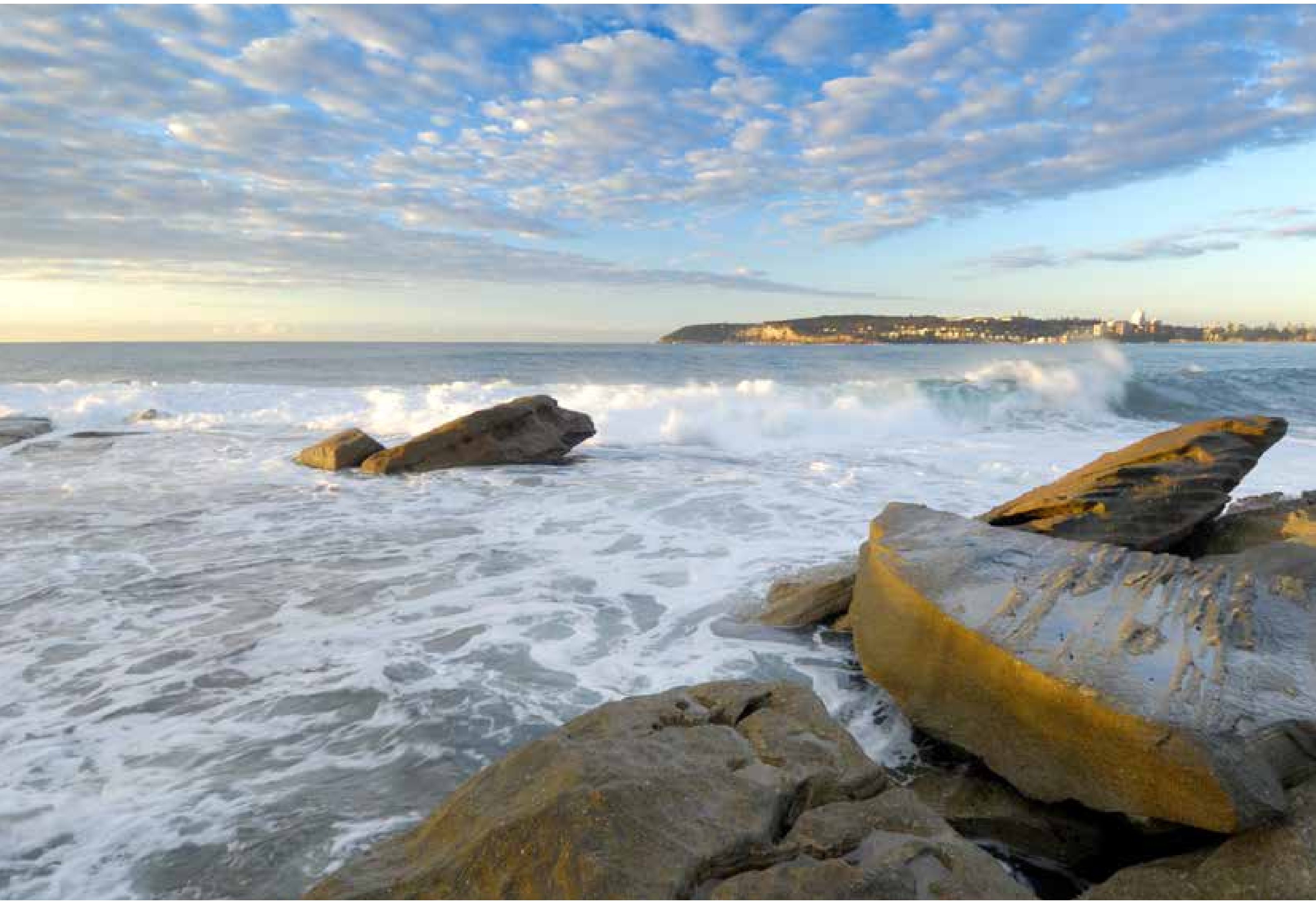
Sydney Harbour

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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Seagrass cover in the estuary was around 59.2 ha in 1978. In 1986 this had grown to 87.4 ha, before being reduced to an estimated 49.5 ha in 2003. Seagrass persistence in certain areas of the harbour are variable. Seagrass meadows around Rose Bay and Middle Harbour, for example, show dramatic changes in the extent of seagrass (West and Williams 2008). Across the whole harbour, 25 % of all mapped seagrass meadows were consistently present over all time periods. The other 75 % of seagrass meadows were ephemeral and were not present over all time periods.

Knowledge Gaps

Currently, there are no harbour wide management strategies for mangroves, seagrass and saltmarsh in Sydney Harbour. This is despite the suggestion the future of mangroves in the harbour is threatened by their supposed low genetic diversity (Melville and Burchett, 2002). However, under the *Fisheries Management Act 1994,* harm to vegetation (including all three macrophyte types) is illegal. Therefore removal or damage can result in fines. Further, there are now 'Habitat Protection Guidelines' set out by the NSW Government.

Practices that aim to minimise disturbance to mangroves, but at the same time allow public access, such as the building of walkways, can themselves have effects on the local biota. For example, Kelaher et al. (1998) demonstrated that the abundance of the semaphore crab, *Heloecius cordiformis*, was higher closer to boardwalks than further away due to the environmental changes (e.g. changes in sediment structure) associated with the boardwalks.

Other than distributional data, the only species we have substantial information on are mangroves, and even that is limited (Ross and Underwood, 1997; Chapman, 1998; Ross, 2001; Clynick and Chapman, 2002; Chapman et al., 2005; Melville et al., 2005; Melville and Pulkownik, 2006; Tolhurst, 2009). We have little understanding of how the resilience of these valuable habitats respond to environmental change (see Threats), and how changes in the abundance and structure mangroves, seagrasses and saltmarsh affects associated biodiversity and ecosystem function within Sydney Harbour.

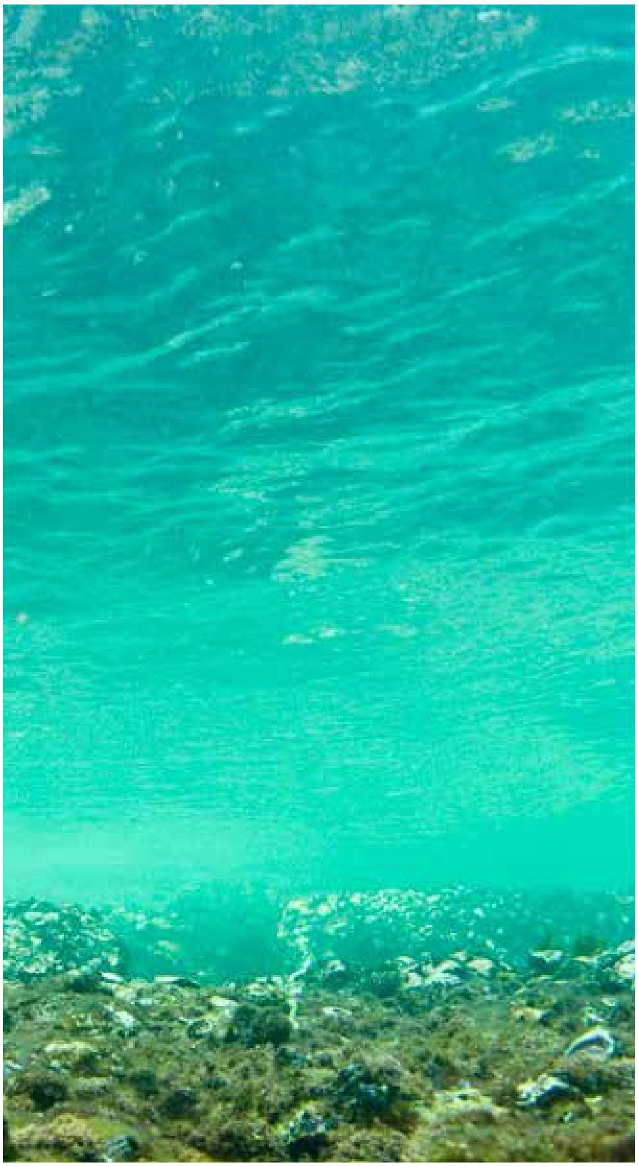
Open Water / Pelagic Systems

Little is known of pelagic flora and fauna in Sydney Harbour, with most studies focusing on water quality.

Outbreaks of both toxic and non-toxic algal blooms have been observed since the 1930's. Blooms of toxic algae have occurred in the estuary in 1983, 1996, and 1999, however similar outbreaks have thought to have occurred prior to this.

A single study has examined the sizes of fin-fish in Sydney Harbour, using commercial fishing by-catch. 90 % of all by-catch were found to be less than 20 cm in length. Invertebrate species such as shrimp and crabs were consistently caught at around 100 individuals per day.

Sydney Harbour is home to one of five little penguin colonies found on the eastern coast of Australia.



General Introduction and Context

Open water is a major habitat in estuaries and marine embayments. The contribution of this habitat to sustaining biodiversity and ecosystem function is well recognised through its role in the transport, dilution and transformation of dissolved and particulate materials that impact estuarine ecology. It also provides habitat for planktonic food webs (Cloern 2001), facilates life-stage transitions for meroplankton and fishes (Potter and Hyndes, 1999), and acts as a corridor for the movement of species at higher trophic levels such as fishes and mammals (Gillanders et al., 2011; Gaos et al., 2012).

The species that occupy these habitats span orders of magnitude in terms of size (microorganisms to mammals; 10^{-6} to 10's m), and spend at least part of their lifecycle in the water column with little direct interaction with the benthos. For the purposes of this review, we do not consider organisms attached to free-floating debris or watercraft to be open water biota (see Sant, 1990; Widmer and Underwood, 2004).

Much of the global literature on estuarine open water habitats is dominated by impacts on water quality, i.e., responses by lower trophic levels to nutrient inputs, contaminants, changes in hydrology and translocation of species (Cloern 2001). However, the dependency of larger organisms on open water habitats is being increasingly recognised through use of stable isotopes (Fry, 2008), geochemical signatures in fish otoliths (Campana and Thorrold, 2001) and more recently with observation technologies such as remote underwater video, global positioning satellite and underwater acoustic tags, that show use of estuaries by apex predators and marine mammals (Becker et al., 2010; Carlson et al., 2010).

The use of pelagic habitat by different organisms is highly size-dependent and determines their risk to habitat degradation. Most microscopic holoplankton (e.g., phytoplankton) are incapable of independent movement (their position is primarily determined by the surrounding currents), and are therefore at greatest risk to deterioration in water quality through constant exposure. Local flow dynamics such as estuarine plumes and fronts are very important to the growth and transport of plankton and small fish (e.g. Kingsford and Suthers, 1994). However, some planktonic organisms can modify their position within these flows by migrating vertically (Epifanio, 1988; Doblin et al., 2006). For larger organisms, pelagic habitat may serve primarily as a corridor for movement. Such meroplanktonic organisms that actively enter or exit the pelagic habitat on various time scales are likely at less risk of declines in habitat quality. Indeed Zhang et al. (2009) found that pelagic fish and mesozooplankton change their behavior and spatial distribution due to hypoxia in the northern Gulf of Mexico.

Open Water Habitats in Sydney Harbour

Surprisingly, little is known of the open water habitats of Sydney Harbour. Most studies in this environment have focussed on water quality and contamination (see Contamination), or the input of nutrients from the surrounding catchment. Studies on fish are generally focussed on benthic reef dwelling species (see Rocky Reef), or the effects of commercial and recreational fishing in the harbour (see Fishing).

Studies of phytoplankton in Sydney Harbour have been limited to those on saxitoxin-producing species involved in harmful algal blooms (Murray et al., 2011) due to their role in the oyster industry. Sydney Harbour has been identified, however, in a contemporary synthesis of locations of both harmless and harmful algal blooms along the coast of New South Wales (Ajani et al. 2001). Algae with direct toxic effects on either humans or harbour species have been reported in Sydney Harbour since colonisation, but blooms of these algae are rare. *Alexandrium catenella, Chattonella gibosa* and *Alexandrium* sp. have had reported outbreaks throughout the Parramatta River during October 1983, November 1996, and November 1999 (Ajani et al., 2001). *C. gibosa* is linked to high mortality of yellowtail and sea bream, as well as farmed bluefin tuna (Marshall and Hallegraeff, 1999). Other unidentified blooms in Sydney Harbour have been reported since European colonisation, but our limited taxonomic knowledge has meant these blooms have gone without study, and potential effects are unknown (Ajani et al., 2001).

Several 'potentially harmful' blooms of dinoflagelate algae have been reported. Both *Scrippsiella trochoidea* and *Gonyaulax polygramma*, while not toxic, have been known to grow to such densities as to create anoxic conditions in the water column. *S. trochoidea* last bloomed in Sydney Harbour in 1890, while *G. polygramma* bloomed in July 1984 (Ajani et al., 2001). During the period between 1890 and 1999 several outbreaks of harmless micro algae occurred, including *Gymnodinium sanguineum* (1930–1932), *Trichodesmium* sp. (1984) and most recently *Noctiluca scintillans* (1999). These blooms had no discernible impact on either human health or the ecology of Sydney Harbour and simply discoloured the water (Ajani et al., 2001). This discolouration was particularly evident during outbreaks of *N. scintillans*, a large (200-280 μm), pink, heterotrophic dinoflagellate that can cause a notorious 'Red Tide' event. Interestingly, the first recorded outbreak of *N. scintillans* was in Sydney Harbour in 1860 when George Bennet noted the sometimes-luminescent

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properties of the alga (Bennet, 1860). Blooms of *G. sanguineum* were also noted early last century. These blooms occurred every July to August from 1930 to 1932. Again, this large dinoflagellate is harmless and causes simple discolouration of the water column.

There are no published studies on zooplankton in Sydney Harbour, however, there have been assessments of larger pelagic invertebrates such as prawns in trawl by-catch (Liggins et al., 1996). By-catch refers to the incidental catch of non-targeted species by fishing trawlers. Commercial fishing was banned in 2006 within Sydney Harbour due to high levels of organic contamination in fish. However, prior to the cessation of fishing, Liggins et al. (1996) quantified the abundance of organisms caught by trawlers to give an assessment of open water fin-fish and invertebrate abundances in the harbour. Almost 219 000 fish were caught as by-catch during two years of sampling. Interestingly, most of the by-catch species noted by Liggins et al. (1996) were small. Twelve commercially important species of fin-fish were identified, seven of which were consistently caught at very small sizes (90 % were less than 20 cm). While most of the by-catch 'community' consisted of fin fish, crustaceans were also caught in large numbers. Two-spot crab *Ovalipes australiensis*, blue swimmer crab *Portunus armatus* (previously *P. pelagicus* in Australia), and mantis shrimp (family: *Squillidae*, several species) were consistently caught at over 100 individuals per day during the study. Work on higher trophic level, open water species, such as fish with only intermittent benthic associations has been restricted largely to recreational fisheries studies which look at catch and release mortality (Roberts et al., 2011) or levels of effort and catch in the fishery (Sant, 1990; Ghosn et al., 2010; Steffe and Murphy, 2011) (see Fishing).

Sydney Harbour is home to one of only five Little Penguin *Eudyptula minor* colonies on the south east coast of Australia. This colony is located along the northern foreshore of the Harbour from Manly to North Head (Priddel et al., 2008). At last count there were 56 breeding pairs in the Sydney colony. Reports from 1912, however, indicate that this colony was much larger (Priddel et al., 2008). In 1954 unverified anecdotal reports suggested that approximately 300 penguins were shot (NPWS, 2000). Habitat destruction, dog predation, car accidents, and human vandalism are blamed for the steep decline in Little Penguin numbers in Sydney Harbour. Studies of other macro-fauna, including large mammals, is completely lacking in Sydney Harbour, or is not presently published, although there are periodic sightings of humpback and Southern Right whales in the harbor during the months May-September. There is ongoing acoustic tagging study of bull sharks *Carcharhinus leucas* in the harbour (NSW Government *unpublished*), but there is no published work to date.

Knowledge Gaps

The open water habitat is characterized by many transient taxa with movements driven by ontogeny or by tidal, diel, seasonal or even annual migrations. The ecological and biochemical importance of materials and biota exchanged through the entrance to the harbor remains a significant knowledge gap. In a manner similar to San Francisco Bay, where shifts in the northwest Pacific Ocean from a warm to cold phase alter the immigration patterns of predators into the bay (Cloern et al. 2007), changes in near and offshore oceanography, including increased influence of the East Australia Current, have the potential to strongly influence the open water habitats of Sydney Harbour.

While the delivery of nutrients and contaminants to open water habitats of the harbour is beginning to be understood (see Contamination and Nutrients and Turbidity), we currently know very little about either the direct or indirect effects of these processes on open water or benthic biota. We know of typically strong links between water quality and planktonic organisms but this has not been well studied in Sydney Harbour. This is alarming given that run-off, contamination, and nutrient inputs are delivered directly into the water column and may be exacerbated by climate change. This may be particularly important for areas of the harbour that are slower to flush, such as the inner parts of Port Jackson and the Parramatta River.