harbour are necessary to (i) identify whether these are the same occurring in similar shores in NSW and, if not, (ii) what are the processes influencing these differences. This basic science is necessary to prevent and/or manage further impacts that these habitats.