

ENVIRONMENTAL CHANGE

SYDNEY HARBOUR ESTUARY



Source: Shutterstock

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SYDNEY HARBOUR: AN ESTUARY AND A MARINE ENVIRONMENT

ENVIRONMENTAL SNAPSHOT: ESTUARIES

'Estuaries are partially enclosed bodies of water along coastlines where fresh water and salt water meet and mix. They act as a transition zone between oceans and continents. An estuary has a free connection with the ocean. Fresh water input from land sources (usually rivers) dilutes the estuary's salt content' (1).

Environmental processes

Most estuaries were formed around 12,000 years ago when rising sea levels flooded river valleys while others formed due to glacial erosion or tectonic forces.

Rivers carry sand, silt and plant matter downstream where it is deposited in estuaries to create a nutrient rich environment. Daily tides, **rainfall and runoff** result in a mix of saltwater and freshwater – salinity decreases moving upstream in the estuary. The **landscape and topography** of an estuary will determine its unique characteristics.

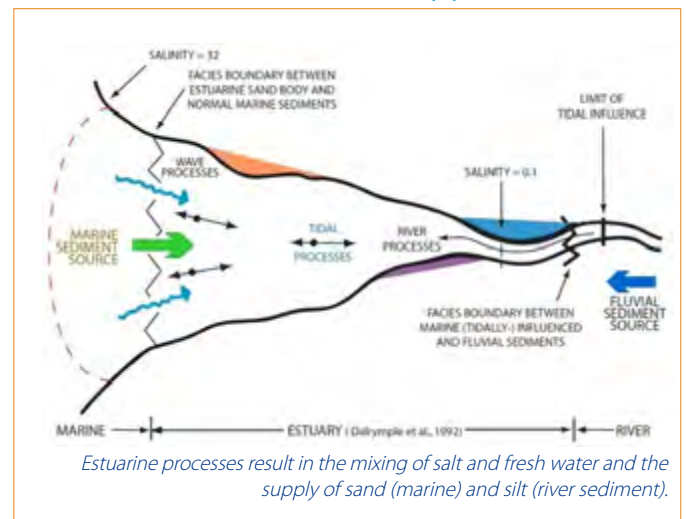
'It's the transport of nutrients and biological matter washed from land to sea and back that makes an estuary productive' (2)

'A healthy estuary produces between four and ten times as much organic matter as a cornfield of the same size'

Sources

1. Estuarine Science <http://omp.gso.uri.edu/ompweb/doee/science/descript/whats.htm>
2. How do estuaries work? <https://www.howitworksdaily.com/how-do-estuaries-work/>
3. Estuarine Science <http://omp.gso.uri.edu/ompweb/doee/science/descript/whats.htm>
4. Estuaries: Where the river meets the sea <https://www.nature.com/scitable/knowledge/library/estuarieswhere-the-river-meets-the-sea-102734157>

SOURCE A: Estuarine Processes (4)



Estuarine processes result in the mixing of salt and fresh water and the supply of sand (marine) and silt (river sediment).

The importance of estuaries

1. **Habitats** for a diversity of marine species that thrive in a protected environment with abundant food. The life cycle of many commercial fish species is linked to estuaries while birds and mammals, rely on them for food and nesting or nurseries sites.
2. **Environmental services** of such as mangroves, salt marshes and oysters reefs
 - filter sediment and pollutants from the water as it moves from land to sea
 - act as buffers against storms and tidal surges.
3. **Economic importance.** Coastal activities, commercial and recreational fishing, boating, and tourism provide 28 million jobs and generate over 20 billion dollars of income each year.
4. **Recreation** at ocean and bay beaches and marinas.
5. **Cultural significance.** People have always used estuaries for food and transportation. For indigenous communities there is a cultural link to the land and sea within and around estuaries.

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SYDNEY HARBOUR ESTUARY

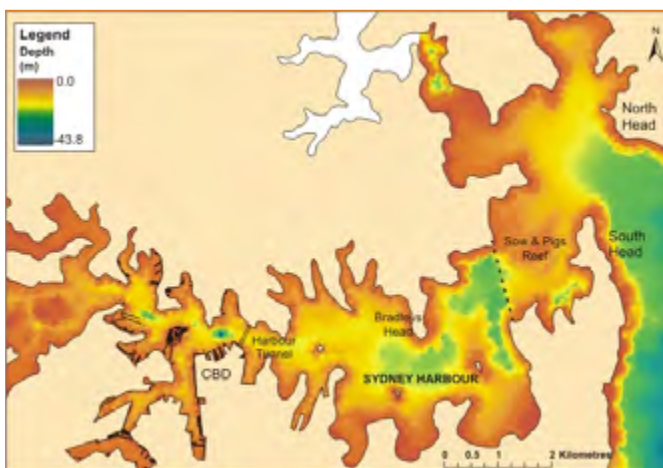
Sydney Harbour, one of the largest estuaries in the world, is a drowned river valley with a wide, open mouth, and many bays and inlets. The structure of the harbour creates a wide variety of habitats that support a high level of biodiversity compared to comparable estuaries around the world. Until the 1950's very little was known about what was below the surface of Sydney Harbour, but today that is changing as research scientists investigate the marine environment to better understand its features, functioning and threats.

SOURCE B: Sydney Harbour Estuary and catchment



Source: Environment NSW <https://www.environment.nsw.gov.au/ieo/SydneyHarbour/maplg.htm>

SOURCE C: Natural bathymetry of Sydney Harbour



Source: Ozcoasts http://www.ozcoasts.gov.au/geom_geol/case_studies/sydney_final_report.jsp

For map showing submarine contours visit the Port Authority of NSW website <https://www.portauthoritynsw.com.au/sydney-harbour/pilotage-navigation/pilotage-harbour-masters-directions/port-passage-plan/>

GEOGRAPHICAL FACTS

- Extent – 30 km west to Parramatta
- Surface area approx. 50 km² with a total catchment of 500 km²
- 3 km wide at the heads – up to 30 m deep
- Major components
 - Port Jackson (Sydney Harbour)
 - Middle Harbour
 - Parramatta and Lane Cove Rivers (main tributaries)
- The natural beauty attributed to the complex shoreline and topography
- 90% of the catchment is urbanised or industrialised
- 50% of the foreshore is armoured
- The surrounding population is 5 million people
- The seabed is heavily contaminated from Sydney's industrial past

Source: Sydney Institute of Marine Science <http://sims.org.au>

ENVIRONMENTAL PROCESSES AND FUNCTIONING

A number of related processes create physical conditions for a diversity of habitats and species within the harbour. These include:

Tides

Sydney Harbour is a tide-dominated estuary that extends inland to the Parramatta weir where the tidal influence ends. The tidal range is considered to be small at 2.1 metres. Before the river valley drowned as the sea level rose, the coastline was 3 to 5 km east of where it is today. The flooding of the river valley was followed by sedimentation, erosion, deposition that created a complex marine environment.

Relief and landforms

The underwater relief (bathymetry) of the harbour has an average depth of 13 metres, with deep channels and shallow areas from 3 to 5 metres deep. Some channels used for shipping are 28 to 45 metres. There are large, shallow bays between headlands and intertidal zones exposed at low tide and submerged at high tide.

Water flows

Salt and fresh water flows into the estuary supply a mix of sand (marine) and silt / mud (river) that settles on the floor and shoreline creating different habitats.

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Salinity

Saltiness varies with the inflow of freshwater and saltwater – this is determined by precipitation, runoff and evaporation in the catchment, daily tides, prevailing winds and extreme weather events such as East Coast Lows.

Freshwater catchments

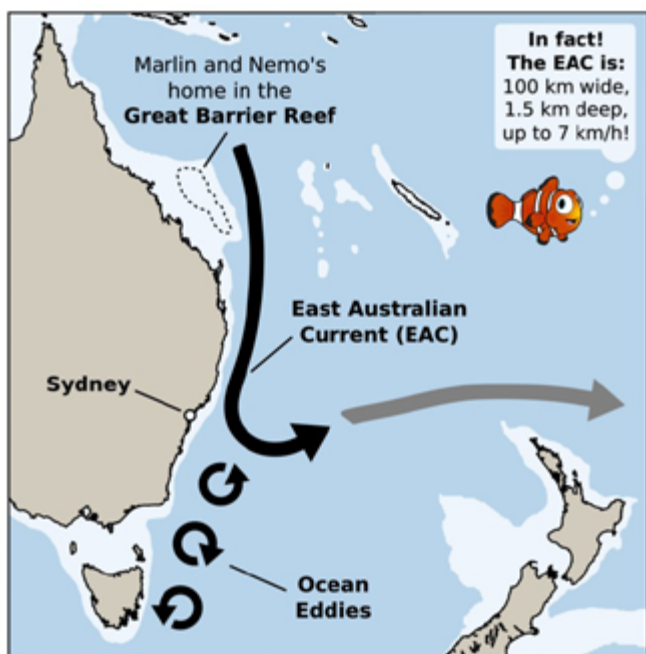
The Sydney Harbour catchment has been described as dry with periodic high precipitation events, a feature that limits freshwater flushing in many bays and inlets leaving saltier habitat conditions. The main Sydney Harbour catchments are Parramatta, Lane Cove and Middle Harbour, however runoff also comes from small creeks and stormwater outlets.

The East Australian Current

This current brings warm nutrient poor water down the east coast of Australia. Current speeds off Sydney can be up to 1.5 m/s. Over time, this current has strengthened making Sydney and eastern Australia climate change “hotspots” and impacting on the marine environment and its habitats and species. An increasing number of tropical species are being found within the estuary, some now ‘wintering’, meaning they can survive further south all year round.

The story of NEMO is a reality in Sydney Harbour.

SOURCE D: The East Coast Current



Source: <https://blog.csiro.au/things-warm-up-as-the-east-australian-current-heads-south/>

The EAC starts at the Great Barrier Reef and travels south to Sydney before turning eastward to New Zealand.

Variation and diversity

Variations in the natural environment within Sydney Harbour have created a diversity of habitats that support a large number of species. These habitats have distinct characteristics, yet are interconnected through the movement of water, nutrients, sediments and organisms within the entire estuary. A change in one place can influence the entire marine environment.

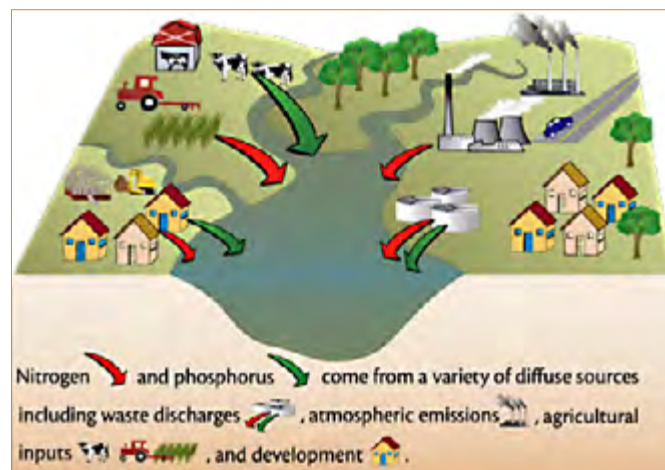
The importance of understanding the Sydney harbour environment

With over 3000 marine species, Sydney Harbour is a biodiverse waterway because of the variety of habitats, varying types of sediment, water depth, and vegetation. Aquatic organisms require different light, salinity, temperature, air exposure conditions. Changing conditions such as the East Coast Current can impact on biodiversity. Understanding these environmental limits is important for environmental management.

Threats to Estuaries

Urban development, agriculture and aquatic Industries, over-fishing, habitat loss, boating, structures, erosion, sedimentation and pollution, dams and power stations, litter.

SOURCE E: Threats to estuaries



Source: Integration and Application Network (IAN)



Parramatta River, Parramatta. Source: <https://commons.wikimedia.org/wiki/>

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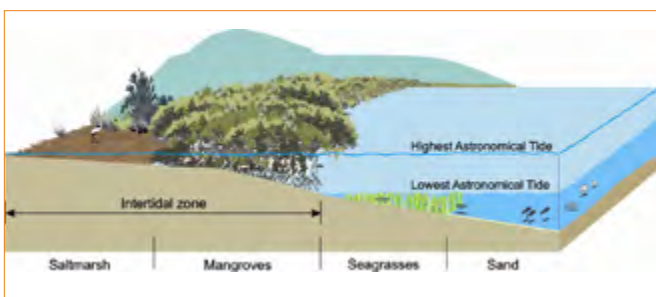
THE NATURAL HABITATS OF SYDNEY HARBOUR

Subtidal rocky reefs occur where the harbour bottom dips from the shoreline to deep channels such as Dobroyd Head and Middle Head. In this habitat native kelp beds support high levels of biodiversity including sea-urchins, sponges, algae, seahorses and fishes. There are 45 species of wrasses, 32 species of gobies and 26 species of damselfishes as well as endemic species such as the Sydney Scorpionfish. Compared to other urban estuaries such as Melbourne's Port Phillip Bay, Sydney Harbour rocky reefs have high levels of fish biodiversity at 25–25 species per 500 m².

Rocky intertidal shores include fragmented areas of natural shoreline ranging from flat or gently sloping sandstone shelves to vertical walls. Habitat forming species such as oysters and algal beds are found in patches that support high levels of biodiversity. Much of this habitat in Sydney Harbour has been replaced by human structures such as seawalls.

Soft bottoms and beaches support seagrass, mangrove and saltmarsh vegetation communities. Mangroves (mainly Grey Mangrove and River Mangrove) are the basis for detritus-based (decaying plant matter) food webs that support a variety of species including algae, barnacles, molluscs and fish. Saltmarsh found landward of the mangroves, and seagrasses (submerged plants), which once dominated places with soft sediment, have largely been cleared. Estimates state that seagrasses now occupy less than half the area (51.7 ha) they did in 1943 while mangroves have increased in that time.

SOURCE I: Soft harbour bottoms and beaches



Source: <https://www.ces.vic.gov.au/sotb/chapter/mangroves-saltmarsh>

Open waters support plankton-based food webs. Deeper water transports material from upstream to other habitats and supports the migration of fishes and mammals between the estuary and the ocean, including annual migrations of Humpback and Southern whales and the Little Penguin that nests between Manly and North Head.

SOURCE J: Little Penguin timeline in Sydney Harbour



Source <https://www.environment.nsw.gov.au/topics/animals-and-plants/native-animals/native-animal-facts/little-penguin/manlys-little-penguins/where-can-i-see-them>

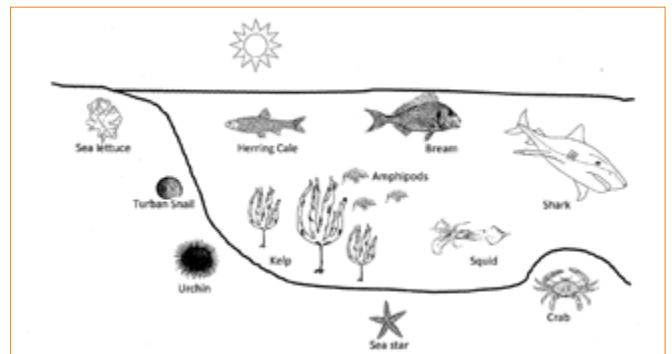
Source F: Rocky reef and intertidal shore habitats



Source: <https://www.localiving.com.au/manly/beaches-off-the-beatentrack/reef-beach/>

SOURCE G : Rocky reef species in Sydney Harbour

Kelp is the main habitat forming organism rocky reefs.



Source: Sydney institute of marine science

SOURCE H : Species zoning



Source: The Marine Biological Association <http://www.mba.ac.uk/factsheet-rocky-shore>

HABITAT FORMING ORGANISMS

Some species within the different habitat types of the harbour have important values including filtering water, stabilising and protecting shorelines and supporting high levels of terrestrial and aquatic biodiversity through food chains and food webs. These species provide food and shelter to many animals. They include:

- Mangroves and saltmarshes
- Oysters
- Kelp

Human activities in and around the harbour have severely reduced populations of these organisms and in doing so impacted on water quality and biodiversity in the estuary. Habitat restoration efforts to restore some of these habitats have increased in recent years.

SIGNIFICANCE FOR ABORIGINAL AUSTRALIANS

The first peoples

It is estimated that over 1500 Aboriginal people from several different clans lived around the Sydney Harbour Estuary before 1788. These clans included the Gadigal, Wangal, Wallumedegal, Boromedegal, Gamaragal, Borogegal, Birrabirragal and Gayamaygal. Archaeological evidence from rock engravings, shell middens and artefacts as well as historical artworks show that fish were an important source of food for groups living around Port Jackson and Parramatta and Georges Rivers.

* Shell middens are the location of campsites and 'dinner-time' camps, and the shells are principally the remains of past meals



Aboriginal people using bark canoes, spear-fishing, diving, swimming, and returning to shore

Detail from Lycett, Joseph: Fishing [Port Jackson], 1817. National Library of Australia Source: <http://nla.gov.au/nla.pic-an2962715-s17>

SOURCE K : Mangroves, oysters and kelp



Benefits of oysters. Source: <http://theleadsouthaustralia.com.au/environment/surprising-benefits-oysters-no-not-thinking>. Kelp forest. Source: johnwtturnbull/14545258891/. Mangroves: UNESCO. Source: <https://es.unesco.org/node/293694>

SOURCE L : Living on the harbour

'People lived on the south-eastern edge of Australia well before the sea started rising around 11,000 ago. Humans witnessed the inundation, albeit over generations, and adapted to the changing environments. Ultimately, they retreated to occupy the foreshores that were created when the waters finally stopped rising some 6,000 years ago. By then what had been a river valley was a complex harbour of many coves, headlands and points, with three estuarine arms to the immediate north, north-west and west.

At some time before or after the water stabilized, these people established territories around the waterway based upon family groups. By the 1700s, there were at least eight clans occupying specific parts of the harbour foreshores. These were 'saltwater people' who gathered much of their food from the waterway and for whom the meaning of place was all-important. The land, shore, and probably the harbour itself, were imbued with social and spiritual significance. Headlands, points and coves were named from Boree (North Head) along to Parramatta, at the end of the Harbour's western estuary, and back around to Tar-ral-be (South Head).

The local sandstone was ideal for engraving, so on rock platforms along the waterway, the harbour's first people carved images of the animals they saw and hunted and to which they may have attached totemic significance.

Source: https://dictionaryofsydney.org/entry/sydney_harbour_a_cultural_landscape. Information on the site based on the following publication. - Val Attenbrow, *Sydney's Aboriginal Past: Investigating the Historical Records*, second edition, University of NSW Press, Sydney, 2010

ENVIRONMENTAL CHANGE

Artificial structures and shoreline modification

Sydney Harbour is one of the most modified harbours in the world. While under water impacts are invisible to most people, the extent of urban development and modifications to the shoreline are the most dominant and visible change. Today, 90% of the catchment is urbanised or industrialised and 50% of the foreshore armoured.

Structures include seawalls, marinas, jetties and pontoons. Reasons for structures:

- Reclamation
- Protection
- Recreation
- Economy (trade, tourism)
- Community

Nature of change

1. Nutrients, microplastics and litter have increased.
2. Intertidal habitats have been modified by artificial structures.
3. The water cycle has changed – water diversion and hard urban surfaces have altered freshwater runoff, sediment and nutrient flows.
4. Aquatic species have been overexploited or reduced by habitat destruction through land reclamation and building seawalls to replace the natural shoreline.
5. Industry has caused high concentrations of contaminants in harbour sediments and water.
6. Introduced species are altering habitats and food webs, threatening native species, and reducing commercially important species.
7. Climate change is impacting on habitats and biodiversity.



Circular Quay seawall. Source: L Chaffer

'The City of Sydney', drawn by M.S. Hill in 1888, shows an aerial view of the city



Source: City of Sydney Archives. <https://historycouncilnsw.org.au/new-home-dictionary-of-sydney/>

What's wrong with Sydney Harbour today?

'A common perception is that cities, and their associated ecological impacts end at the waterline. However, coastal cities such as Sydney are also highly modified underwater. Below the waterline in Sydney Harbour there is a dense network of coastal infrastructure, the sediments hold a legacy of chemical contamination and shipping activities contribute further stress through antifouling biocides and invasive species.'

Source: Sydney Marine Science – <http://engonet-sims.azurewebsites.net/directory/59/putting-sydney-harbour-into-marine-rehab&sa=D&ust=1542237211549000&usg=AFQjCNEOZbXhspCDsBdLKwWUmfXbObSWdQ>



Circular Quay Sydney. Source: L Chaffer

Photographs show Sydney Harbour today where a heavily armoured shoreline has replaced natural habitats

CUMULATIVE IMPACTS

Pollution in the harbour is caused by poor waste management, Sydney's industrial past industry and stormwater runoff. Although industrial waste disposal to Sydney Harbour is now regulated, past pollutants remain in the sediments on the harbour floor where they can be injected by organisms and enter food chains. Warnings about eating fish caught west of the Sydney Harbour bridge are evidence of this pollution.

Plastic and microplastic pollution

More recently, plastics (including microplastics) and cosmetic products (microbeads) have become issues in relation to water quality. Plastic container deposit schemes, plastic bag and microbead bans and education programs about microplastics are recent efforts to reduce these pollutants.

Stormwater runoff adds to water pollution preventing habitats such as oysters from recovering to a level where they can improve sediment and water quality through natural filtering. Restoration projects include creating oyster reefs and tiling seawalls to attract habitat forming species with water filtration powers. Living seawalls are now seen as the 'rooftop gardens' of the harbour.

Nutrients including nitrogen, phosphorus and carbon are recycled through harbour food chains and keep habitats functioning healthily. Excess nutrients from human sources such as fertilisers and sewage can cause problems such as eutrophication (where excess nutrients lead to the growth of algae that increase turbidity). This in turn interrupts food chains by reducing the sunlight available for photosynthesis by aquatic plants such as Kelp and seagrasses.

Education and effort to intercept and treat stormwater runoff to remove nutrients are ways of addressing this issue.

Ships, boating and fishing

Recreational boats, ferries and cruise ships along with fishing activities and infrastructure such as moorings and marinas have multiple impacts including:

- removing large fish from aquatic food webs
- causing propeller damage, wash, noise and pollution from antifouling paints and oil spills.
- Reducing biodiversity through animal strikes, sediment resuspension, anchor drag, and transporting introduced species that can compete with native species for food and habitat

Establishing marine parks and designing and building fish friendly moorings, piers and jetties are efforts to manage these issues.

SOURCE M: Microplastic pollution



Source: <http://www.waterkeeper.ca/cases-microplastics>

'Harbour-dwellers that thrive in the crevices of pilings and pontoons are often invasive species hostile to Sydney's natural ecosystem and include sea squirts and bristle worms which spread across habitats, driving indigenous marine life away.'

Marine ecologist Dr Katherine Dafforn. Source: <https://www.smh.com.au/national/its-war-down-there-sydney-harbour-a-marine-battleground-between-invasive-and-local-species-20140807-101dt1.html>

'In Sydney Harbour, recreational boat density has increased at approximately 2 per cent per year. Moorings affect the seabed when their attached chains scour the sediment, disturbing seagrasses. Seagrass-friendly moorings have been installed at some locations...'

State of the environment Report 2016. <https://soe.environment.gov.au/theme/coasts/topic/2016/coastal-waters>

Climate change is a growing concern. Rising temperatures are causing changes to water temperatures and impacting on the distribution of aquatic species, their growth and reproduction. Tropical fish are now commonly found in Sydney Harbour, with some surviving through winter. The impact on of tropical grazing fish on sea grasses and kelp beds is already being seen off the coast. Predicted sea levels rises will impact on intertidal habitats.

'By 2050 sea levels are predicted to rise by up to 40cm from 1990 levels, and by 90cm by 2100... a one centimetre sea level rise could potentially result in one metre of erosion.'

Rising sea levels will eat away habitats, particularly in low-lying areas like mangroves or marshes.

Source Cool Australia <https://www.coolaustralia.org/sydney-harbour-secondary/>