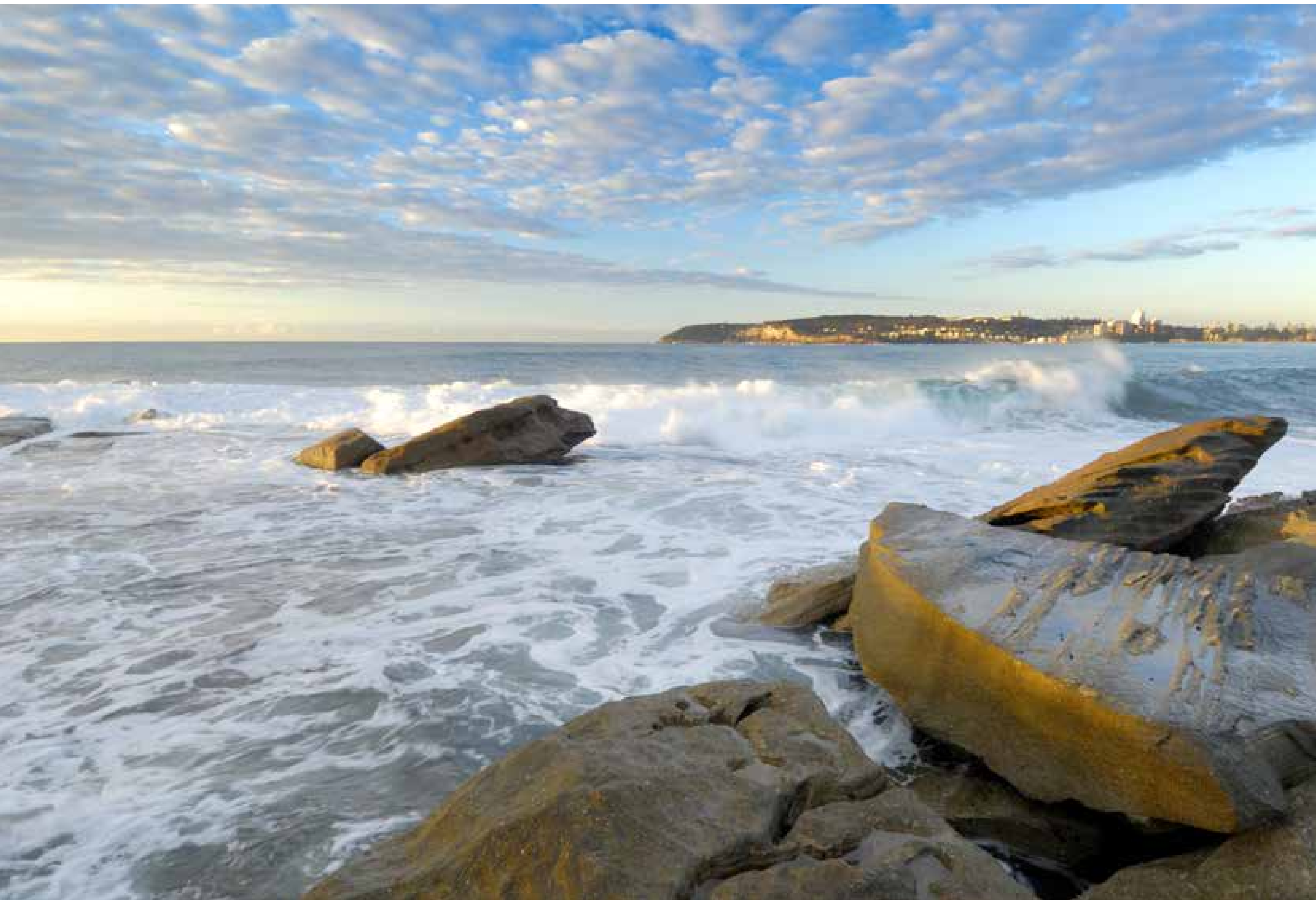
Sydney Harbour

A systematic review of the science 2014



Sydney Institute of Marine Science Technical Report

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Recommended Citation
Hedge L.H., Johnston E.L., Ayoung S.T., Birch G.F., Booth D.J., Creese R.G., Doblin M.A., Figueira W.F., Gribben P.E., Hutchings P.A., Mayer Pinto M, Marzinelli E.M., Pritchard T.R., Roughan M., Steinberg P.D., 2013,
Sydney Harbour: A systematic review of the science, Sydney Institute of Marine Science, Sydney, Australia.

National Library of Australia Cataloging-in-Publication entry
ISBN: 978-0-646-91493-0
Publisher: The Sydney Institute of Marine Science, Sydney, New South Wales, Australia

Available on the internet from www.sims.org.au

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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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Acknowledgments

The authors are incredibly grateful for the independent reviews of this report conducted by Prof. Frank Talbot AM, Former Director of the Australian Museum, and the United States Smithsonian National Museum of Natural History; and Prof. Peter Fairweather, of The School of Biological Sciences at Flinders University, Adelaide, Australia.

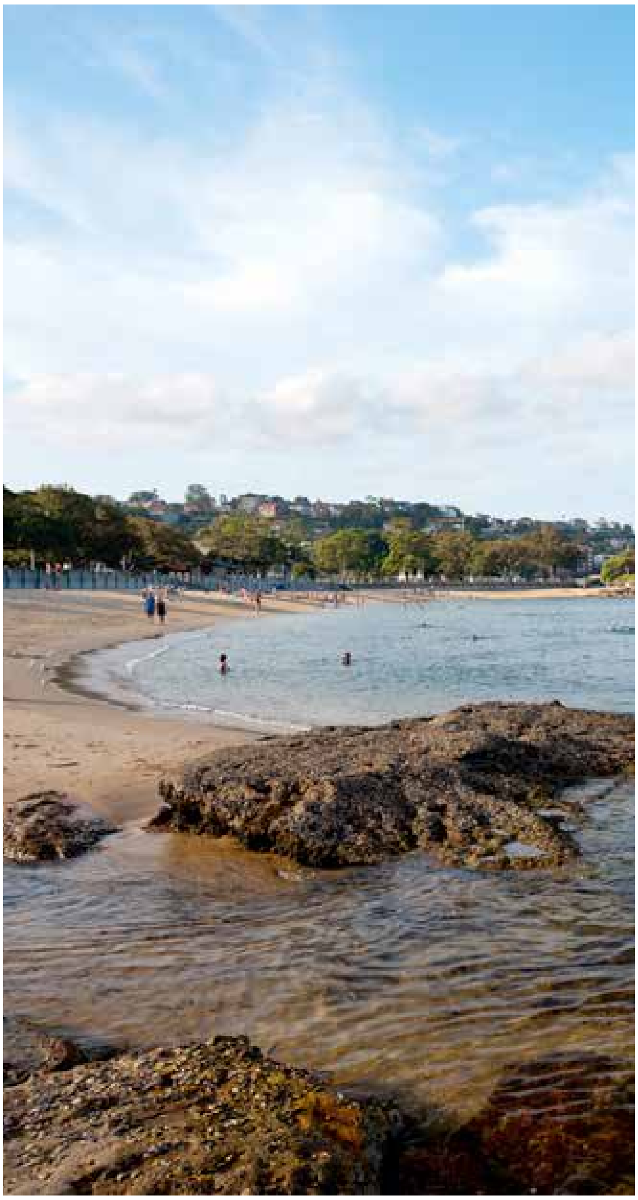
Soft Bottoms and Beaches

Over 2473 species of molluscs, polychaetes and echinoderms have been recorded in Sydney Harbour. This is likely an underestimate, given the poor state of sampling within Sydney Harbour.

Sydney Harbour's beaches are one of the least studied ecosystems. Only four peer-reviewed articles have analyzed data from these systems despite the social and economic importance of these areas.

Richness estimates, like those above, are largely based on sub-tidal environments. Intertidal and foreshore communities have received no scientific attention.

Gene sequencing and other molecular techniques are in development to try to address the difficulties of sampling sediment meiofauna.



General Introduction and Context

The sedimentary seafloor of an estuary can be extremely diverse. Biota in this system range from bacteria to benthic feeding whales and sharks (Lenihan and Micheli, 2001). Most of the species, however, are small invertebrates such as worms and molluscs that burrow into the sediment and live entirely hidden from view (Snelgrove, 1997). In some instances the abundance of these taxa can be enormous. Over 78 000 worms alone can inhabit one square metre of sediment (Lenihan and Micheli, 2001). The composition of these communities varies according to sediment size, type, and organic content. These parameters are, in turn, controlled by abiotic factors such as current strength, wave activity and successional processes after disturbance (Lenihan and Micheli, 2001).

Most of the sediment infauna can be found within the top few centimetres (Hutchings, 1998; Lenihan and Micheli, 2001). These organisms often act as bio-turbators, having profound effects on nutrient cycling, oxygenation, water content, porosity and chemical make-up (Kogure and Wada, 2005). Sediment infaunal communities can include a myriad of functional groups that are an important food source for higher trophic levels, including benthic fish, prawns, and wading seabirds (Snelgrove, 1997).

Distribution of sediment dwelling fauna can vary according to the myriad of reproduction strategies employed. Many taxa have directly developing larvae that allow for quick colonisation of nearby areas, whereas others have planktonic larvae that allow organisms to drift and colonise sites much further away (Grassle and Grassle, 1974). Most of this activity goes unnoticed by the casual observer, and often the only signs of sediment infauna are pits and mounds on the seafloor, creating the appearance of a moon like environment. Additionally, various 'islands' of small hard substrate can become available within a 'sea' of soft sediment (Hutchings, 1990). These islands can form three-dimensional structures that determine fish community composition, and settlement patterns of other invertebrate species (Hutchings, 1990).

left: Balmoral Beach, locatied on the northern side of Sydney Harbour. Sydneysiders take great pride in their harbour's beaches. These environments, however, are one of the least studied in the estuary.

Sediment Flora and Fauna in Sydney Harbour

No comprehensive surveys of soft bottom benthic communities of Sydney harbour have been undertaken, but some indication of the diversity is given by Australian Museum collection records (Hutchings et al., 2013). To date the total number of polychaete, crustacean, echinoderm and molluscan species recorded from Sydney Harbour stands at 2473. This compares with 1636, 981 and 1335 species known from nearby Botany Bay, Port Hacking (Fraser et al. 2006) and the Hawkesbury River (Hutchings & Murray, 1984), respectively. The infauna tallied above is certainly a significant underestimate of true species richness since many areas of the harbour are poorly sampled.

There has been little work identifying the species present in the iconic sandy beaches of Sydney Harbour. Only four studies were classified as having investigated infaunal communities within beach sediment environments (Dexter, 1983, 1984; Keats, 1997; Jones, 2003). Jones (2003) conducted a rigorous assessment of the impact of an accidental oil spill on the abundance of a single amphipod species (*Exeodiceros fosser*) at several harbour beaches west of the Sydney Harbour Bridge. And Keats (1997) made a qualitative assessment of the Gastropod fauna of Spectacle Island, found near the western suburb of Drummoyne. Only Dexter (1983, 1984) has made a holistic assessment of the communities found within sandy sediments in Sydney Harbour's outer beaches. Mud flats west of the bridge, however, have been sampled by the Australian Museum and these data have been incorporated into the above indications of sediment diversity (Hutchings et al., 2013). The richness estimates above are largely based on subtidal species, and specific site records are yet to be accurately correlated with the major sedimentological types identified in the harbour, each of which will probably have a characteristic infaunal community.

There have been only two studies found during our systematic review process that quantified diversity within the sediment using newly developed gene sequencing methods (Chariton et al., 2010; Sun et al.,2012). Here, 4640 Operational Taxonomic Units (OTUs) were uncovered in the muddy, fine fraction of sediment at sites including Balmain, Glebe, North and South Heads, Rushcutters and Rose Bay and Clifton Gardens (Sun et al., 2012). This is likely to be a conservative estimate as Sun et al. (2012) used 454 Pyrosequencing; where debate exists as to the interpretation of 'rare' sequences. Chariton et al. (2010) also used 454 Pyrosequencing on a smaller scale to determine the abundance of taxonomic groups in only two sites within the main estuary, the Lane Cove and Parramatta Rivers: 10,091 different OTUs were identified in 262 Orders, 122 Classes, and 54 Phyla. Note that this estimate of diversity included metazoans (such as bivalves and polychaetes) as well as microzoans (e.g. Ascomycota and Bacillariophyceae) and similar precautions in data analysis to Sun et al. (2012) need to be taken.

Knowledge Gaps

Sediment systems in Sydney Harbour are one of the most understudied of all its environs. Only a single study is currently published (at time of publication of this report) that has comprehensively investigated the diversity of bottom sediments (Hutchings et al., 2013). Even here, this examination focussed on only four taxonomic groups (molluscs, crustaceans, echinoderms and polychaetes), and did not sample any sandy beaches that are common east of the Sydney Harbour Bridge (Hutchings et al., 2013). Only two studies have investigated sandy beach communities east of the Harbour Bridge, and so we have little understanding of beach sediment fauna. Much of the work on the sediment of Sydney Harbour has been in the context of contamination modelling and, even here, fewer than 10 studies examine effects of this contamination on the sediment fauna, and these only generally investigate sub-tidal areas.

Our understanding of bacterial communities also lacks detail. Many workers worldwide are highlighting the importance of microbiota to stable functioning of ecosystems (Sun et al., 2012). These microbial taxa are particularly important as they form the basal elements of many food chains, can alter the sediment chemistry and restrict nutrient availability (Gadd and Griffiths, 1977; Sun et al., 2012).

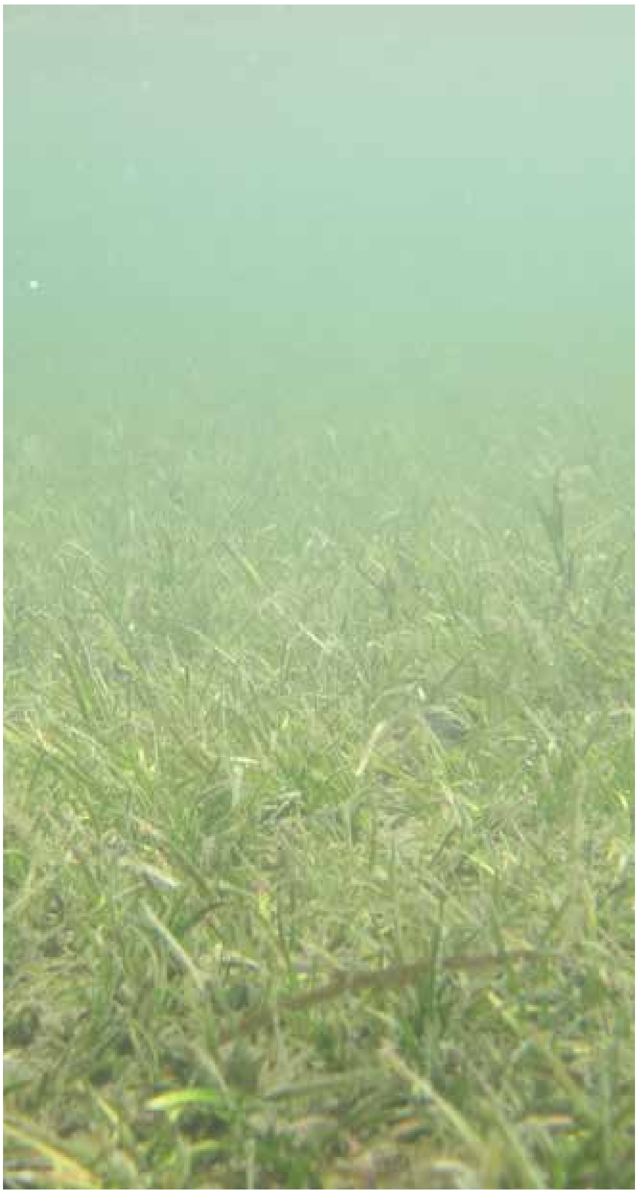
We hypothesise that overall benthic species richness and diversity is higher in the harbour than in adjacent estuaries (Botany Bay, Port Hacking and the Hawkesbury River) owing to the more complex geomorphology, diversity of sediment types and high degree of tidal flushing. However, a competing hypothesis is that increased diversity results from strong nutrient enrichment from human activities in Sydney Harbour. Our contentions cannot be robustly tested with the current state of knowledge. Although substantial areas of Botany Bay have been surveyed (Wilson 1993, 1998) and selected habitats (sandy sediments) have been systematically sampled in Pittwater and Port Hacking, similar studies have not been conducted in Sydney Harbour, highlighting the priority for detailed benthic surveys of the area. Only after examining what is present in Sydney Harbour sediment, can we begin to ask the more complex and nuanced questions that have been being examined in other habitat types in estuaries around the world.

Soft Sediment Macrophytes

The NSW Government has undertaken mapping of sub-tidal macrophytes in Sydney Harbour using aerial photographs. Mangroves and saltmarsh are restricted to intertidal regions in Lane Cove River, Middle Harbour, and Parramatta River.

Saltmarsh has declined in Sydney Harbour and less than 37.5 ha remain. Of the 757 patches of saltmarsh remaining, most are small (< 100 m^2) and isolated.

Mangroves have become more common in Sydney Harbour. Over 184 ha have been observed in the Harbour, despite being relatively uncommon prior to the 1870's.



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General Introduction and Context

Estuaries contribute US$7.9 trillion annually to the global economy (Costanza et al., 1998). Much of this wealth can directly or indirectly attributed to estuarine flora. In estuaries, the main vegetation types are seagrasses (worth AUS$19,000 ha.yr^{-1}), saltmarsh and mangroves (AUS$9,990 ha.yr^{-1} combined; Costanza et al., 1998)). These three habitats support the ecological and economic wealth of Australia's productive estuarine ecosystems. In this section of the report we deal with seagrasses, mangroves and saltmarsh collectively. However, it is important to note that the three floral types are not without significant differences in ecology.

Seagrasses are the only estuarine plants that can live totally submerged in oceanic water. While not truly grasses (i.e. not in the family Poceae), they are angiosperms (flowering plants). The term seagrass itself refers to a taxonomic grouping with much convergent morphology (Connell and Gillanders, 2007). Like most angiosperms, seagrass roots provide a mechanism for nutrient uptake. Unlike many terrestrial plants, however, a complex rhizome system linking individual shoots across several square km provides much of the structural support needed in high energy submerged environments. Rhizomes, shoots and roots often form extensive biological mats over the seafloor. *Posidonia* spp. in southern Australia, for example, are sometimes known to form mats almost 7 m high (Kuo and den Hartog, 2006). The fibrous leaves, roots, shoots and rhizomes can provide much of the primary production in estuarine systems (Connell and Gillanders, 2007). *Posidonia australis* is implicated as an extremely important food source, even when dead. Here, large amounts of decaying 'wrack' are often washed up onto south east Australian shorelines to form the base of extensive food chains (Kuo and den Hartog, 2006).

The term mangrove refers to a group of about 55 species of phylogenetically unrelated plants that have adaptions allow for living in high salinity environments (Tomlinson, 1986). Mangroves form extensive forest systems along the intertidal areas throughout the tropical and warm-temperate world (usually between 25° N and 25° S, Connolly and Lee, 2007). In these areas, water temperatures do not usually fall below 20°C during winter.

Like mangroves, the term saltmarsh refers to an ecological grouping, and includes grasses and herbaceous shrub-like plants that inhabit the upper shoreline above the mean tidal height. Saltmarshes provide a number of important ecosystem services. These include sediment stabilisation and protection, filtering of sediments and nutrients, and supporting fisheries (Pennings and Bertness,