Centre for Research on

# Ecological Impacts of Coastal Cities

# Building seawalls to sustain intertidal biodiversity in altered and urbanized estuaries

Progress Report 2008

The University of Sydney

# Introduction

The research project *Building seawalls to sustain intertidal biodiversity in altered and urbanized estuaries* is funded by an Australian Research Council (ARC) Linkage Grant (2006-2008).

This project brings together, as collaborating partners with the Centre for Reseach on Ecological Impacts of Coastal Cities (EICC) at the University of Sydney, many of the bodies who have responsibility for construction and repair of seawalls and the management of estuaries in NSW. This includes representatives of local government and state agencies as well as an independent consultant ecologist. They are:

• Bio-Analysis: Marine, Estuarine & Freshwater Ecology
• Department of Environment and Climate Change
• Hornsby Shire Council
• Mosman Municipal Council
• North Sydney Council
• NSW Department of Primary Industries (Fisheries)
• NSW Maritime
• Sydney Ports Corporation
• Wyong Shire Council

This research is designed to provide managers throughout Australia and overseas, with reliable and robust information about the ecological effects of building seawalls and altering shorelines on coastal biodiversity. It aims to identify and evaluate options for constructing seawalls that best support natural biodiversity. This research will provide ecological information necessary to underpin many environmental decisions.

# General Overview

Altered shorelines, particularly the construction of long stretches of seawalls, have major ecological impacts. Although they provide habitat for intertidal organisms, many intertidal animals in NSW do not (and possibly cannot) live on seawalls as they are currently constructed. Seawalls differ from natural rocky shores in important ways. First, around Sydney, they tend to be steep, often vertical. Second, seawalls have fewer cracks, crevices and overhangs compared to rocky shores and some habitats (e.g. rock-pools) are completely missing. These factors are known to affect the distributions and abundances of intertidal organisms. Vertical seawalls have a compressed intertidal area (1 – 2 m) compared to natural gently sloping shores (10s of metres) in NSW. This crowds many species, that do not normally live in close proximity, into very small areas, which may affect associations between mobile species (potentially competing for the same resources), between mobile animals and sessile organisms which potentially compete for space, (but also provide habitat for many animals) or between different species of sessile organisms.

Building seawalls that can help to sustain intertidal biodiversity in altered and urbanized estuaries is a research priority. It involves evaluating what are the effects of connecting natural shorelines to built structures, effects on natural ecological processes, plus evaluating different ways of minimising impacts. Much of this research is cutting edge and is not yet being done elsewhere. Presentations of preliminary results at conferences have been extremely well received – including a mixture of admiration and envy at the strong relationships the EICC has with its industry partners.

The fieldwork for some of the projects, such as the rebuilding of the seawalls at White Bay and McMahon's Point has been completed and these projects are now being evaluated. Results are being analysed and several publications prepared for peer-reviewed journals and public dissemination, with the expectation that they will be well received. Other projects, such as recruitment onto sandstone and concrete in the Hawkesbury, are at a much earlier stage, having progressed successfully over the last few months. We aim to complete all the projects by the end of 2008. As is so often the case with good quality research, the results of these projects have thrown up many new questions to be investigated by further experimentation in the future. The results from some projects have been more conclusive than others. The location of the study sites has played a large part in this. High-energy, wave-exposed sites such as McMahon's Point appear to be more responsive to changes in seawall construction than are sheltered sites, such as White Bay.

We are confident that we are succeeding in meeting one of the key aims of this grant, namely to increase the body of ecological knowledge available to our partners, to assist them in making decisions about shoreline alterations and managing the estuaries of NSW.

# Rebuilding the Seawall at McMahon's Point

An extensive seawall at McMahon's Point was in disrepair and needing to be rebuilt as part of North Sydney Council's programme of repairing and re-designing many of their seawalls. The original seawall was made of sandstone blocks, but, in order to provide adequate support and resistance to wave-action in the long term, a pre-cast concrete seawall was constructed. It was then faced with large sandstone blocks to resemble the original wall.

*Final stages of rebuilding the seawall at McMahon's Point*

The new construction incorporates deep 'rock-pools', embedded into the sandstone facing at high-, mid- and low-tidal levels. These are designed to retain water during low tide. It is expected that they will add novel and important habitat to what is otherwise a typical seawall (vertical and rather featureless) and that this new habitat will enhance the numbers and types of animals and plants that can live on this constructed intertidal shore.

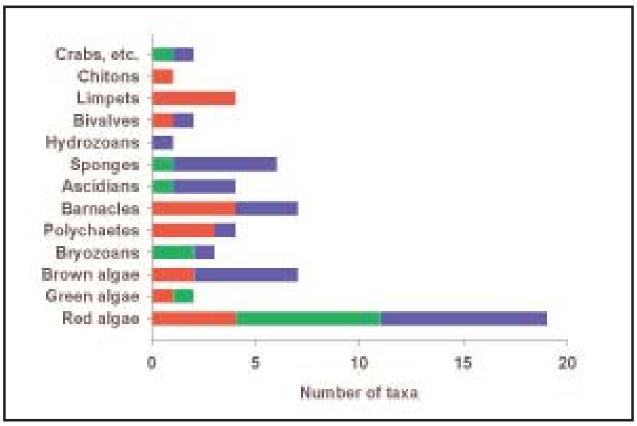
*One of the rock-pools embedded in the seawall*

Our close collaboration with North Sydney Council and their consulting engineers, Macleod Consulting and John Nixon Engineering, has ensured that the design of the construction meets the requirements of a rigorous ecological experiment. Pools have been added to 3 different sections of the wall, with intervening sections without pools, allowing an unconfounded test of the effects of pools on biodiversity in the pools themselves and on the surrounding rock wall. There are also 6 pools at each of 3 different tidal heights, interspersed throughout each section, to ensure adequate replication for powerful analyses.

This project is unique in its innovation and scope. Seawalls have not previously been enhanced with such numerous and extensive habitats. We expect the results of this study will be of interest world-wide to those who build or commission the construction of seawalls and who wish to enhance or maintain local levels of intertidal biodiversity.

The number of species that recruited to the experimental rock-pools and cavities is much greater than those found on the surrounding unmodified seawalls. The greatest difference was found at the mid-tidal height, were the average number of species was at least three times greater in artificial rock-pools than on unmodified sections of seawall at the same height on the shore.

Most of this difference was due to an increase in the number of species of algae and sessile animals. At this stage, there is little difference in the abundance of mobile animals among the various habitats.




*Number of taxa found on the rebuilt seawall at McMahon's Point. Red is on the seawall surrounding the caves, green is on the walls inside the caves and blue is in the pools.*

# Rebuilding the Seawall at White Bay

*The old seawall at White Bay*

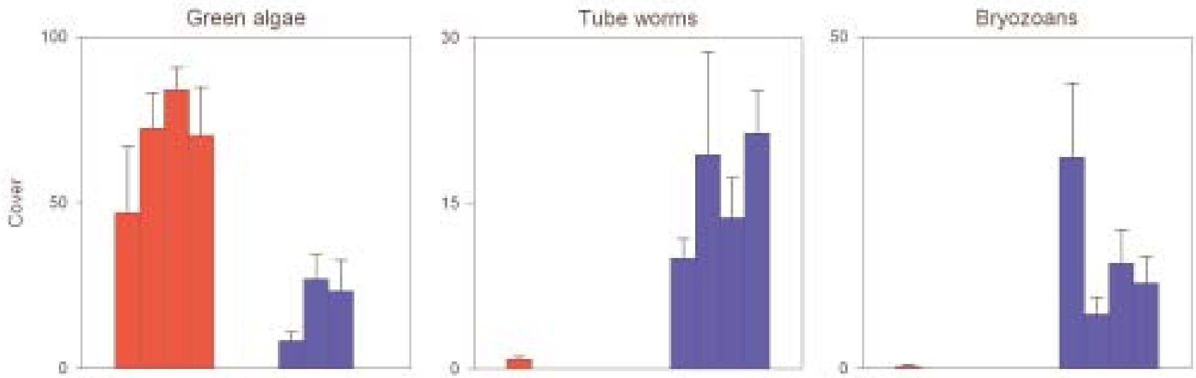
*The new stepped design*

Parts of an old vertical concrete seawall at White Bay were due to be demolished and rebuilt. Sydney Ports Corporation considered several different designs, most of which consisted of an inclined rubble-bank of some description. The design that was chosen to replace the old seawall is a stepped wall made of large rough-cut sandstone blocks.

This stepped design means that the seawall has horizontal surfaces, approximately 0.5m wide and vertical surfaces, approximately 0.3m high, at various heights on the shore - increasing the intertidal area as well as potentially allowing for small rock-pools.

The site has been sampled to compare the types and abundances of organisms found on vertical versus horizontal surfaces and to measure how species change over time. The results of this experiment will be used as part of our advice to those who design, repair and build seawalls.

White Bay is, however, a very sheltered area of the Harbour and organisms are slow to recruit. Despite this, there are now apparent differences between assemblages of organisms that recruit to the two surfaces. Specifically, there is a much greater cover of green algae on horizontal than vertical surfaces. These are an important food source for many grazing molluscs. The vertical surfaces had greater covers of sessile invertebrates, such as tube worms (*Spirorbinae*) and bryozoans (*Watersipora subtorquata*), some of which provide biogenic habitat for other species.




*Average percentage cover (SE) of algae or sessile invertebrates on the seawall at White Bay. Red bars are horizontal surfaces and blue bars are vertical surfaces.*

# Tuggerah Lakes

Tuggerah Lakes is an important area for tourism, recreation and fisheries. Urban development is increasing, particularly along the lakes' fronts. Some areas are protected from erosion by seawalls, but this may cause accumulation of seagrass wrack and macro-algae. Decaying seagrass smells unpleasant and is a nuisance for those living nearby or using the estuary. It may also affect the animals living in the sediment which are an important component of the lake biology. In partnership with Wyong Shire Council, we have started work at Tuggerah Lakes on a project aimed at identifying the effect of building seawalls on adjacent muddy sediments and accumulation of wrack.

This project began by sampling an area for 6 months to identify natural patterns in the existing benthic animals and seagrass. Dr. Danny Roberts and his team from BIO-ANALYSIS: Marine, Estuarine and Freshwater Ecology are looking at the seagrass, we are looking at the organisms living in the sediments and Dr. Peter Scanes and his team from the Department of Environment and Climate Change (DECC) are using micro-probes to look at the soil chemistry and sedimentary processes.

In September 2007, Wyong Shire Council built 2 wooden fences in the area to mimic seawalls. This was followed by a drop in the water level in the lakes which prevented the accumulation of wrack. Lake levels have now risen again and wrack is starting to accumulate against the 'seawalls'.

Sampling due to begin in February was, however, delayed due to high water levels. Changes in water levels are causing many problems for progress in this project.

As urbanization increases in this environment, more seawalls are being built to protect property on the edge of lakes. This research will help identify what impact seawalls may have on the ecology of the sediments in front of them and whether recovery from these potential impacts is possible on removal of the seawalls.

*Core sampling at Tuggerah Lake; DECC mobile laboratory; Constructing the first fence at Tuggerah Lake; One of the finished fences - an artifical 'seawall'; Wrack accumulating against the artificial seawall*

# What effect does material have on the ecology of artificial habitats?

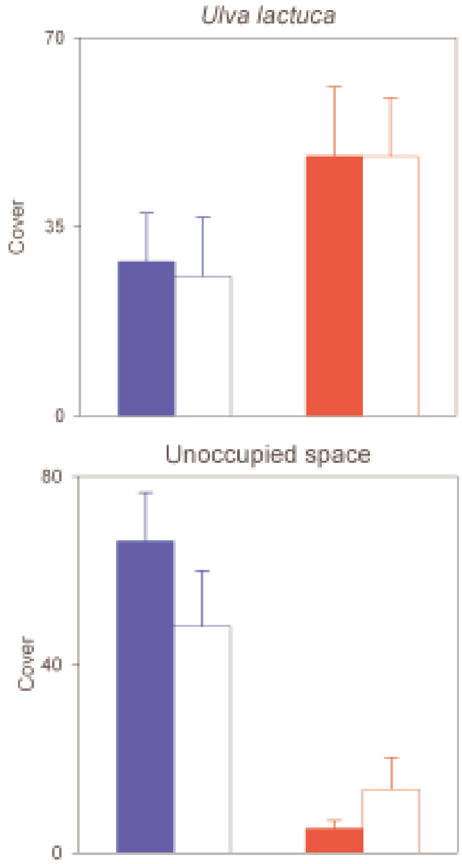
*Complex & smooth plates before attachment to the wall*

Artificial structures, in particular seawalls, may be built of different material, depending on cost, aesesthetics and durability. The material chosen may, however, have an impact on the biodiversity that any seawall can support.

We have started experiments with the support of North Sydney Council at Kirribilli and Kurraba Point to investigate differences in recruitment of organisms to concrete and sandstone. At the two locations, four types of panels have been attached to existing seawalls: Smooth concrete, smooth sandstone, complex concrete and complex sandstone. Complex plates include small, shallow holes. The plates are being sampled at regular intervals to determine any effect that material and/or complexity have on organisms recruiting to the plates.

Sampling the plates

After a few months the cover of algae was greater on sandstone than on concrete plates regardless of complexity. The green algae *Ulva lactuca* had a greater cover on the sandstone than concrete plates, while the encrusting red algae *Hildenbrandia rubra* was only found on sandstone plates. In contrast, most of the concrete plates was unoccupied space.




*Average percentage cover (SE) of algae and unoccupied space on plates attached to the seawall at Kirribilli and Kurraba Point. Blue bars are concrete plates, red bars are sandstone*

## Oyster recruitment and mortality at Brooklyn, Hawkesbury River

This new project in the Hawkesbury River, in conjunction with Hornsby Shire Council, is testing hypotheses on the recruitment and mortality of oysters, specifically the native Sydney rock oyster, *Saccostrea glomerata* and the introduced Pacific oyster, *Crassostrea gigas.*

The first part of the project will test the hypotheses that there will be greater recruitment of oysters onto concrete than sandstone surfaces and that inclination of the substrata affects the settlement of oyster spat. Previous experiments elsewhere have shown greater settlement on concrete than sandstone surfaces. Inclination could be important for a number of reasons including increased intertidal area, more closely mimicking natural rocky shores, changes in insolation and differences in wave interaction with the wall. This experiment aims to give information on whether building the seawalls with a more gentle slope will change the resulting assemblages.

These hypotheses are being tested by attaching settlement panels to poles driven into the existing substrata at the railway causeway at Brooklyn on the Hawkesbury River. The panels are composed of either sandstone or concrete and are attached vertically or at a 45 degree angle . Within 3 weeks, algae was growing on the sandstone plates, but not on the concrete ones.

The second part of the experiment will examine oyster mortality. Sydney rock oyster (*S. glomerata*) spat will be settled on the plates at the NSW Fisheries oyster hatchery at Port Stephens and transported to sites at Brooklyn. Mortality of the oyster spats will be measured through regular sampling.

*Concrete and sandstone panels deployed at the railway causeway at Brooklyn*

# Wrack Tracker

*Wrack Trackers being attached to bunches of wrack before deployment*

The Wrack Tracker has been developed by the Centre in collaboration with Associate Professor Stefan Williams and his team at the Australian Centre for Field Robotics at the University of Sydney. The device is attached to floating wrack. As it moves about the lake with the floating wrack, it records its position and transmits the data to the laboratory in Sydney. The data can be plotted on a map to find out where the tracker has travelled and at what speeds over the recording period.

Prototype devices have been trialled in Tuggerah Lake with much success. There are plans to trial the tracker in Budgewoi Lake, which is smaller than Tuggerah Lake with a completely different set of hydrological conditions.

Plans are currently underway to try to build a series of 10 devices which would allow us to map wrack movement over larger scales. This research will increase our understanding of the processes that transport wrack from seagrass beds to where it accumulates on shorelines.

*Deploying the prototype devices in Tuggerah Lake*


*The path the tracker took and the speed of the tracker. The scale runs from blue as fast to red as slow.*

# Effects of construction material on micro-algae food sources and competition between Limpets on seawalls

The project (which is part funded by a Sydney Aquarium Conservation Foundation grant),is examining competition between species brought into close proximity on seawalls due to the constriction of the intertidal zone. This research is being done with Dr. Ljiljana Iveša, who is visiting the EICC from the Center for Marine Research, Institute 'Ruđer Boškoviæ', Rovinj, Croatia. Dr Iveša will be at the EICC for six months as a visiting academic fellow.

Observation suggested that grazing limpets *Siphonaria denticulata* and *Patelloida latistrigata* show different patterns of abundance between concrete and sandstone walls, with *Siphonaria denticulata* more abundant on sandstone and *Patelloida latistrigata* showing the opposite pattern. The project aims to look at whether differences in abundance of the limpets are due to the physical nature of the surface, to changes in food supply or interactions with other species.

*A set of plates at Carenning Cove*

Grazing gastropods have a major influence on the structure of intertidal assemblages, such as micro-algal resources. Their inter- and intra-specific competitive interaction, their complex relationship with physical and biogenic features of habitats, changes to their relative abundances and disturbances are likely to have major impacts on the surrounding intertidal assemblages. Recently, colour-infrared (CIR) imagery and spectrometry has been show to be an effective method for testing hypotheses about grazing in intertidal gastropods.

In this experiment, we used concrete and sandstone panels to mimic patches of seawall, in two locations in Sydney Harbour: Careening Cove and Cremorne Point. *P. latistrigata* and *S. denticulata* were added to panels as single species or in combination, with densities mimicking those on natural walls in the vicinity. Each panel was surrounded by a plastic fence to prevent the limpets from leaving. Wax discs were set in the panels to record impressions of limpet feeding marks and provide a quantitive measure of grazing intensity.

Sampling includes measures of micro-algae using a field spectrometer and modified colour/infra-red camera, recruitment of *P. latistrigata* and *S. denticulata*, mortality and growth .

*Sampling plates at Cremorne Point*

# Processes involved in the breakdown of wrack in an urbanized estuary

## Giordana Cocco - Ph.D. Student

The aim of this research is to investigate patterns and processes involved in the decomposition of wrack. Wrack is a serious ecological, economical and social issue in the Tuggerah Lakes (Central Coast) where it accumulates throughout the year and often forms large, long-lasting beds which cover much of the nearshore area. In the past year, research has focused on developing an effective method for measuring decomposition of wrack in the field. Preliminary field-studies indicated that traditional litter-bags made of plastic mesh were inappropriate, as they allowed a considerable amount of detritus to enter and leave the units, a problem not acknowledged in the literature on this topic. Plastic containers in which windows were cut on the sides, top and bottom and then lined with flyscreen-mesh, turned out to be effective units to measure decomposition of wrack.

Various models about decomposition of wrack are being examined, using clumps of the seagrass *Zostera capricorni*. This is the most abundant species in the wrack. I am also testing the model that the presence of wrack would enhance the growth of the abundant macroalgae, *Chaetomorpha linum*, which is a local problem in the lake.

*Seagrass wrack accumulating*

Some of the above investigations are still in the process of being completed. Preliminary results showed, however, that decomposition was significantly greater in the water (nearshore and offshore) than on land and faster in an undeveloped bay (Tuggerah Bay) compared to a developed one (Chittaway Bay). Neither macro-algae nor macro-fauna significantly influenced the decomposition of wrack.

Future plans are to investigate the potential effects of development, season, bottom composition (i.e. bare versus seagrass beds) and incubation time on the decomposition of *Zostera.*

# Structure of assemblages on sandstone, concrete and basalt boulders in Sydney Harbour

## Danielle Green - B.Sc. (Hons) Marine Science Student

Boulder-fields are very important intertidal and shallow subtidal habitats which support a large diversity of species, including many rare species. Therefore the addition of boulders to artificial habitats such as seawalls may have the potential of increasing the diversity of the species in the area. There is also a perceived need to place boulders at the base of seawalls in order to dissipate wave energy and reduce erosion of the seawall. In most cases, sandstone boulders are used, which are similar to the naturally occurring bedrock underlying the region. In some instances, however, boulders composed of igneous rock are used because this erodes at a slower rate than does sandstone. Very few studies have examined the effects of these types of rock on intertidal boulder-field assemblages in urbanized estuaries.

The aims of this project were first to identify patterns of sessile and mobile species already present in sandstone, basalt and mixed (including concrete boulders) boulder–fields in Sydney Harbour. It was then assessed whether these differences were due to the location of the boulder-field or the properties of the different types of rock in field experiments.

*Sampling at Rozelle Bay*

# Related projects of interest not funded by ARC Linkage Grant

## Ecological engineering by Oysters on seawalls, provides habitat for Whelks

Dr Angus Jackson


*Tagged Morula Whelks*

Differences in presence and abundances of species can affect the ecological function of habitat. On rocky shores, the mulberry whelk is a common and important predator that can alter numbers of prey considerably. Knowledge of how and why populations of predators differ on artificial substrata is essential to the understanding these habitats.

This project investigated how densities and sizes of whelks differed between natural rocky shores and seawalls and sought reasons for these differences. Sampling indicated that abundances and sizes of whelks were very variable among locations. The whelk was absent from or rare on most seawalls. On some seawalls, however, where the Sydney rock oyster was abundant, densities of whelks were similar to those on rocky shores. Whelks were also larger where there were many oysters. Individually tagged whelks were used to study whether differences in growth or survivorship could explain the differences in densities or sizes. There was some evidence that greater survival of whelks in habitats with many oysters could explain differences in density. On seawalls, but not on rocky shores, slower growth could help explain the smaller size of whelks where there were few oysters.

A popular concept in ecology is that some species, called ecological engineers, alter resources for other species. Oysters often act as engineers, altering habitat for other species, for example, by providing shelter from predation or inclement conditions. On seawalls, crusts of oysters appeared to have different structures: in some places they seemed simple, but in others, they seemed to be much more elaborate. Sampling showed that whelks were common only in some places with elaborate crusts of oysters and were sparse everywhere else. This raised the question of why they could live in some places, but not others.

The numbers of whelks could be greater on some seawalls because of the elaborate structure of the oysters or because of some other feature of those seawalls that also causes oysters to grow in elaborate crusts. To determine which was important, experiments were done at six seawalls, manipulating oyster crusts to be elaborate or simple, to investigate how whelks respond to the different habitat. Whelks dispersed more rapidly from simple crusts, suggesting that conditions in this habitat may be unfavourable when compared with elaborate crusts. Differences in dispersal among habitats may explain the differences in numbers of whelks on seawalls with different types of crust. Simple oyster crusts may not provide sufficient shelter from impacts such as boat wash or heat stress.

This study demonstrated that the structures of oyster crusts create suitable habitat for whelks on some seawalls but not on others.

## Biodiversity in remants of natural habitat in Sydney Harbour

Dr Paris Goodsell

Much of the natural habitat in Sydney Harbour has been lost or separated into remnant habitats by the construction of seawalls. This process is known as ‘fragmentation’ and results in areas of natural habitat which are small and separated by large distances from one another, often by less suitable habitat. Habitat fragmentation is globally recognised as a threat to biodiversity because there are fewer resources (e.g. space and food) in smaller habitats and when habitats are far apart, organisms must move larger distances over inferior habitat to gain resources.

Rocky shores in Sydney Harbour are naturally patchy and separated either by seawalls or by other natural habitats such as mangrove forests and beaches. The presence of seawalls is likely to change the natural connectivity of the coastline. By mapping the length of seawalls and natural habitat in most of the Harbour, it was shown that more patches of rocky shore were bordered by seawalls than by other natural habitats. Patches of rocky shore bordered by seawalls were significantly smaller than those bordered by other natural habitat. They were also further apart from one another than were natural patches.

We also compared the biota on different rocky shores to test if patterns of diversity match those that would be expected when habitats are fragmented. The number of taxa, number of unique taxa and variability in the number of taxa were all greater in natural patches than on shores separated by seawalls, although not all analyses were statistically significant. This research shows that the composition and configuration of 'seascapes' is more important to the ecology of marine organisms than previously thought and that rebuilding our shorelines alters the intertidal 'seascape'.

*Fragmented habitat: seawall and rocky shore*

## Conferences, Invited Seminars and Presentations

### Critical changes to intertidal shorelines in urbanized estuaries: novel ways of improving altered habitat to maintain biodiversity

Professor M. G. Chapman

*Change in Aquatic Ecosystems: Natural and Human Influences,* 4-6 July 2007, Plymouth, UK

Until relatively recently, the effects of urbanization of marine habitats has focussed on contamination of water and sediments from disposal, spills and runoff. The loss, alteration and fragmentation of habitats by urban development, long the concern of terrestrial ecologists, have largely been ignored, except for those intertidal habitats dominated by large plants, such as wetlands, mangroves and saltmarsh. Intertidal habitats are limited in extent because they occupy that narrow fringe between the land and the sea subjected to tidal change. They are linear habitats, with strong upshore environmental gradients. Species in intertidal habitats occupy particular habitats, which is set by abiotic conditions and/or biotic interactions. Loss of or changes to intertidal habitats over large scales are therefore likely to affect many taxa, which do not have other habitats into which they can retreat.

Urban estuaries are greatly altered by development and with increasing urbanization; on the coast in particular, this is likely to increase. Of all marine habitats, the intertidal areas have been most affected, with replacement of many natural shores by built structures, including seawalls, groynes, marinas, etc. Although these structures differ markedly from natural shores, cursory examination suggests that they provide useful habitat for intertidal organisms, many of which reach large cover or densities on these structures. Detailed sampling shows that, in Sydney Harbour at least, intertidal seawalls do not provide suitable habitat for many taxa, which either do not live on artificial structures, live at abnormal densities or do not grow large, thus affecting reproductive output.

Comparison of the physical structure of built seawalls compared to rocky shores indicates some major features of habitat that are generally lacking on seawalls. Imaginative engineering may, however, be able to supply surrogates for these habitats. Some of the engineering changes to seawalls that are being trialled in Sydney Harbour will be described, with preliminary data on their effects on intertidal diversity.

### Collaborative research projects to develop and assess methods for improving seawalls as intertidal habitat

Dr D.J. Blockley and Professor M.G. Chapman

*16th NSW Coastal Conference,* 7-9th November 2007, Yamba, NSW

Urbanization of coastal areas has led to the replacement of many natural intertidal habitats with artificial structures, in particular seawalls. Increasing coastal populations resulting in further urbanization, coupled with rising sea-levels and increases in frequency and intensity of storms due to climate change will mean that seawalls will probably become more common. If intertidal animals and plants are to be sustained and protected, the impacts of seawalls need to be established and methods of improving the quality of seawalls as habitat needs rigorous experimental research. Despite the ubiquitous nature of seawalls worldwide and recent research showing that they are very different habitats from natural rocky shores, insufficient research has been done to evaluate different ways to build seawalls to make them better habitats. The necessary research that will give answers to mangers about how seawalls should be constructed requires collaborations between those building the seawalls (e.g. local councils, engineers, etc.) and those with scientific expertise in experimental ecology. New walls are being built and large stretches of existing seawalls are in need of maintenance or restoration. These maintenance and building programmes have formed the basis of collaborative research to test experimentally various methods of enhancing seawalls. By working in consultation with managers and engineers, methods have been developed to incorporate features into seawalls that are aesthetic, structurally sound and support a greater diversity of marine organisms. Results of some of these innovative studies will be discussed, with emphasis on the importance of partnerships between researchers and managers to address the environmental problems of coastal urbanization.

## Re-engineering altered shorelines to increase intertidal biodiversity in urbanized estuaries

Professor M.G. Chapman
University of Santiago de Compostela, Spain, 10th July 2007

Urbanization is known to have major environmental impacts but most research has focused on changes to terrestrial habitats. Many of the larger coastal cities are, however, on the coast, particularly in estuaries and coastal urbanization is expanding faster than are inland towns and cities. Yet changes to coastal habitats is largely ignored when impacts of urbanization are considered. Altering shorelines can lead to intertidal habitats being fragmented and lost, particularly by their replacement by built structures. Of these, seawalls are the most pervasive, replacing > 80 % of natural habitat in many urbanized estuaries. Seawalls have varying slopes and complexities and are built of diverse material. At first glance, they appear to support diverse intertidal biota, but extensive research in Sydney Harbour has shown widespread changes to the intertidal assemblage. This is mainly due to the paucity of mobile animals (urchins, starfish, molluscs, etc.) that live on walls. Numbers do not tell the whole story because at least one species of limpet has very large populations on seawalls, but the animals do not grow large and have reduced reproductive output.

Focus of our research is now not simply to describe changes to assemblages of animals and plants that live on intertidal seawalls compared to natural habitats, but to focus on methods that walls may be built to enhance their value as habitat. Two new walls, at Quakers Hat and White Bay in Sydney Harbour, are being evaluated for the effects of increasing the slope and thus intertidal area of the wall by providing vertical and horizontal surfaces rather than a flat facade. The provision of indented crevices or flush surfaces between blocks of sandstone at Kirribilli showed indentations could increase diversity and abundances of many taxa at midshore levels. Recent research that provides larger pools in the facades of the walls also shows that these can increase local biodiversity many times, allowing many species that normally cannot live in these habitats to colonize and survive.

## Restoration of habitat in urbanized estuaries: practice and theory

Professor M.G. Chapman
University of Vigo, Spain, 12th July 2007

Despite a world wide emphasis on increased protection of coastal habitats, many habitats and the species within them are continuing to be lost by changes to water quality and more importantly urbanization. Loss or degradation may be due to factors such as eutrophication, or more commonly the loss or reduction of intertidal habitats due to replacement by built structures. Of these, seawalls are the most pervasive, replacing > 80 % of natural habitat in many urbanized estuaries. This has led to increased focus on the need to attempt to actively rehabilitate or restore degraded habitat.

Restoration may be as simple as removing a disturbance, which is illustrated by changes on seawalls when wharves which continually shade them are removed. Alternatively, components of habitat can be added. This is illustrated by two research projects. The first added seagrass wrack to a denuded sandflat on the central coast, thereby increasing cover of saltmarsh plants. The second added indented crevices between sandstone blocks on a seawall at Kirribilli that was being repaired. This increase diversity of intertidal animals and plants on those walls. The extreme end of restoration is creation of new habitat, such as boulder-fields, pools in seawalls or urban saltmarshes. Many studies have shown we are successful at creating habitat, at least for some biota. Many of the major problems with ill-defined aims of restoration and the consequences of this for assessment of its success or failure are discussed.

Restoration may be done for anthropogenic (goods and services, aesthetic value, education, spiritual satisfaction) or ecological (conservation, replacement of lost habitat, enhancement of existing ecological functions), but these are seldom scientifically tested in urban restoration projects. It is necessary to view these aims with a touch of realism when describing small restoration projects within a highly urbanized and altered setting.

### Ecological impacts of estuary management with respect to constructing seawalls at the entrance to Tuggerah Lake

Professor M.G. Chapman
*Central Coast Environmental Education Workshop, Forum 1: The Great Seawall Debate*
Wyong Shire Council, 30th September, 2006

Tuggerah Lakes is one of many ICOLS in New South Wales; estuarine systems which alternately have open or closed access to the sea. Many of these are managed to keep the entrance open. A number of different examples of ICOLS was presented. These estuaries are typically very shallow, with poor tidal flushing and dominated by soft sediments, but are also heavily used for fishing, recreation and increasing urbanization. This combination of environmental conditions and human usage has led to varying environmental problems in ICOLS and conflict with stakeholders who perceive different use of these habitats.

The particular environmental issues discussed in this talk, with respect to current problems (perceived or real), management and the proposed permanent opening of the entrance using seawalls included (i) problems with macro-algae blooms and decomposition of vegetation along the shoreline, (ii) potential loss of valuable intertidal habitat, such as saltmarshes, (iii) spread of mangroves, (iv) potential changes to biological processes within seagrass and their flow-on to other components of the environment. Finally, the seawall as a habitat in its own right was described, with respect to species that might settle and live on the wall and species that might accumulate around the wall in the open water.

## Relevant Publications 2006 - Present

Blockley, D. (2007) Effect of Wharves on intertidal assemblages on seawalls in Sydney Harbour. *Marine Environmental Research* 63, 409-427

Blockley, D and M.G. Chapman (2006) Recruitment determines differences between assemblages on shaded or unshaded seawalls. *Marine Ecology Progress Series* 327, 27-36

Blockley, D. & M. G. Chapman (In press). Exposure of seawalls to waves within an urban estuary: effects on intertidal assemblages. *Austral Ecology*

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