CASE STUDY

Sydney Harbour – enhancing seawall sustainability

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More than 50% of the Sydney Harbour foreshore is armoured by seawalls for land reclamation and coastal protection purposes. Seawalls are generally flat, featureless structures (Figure 1a) in comparison to rocky shores - their closest natural habitat type (Figure 1b).

Figure 1. a) Example of a typical seawall.

b) Example of a natural rocky foreshore.

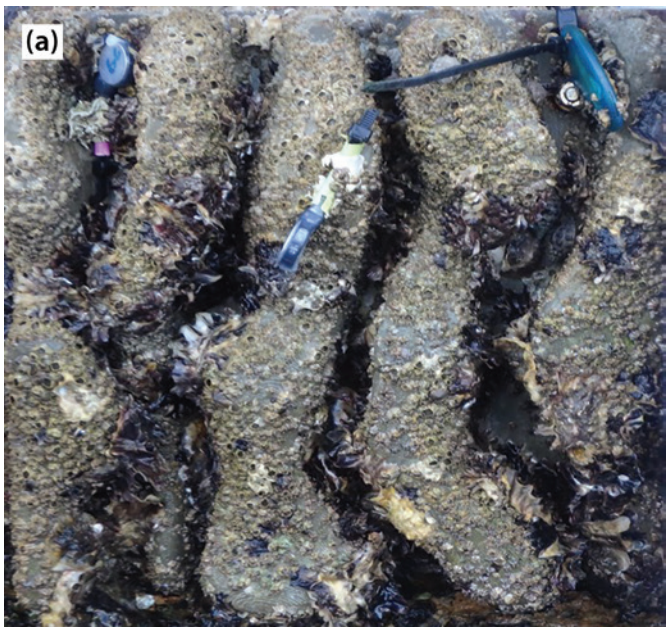

Figure 2. Complex tiles (a, left) and flowerpots (b, right), retrofitted to seawalls to mimic important microhabitats of rocky shores which are missing or rare in existing seawall designs of Sydney Harbour.

These existing seawalls generally have reduced species diversity and ecosystem functioning relative to natural rocky shores. The seawalls' predominately vertical surfaces provide a reduced surface area for colonisation of organisms as compared to the largely horizontal surfaces of natural rocky shores, in addition they may lack important features such as crevices and rockpools that provide shaded, moist microhabitats, and protect inhabitants from predation.

The replacement of natural foreshores with seawalls has resulted in a:

- loss of biodiversity, and a reduction in the abundance of ecologically important species such as oysters [2, 6]
- loss of ecosystem function provided by key species (e.g. filtering by oysters that helps to maintain water quality)
- spread of introduced species, including marine pests[4].

In Australia and globally, oyster reefs have been reduced to a fraction of their historic abundance due to overharvest and disease [8, 1]. Further, many areas worldwide have experienced over 50% loss of the natural foreshore, once occupied by oysters, to artificial structures such as seawalls. In Sydney Harbour, there is a growing interest in enhancing the abundance of the rock oyster *Saccostrea glomerata* on seawalls because of their ability to facilitate dense and diverse invertebrate and fish species assemblages, and maintain cleaner waters through filter feeding [10, 11].

The sustainability of Sydney's seawalls needed to be enhanced. Ideally sustainability should have been incorporated at the design-stage through consideration of ecological principles, in lieu of this foresight; approaches are needed for addressing existing structures.

Project steps

Establish goals

This project had two goals: 1) to enhance biodiversity on seawalls and 2) enhance the abundance of a functionally important species, the Sydney rock oyster.

Previous studies have indicated that amongst the species found on rocky shores, those that are rare or absent from seawalls are habitat specialists that inhabit crevices and rockpools[3]. Provision of microhabitats on seawalls that perform a similar function to naturally occurring crevices and rockpools may serve to enhance biodiversity by protecting specialists from predators and environmental stressors and increasing the abundance of functionally important species.

Design habitat enhancements, and attach these to seawalls

Two types of habitat-enhancing structures were retrofitted to seawalls to add missing microhabitats and/or increase the surface area for organism attachment: 1) complex tiles designed to mimic the habitat provided by crevices and ridges (Figure 2a and 3); and 2) flowerpots designed to mimic rockpools (Figure 2b and 4).

Figure 3. Complex tiles with crevices and ridges were designed by Reef Design Lab.

Figure 4. Flowerpots were constructed by Antique Stone and attached to the seawall using stainless steel brackets.

Figure 5. Complex tiles in-situ (bottom left corner) retrofitted to a seawall.

The complex tiles had ridges separated by crevices 2.5cm or 5cm deep. The crevices were designed to provide shaded and moist microhabitats for specialist species and to protect oysters, a common inhabitant of crevices, from predation and extreme air temperatures that occur on midday low tides.

Half the tiles were seeded with 52 juvenile rock oysters, 26 of these were placed in the crevices and 26 on the ridges of the tiles.

The 30cm deep flowerpots were designed to be submerged at high tide and retain water as the tide dropped, thereby providing a low-tide refuge for species that could not persist on unchanged seawalls.

Both habitat interventions were attached to seawalls at a mid-tidal elevation. The tiles were attached using a combination of dynabolts and epoxy (Figure 2a and Figure 5); the flowerpots were held in place using stainless steel brackets (Figure 6).

Ecological monitoring

The effectiveness of these retrofitted structures was monitored over a 6-18 month period using a combination of photo quadrats, GoPro videoing and removal of colonising species for laboratory identification. The establishment of intertidal communities, habitat utilisation by fish and survivorship of oysters transplanted onto ridges and crevices of the complex tiles, were compared between the habitat interventions and otherwise featureless surfaces of seawalls.

Figure 6. Flowerpots retrofitted to a seawall.

Successes and lessons learnt

After 12 months, oysters transplanted onto the complex tiles displayed enhanced growth and survivorship as compared to those transplanted onto featureless, flat surfaces. This result was largely due to the greater survivorship of oysters in crevices, where they were protected from predatory fish, than on ridges or flat surfaces – a pattern that was unsurprisingly stronger at sites with higher abundances of fishes[9]. Additionally, many more new oyster recruits had settled into the crevices of the complex tiles than on the ridges or on flat surfaces. Measurements showed the crevices were cooler and retained more moisture than the ridges or flat surfaces (Figure 7), which also resulted in increased settlement and colonisation of other sessile and mobile invertebrates.

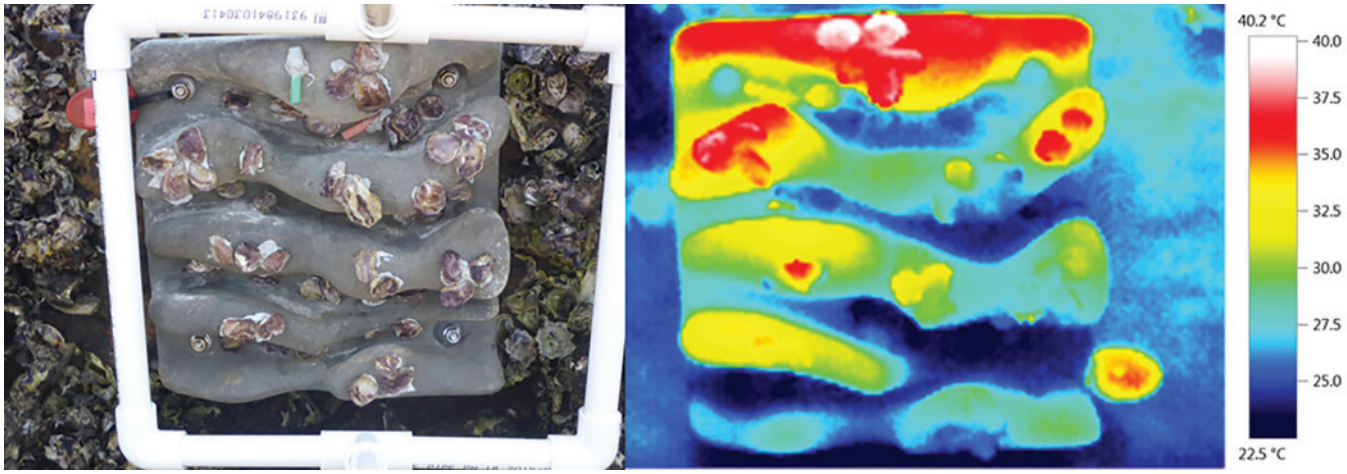

Figure 7. Temperature of the microhabitats and oysters.

Flowerpot additions increased the biodiversity of the seawall by 80% in one year[7]. Many species typical of natural rocky pools, such as fish, starfish, algae, sponges and sea squirts colonised the flowerpots (Figure 8a). In addition, video footage showed that fish visited the pots at high tide (Figure 8b). The flowerpots were not, however, colonised by all species that would be found in natural rock pools.

Design amendments may enhance the effectiveness of artificial rock pools to mimic natural pools, but this has not been tested to date. In addition, some flowerpots in more sheltered areas of the harbour (Blackwattle Bay) retained a lot of sediment. Whether this sediment is of value as habitat is currently being researched. Previous studies have shown artificial pools tend to work better in areas with low sedimentation[5]. In very wave-exposed areas, water-retaining features would be better built into seawalls from planning stages as it can be difficult to engineer them to stay on the seawall.

Figure 8. a) Cushion star in the flowerpot.

b) Luderick in the flowerpot.

Quick facts

Project overview	A largely experimental, collaborative project evaluating the effectiveness of retrofitting seawalls with complex tiles and flowerpots to enhance marine biodiversity on seawalls of Sydney Harbour.
Location and councils	Waverton, North Sydney and Balmain, Leichardt, Blackwattle Bay, Elizabeth Bay, Royal Botanical Gardens.
Cost and time	The total project cost for the complex tiles was $10,000 for materials and labour for fitting 110 tiles. The tiles were fabricated and fitted in 3 months. Monitoring was conducted over 12 months in 2015-2016. Flowerpots cost $300 per pot for construction and fitting. Grants of $115,000 supported flowerpot installation, monitoring costs and community engagement activities related to the research. Flowerpots were constructed and fitted in 3 months. Monitoring was done for 6 to 18 months between 2013 and 2016.
Funding and technical support	Over $215,000 in support has been provided by Harding Miller Foundation, Ian Potter Foundation and the Office of Environment and Heritage, World Harbour Project, City of Sydney Council, Sydney Coastal Councils Group and the Sydney Institute of Marine Science.
Key project facts and outcomes	~100m of 2 x seawalls covered in a total of 110 tiles (55 each site) ~5000 oysters deployed (2,500 each site) ~170m of 10 x seawall sites covered in 80 flowerpots (5-10 per site).
Project partners	The Sydney Institute of Marine Science, Macquarie University, University of New South Wales, and The University of Sydney were involved in deployment, monitoring and research. Reef Design Lab and Antique Stone were responsible for the design and construction of complex panels and flowerpots.

Planning and approvals

All approvals were obtained directly from the seawall structure owners such as local councils on a case by case basis. Written approval and support for the project was provided.

- No development consent was required for the installation of structures along a seawall under the *State Environmental Planning Policy (SEPP) (Infrastructure) 2007* by public authorities. This was due to them being defined as "waterway or foreshore management activities" in accordance with Clause 128(b) of the SEPP and "environmental management works" in accordance with Clause 125 of the SEPP.
- The works were considered under Part 5 of the *Environmental Planning and Assessment Act 1979* through a Review of Environmental Factors (REF) as well as the Clause 228 Guidelines under *NSW Environmental Planning Assessment Regulation 2000*.
- A REF was prepared in accordance with the City of Sydney Part 5 Environmental Impact Assessment Procedures Manual and was classified as a "Level 2 REF".
- Informal support for the installations was provided by Roads and Maritime Services due to Sydney Harbour (land) and therefore a component of the seawall structure falling below Mean High Water Mark. Formal consent was not required due to installations being conducted at Mean High Water Mark.
- No permit was required under the *Fisheries Management Act 1994* from NSW Department of Primary Industries (Fisheries) for these works.
- A Heritage Impact Statement was required for installations at Farm Cove and Beare Park for works affecting heritage items or properties within a Heritage Conservation Area identified in the Sydney Local Environment Plan 2012. The removable nature of the installations was pertinent in gaining approval from the Heritage Council.
- Landowners consent via a s57(2) form was required and submitted to the NSW Heritage Council for installations at Farm Cove. A Standard Exemption No. 7 Minor activity with little or no adverse impact on heritage significance was sought.
- Land Owners Consent under the *Crown Lands Act 1989* was not required by NSW Department of Industry, Lands & Forestry division, as installations occurred at median water height and therefore not on Crown Land.

NOTE: the above approvals apply to the City of Sydney area. Other Councils involved in the project did not require a REF due to the installations being viewed as complying development under the SEPP (Infrastructure).

Always consult with your local Council prior to undertaking any foreshore works or adjustments. They will be able to provide information on what approvals may be required and which government agencies provide these.

References

1. Beck, M.W., Brumbaugh, R.D., Airoldi, L., Carranza, A., Coen, L.D., Crawford, C., Defeo, O., Edgar, G.J., Hancock, B. & Kay, M.C. (2011) Oyster reefs at risk and recommendations for conservation, restoration, and management. *Bioscience*, **61**, 107-116.
2. Chapman, M. & Bulleri, F. (2003) Intertidal seawalls—new features of landscape in intertidal environments. *Landscape and Urban Planning*, **62**, 159-172.
3. Chapman, M.G. & Underwood, A.J. (2011) Evaluation of ecological engineering of "armoured" shorelines to improve their value as habitat. *Journal of Experimental Marine Biology and Ecology*, **400**, 302-313.
4. Dafforn, K.A., Glasby, T.M. & Johnston, E.L. (2012) Comparing the invasibility of experimental reefs with field observations of natural reefs and artificial structures. *PLoS One*, **7**, e38124.
5. Firth, L.B., Browne, K.A., Knights, A.M., Hawkins, S.J. & Nash, R. (2016) Eco-engineered rock pools: a concrete solution to biodiversity loss and urban sprawl in the marine environment. *Environmental Research Letters*, **11**, 094015.
6. Jackson, A. (2009) Biogenic habitat on artificial structures: consequences for an intertidal predator. *Marine and Freshwater Research*, **60**, 519-528.
7. Morris, R.L., Chapman, M.G., Firth, L.B. & Coleman, R.A. (in review) Increasing habitat complexity on seawalls: Large- and small-scale effects on fish assemblages. *Journal of Applied Ecology*.
8. Ogburn, D.M., White, I. & Mcphee, D.P. (2007) The disappearance of oyster reefs from eastern Australian estuaries—impact of colonial settlement or mudworm invasion? *Coastal Management*, **35**, 271-287.
9. Strain, E.M., Morris, R.L., Coleman, R.A., Figueira, W., Steinberg, P., Johnston, E. & Bishop, M.J. (in press) Designing urban structures to reduce fish predation on native bivalves. *Ecological Engineering*.
10. Wilkie, E.M., Bishop, M.J. & O'Connor, W.A. (2012) Are native *Saccostrea glomerata* and invasive *Crassostrea gigas* oysters' habitat equivalents for epibenthic communities in south-eastern Australia? *Journal of Experimental Marine Biology and Ecology*, **420**, 16-25.
11. Wilkie, E.M., Bishop, M.J. & O'Connor, W.A. (2013) The density and spatial arrangement of the invasive oyster *Crassostrea gigas* determines its impact on settlement of native oyster larvae. *Ecology and evolution*, **3**, 4851-4860.

Find out more

Fish Friendly Marine Infrastructure is a NSW Department of Primary Industries (Fisheries) developed program This project has been assisted by the NSW government through its Environmental Trust. More information on Fish Friendly Marine Infrastructure can be found at: **www.fishhabitatnetwork.com.au**, or by calling the NSW Department of Primary Industries (Fisheries) Aquatic Habitat Rehabilitation team on 02 6626 1396.

To find out more about the Sydney Harbour - enhancing seawall sustainability project contact the project team, Sydney Institute of Marine Science, on (02) 9435 4600 or email info@sims.org.au

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