Stage 5 Environmental Change and Management

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SYLLABUS LINKS

STAGE 5: Environmental Change and Management

Environments
Students investigate the role and importance of natural environments

Environmental change
Students investigate human-induced environmental changes across a range of scales

Environmental management
Students investigate environmental management, including different worldviews and the management approaches of Aboriginal and Torres Strait Islander Peoples

Select ONE type of environment in Australia as the context for a comparative study with at least ONE other country.

Students:

- investigate the biophysical processes essential to the functioning of the selected environment
- investigate the causes, extent and consequences of the environmental change
- investigate the management of the environmental change

Key Inquiry Questions

- **How does the Sydney Harbour estuary function?**
- **How do people's worldviews affect their attitudes to and use of Sydney Harbour?**
- **What are the causes and consequences of change in the Sydney Harbour estuary and how can this change be managed?**
- **Why is an understanding of environmental processes and interconnections essential for sustainable management of the Sydney Harbour Estuary environment?**

Aerial view of the Middle Harbour, located north of Sydney central business district - https://upload.wikimedia.org/wikipedia/commons/f/f8/Parramatta_River_From_above_%288450764898%29.jpg

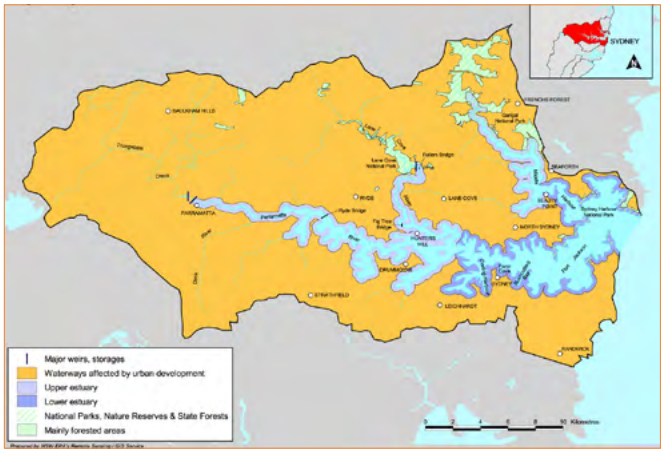
SYDNEY HARBOUR ESTUARY

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, today that is changing as research scientists investigate the marine environment to better understand its features, functioning and threats.

"Over centuries, Sydney Harbour has figured as an invisible ecosystem, traditional country, an industrial underwater, and a place of myth and fantasy. It represents such a large part of the city of Sydney, yet it continues to be hidden in history, and invisible to citizens going about their daily lives."

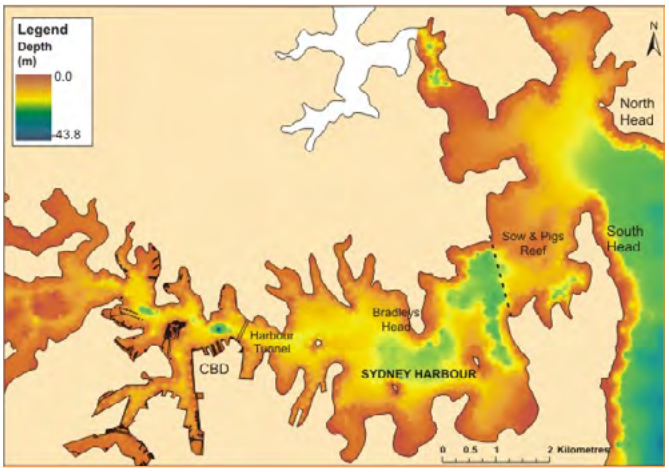
Source: Blog - The Floor of Sydney Harbour – Ann Elias's new research project February 2018 http://sydney.edu.au/environment-institute/blog/floor-sydney-harbour/

Map 1: Sydney Harbour Estuary and catchment



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

Map 2: Natural bathymetry of Sydney Harbour



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

Note: A map showing submarine contours can be found on the Port Authority of NSW website at https://www.portauthoritynsw.com.au/sydney-harbour/pilotage-navigation/pilotage-harbour-masters-directions/port-passage-plan/

Activate prior knowledge

Activity Worksheet 1: Healthy aquatic environments

Activity Worksheet 2: Sydney Harbour Quiz

GEOGRAPHICAL FACTS

- Extent – 30 km west to Parramatta
- Surface area approx. 50 km^2 with a total catchment of 500 km^2
- 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 conditions for a diversity of habitats and species within the harbour. These include:

- Estuarine processes – tides and river flow
- Weather and climate
- Currents eg East Australian Current

Sydney Harbour is a tide-dominated estuary that extends inland to the Parramatta weir where the tidal influence ends. 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 and subsequent sedimentation, erosion, deposition and human activity have created a complex estuarine environment. The underwater topography (bathymetry) of the harbour has an average depth of 13 metres, with deep channels and shallow areas from 3 to 5 metres deep. Some shipping channels are 28 to 45 metres. There are large, shallow bays between headlands and intertidal zones that are exposed at low tide and submerged at high tide.

Parramatta River, Parramatta - https://commons.wikimedia.org/wiki/File:Parramatta_River_-_Parramatta,_NSW_(7834157948).jpg

Estuarine processes

Estuarine processes result in the mixing of salt water and fresh water and the supply of sand (marine sediment) and silt / mud (fluvial or river sediment) that settles on the floor and shoreline.

Variations in salinity and sediment contribute to the different habitats found in the harbour. The estuary can be divided into different units based on the dominant sediment.

- The entrance and lower seaward estuary (sands)
- The central estuary (muddy sands)
- The upper estuary, off-channel bays & intertidal zones (muds)

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

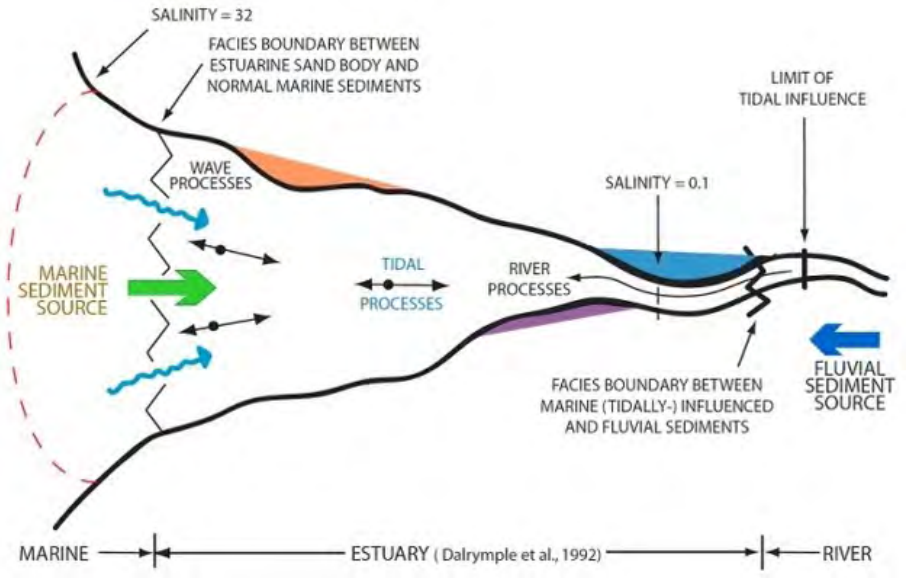
The main Sydney Harbour catchments are Parramatta, Lane Cove and Middle Harbour, however runoff also comes from small creeks and stormwater outlets. The tidal range is considered to be small at 2.1 metres. The Sydney Harbour catchment has been described as dry with periodic high precipitation events, a feature that limits freshwater flushing in many bays and inlets.

To learn more about estuaries see:

- FACT SHEET 1: What is an estuary?
- What's an Estuary? Now you know – https://youtu.be/XLumSN4G5P4

The East Australian Current brings warm nutrient poor water down the east coast of Australia (pushed to the western edge of the ocean by the rotation of the Earth). 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 marine habitats and species. An increasing

Diagram 1: Estuarine processes result in the mixing of salt and fresh water and the supply of sand (marine sediment) and silt (Fluvial or river sediment).



Where would Paramatta be on this diagram?

What is the difference between marine and fluvial sediment?

Why is this important?

Source: Nature – https://www.nature.com/scitable/knowledge/library/estuaries-where-the-river-meets-the-sea-102734157
Bianchi, T. S. (2013) Estuaries: *Where the River Meets the Sea.* Nature Education Knowledge 4(4):12

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.

Can you identify features of the lithosphere, hydrosphere and atmosphere in the Sydney Harbour Estuarine environment?

THE NATURAL HABITATS OF SYDNEY HARBOUR

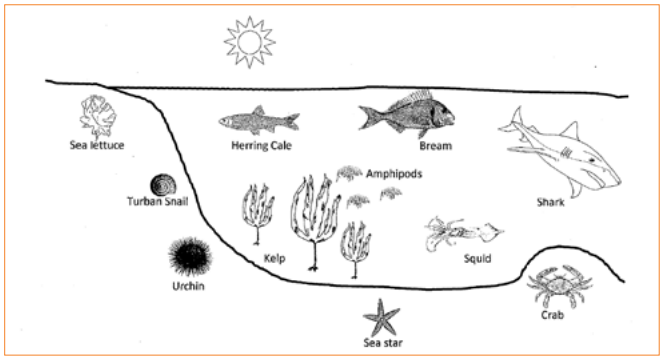
The topographic and hydrologic variations within Sydney Harbour created a diversity of habitats that support a large number of species diversity. These habitats have distinct characteristics, yet are interconnected through the movement of water, nutrients, sediments and organisms within the entire estuarine environment.

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.

Photo 1: Subtidal rocky reefs and rocky intertidal shore habitats

Source: https://www.localliving.com.au/manly/beaches-off-the-beaten-track/reef-beach/

Diagram 2: Kelp is the main habitat forming organism for species on subtidal rocky reefs.

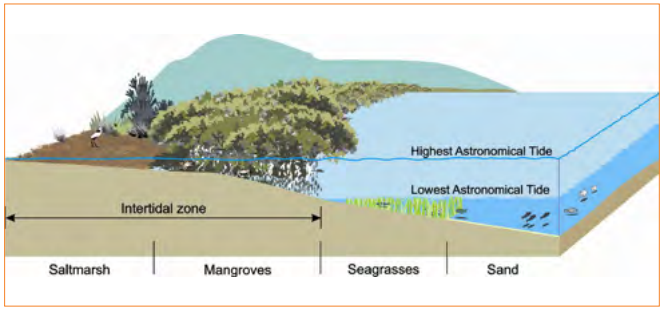


Source: Sydney institute of marine science

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.

Diagram 3. Habitats on soft harbour bottoms and beaches



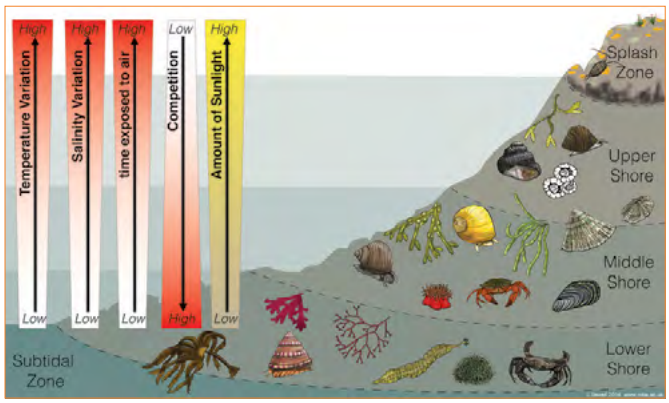
Source: https://www.ces.vic.gov.au/sotb/chapter/mangroves-saltmarsh

Open waters support plankton-based food webs. The deeper water in this zone transports dissolved and suspended 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 Right whales (May–September). A Little Penguin colony found between Manly and North Head spends the day at sea, up to 20km off the coast, feeding on small fish, squid and krill. They return to their land-based colonies after dark.

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.

Diagram 4: Different species require different environmental conditions on an intertidal rocky headland.



Source: The Marine Biological Association http://www.mba.ac.uk/fact-sheet-rocky-shore

Using Diagram 4:

Can you identify plants and animals found in the Middle Shore zone of a rocky headland and describe the environmental conditions they prefer? (A search of 'intertidal zone creatures' might help your identification)

How might environmental conditions change in the upper shore zone with a rise in sea level and how might plants and animals react?

Activity Worksheet 3: A Sydney Harbour Food Web

Activity Worksheet 4: Identify Sydney Harbour estuarine habitats.

KEY HABITAT FORMING ORGANISMS IN SYDNEY HARBOUR

There are certain species within the different habitat types in the Sydney Harbour that have significant environmental values including filtering water, stabilising and protecting shorelines and supporting high levels of terrestrial and aquatic biodiversity through food chains and food webs. The species include:

- Mangroves and saltmarshes
- Oysters
- Kelp

Photo 4. Mangroves are often known as 'nurseries of the sea' for the role they play in supporting small fish and other marine creatures.

Source: UNESCO https://es.unesco.org/node/293694

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.

Activity Worksheet 5: Can oysters save Sydney Harbour? A Geographical Inquiry

Photo 2.: In sheltered bays, Sydney rock oyster reefs provide a haven for invertebrates and fish.

Source: The surprising benefits of oysters. – http://theleadsouthaustralia.com.au/environment/surprising-benefits-oysters-no-not-thinking/

Photo 3. *Ecklonia radiata*, the most common kelp found in Sydney Harbour, provides food and shelter to many animals in the ecosystem.

Source: John Turnbull, Creative Commons https://www.flickr.com/photos/johnwturnbull/14545258891/

ENVIRONMENTAL USE, CHANGE AND MANAGEMENT

1. Significance of the Sydney Harbour Estuary for Aboriginal Australians

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

Textbox 1: Dictionary of Sydney

'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).

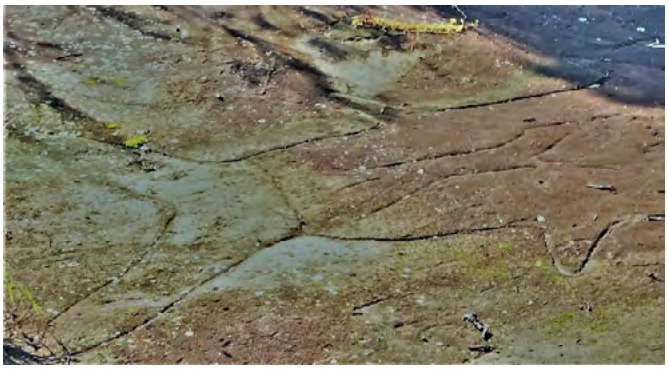
The local sandstone was ideal for engraving, so on rock platforms along the waterway, the harbour's first people carved images of the animals they saw and hunted and to which they may have attached totemic significance.

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

Artwork 1. Aboriginal people using bark canoes, spear-fishing, diving, swimming, and returning to shore

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

Photo 5: An ancient engraving of a whale carved on a headland by the Cammeraygal people.



Source: Coal Loader Centre for Sustainability, in Waverton. https://www.atlasobscura.com/places/aboriginal-carving-whale

2. Urbanisation and population growth

Artwork 2: Dictionary of Sydney- '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/

Use Google Earth to take a screen capture of this view of Sydney today and compare the differences.

Create a sketch map and label places you recognise around the harbour.

3. Anthropogenic change: Human impact on the Sydney Harbour Estuary since 1788

1. Nutrients 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.

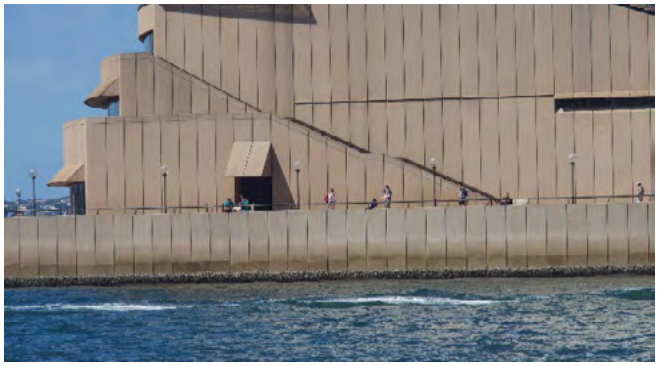
Activity Worksheet 6: Investigating threats to estuaries using conceptual models

4. 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=AFQjCNEOZbXhspCDsBdLKwWUnfXbObSWdQ

Images 6–11 of Sydney Harbour foreshore today show the heavily armoured shoreline that has replaced natural habitats, particularly east of the Anzac Bridge.



Photos by Lorraine Chaffer

The *cumulative impacts* of human activities on Sydney Harbour today include

1. Water pollution (nutrients, chemicals, bacteria and pathogens, dioxins, litter, plastics and microplastics)
2. Interference with natural habitats and processes - the water cycle, food chains and nutrient cycles and alien species
3. Artificial structures and habitat modification – seawalls, land reclamation, dredging, boating and fishing.
4. Climate change

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 injested by organisms and enter food chains. Warnings about eating fish caught west of the Sydney Harbour bridge are evidence of this 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 this 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 inpacts 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.

'Urban sprawl beneath the waves provides shelter to marine invaders that have hitchhiked into our harbour on travelling ships. 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, 'It's war down there: Sydney Harbour a marine battleground between invasive and local species' 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 a rate of approximately 2 per cent per year, with additional moorings needed to secure boats when not in use. Almost 22,400 registered recreational vessels are expected for the harbour by 2021. Moorings affect the seabed because their attached chains scour the sediment, often disturbing seagrass and sediment infauna. Seagrass-friendly moorings (those without chains to disturb the seabed) 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. According to a recent report by the NSW Department of Climate Change, one centimetre of sea level rise could potentially result in one metre of erosion.

Rising sea levels will eat away at habitats, particularly in low-lying areas like mangroves or marshes. Combine the rising sea levels with an increase of climate-related storm surges and marine habitats take a belting.'

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

Student activities:

- Analyse quantitative and qualitative data such as graphs and sea level modelling maps (GIS) to draw conclusions about the impact of climate change on Sydney Harbour. Ozcoasts maps show modelling under different scenarios for different sections of the harbour. See https://ozcoasts.org.au/maps-data/
- Examine and discuss media reports such as:

  Sydney Harbour's corals are bleaching https://www.mq.edu.au/newsroom/2016/04/19/sydney-harbours-corals-are-bleaching/

  Sydney's waters could be tropical in decades, here's the bad news… https://theconversation.com/sydneys-waters-could-be-tropical-in-decades-heres-the-bad-news-31523

  - Note the key points
  - Assess the material and ideas for validity, reliability, usefulness
  - Find evidence to support the claims
  - Create a media evidence file

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

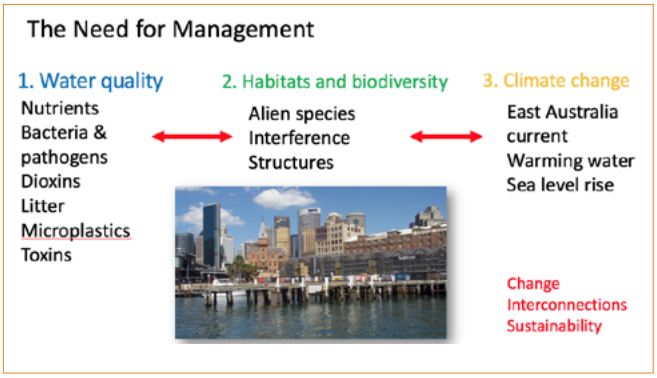
Reasons for structures:

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

Photo 12: Shoreline modifications at Chowder Bay

MANAGEMENT OPTIONS

Screen capture: Sydney Harbour Presentation GTANSW Annual Conference 2018



Source: L Chaffer

1. Managing water quality

Inquiry questions

- How can the quality of water entering Sydney Harbour be improved?
- Where is this being implemented and by whom?
- Are strategies effective?
- What criteria are used to make this judgement?

Catchment management & Water Sensitive Urban Design can significantly improve Sydney Harbour water quality. Water Sensitive Urban Design (WSUD) uses better urban planning and design to reuse stormwater, stopping it from reaching our waterways by mimicking the natural water cycle as closely as possible.

Some examples of WSUD include:

- Raingardens
- Grassed swales & porous paving
- Constructed / artificial wetlands
- Onsite capture & storage – rainwater tanks
- Maintaining & replanting riparian revegetation
- the 'Naturalisation' of waterways through local government planning and projects

Photo 13: Raingarden

Source: *Pollution Removal Performance of Laboratory Simulations of Sydney's Street Stormwater Biofilters* James Macnamara and Chris Derry, Western Sydney University

2. Managing habitats and biodiversity

Inquiry question

- How can the biodiverse habitats and species in Sydney harbour be protected and enhanced?

Strategies for restoring and protecting habitats and biodiversity:

- Shoreline and habitats restoration
- Retrofit for habitats / mimic natural complexity e.g. flowerpots, tiles, artificial reefs
- Eco- engineering – living walls, fish friendly structures, reefs, piers & wharves
- Protected areas (National Park, Marine reserve)
- Urban Development guidelines & legislation

See Fact Sheet 2:
Strategies to enhance biodiversity

3. Protected areas

The aim of marine protected areas is to:

- conserve marine and shoreline plant and animal biodiversity
- protect fish habitats
- facilitate educational activities & scientific research.

1. Sydney Harbour National Park

   The *management plan* for the park includes management of the foreshore area that impacts on the aquatic environment

2. NSW Marine protected areas /North Harbour Marine Reserve

   The reserve features a variety of habitats and species including sheltered coves that contain seagrass habitats: nearshore reefs that support kelp habitats used by species such as seahorses and sea dragons: rocky reefs and kelp beds that support invertebrates and fish and boulder habitats in deeper water support sponges and corals. In summer, tropical fish arrive by the East Australian Current (EAC) are common. Critical habitat for the little penguin is in the reserve.

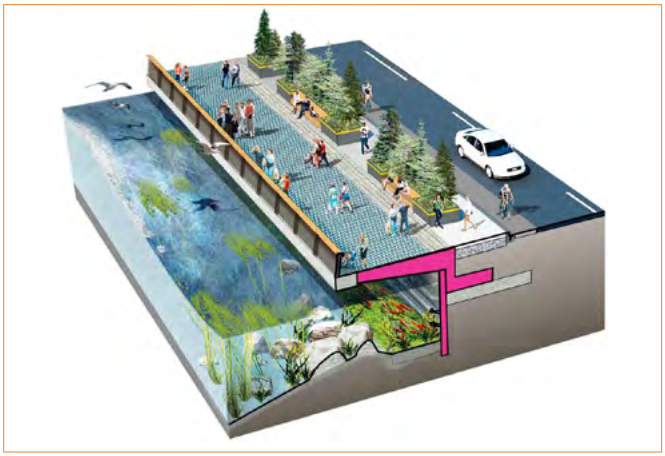
Photo 14: Barrangaroo Headland

Source: http://www.barangaroo.com.au/the-project/news/awards-keep-coming-for-barangaroo-reserve/

4. Urban renewal project design: Can it be harbour friendly?

The opportunity exists for urban renewal projects on Sydney Harbour to incorporate features that create habitats that will encourage a diversity of habitats and species. At Barrangaroo Headland a rocky shore was created using sandstone blocks. Other sites around Sydney Harbour earmarked for redevelopment / renewal such as the Bays Precinct will be interesting to watch to see if the designs incorporate Water Sensitive Urban Design features and biodiversity friendly infrastructure.

Diagram 5: An example of a biodiversity friendly harbour infrastructure in Seattle



Source: https://www.eopugetsound.org/magazine/seawall

Read about future plans for the Bays Precinct

'Providing a mix of green shorelines and living sea walls' http://thebayssydney.nsw.gov.au/destinations/bays-waterfront-promenade/

The transformation Plan https://thebayssydney.nsw.gov.au/assets/Document-Library/Reports-and-Plans-2014-/2015-Transformation-Plan.pdf

Artwork 3: An artist's impression of the Glebe Island White Bay Power Station and foreshore redevelopment.

Source: http://www.abc.net.au/news/2015-10-22/sydney-harbour-foreshore-redeveloped-global-tech-hub-government/6876784

Satellite image: The harbour front area known as the Bays precinct

Source: https://thebayssydney.nsw.gov.au/destinations/bays-waterfront-promenade/

See Activity 7: Design Project

THE FUTURE

The future health of the Sydney Harbour Estuary will be influenced by actions taken by individuals, groups, businesses, governments and non-government organisations.

Research will provide scientific data on which to make management decisions. Sydney's universities and the Sydney Institute of Marine Science (SIMS) have several research projects underway and are trialing innovative solutions to enhance marine biodiversity in the harbour. SIMS scientists study a range of impacts resulting from urbanisation including heavy metal pollution and the invasion of degraded habitats by marine pests. The World Harbour Project was initiated by the Sydney Institute of Marine Science with the aim of the of linking, facilitating, and enhancing programs of research and management across major urban harbours of the world.

Watch this video about the work being done at SIMS https://www.youtube.com/watch?v=8TVGceFEa50.

Learn about Sydney's newest Living Seawall https://www.youtube.com/watch?v=MgwuxPfCMhw

Technological innovation will underpin new harbour friendly urban design and infrastructure development

Sustainable Design principles already exist for developers to follow when undertaking urban projects that could impact on the harbour. See *'Guiding principles for marine foreshore development'* https://thebayssydney.nsw.gov.au/assets/Document-Library/Precinct-Wide-Technical-Studies-Underway-2015-/2016-Guiding-Principles-for-Marine-Foreshore-Developments.pdf

Legislation to improve water quality and protect biodiversity and habitats and create new protected areas will remain important and must respond to threats in a timely manner. Organisations with waterfront developments such as Taronga Zoo need a licence to release water into Sydney Harbour and are required to publish pollution monitoring results each year. The 2018 report from Taronga Zoo can be found here. https://taronga.org.au/conservation-and-science/sustainability/water

Conclusion: Worldviews

Activities

- Examine different environmental world views
- Summarise attitudes to Sydney Harbour environments at different periods of time eg 1700, 1788, 1888, 1988, 2018
- Discuss how and why worldviews about the Harbour changed over time
- Propose ways individuals can contribute to the sustainable management of Sydney Harbour?

FIELDWORK OPPORTUNITIES

Visit sites around Sydney Harbour or catchment

- Examine stormwater outlets / discuss stormwater vs sewer system water.

  Note: *This can be anywhere in the catchments of Sydney Harbour with the added task of tracing the path of stormwater in a suburb to the harbour.
- Do water quality testing (e.g. Measure - turbidity, nutrients, Dissolved Oxygen, microplastics)
- Observe species / habitats / (e.g. dip – netting, observation, photographs, tally)
- Visit sites to investigate strategies to minimise pollution from stormwater and waste e.g. Taronga Zoo, Darling Harbour, Circular Quay, local stormwater drains or a public place
- Visit artificial structures to assess the impact

Use a dedicated fieldwork provider such as:

- Observatory Hill Environmental Education Centre (Barrangaroo, Bays Precinct and Sydney Harbour studies)
- Sydney Institute of Marine Studies (Marine environments and research)
- Bicentennial Park (Wetland studies)
- Taronga Zoo (Sustainability)
- Tribal warriors (Indigenous studies & harbour cruise)

Monitor temporal change at new urban renewal project sites.

Students in future years could make data comparisons.

Collect media files over time – these could be useful if sites cannot be visited in the future.

This resource is to support the PPT presentation on Sydney Harbour from the 2018 GTANSW Annual Conference.

There are two PPT presentations accessible to members on the GTANSW website.

Many thanks to Alana Rooney (SIMS) and Mariana Mayer Pinto (UNSW) for guidance and resources

There is also a PPT presentation on New York Harbour as a comparative study.

RESOURCE LIST

Significant resources used in the development of this unit resource. Other references are included throughout the article, Activity sheets and Fact sheets.

NSW Geography Syllabus K–10 https://syllabus.nesa.nsw.edu.au/hsie/geography-k10/

Office of Environment & Heritage – Estuaries of NSW http://www.environment.nsw.gov.au/estuaries/index.htm

Ozcoasts (Estuarine models) http://www.ozcoasts.gov.au/conceptual_mods/index.jsp

SIMS (Sydney Institute of Marine Science) http://sims.org.au

Sydney Harbour: Beautiful, diverse, valuable and pressured. Regional Studies in Marine Science Vol 8 Part 2 2016 (paywall) J. Banks, L.H. Hedge, C. Hoisington, E.M. Strain, P.D. Steinberg, E.L. Johnston. https://www.sciencedirect.com/science/journal/23524855

Pollution in Sydney Harbour: sewage, toxic chemicals and microplastics Briefing paper No 03/2015 https://www.parliament.nsw.gov.au/researchpapers/Pages/pollution-in-sydney-harbour-sewage-toxic-chemica.aspx (Free download)

Our harbour; Our Asset (Free download) https://www.sims.org.au/page/20/publications

Building 'blue': An eco-engineering framework for foreshore developments Journal of Environmental Management Vol 189, 2017 (paywall) Mayer-Pinto, M; Johnston, E. L; Bugnot, A. B; Glasby, T. M; Airoldi, L; Mitchell, A & Dafforn, K.A.

Sydney Harbour: a review of anthropogenic impacts on the biodiversity and ecosystem function of one of the world's largest natural harbours Marine and Freshwater Research. 66. 1088–1105. Mayer-Pinto, M; Johnston, E. L; Hutchings, P A; Marzinelli, E. M; Ahyong, S. T; Birch, G; Booth, D. J; Creese, R. G; Doblin, M. A; Figueira, W; Gribben, P. E; Pritchard, T; Roughan, M; Steinberg, P. D; Hedge, L. H. 2015.

Guiding principles for marine foreshore development. https://thebayssydney.nsw.gov.au/assets/Document-Library/Precinct-Wide-Technical-Studies-Underway-2015-/2016-Guiding-Principles-for-Marine-Foreshore-Developments.pdf

Sydney Harbour: enhancing seawall sustainability. https://www.fishhabitatnetwork.com.au/userfiles/files/CASE%20STUDY%20-%20Enhancing%20Seawall%20Sustainability%20Sydney%20Harbour.pdf

Department of planning and environment coastal plans http://www.planning.nsw.gov.au/Policy-and-Legislation/Coastal-Reforms/Marine-estate-reform

World Harbour Project http://www.worldharbourproject.org

NSW Dep't Primary Industries – Marine Protected Areas https://www.dpi.nsw.gov.au/fishing/marine-protected-areas/aquatic-reserves/north-harbour-aquatic-reserve

Know your microplastics http://www.waterkeeper.ca/cases-microplastics/

Sydney Opera House Sustainability Plan https://www.sydneyoperahouse.com/content/dam/pdfs/environment/ESP_2017-19.pdf

Image source: Shutterstock

ACTIVITY 1:
HEALTHY AQUATIC ENVIRONMENTS

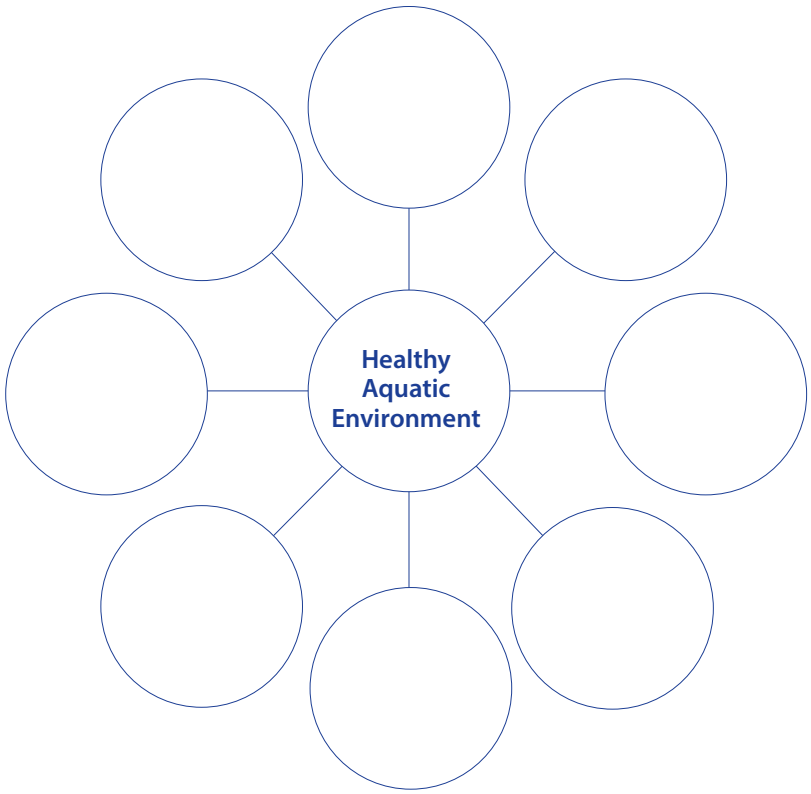
1. THINK, PAIR, SHARE

a. Distinguish between aquatic and terrestrial environments

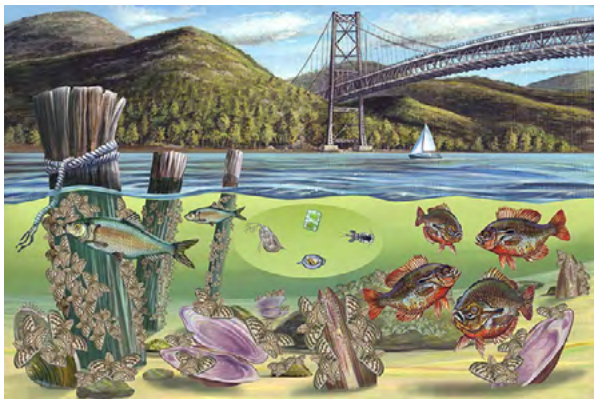
b. Identify some aquatic environments you know

2. SEE SAW

Work in pairs to add features of a healthy aquatic environment to the following mind map.
See-Saw so each student contributes in turn – do not progress until your partner has contributed an idea.
After 5 minutes – study the images on the following page.
See-Saw again to confirm or change the ideas on the mind map.



Source: https://water.usgs.gov/nawqa/ecology/pubs/cir-1391/images/NaturalStream.pdf



Source: https://www.amnh.org/education/resources/rfl/web/riverecology/explore.html

Source: https://pxhere.com/en/photo/1372124
The image is released free of copyrights under Creative Commons CC0

You might also like to visit this interactive diagram of Oyster Harbour, WA – https://rei.dwer.wa.gov.au/estuary/oyster-harbour/estuary/

INQUIRY QUESTION

Do you think Sydney Harbour is a healthy aquatic environment? YES NO
Justify your answer

ACTIVITY 2: SYDNEY HARBOUR QUIZ

1. The city of Sydney is very young.
   How old is the harbour on which it was built?
   a) 25 Million Years
   b) 10 Million Years
   c) 100 000 years
   d) 10 000 years

2. Tidal ranges vary hugely around Australia from less than 1m at Portland, Victoria to more than 10m at Derby, Western Australia. Being connected to the open ocean Sydney Harbour is also subjected to tidal changes. What is the maximum difference between the high and low tide in Sydney Harbour?
   a) 0.5m
   b) 2.1m
   c) 5.3m

3. Seagrass beds provide important nursery grounds for baby fish. How many species of seagrass occur in Sydney Harbour?
   a) 3
   b) 15
   c) 30

4. The Eastern blue groper is one of the most charismatic fish in the Harbour. They can grow up to 120 cm, but how long can they live?
   a) 5 years
   b) 10 years
   c) > 30 years

5. The East Australian Current flows southward from the Great Barrier Reef along the coast of NSW. In the film 'Finding Nemo' Nemo's dad Marlin travelled southward in the EAC from the GBR to Sydney. Is this realistic? Do we find tropical fish in Sydney Harbour?
   a) Yes
   b) No

6. If you answered yes, how many days do you think it takes for a fish to arrive in Sydney Harbour if it came from Heron Island (approximately 1500km north of Sydney), assuming the EAC flows at 1 m/s?
   a) 17 days
   b) Two months
   c) Half a year

7. Sydney Harbour can be a busy waterway! Approximately how many boats were registered in Sydney Harbour in 2014?
   a) 5000
   b) 9 000
   c) 20 000
   d) 50 000

8. One Sydharb is an official Australian unit of measurement. It is used to measure volume and is equivalent to the volume of water in Sydney Harbour.
   A Sydharb of water equals?
   a) 250 gigalitres
   b) 500 gigalitres
   c) 750 gigalitres
   d) 1000 gigalitres

9. There are more species of fish in Sydney Harbour than along the coast of the United Kingdom. How many fish species are in Sydney Harbour?
   a) Fewer than 380
   b) 480
   c) 580
   d) Over 580

10. How much of the 322km long Sydney Harbour shoreline is reclaimed land?
    a) 25%
    b) 30%
    c) 40%
    d) Over 50%

Can you add ONE extra thing you know about Sydney Harbour?

Source of Quiz Questions: Sydney Institute of Marine Science. Answers on Page 53.

ACTIVITY 3: BIODIVERSITY

1. CREATE A SYDNEY HARBOUR FOOD WEB

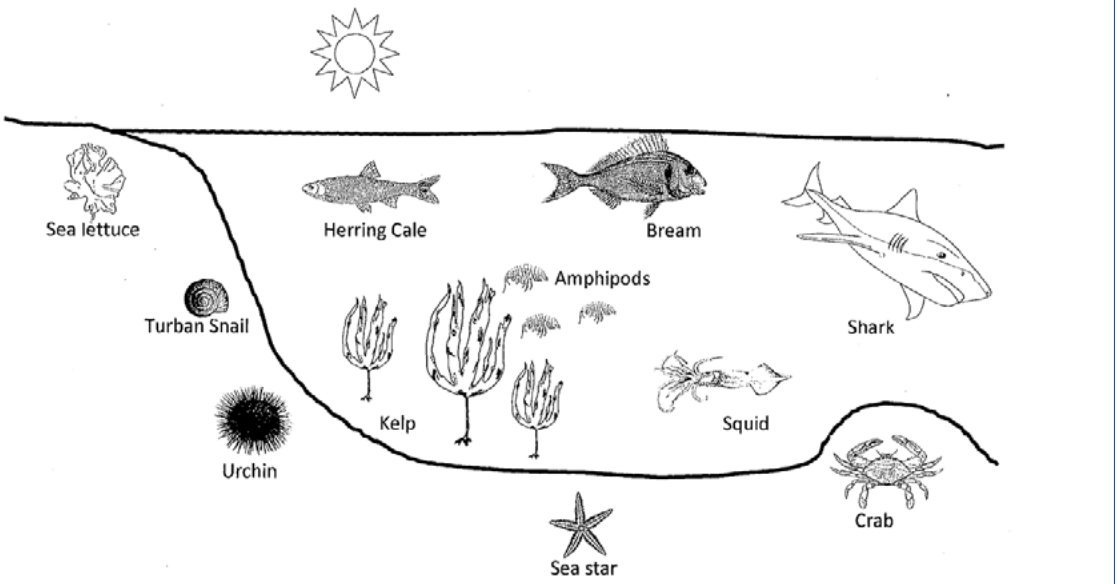
The following diagram illustrates common species found in a Subtidal Rocky Reef habitat.

Large algae (kelp) are the main habitat forming organisms in the subtidal rocky reefs. ***Ecklonia radiata*** is the most common type of kelp found in Sydney Harbour and it creates large underwater forests, providing food and shelter to many animals in the ecosystem.

A food web consists of all the food chains in an ecosystem. Each living thing in an ecosystem is part of multiple food chains. The sun provides the energy for plants to produce food. This is the beginning of every food chain.

Start with an arrow beginning at the sun, then show the flow of energy through the producers and consumers to the top predators. Can you draw a possible subtidal food web?

Natural Subtidal Rocky Reef Food Web



Source: Sydney Institute of Marine Science

2. SOFT BOTTOM AND BEACH SPECIES

Undertake a geographical inquiry to identify a variety of species that occupy mangrove, seagrass and saltmarsh habitats in NSW estuaries (including Sydney Harbour Estuary).

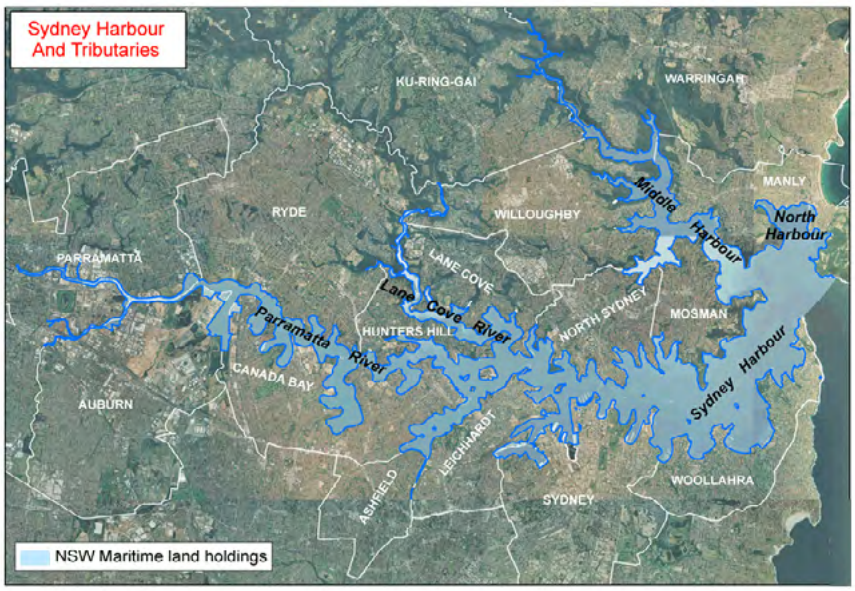
ACTIVITY 4:
IDENTIFYING SYDNEY HARBOUR HABITATS

Use Google Earth (or alternative source of satellite images) to fly over and zoom in on sections of Sydney Harbour Estuary between North Head and Parramatta.

For each of the habitats in the boxes below find 2 locations where that habitat is observed. Use arrows to show these locations and add place names to the habitat box.

Subtidal rocky reef habitats

Rocky intertidal habitats



Source: NSW Road and Maritime Services - http://www.rms.nsw.gov.au/images/maritime/property-planning/leasing/sydney-aerial-lg.gif

Soft bottom and beach habitats

Open water habitats

Paste a photograph (digitally) or complete a photo-sketch of one location or species found at one of the locations you have identified.

ACTIVITY 5:
CAN OYSTERS SAVE SYDNEY HARBOUR?

Inquiry Questions

What is a habitat forming species?

Why have populations of oysters in Sydney Harbour declined?

Why are recent management strategies for Sydney Harbour focused on restoring key species such as oysters?

Investigation

Research each of the following areas:

1. The environmental importance of oyster reefs
2. Human uses and impact on oyster habitats in Sydney Harbour since 1788
3. Management strategies to restore oyster habitats in Sydney Harbour
4. How the environment of Sydney harbour will benefit from oyster restoration.
5. Global trends in oyster habitats distribution
6. Strategies used in another country to restore or protect oyster habitats.

Answer the question 'Can oysters save Sydney Harbour?'

Create an infographic summarising your key research findings.

Use the images and websites below to inspire your research.

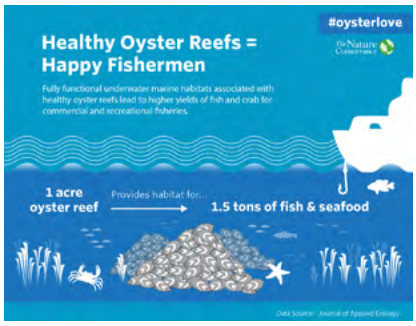
Weblinks

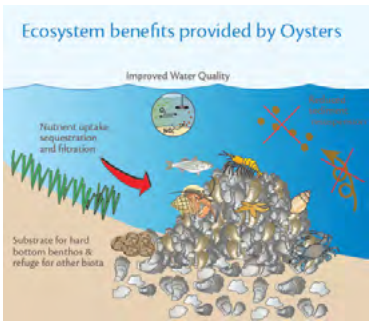
The surprising benefits of oysters – and no, it's not what you are thinking
https://theconversation.com/the-surprising-benefits-of-oysters-and-no-its-not-what-youre-thinking-90697

Oysters: Ecological superheroes with a dark past
https://www.adelaide.edu.au/environment/marine-biology/research/oyster-reefs/oysters/

Restoring shellfish reefs https://www.youtube.com/watch?time_continue=1&v=Dn8dZrWK7fM

SIMS Sydney Harbour Research Program. Habitat restoration
http://engonet-sims.azurewebsites.net/page/115/habitat-restoration





Sources for images

For the love of Oysters – https://blog.nature.org/science/2016/02/11/love-oysters-seafood-water-oceans/
Living Seawalls in Sydney Harbour – https://www.sims.org.au/news/30/volvo-partners-with-sims
NOAA Office – http://chesapeakebay.noaa.gov/oysters/oyster-reefs

ACTIVITY 6: THREATS TO ESTUARIES

Sydney Harbour faces the same environmental threats as other estuaries around the world.

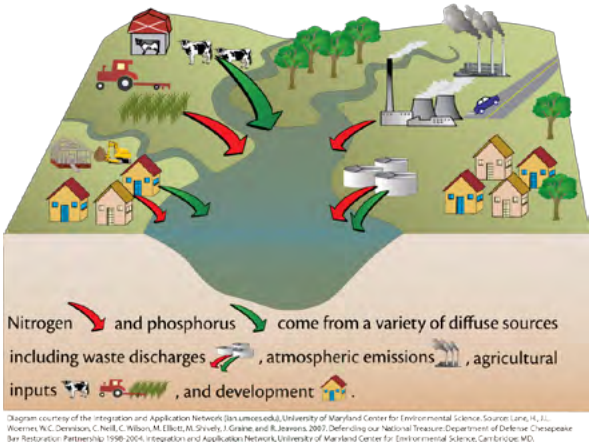
Inquiry Questions

What are the main threats to estuarine environments such as Sydney Harbour?
What has been the cumulative impact of these threats on the Sydney Harbour estuary?
Is Sydney Harbour a healthy, well-functioning environment?

Class discussion

Examine the conceptual diagram / model here and on the next page:

- Identify the purpose of this type of diagram or model
- assess the value of conceptual models for learning about environmental change and management
- look up terminology you do not know eg. benthic, eutrophic



Source: Integration and Application Network (IAN

Group task

Each group will use ONE conceptual model from the Ozcoasts website to investigate threats to an estuarine environment such as Sydney Harbour. https://ozcoasts.org.au/conceptual-diagrams/stressors/

1. Choose ONE of the following conceptual models
   - Toxicants
   - Pest species
   - Bacteria / pathogens
   - Litter (including plastics / microplastics)
   - Habitat removal / disturbance
   - Nutrients
   - Biota removal /disturbance (Loss of biodiversity)
2. Examine the model to determine
   - The cause or source of the threat to the estuary
   - The impacts of the threat on the environment and people living around that estuary.

   Summarise this information into a table
3. Develop a hypothesis based on the degree to which this threat is impacting on Sydney Harbour
4. Research evidence for the impact you are investigating for Sydney Harbour

   Be specific in your search e.g. Microplastics / toxic substances in Sydney Harbour.

ACTIVITY 6: THREATS TO ESTUARIES

Class plenary

Contribute to a class discussion of the cumulative impacts of a range of different threats on the Sydney Harbour environment.

1. Record the key ideas from each group on a mind map.
2. Create several flow diagrams to show the cause and effect of different threats.
3. Answer the following questions in short paragraphs.

Inquiry Questions

What are the main threats to estuarine environments such as Sydney Harbour?

What has been the cumulative impact of these threats on the Sydney Harbour estuary?

Is Sydney Harbour a healthy, well-functioning environment?

Extension

Create a hand drawn or digital conceptual model summarising the key threats to Sydney Harbour.

Explain your model to TWO other students. Ask for feedback. Revise your model.

Source: http://ian.umces.edu/blog/2016/10/11/conceptual-diagrams-turning-science-into-graphic-art/

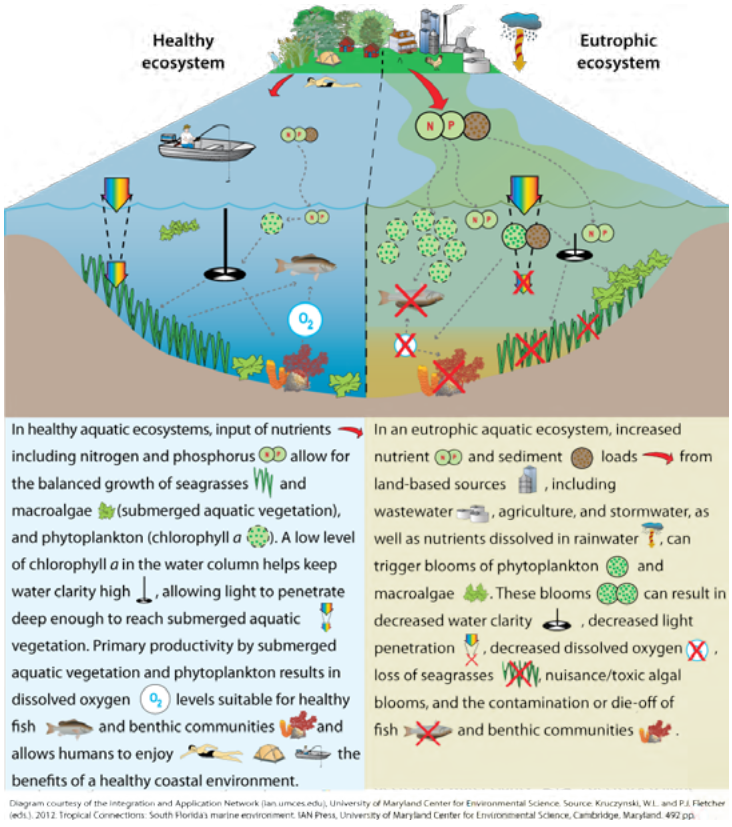


Diagram courtesy of the Integration and Application Network (ian.umces.edu), University of Maryland Center for Environmental Science. Source: Kruczynski, W.L. and P.J. Fletcher (eds.). 2012. Tropical Connections: South Florida's marine environment. IAN Press, University of Maryland Center for Environmental Science, Cambridge, Maryland. 492 pp.

Conceptual diagram comparing a healthy system with no or low eutrophic condition to an unhealthy system exhibiting eutrophic symptoms. From Bricker et al., 2007.

ACTIVITY 7:
DESIGN A NEW HARBOUR SHORELINE

INSTRUCTIONS

Choose a location on Sydney Harbour where the shoreline has been replaced by infrastructure such as at Farm Cove where the Botanic Gardens meet the harbour.

Develop Inquiry Questions (Examples)

- What's wrong with Farm Cove?
- What are some future threats to the environment at Farm Cove?
- How might Farm Cove be made more sustainable for the benefit of the Sydney Harbour environment?

Conduct a site visit if possible. For example, at Farm Cove walk from the Opera to Mrs Macquarie's Chair making observations, taking measurements and taking photographs to record the current state of the shoreline.

Use secondary sources to provide background information e.g. current and historical maps and photographs, diagrams

Use Google Earth to locate and draw elevation profiles of the site

Discuss what is wrong with the location. Consider questions such as - Is it environmentally sustainable? Is it fish friendly? Are there any habitats and living organisms present? What criteria might be used to assess sustainability?

Study the Design Brief and template provided.

Work in pairs to create a proposal to enhance the sustainability of the selected shoreline

Present and justify the proposal to the class and invited community members.

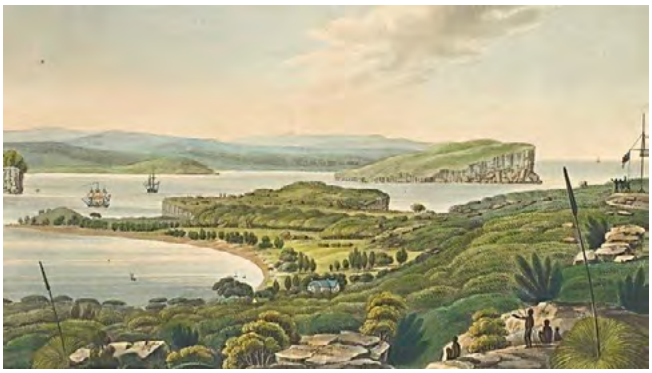
Examples based on Farm Cove

Source: https://en.wikipedia.org/wiki/Royal_Botanic_Garden,_Sydney

Source: Google Earth screen capture L Chaffer

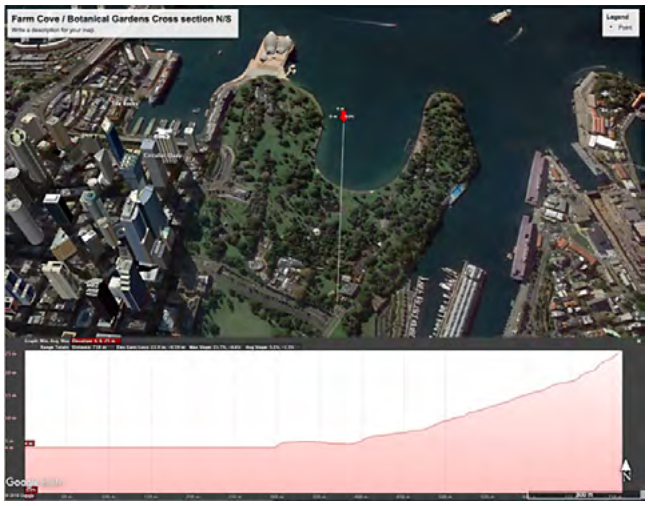
ACTIVITY 7: DESIGN A NEW HARBOUR SHORELINE

What was Farm Cove like? Then and now maps.



LEFT: Convict Sydney - https://sydneylivingmuseums.com.au/convict-sydney/governors-domain#gallery-1

RIGHT: Joseph Lycett 'View of the Heads, at the entrance to Port Jackson, New South Wales', 1825 https://www.theaustralian.com.au/arts/seeing-was-believing-in-the-early-days-of-australias-white-settlement/news-story/d757a4ce5b40b1c98b3794896d09d109?sv=5d53c7579440cd6b10c89d4bd29f3cc8



LEFT: Google Earth digital elevation profile

RIGHT: Climate Change Model Source: http://www.abc.net.au/news/2017-05-23/coastal-areas-at-risk-new-climate-study-reveals/8549934

LEFT: Topographic Map
Screen capture from six maps
Parramatta Map

Photographs of seawall and footpath. Source: L Chaffer

Note: Farm Cove has heritage status and the wall cannot be altered. This is a hypothetical.

Create a New Harbour Shoreline: Design brief

Brief	**Options**	**Justification**	**Sustainability** **How does your plan achieve sustainability?** **Environmental, Economic, Social**
You have an opportunity to change the Sydney Harbour foreshore at one location What would you do to enhance the sustainability of Sydney Harbour at this location? What area will you include in your design? The aim is to promote biodiversity and harbour health while meeting the social, environmental and economic demands on the site	REPLACE e.g. Living shoreline,		
	RETROFIT e.g. Eco-engineering: Living seawall		
	RETHINK e.g. Offshore reef		
	REDESIGN Your unique idea		

MY PROPOSAL DRAFT

DESIGN DRAWING	DESIGN EXPLANATION

See what a masterplan might look like at
https://www.smh.com.au/national/nsw/fivestar-150room-hotel-blooms-in-radical-botanic-gardens-and-domain-revamp-20140405-365qo.html

ACTIVITY 2: Answers

1d Sydney Harbour was formed just over 10 000 years ago. As the sea level rose, the ocean flooded into a valley hilly river system. Sydney Harbour is known as a ria (drowned river valley).

2b Sydney is known as 'micro-tidal' and experiences a maximum 'tidal range' just over 2.1 m. The Harbour is a tide dominated estuary. The tides determine water level, salinity, current strength and direction and aquatic species throughout the whole harbour. Estuarine environments are among the most species rich on Earth.

3a Several species of seagrass have been recorded but seagrass beds are dominated by 3 taxa. Sea grasses are habitat forming and important for biodiversity.

4c. Blue gropers can live in excess of 35 years!

5a Yes … on the increase!

6a. Note: Time = Distance divided by speed (T = D/S)

7c. As of 2009 there were 20,000 boats registered in Sydney Harbour. Most of these were between 4–6 meters in size.

8b. 500 gigalitres (1 Gigalitre is 1,000,000,000 litres)

9c. Over 586 species of fish are found in Sydney Harbour…. rich estuarine biodiversity. There are over 3000 marine species in the harbour.

10a. 77km of the shoreline is reclaimed land (about 25%) – but 50% is armoured by seawalls for reclamation as well as protection of property. Sydney Harbour is one of the world's most modified harbours.

Photo: L Chaffer

FACT SHEET 1: WHAT IS AN ESTUARY?

'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].

Estuary functioning (processes)

Most estuaries were formed approximately 12,000 years ago when rising sea levels flooded river valleys while others formed due to glaciation (erosion) and tectonic forces (crustal movements).

Rivers carry sand, silt and plant matter downstream where it is deposited on floodplains or in estuaries to create a nutrient rich environment. Daily tides and climatic events result in a mix of saltwater and freshwater – salinity decreases moving upstream in the estuary. Precipitation, river discharge, tide sizes and the 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 so productive'[2].

The importance of estuarine environments

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, including migratory species, and mammals, rely on them for food and nesting or nurseries sites.

   'A healthy estuary produces between 4 and 10 times as much organic matter as a cornfield of the same size'[3].

2. ***Vegetation communities*** such as intertidal salt marshes and habitat forming marine species such as oysters filter sediment and pollutants from the water as it moves from land to sea. These communities also act as buffers against climate and tidal stresses such as tidal surges.
3. ***Estuaries*** are economically important. Coastal activities, commercial and recreational fishing, boating, and tourism provide 28 million jobs and generate more than 20 billion dollars of income each year.
4. ***Estuaries*** are a popular recreational destination. In 1993 more than 180 million Americans (about 70% of the population) visited ocean and bay beaches. Rhode Island has more than 85 marinas, 28 yacht clubs, 16 boat builders, 9 sailing schools, 100 public launching sites and swimming at more than 100 beaches.
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.

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

FACT SHEET 1: WHAT IS AN ESTUARY?

Threats to Estuaries[4]

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

> *'Estuaries have become part of our history and our heritage. They will be a part of our future if we can find sustainable ways to use them and preserve their health[5].*

Diagram 1: Important linkages between physical (e.g., tidal currents, river discharge, and groundwater) and biological (e.g., fish migrations, larval transport) processes in estuaries[6]

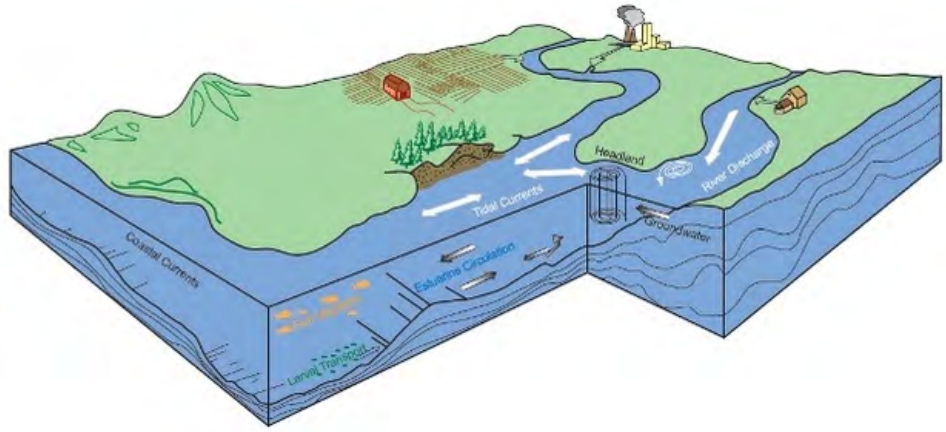
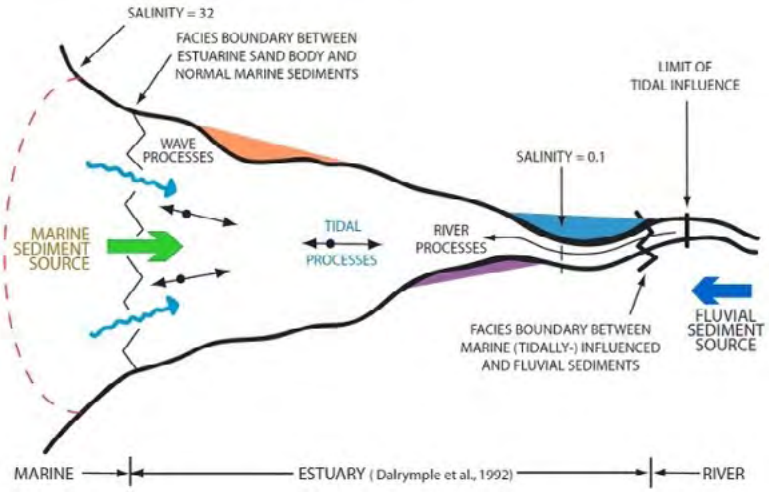


Diagram 2: Typical zones in an estuary moving from inland, where fluvial (freshwater /river) processes dominate, to the mid- and mouth regions where tidal and wave processes are the dominant controlling physical forces[7].



4. Biome: Estuaries https://biome-estuaries.weebly.com/threats-to-estuaries.html
5. Estuarine Science http://omp.gso.uri.edu/ompweb/doee/science/descript/whats.htm
6. Estuaries: Where the river meets the sea https://www.nature.com/scitable/knowledge/library/estuaries-where-the-river-meets-the-sea-102734157
7. Estuaries: Where the river meets the sea https://www.nature.com/scitable/knowledge/library/estuaries-where-the-river-meets-the-sea-102734157

FACT SHEET 2: ARTIFICIAL STRUCTURES AND SHORELINE MODIFICATION

CHANGING THE SHORELINE

Sydney Harbour is one of the most modified harbours in the world with 50% of the harbour armoured with sea walls. These walls were constructed:

- when foreshore land was reclaimed for development, transport or recreation
- to facilitate infrastructure such as Circular Quay jetties and the opera house
- to protect property from flooding or storm damage.

The walls effectively replaced natural sloping, soft sediment shorelines and habitats with a straight hard surface. Piers and jetties allow water movement but create shady habitats preferred by many invasive species.

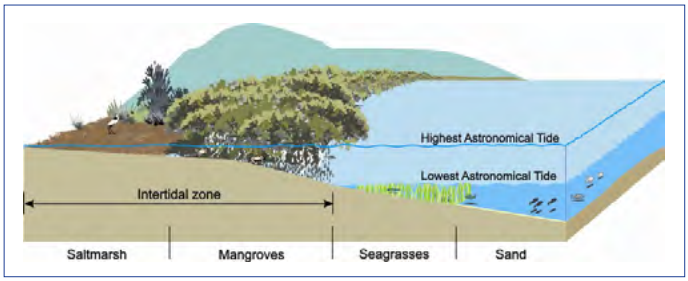


Diagram 1: On a natural shoreline, tidal changes create habitats and microhabitats in the intertidal zone that support marine plants and animals e.g. sponges, algae, molluscs, crustaceans and fish communities.

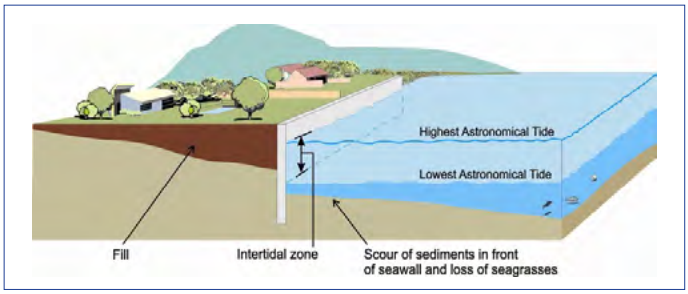
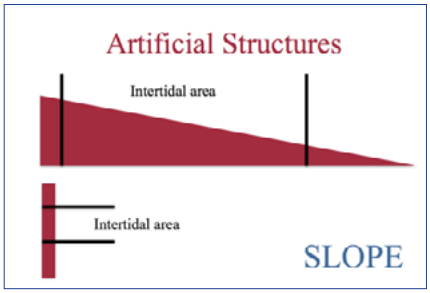


Diagram 2: Modified shorelines restrict natural tidal fluctuations and only those organisms that can survive on near vertical surfaces remain.

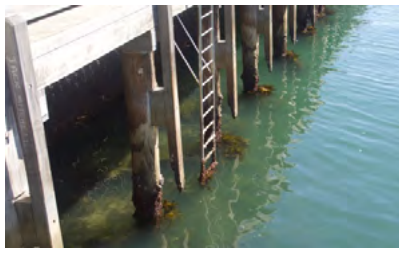
Diagrams from Office of Environment and Heritage via Fish Habitat Network – https://www.fishhabitatnetwork.com.au/projects/environmentally-friendly-seawalls-fish-friendly-marine-infrastructure



Source: Alana Rooney SIMS

Diagram 3 (left): Changing the shoreline from sloped to vertical

Photos: Examples of harbour modification



Source: L Chaffer

FACT SHEET 2: ARTIFICIAL STRUCTURES AND SHORELINE MODIFICATION

MANAGEMENT OPTIONS

Eco- engineering – new shoreline design or 'blue' design

Planners and developers are rethinking shorelines to more closely mimic natural foreshores. The most recent example is the Headland Park in Barangaroo Reserve where the design was based on ecological principles. Sandstone blocks of different sizes replicated natural sandstone headlands and were stepped to decrease slope and create rock pools.

Designing seawalls that incorporate ecological principles. For example:

- decreasing vertical slopes
- incorporating shallow habitats
- increasing the complexity of surfaces to create habitats
- adding 'skylights' into walkways or jetties to reduce shading effects

Retrofitting for biodiversity: Creating living walls

Attaching *concrete 'flowerpots'* that mimic some of the functions of natural rockpools (such as retaining water at low tide) onto existing seawalls. Examples include the Glebe foreshore & Botanic Gardens seawall. In less than a year the pots had 40% more algal species and 39% more immobile animals & 118% more mobile species than other seawalls. This benefited species such as fish by providing increased habitat and food supply.

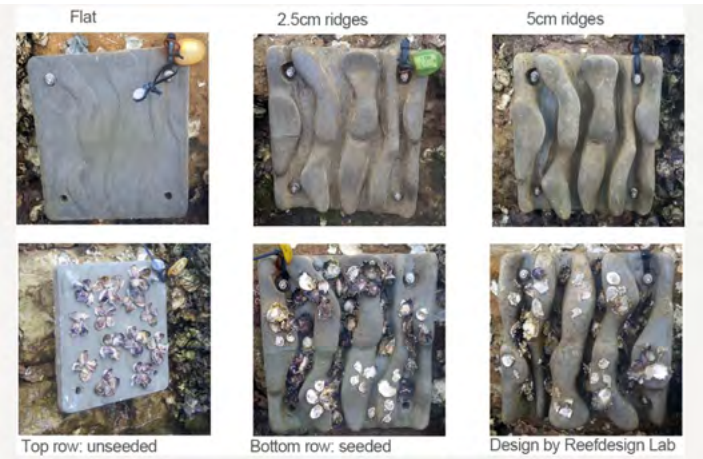
Photo: Flowerpot attached to seawall

Source: http://www.abc.net.au/catalyst/stories/2936248.htm

Read more:
Flowerpots tackle Sydney Harbour's aquatic housing crisis
http://www.abc.net.au/radionational/programs/offtrack/flowerpots-tackle-sydney-harbours-aquatic-housing-crisis/6148966

Environmentally Friendly Seawalls: A Guide to Improving the Environmental Value of Seawalls and Seawall-lined Foreshores in Estuaries
https://www.environment.nsw.gov.au/research-and-publications/publications-search/environmentally-friendly-seawalls

Photo: World Harbour Project



Attaching *3D-printed concrete tiles* to add complex surfaces that can be seeded with key habitat forming species (the Sydney rock oyster, and the calcareous red algae) and attached to seawalls. Over a year experimental sites showed that these features attracted significant marine life such as seaweeds, crabs and fish.

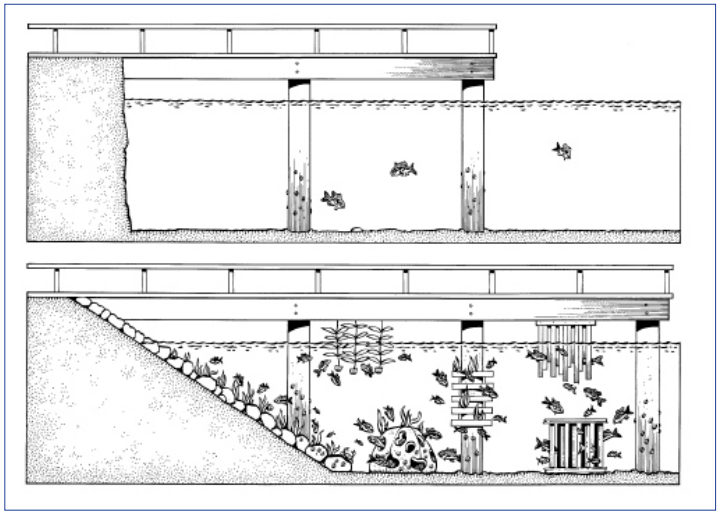
Source: http://www.worldharbourproject.org/workgroups/green-engineering/

Fish friendly infrastructure

Infrastructure suited to design and construction for fish friendliness includes small boat harbours and marinas, jetties, pontoons, boat ramps, boardwalks, mooring buoys and fishing platforms.
The aim is to create structures that:

- cause minimal disturbance to the existing environment
- incorporate features that provide habitats in which native fish can live.
- allow recreational and commercial activities to exist in balance with nature

Diagram of a fish friendly jetty



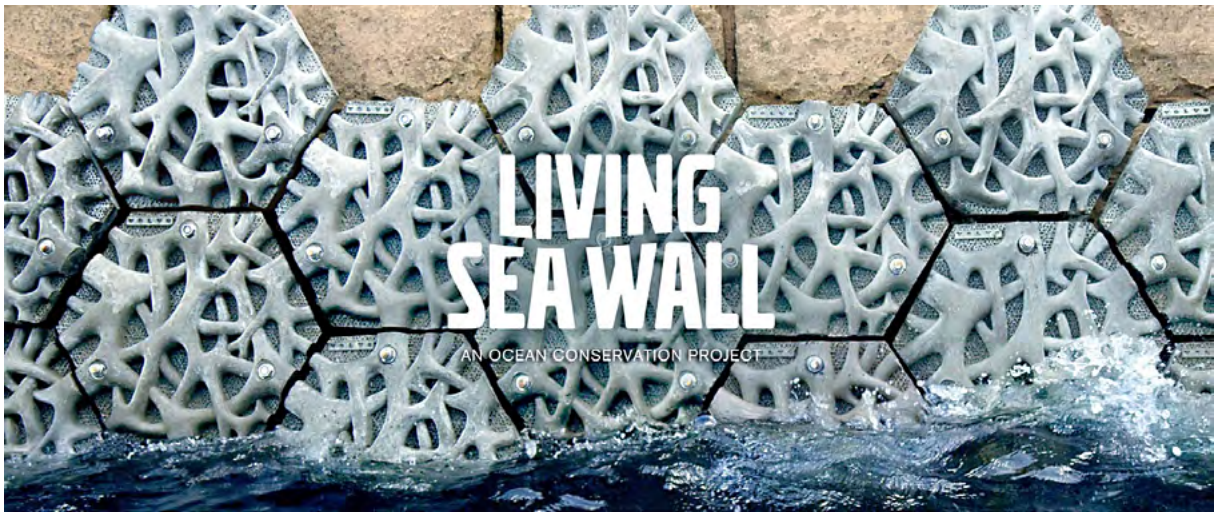
Source: https://www.daf.qld.gov.au/business-priorities/fisheries/habitats/policies-and-guidelines/fish-habitat-factsheets/what-are-fish-friendly-structures

Artificial reefs are being created to encourage habitat forming species in places where infrastructure has significantly reduced habitat such as around the Sydney Opera House and beneath large areas of infrastructure such as ferry wharves.

How a new Opera House reef project will breathe life into Sydney Harbour
https://www.sydneyoperahouse.com/backstage/backstage-articles/a-healthier-harbour.html

Photo and information, Sydney Opera House Trust

Screen capture from Sydney's newest living sea wall



Learn more at:

One of the worlds largest living seawalls – https://www.facebook.com/7newssydney/videos/one-of-the-worlds-largest-living-seawalls-has-been-launched-in-sydney-harbour-to/345909836163615/

Volvo Living Seawall – https://www.volvocars.com/au/about/australia/living-seawall