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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The Natural Environments of Sydney Harbour

Subtidal Rocky Reef

One study that mapped 1.58 km^2 of reef along the north head shoreline found that the reef comprised of macroalgae (37 %), urchin barren (18 %), and a mixture of barrens and algae (25 %).

Most other research focused on *Sargassum* and *Ecklonia* spp. and associated epifauna.

Small scale processes (10 cm's) rather than larger scale processes, seem to determine patterns of turfing algae and associated epifauna in Sydney Harbour.

Natural disturbances, such as storms, swell, and grazing by herbivores can affect kelp abundances and associated diversity.

We have no knowledge of the dynamics of urchin barrens in Sydney Harbour, nor how differences between coastal and estuarine conditions can affect Sydney Harbour's biota.

General Introduction and Context

We use the definition of subtidal reefs put forward by Witman and Dayton (2001), that is "any benthic habitat composed of hard substrate from the intertidal / subtidal fringe down to the upper limit of the deep sea". Importantly for Sydney Harbour, this definition includes cobble and boulder fields as well as solid rock walls (artificial as well as natural).

Subtidal rocky reefs are some of the most diverse and productive environments in the world (Dayton, 1985; Schiel and Foster, 1986; Steneck et al., 2002). This diversity mainly stems from the dense kelp beds that have come to define these systems (Mann, 1973; Schiel and Foster, 1986; Steneck et al., 2002). Unlike the well studied giant kelp forests in western USA, the dominant form of kelp in eastern Australian coastal waters is the much smaller *Ecklonia radiata* (Connell, 2007). Along the east coast of Australia, the shallowest areas of subtidal reefs are dominated by fringe habitat, composed of patchy *Ecklonia*, fucoids (e.g. *Sargassum* spp.), dictyotalean algae (e.g. *Zonaria* spp.) and geniculate corallines (e.g. *Amphiroa* spp. and *Corallina* spp.) (Underwood et al., 1991). There is, however, large temporal and spatial variability in macrophyte distribution and abundance. Similar areas in other places, particularly south of NSW, are often dominated by the fucoid *Phyllospora comosa*, with the exception of open-coast reefs surrounding Sydney Harbour where this alga appears locally extirpated (Coleman et al., 2008). These habitats support large numbers of the sea-urchins *Heliocidaris erythrogramma* and *Centrostephanus rodgersii* and turbinid snails. In addition, *Ecklonia* provides habitat to many mobile and sessile epibiota. For instance, the canopy-dwelling sea-urchin *Holopneustes purpurascens* inhabits the thalli of *Ecklonia* spp. (Steinberg, 1995; Marzinelli et al., 2011) and the surfaces of kelp fronds often are colonised by filamentous algae, bryozoans and hydroids (Fletcher and Day, 1983; Marzinelli et al., 2009, 2012). *Sargassum* spp. beds also support diverse assemblages of organisms, particularly isopods and amphipods

left: Subtidal rocky reefs in Sydney Harbour are dominated by sea urchins that create 'barrens' of bare rock. We have little data on the role of these barrens in the natural ecology of the harbour, or whether the abundance of these barrens has changed through time.

top right: Subtidal rocky reefs are some the most diverse environments in the harbour. In this photo the solitary ascidian *Herdmania momus* can be seen growing amongst the algae *Dilophus* sp.

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(Poore and Lowry, 1997; Poore and Hill, 2005). Beds of the ascidian *Pyura* spp. may also dominate the shallowest areas, supporting several species of snails and chitons (Underwood et al., 1991). Although some habitats (e.g. fringe) appear to follow a depth gradient, the two main types of reef habitats < 25 m deep in the harbour, i.e. kelp beds and barrens, do not seem to be related to depth (Underwood et al., 1991). It is only at much deeper depths (> 25 m) where kelp abundance decreases and other taxa such as sponges start to dominate (Underwood and Kennelly, 1990).

The slope of the underlying bedrock can strongly influence community composition. The kelp communities discussed above often dominate horizontal substrates. However, vertical areas, such as rock walls, have higher abundances of sessile epifaunal invertebrates (Witman and Dayton, 2001). Even within invertebrate communities there are strong differences between assemblages on vertical and horizontal substrates. On the east coast of Australia, barnacles (such as *Amphibalanus variegatus*) and serpulid worms (including *Hydroides elegans* and *Pomatocerus taeniata*) dominate on horizontal surfaces, while abundances of spirorbid worms increase on vertical surfaces (Glasby and Connell, 2001). The angle of underlying rocky reef substrata therefore plays an extremely important role in structuring the epibiota that grows on it. The structural differences between communities on horizontal and vertical surfaces is one of the most noticeable differences in this habitat worldwide (Witman and Dayton, 2001).

Subtidal Reef in Sydney Harbour

Only one study has quantified the abundance of reef habitat within Sydney Harbour. Creese et al. (2009) mapped approximately 1.58 km^2 of reef in Middle Harbour. These reefs are dominated by macroalgae / kelp (37 %), barrens (18 %) or a mix of macroalgae and barrens (25 %). Turfs and sessile invertebrates are less dominant (58 %). The types of reef habitats within the Harbour are similar to those found on the open coast of NSW (Underwood et al 1991).

Most of the research on natural subtidal reefs in the Harbour has focused on habitat-forming macroalgae, particularly *Ecklonia* and *Sargassum*

spp., and/or the organisms they support. Despite the occurrence of macroalgal dominated reefs in the Inner Harbour (King and Farrant, 1987), most studies have been done in Middle Harbour, near the entrance to the estuary (Table 1).

In these reefs, beds of *Ecklonia* spp. support very diverse assemblages of green (e.g. *Enteromorpha* sp., *Codium* sp.), brown (e.g. *Zonaria* spp., *Dyctyota* spp.) and red understory algae (e.g. *Amphiroa* spp., *Delisea* spp.), invertebrates such as sponges (e.g. *Myxilla* spp.), bryozoans (e.g. *Watersipora* spp.), cnidarians (e.g. *Sertularia* spp.), annelids (e.g. syllid polychaetes), echinoderms (e.g. *Centrostephanus* and *Heliocidaris* spp.), molluscs (e.g. *Turbo torquatus*), crustaceans (e.g. barnacles and crabs), and chordates such as ascidians (e.g. *Didemnum* spp.) and fish (e.g. luderick *Girella tricuspidata*, kelp fish *Chironemus marmoratus*) (see Kennelly,1987; Connell and Glasby, 1999; Glasby, 1999; Clynick et al., 2008, for a list of species found in these communities in Sydney Harbour). Of 586 species of fish recorded in Sydney Harbour, over 60 % inhabit subtidal reefs (Booth 2010) highlighting the importance of rocky reefs for fish diversity in the Harbour.

Few studies have focused on subtidal reef habitat forming species other than kelp in the Harbour. Communities of turfing algae varied in composition and relative abundances at very small spatial scales (10's of centimetres), suggesting that small scale processes influence patterns of distribution and abundance of these subtidal turfs in the estuary (Coleman 2002). These results are consistent through time, suggesting that larger scale processes may not have discernible effects on Sydney's turfing algae (Coleman, 2002). There are also several deep-water reefs (> 20 m) in the Harbour, supporting very diverse assemblages of sponges, as well as ascidians, bryozoans and cnidarians (Roberts et al., 2006).

In Sydney Harbour, several studies have gone beyond establishing ecological patterns to determine key processes acting on subtidal reef communities. Natural disturbances, such as storms, are generally seen as a strong structuring force in these kelp communities (Dayton,1985). In the Harbour, natural disturbances influence the composition and relative abundance of understory assemblages in Ecklonia beds (Kennelly, 1987a.b). Storms can dislodge the kelp creating clearings

Table 1. Ecological studies published on the extensive Kelp beds that can be found throughout the entire Sydney Harbour estuary. The kelp species that dominate the sub-tidal rocky reefs in Sydney Harbour are more well studied than most other systems.

Locations	Research topic	References
Balmoral, Taronga Zoo, Mrs Macquaries point and Drummoyne	Patterns of abundance of understory algae	Farrant and King (1982)
Fairlight	Colonization of understory species	Kennelly (1983), Kennelly and Larkum (1983)
Fairlight	Patterns of abundance of understory species	Kennelly and Underwood (1984, 1985, 1992)
Fairlight	Growth and primary productivity of kelp	Larkum (1986)
Fairlight	Patterns of abundance and reproduction of understory algae	King and Farrant (1987)
Fairlight	Effect of physical disturbance on understory species	Kennelly (1987, 1987b and 1989), Kennelly and Underwood (1993)
Fairlight	Effect of turfing algae on kelp recruitment	Kennelly (1987c)
Fairlight	Effect of fish predation on understory species	Kennelly (1991)
Nielsen Park	Chemical defences and other factors influencing epiphytes on kelp	Jennings and Steinberg (1994 and 1997)
Dobroyd Head, Grotto point and Middle Head	Cover of subtidal habitats	Creese et al. (2009)
Chowder Bay, Balmoral Beach and Quarantine Station	Effects of man-made structures on ecological patterns and processes of kelp epibiota	Marzinelli (2012), Marzinelli et al. (2009), Marzinelli et al. (2011 and 2012)
Watsons Bay, Balmoral, Little Manly, Cobblers Beach, Nielsen Park, Obelisk Bay	Effects of storm-water runo on mobile epibiota on kelp	Ghedini et al. (2011)

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.

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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.