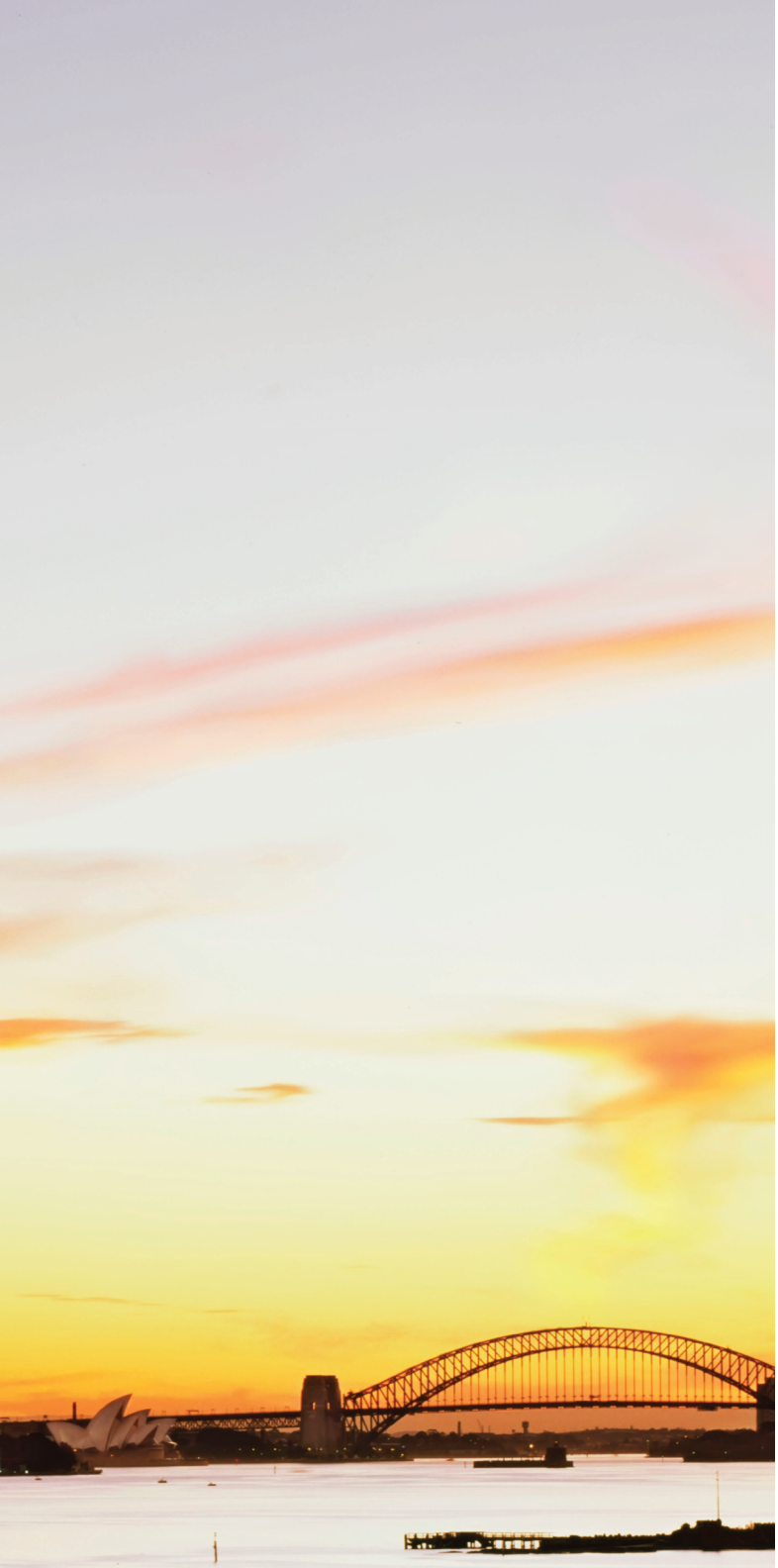

Sydney Harbour Background Report 2014

Report prepared for NSW Department of Primary Industries by the Sydney Harbour Research Program at the Sydney Institute of Marine Science

April 2014

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Document Control

Version	Status	Date	Author	Reviewer
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2	Final Draft	April 2014		Prof. Emma Johnston
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Final Submitted	Submitted	June 4th 2014		

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1 Executive Summary

Sydney Harbour is a national icon, recognised throughout the world as the natural jewel at the heart of Australia's largest city. The embayments of the estuary, formed from the drowning of a river valley some 10,000 years ago, harbour a diverse range of habitats and systems. A sophisticated understanding of Sydney Harbour is needed to most effectively manage the confluence of intense human activity and its great diversity of natural systems. We also need to extend our understanding of how natural systems influence the economy of the City of Sydney, New South Wales, and the nation more generally. There needs to be an understanding of the social values linked to the harbour from the Sydney community, and how the harbour's natural systems are currently responding to the full range of threats and stressors imposed on it by a highly urbanised catchment.

This report collates the available information pertaining to the ecological assets of Sydney Harbour, the documented threats to those assets, and the economic and social values that people attribute to the Harbour.

The distribution of ecological assets The most comprehensive analyses of ecological assets in Sydney Harbour have been conducted by NSW Department of Primary Industries (NSW DPI). Several large datasets that map the distribution of mangroves, seagrass, sediment, rocky reef and kelp have been collected by that department.

At the time of the most recent government assessment in 2000, there are over 51 ha of seagrass, 184 ha of mangroves, and 37 ha of saltmarsh in Sydney Harbour. Seven species of seagrass are known from the estuary but nomenclature of the group is unclear, leading to doubts over the true species richness in the harbour. Most seagrass is found at shallow depths in the outer harbour areas. Mangroves in Sydney Harbour are one of few species that have increased in abundance since european colonisation. Most mangrove forests are dominated by *Avicennia marina* and are found in the upper reaches of the Parramatta and Lane Cove rivers, although a small forrest can also be found in the upper reaches of Middle Harbour. Conversely, the extent of saltmarsh in Sydney Harbour has declined dramatically since colonisation and it is estimated only 37 ha remain. The largest contiguous remaining patch of saltmarsh exists within the Newington Nature Reserve along the Parramatta River.

Sediment flora and fauna in Sydney Harbour has not been well characterised. Some 2472 different mollusc, polychaete and crustacean species are recorded from the harbour, however the habitat associations and distributions of these taxa are currently unknown. Similarly, the rocky shoreline of Sydney Harbour is mostly researched in the context of artificial structures, but some indication of natural shoreline taxa is given by 38 different peer reviewed publications.

Surprisingly little is known of the pelagic environment of Sydney Harbour. Some unpublished reports since 1991 document fish abundances in the Homebush Bay area, and recent work has investigated larval fish ecology in response to contaminants. Further, a single unpublished poster pertaining to NSW Department of Primary Industries shark tagging was the only documentation of pelagic macro fauna in the harbour collated in this review.

NSW Office of Environment and Heritage, with NSW Roads and Maritime Services, maintain the most comprehensive data on foreshore vegetation available. Maps (1:2000) have been produced that document the spatial extent of over 55 different canopy forming species and the distribution of 36 different community types (including hard substrate, weeds and gardens). Almost 45,5123 m^2 of 'over water man-made substrate', and 638,6872.48 m^2 of gardens and weeds are found throughout the estuary. The remaining natural vegetation communities around Sydney Harbour (particularly in the Middle Harbour sub-catchment) are comprised of coastal sandstone gully forests and ridge top woodlands.

The distribution of threats and stressors Sydney Harbour sits within a metropolis of over 4.6 million people. Such a large urbanised catchment brings with it a range of threats and stressors. The sediment of Sydney Harbour is notoriously contaminated with a range of compounds, the foreshore is heavily modified, and stormwater runoff raises nutrient concentrations after each rainfall event. Additionally, we have little understanding of the distribution and effects of resource extraction, including recreational fishing, or the role of non-indigenous species in changing the harbour's natural systems.

The metallic, metalloid, and organometallic contamination of the Sydney Harbour seafloor is relatively well characterised. Almost 110 peer reviewed reports investigate sediment contamination in the harbour, and several unreviewed reports document sediment contamination across several locations. Homebush Bay has received considerable attention in the published and unpublished literature, particularly in the lead up to – and just after – the Sydney 2000 Olympic Games. Almost 100 % of the sediment in Sydney Harbour exceeds Interim Sediment Guideline trigger values that prompt further investigation into activities thought to disrupt the seafloor. Over 50 % of the sediment has lead concentrations over the Interim Sediment Guideline-High level, and the upper embayments and inlets generally have metal concentrations thought to cause adverse biological effects. Conversely, the distribution of nutrient enrichment in the harbour is far less understood, but is currently under investigation.

Elevated dioxin levels in fish caused the closure of all commercial fishing operations in 2006. Dioxin concentrations are predictably highest in the Homebush Bay area, where dioxin levels in Semi Permeable Membrane Devices (SPMDs) exceeded United States EPA guidelines. At sites near the Sydney Harbour Bridge, dioxin levels were at – or just below– these US EPA guidelines. Dioxins in SPMDs increased over 3.9 fold during the summer months.

The National Health and Medical Research Council (NHMRC) established that average consumption of seafood caught in these contaminated areas would lead to dioxin intake 190 % greater than monthly tolerable levels for humans. Given the persistence of dioxins in the environment, the toxic nature of the compounds and the large costs of sediment remediation, it seems likely that the bans should remain in place into the distant future. Despite warnings not to consume seafood caught west of the Sydney Harbour bridge, both Ghosn et al. (2010) and internal SIMS research, has shown that fishing continues in this western area.

Although commercial fishing was banned in Sydney Harbour in 2006 due to concerns over dioxin contamination in seafood, there remains a large recreational fishery. Recreational fishers harvested around 74 tonnes of fish in the summer of 2007-2008 (Ghosn et. al. 2010). Catches of several of the targeted species were predominantly undersized. This may be due to non-compliance with the fishing regulations and may suggest the need for targeted compliance operations to address the apparent retention of undersize fish. This pattern may also be due to unknown ecological/biophysical parameters or current or historic fishing practices that may have reduced the average fish size in Sydney Harbour. Further surveys are needed to ascertain the reasons for under-sized fish catches.

Social values of Sydney Harbour Sydney Harbour provides immense social value for a broad range of stakeholders. It is surrounded by a large population and is an important recreational and social centre. The harbour also represents significant cultural, historic and spiritual value to the wider Australian community.

There exists almost no evaluation of the social values placed on Sydney Harbour. This report presents the first description of social valuation of the harbour that we are aware of, and should act as a preliminary guide to directing further research. Investigating social values will become particularly important if the management arrangements of Sydney Harbour were to change. Values may be consistent among various stakeholders, or conversely, values may differ under different contexts leading to stakeholder conflict.

In Sydney Harbour, stakeholders are divided between organisational and community. Organisational stackholders include various federal and state government agencies. Organisational stakeholders could also include the local councils within the catchment, the shipping industry, and the recreational fishing and diving industries.

There are many community stakeholders who value the harbour. These include groups such as commuters, swimmers, divers, walkers, fishers, boaters, picnickers and residents. The values, or the judgement of 'what is more important' in life for these groups, is much harder to quantify. Utilitarian values of these groups could include the products and services extracted from the environment, the recreational amenity, scientific knowledge or cultural and spiritual philosophical values. The Sydney Regional Environment Plan (2005) represents community values through widespread consultation, and values are generally represented in the aims of the plan; protection for an outstanding natural asset, heritage significance, healthy sustainable environment, effective transport, rich vibrant culture, accessibility, and protection, maintenance and rehabilitation of 'ecological areas'. The social values of the Sydney Harbour community are also presented in a number of local and state based management plans.

The economics of harbour use Almost nothing is known of the economic benefit of a functioning Sydney Harbour ecosystem. Like social data, some indication can be gained by studying the publicly available websites and annual reports of several private and public organisations, however data is sparse and disparate.There are several possible reasons for this, largely relating to the scope of the question and data issues. Economic data, for example, are not collected about the harbour itself. Instead, the harbour is taken for granted as beautiful and appealing, a major asset for the city, and a setting for some very large economic activities, but the values of use or proximity to the harbour are not separated out of data on economic activity.

Many people, organisations and businesses make use of the harbour. This background research therefore includes studies where certain aspects of the harbour have been assessed. It also lists other sources where data may be found showing relevance to different kinds of values of activities associated with Sydney Harbour and its numerous and varied users. It also includes a section on some identified economic risks and finally some examples of economic assessments of closely linked cities and coastal environments elsewhere.

The sources are listed with reference to different sorts of activities and users. Since the harbour influences most of the major activities in the city, from tourism and transport to watersports and hiking, the amount of possibly relevant data is nearly limitless. The approach here has been to examine studies (where possible) and official sources of data from government and other agencies.The most up-to-date information was often found on official websites.

Sydney Harbour is arguably Sydney city's greatest environmental asset. It brings enormous economic value to the city, its inhabitants and its visitors. It is the basis for some business revenues and contributes to many more. It allows for shipping trade, attracts tourists and elevates land prices in its vicinity. Residents and visitors enjoy its waters, engage in various activities on its foreshores and benefit from environmental quality and ecosystem services, only some of which they can see and much more.

1.1 Agency acronyms and useful definitions

- **SIMS** Sydney Institute of Marine Science
- **MEMA** Marine Estate Management Authority
- **Sydney Harbour** Comprising all the waters within an imaginary line joining North Head and South Head. Including North Harbour and Middle Harbour. For the purpose of this report, the harbour finished at the Parramatta Weir (-33.813288°, 151.010012°) and the Lane Cove Bridge (-33.800718° 151.143627°).
- **NSW DPI** New South Wales Department of Primary Industries, as part of New South Wales Trade and Investment.
- **SHRP** Sydney Harbour Research Program, research group at SIMS.
- **NSW RMS** New South Wales Roads and Maritime Services as part of Transport for New South Wales.
- **NSW OEH** New South Wales Office of Environment and Heritage.
- **LGA** Local Government Area.
- **NSW I & I** New South Wales Industry and Investment.
- **SCCG** Sydney Coastal Councils Group.
- **SIMS SoH 2014** SIMS State of the Harbour Report 2014.
- **SPC** Sydney Ports Corporation.

2 Introduction

2.1 Context of this report

This report has been prepared for the Department of Primary Industries by the Sydney Institute of Marine Science (SIMS). It is to be presented to the NSW Marine Estate Management Authority (MEMA) as part of a larger initiative to investigate current natural resource management within and around Sydney Harbour.

The objectives of the report are to:

1. Outline data pertaining to the spatial distribution of ecological assets in Sydney Harbour.
2. Outline data available pertaining to the spatial patterns of resource use.
3. Synthesise the current knowledge of the contamination status of fish and sediments in Sydney Harbour, and provide expert comment on likely future trends and distributions
4. Synthesise the current knowledge of the economic benefit from various types of harbour use.
5. Synthesise the current knowledge of the values held by the community regarding Sydney Harbour.

The content of this report focused, firstly, on the scientific knowledge of Sydney Harbour. That is the currently published, peer reviewed work found within the world's scientific databases. This review also included many unpublished, un-reviewed, works from various state agencies and private environmental firms that were collated after consultation between SIMS and various Sydney Harbour stakeholders. Importantly, this collation of 'grey' literature will be far from complete. There are no central repositories for such reports. Knowledge of an unpublished report's existence is sometimes the only means by which it can be found and included. SIMS staff relied on local council and state government consultation, web based searching, and prior knowledge to collate these reports. Only those reports where actual digital or physical copies could be obtained by SIMS were included in this report. This precluded reports whose titles may have indicated relevance to Sydney Harbour, but were unable to be accessed or did not arrive in time for inclusion.

Included is a list of documents pertaining to each of the objectives outlined above (Appendix A and B).

An note on tense Throughout this document, tense is used to indicate and differentiate the activities associated with the 'Literature review', from what is accepted scientific theory based, not only on the documents collated during the review, but also the wider scientific literature. That is, *past* tense is used when describing the documents that were uncovered during the review process, while *present* tense has been used when describing established science pertaining to the harbour or synthesising knowledge based on collated documents.

2.2 Data compilation methods

2.2.1 Synthesis of SIMS SoH Report (SHRP Review 2014)

In 2012 The SHRP engaged with 12 university and government based scientists to undertake a review of published literature with data pertaining to Sydney Harbour. This report used systematic literature review methods combined with a two-day workshop and questionnaire to canvass the world's databases for published literature. Additionally, several easily accessible, but unpublished, reports were included in this review if they were assessed as being from a reliable source (e.g. NSW Government reports). This report used the findings of the SIMS SoH (2014) systematic literature review as a starting point and then built on it.

2.2.2 NSW Governement Agencies

The NSW DPI, NSW RMS, NSW OEH and various local councils were approached by SIMS staff and asked to provide any relevant documentation with data or information pertaining to Sydney Harbour. State agencies had collated several large spatial datasets on habitat distributions and bathymetry. Local governments were asked for copies of consultant reports, State of the Environment Reports and local waterway quality assessments they may have commissioned. For LGAs with recent ($>$ 2010) Coastal Zone Management Plans, we simply used the Data Compilation section of that reporting process. In January 2011, for example, the consulting group 'Cardno' was commissioned by the Parramatta City Council and the NSW OEH to undertake a Parramatta River Coastal Zone Management Plan (CZMP). As part of this process, over 120 unreviewed reports with data pertaining to Sydney Harbour were collated by the consultants.

During that process the title and executive summaries of the consulting and local government reports were read. If these indicated that the document may be relevant then a further scan of the whole report was conducted. Many of these reports pertain to flora, fauna, and communities within the LGA itself, without specifically discussing harbour or foreshore biota.

2.2.3 Synthesis of SIMS Report (Hedge et. al. Harbour Use Progress Report 2013)

In June 2013 SIMS began a study of localised recreational activities in Sydney Harbour. This work is ongoing, but data from initial sampling have been collected and synthesised in an unpublished, internal SIMS report. The data collected during these surveys included the spatial distribution of shore and boat-based fishing, anchoring activities, recreational boating distributions and unpowered vessel use across the whole harbour, from the Kissing Point Ferry wharf, to North and South Head (not including Middle Harbour).

The data presented in this report is a synthesis of these Harbour Survey activities and the data up to the end of 2013. Hedge and co-authors plan to publish this data in full in the peer-reviewed literature.

2.2.4 Data Availability

Presented in Appendix A and B is a citation for every document collated during this Background Report. The availability of these documents varies. Published, peer reviewed, articles are usually unavailable from the publishers without a subscription service, however it is common practice for authors to make these papers available on request. Several datasets remain unavailable for public dissemination at the time of this report's publication. This includes the habitat distribution datasets collated from NSW DPI, however these data have generally been presented elsewhere, e.g. Creese et. al. (2009), West and Williams (2008) and Kelleway

et. al (2007). Further datasets, including bathymetry data, can be obtained by contacting the Spatial Data Manager in the relevant state agency.

The analysis and synthesis of the published, peer reviewed, literature (i.e. SHRP SoH, 2014) will be made available for download at *www.sims.org.au*.

2.2.5 Sydney Ports Coorporation

The Sydney Ports Coorporation maintains extensive spatial data on the bathymetry of Sydney Harbour. These sounding data are complemented by NSW RMS sounding data that covers the shallow water areas of Sydney Harbour. Sydney Ports bathymetry is derived from multi-beam sonar data (Reson 7125 SV1 400kHz) and covers much of the deeper harbour.

2.3 Published Literature Overview

308 Published peer reviewed articles and reports were uncovered during the SHRP State of the Environment Report 2014. A further 336 unpublished, unreviewed 'grey' literature, website, fact sheets or media releases were collated for this Background Report.

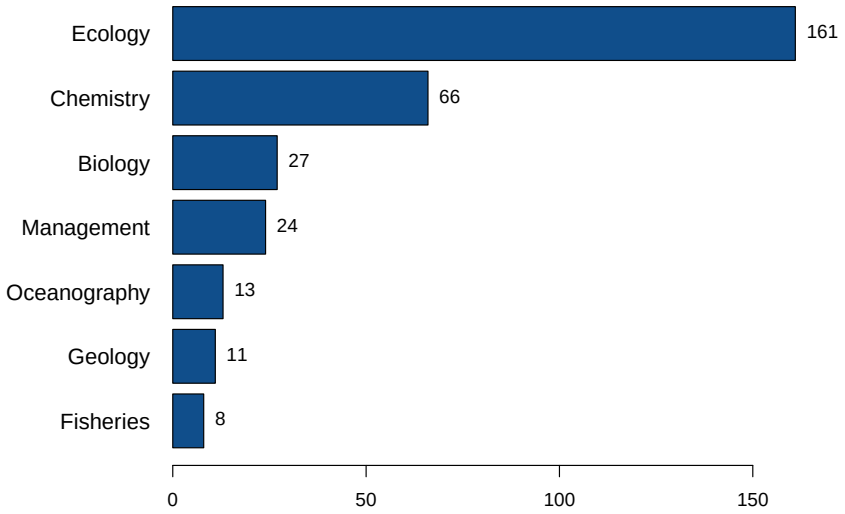

Figure 1: Numbers of published, peer reviewed papes with data pertianing to Sydney Harbour collated during the SHRP State of the Harbour 2014 report. Source: SIMS SoH(2014)

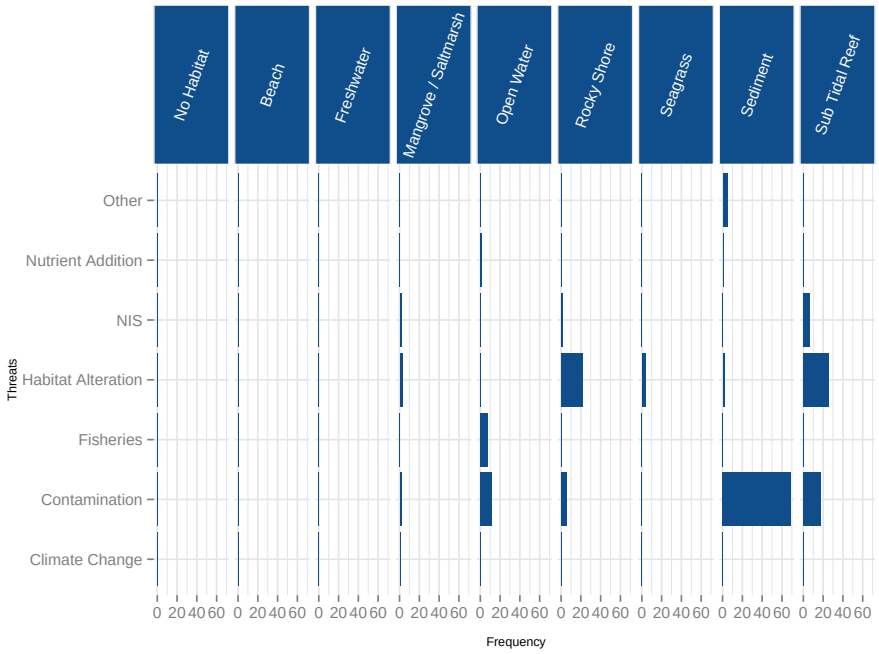

Figure 2: Number of papers per habitat and threat collated during the SHRP State of the Harbour Report 2014. Source SIMS SoH (2014), NIS: Non-Indigenous Species.

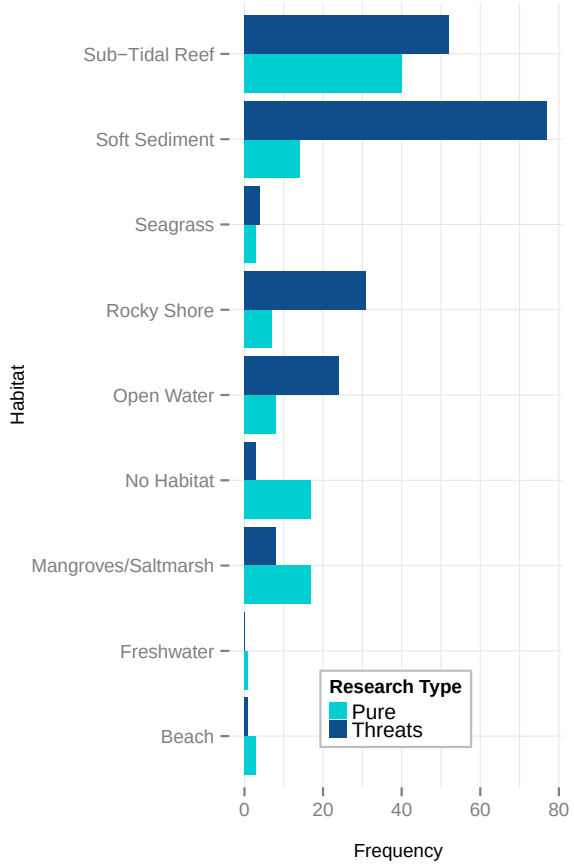

Figure 3: Number of papers per research 'type' and habitat collated during the SHRP State of the Harbour Report 2014. Source SIMS SoH (2014)

3 Study Area Background

For the purposes of this report, and indeed for most of the activities carried out in the SHRP, Sydney Harbour is delineated following the NSW Government MER Programme. The downstream boundary of the Sydney Harbour estuary is an imaginary line joining North and South Head at the shortest point. The upstream boundary is the Parramatta Weir. The Sydney Harbour estuary also contains the Middle Harbour (stopping at -33.743680°, 151.188186°), Lane Cove (up to the Lane Cove Weir; -33.800718° 151.143627°) and Parramatta Rivers.

3.1 The City of Sydney

The City of Sydney has steadily grown since colonisation in 1788 to become the largest city in Australia. In 2012 185 000 residents lived in the City of Sydney LGA, and a further 4.63 million residents lived in the Greater Sydney Metropolitan Area (GSMA). The GSMA stretches for over 60 km south, 30 km north and 50 km west of Sydney's city centre. The population of the GSMA continues to grow at 1.9 % p.a. and the population density in the GSMA currently stands at 380 people.km^{-1}.

3.2 Climate

The GSMA is primarily classified as being temperate–humid, with mean daily temperatures ranging from 26°C in the summer to 8°C in winter. These temperatures are for the city metropolitan areas (measured at Observatory Hill). Temperatures change as you travel west, with a mean high temperate of 28°C in Parramatta in January and 6°C in the winter (Table 1). Climate data is available for Sydney Harbour from several sources including the Bureau of Meteorology. The longest record of climate data is, however, from Sydney Observatory (Lower Parramatta River Stormwater Management Councils (2014)).

Table 1: Average climate variables measured from Observatory Hill in Sydney. Data reproduced from Lower Parramatta River Stormwater Management Councils (2014)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Max temp	25.8	25.6	24.6	22.3	19.3	16.8	16.1	17.7	19.8	21.9	23.6	25.1	21.6
Min temp	18.6	18.7	17.5	14.6	11.5	9.2	8	8.9	10.9	13.5	15.5	17.4	13.7
RH % (9 am)	70	73	73	71	73	74	70	65	62	60	63	66	68
RH % (3 p.m.)	61	63	62	58	56	56	50	49	50	54	56	58	56
Monthly rain (mm)	104	117	132	127	122	132	99	82	70	77	83	79	1224
Number of rain days/yr	12	12	13	12	12	12	10	10	10	11	11	12	137

Three dominant wind patterns affect Sydney Harbour. The strongest southerly winds are observed 17 % of the time while lighter, north easterly, winds are most common; observed 22 % of the time. Westerly winds are observed primarily during the winter and occur 18 % of the time.

West and Williams (2008) presents the most comprehensive, available, analysis of wind direction and strength throughout the estuary, including the spatial interpolation of fetch strength throughout the entire waterway.

Data on common meteorological variables were available from the Bureau of Meteorological through a web based portal (BOM, *bom.gov.au*, accessed 10/3/2014)

3.3 Sub-Catchments

Four major sub-catchments comprise the greater Sydney Estuary. NSW DPI collated spatial information relating to catchment boundaries as part of the NSW I&I Monitoring, evaluation and reporting program (NSW DPI, *www.dpi.gov.au/environment/mer*; Table 2, Fig. 4)

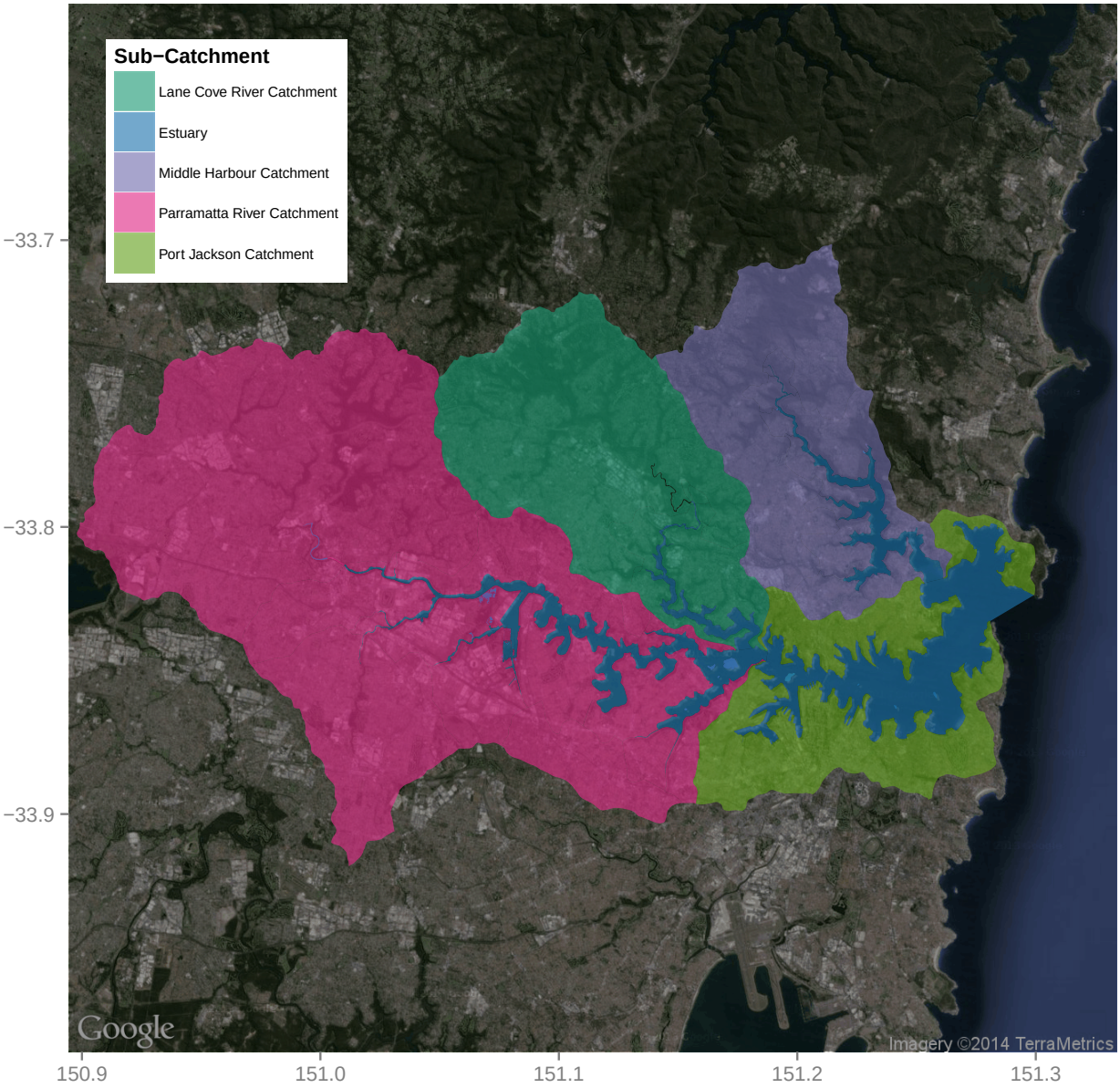

Figure 4: The sub-catchments of Sydney Harbour presented from data collated during the NSW MER process. Sub catchment classifications are taken directly from the NSW OEH data. Data available from NSW OEH by request.

Table 2: Total area (m^2) of the MER estuary classifications in Sydney Harbour. Source: NSW OEH, from MER Reporting

Sub Estuary or Catchment	Total Area
Lane Cove River Catchment Estuary	18184
Lane Cove River Catchment Freshwater	76960
Lane Cove River Estuary	3072.00
Middle Harbour Creek Catchment Estuary	28328
Middle Harbour Creek Catchment Freshwater	48558
Middle Harbour Creek Estuary	6201
Parramatta River Catchment Estuary	80966
Parramatta River Catchment Freshwater	170601
Parramatta River Estuary	14413
Parramatta River Freshwater	98
Port Jackson Catchment	55697
Port Jackson Estuary	29070

4 Estuary Characteristics

4.1 Bathymetry and Topology

The Sydney Estuary is a drowned river valley dissected into Hawkesbury Sandstone and Ashfield Shale (Roy, 1981). As such, the shape and form of the estuary is determined primarily by geology. A flood tide delta formed when the sea level began to rise and fill the river valleys approximately 15 000 years ago.

Data for Sydney Harbour bathymetry was available from both the NSW RMS and Sydney Ports Corporation (SPC, Fig 5). Data was available as depth sounding points in a variety of formats. NSW RMS maintains a record of soundings for shallow water areas, whilst SPC maintains the soundings for deeper areas on a 1m x 1m grid. SPC used a 'shoal bias' approach and the shallowest point in the 1 m grid is used. For this report, a thin spline regression analysis was used to interpolate depth across the entire estuary on a 50m x 50m grid. This provided an indication of depth, however, should only be used as a guide.

Defence Science and Technology (DSTO) as well as the Cooperative Research Centre for Coastal Zone, Estuary, and Waterway Management used multi-beam sonar to map several sections of Sydney Harbour (Skene and Ryan, no date; Ozcoasts, *ozcoasts.gov.au*, accessed 15/3/2014). That data was not collated during our search and the data's availability, quality, and utility was not assessed. The Ozcoasts Program, as part of Geoscience Australia, provides figures and descriptions of geomorphology and sedimentology of Sydney Harbour based on these multi-beam surveys (Ozcoasts, *ozcoasts.gov.au*, accessed 15/3/2014).

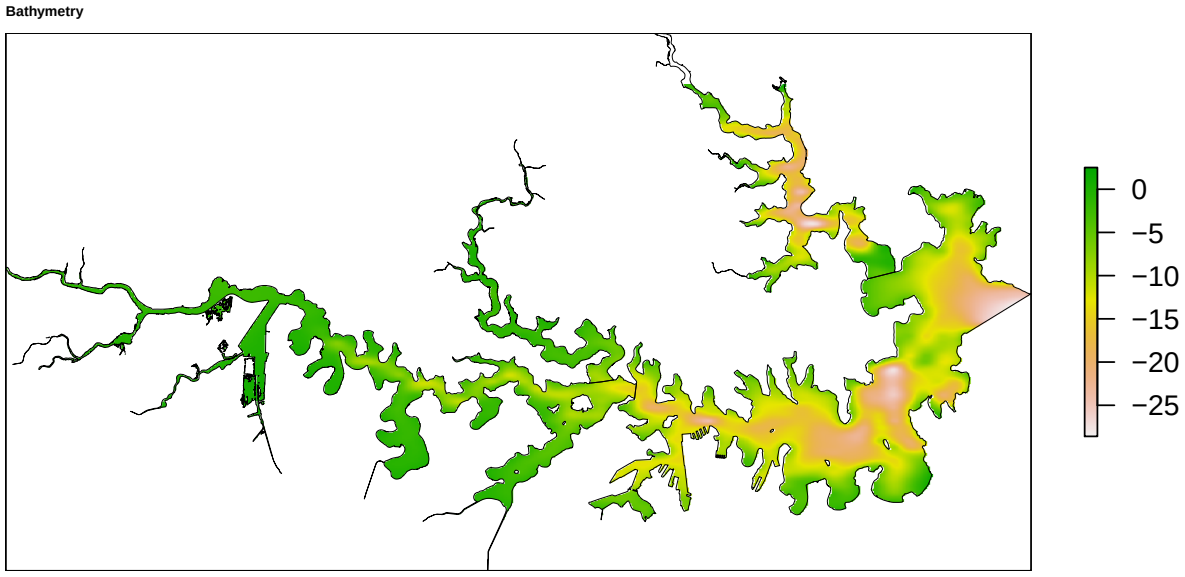

Figure 5: Bathymetry of Sydney Harbour, interpolated using NSW RMS and Sydney Port Corporation depth soundings. A Thin Spline Regression was first modeled from the sounding data and used to populate a 1000 x 1000 raster of Sydney Harbour

4.2 Hydrology and Circulation

Evaporation, precipitation and freshwater inflow control salinity within the estuary. The estuary is generally well mixed and oceanic (30–35 psu) during dry or 'base-flow' conditions ($< 5mm.day^{-1}$). During periods of high precipitation, freshwater inflow is rapid due to large amounts of impervious surfaces in the surrounding

catchment (Beck and Birch 2012a,b). During these events a buoyant fresh layer forms on the surface of the waterbody that can be up to two metres thick.

Tidal patterns generally determine circulation in the Sydney estuary. The tide is diurnal ($M2 = 0.501m$, $S2 = 0.126m$, $K1 = 0.148m$ and $O1 = 0.096m$) and reverses every six hours (Das et. al., 2000). Spring tides in the harbour can have a tidal range of up to 1.6 m, and tidal forcing is strongest towards the Sydney Harbour heads (Middleton et. al., 1997). Ebb flow from the harbour during spring tides can be up to 0.5 $m.s^{-1}$. Associated discharge volumes can be as high as 6000 $m^3.s^{-1}$.

UNSW and the University of Sydney have undertaken some sampling of water circulation characteristics and this was presented in the SHRP State of the Harbour Report (2014). Much of the modelling was similarly unpublished and unavilable (e.g. 'Sydney Water'. models) although extensive information and visualization of circulation patterns were available through the Sydney Harbour Observatory SHO (https://sho.sydney.edu.au/). SHO is a web based platform for the visualization of the CSIRO TasMAN application, mapped to the Sydney Region. Currently this portal is in prototype, however visualizations are available for salinity, water temperature, turbidity and current. In addition some validated and unvalidated harbour models of circulation existed in peer-reviewed published form (e.g. Lee and Birch 2012, Das et al. 2000).

4.3 Flushing and Ocean Exchange

Wind direction and strength can determine flushing rates in Sydney Harbour (SIMS SoH, 2014). Greater water retention occurs under easterly and northeasterly winds in the outer harbour areas. This pattern is reversed in the upper reaches of the estuary. Here retention is highest during easterly and northeasterly winds.

Water age, the period of time between when a parcel of water enters a system and when it is flushed, varies throughout the harbour and is predictably greatest in the upper Parramatta River. Water age in the upper Parramatta is approximately 130 d. Water age in the main body of the harbour varies between 18-42 d depending on wind directions. An easterly, 'up estuary' wind increases water mixing and consequently reduces water age in the main section of the estuary.

5 Data on the distribution of ecological assets in Sydney Harbour

5.1 Sediment Systems

The most comprehensive spatial analysis of bottom sediment characteristics was found in West and Williams (2008). Here a spatial model was interpolated over the whole estuary using a series of sample points. Also presented was a comprehensive appendix with derived statistics of mud, gravel and sand over the estuary for the period 1978–2003. Unprocessed data used in these analyses was unavailable for public dissemination. Comprehensive discussion and analyses of sediment characteristics were also presented in Birch (2007).

Many of the collated consulting reports and local government documents included a description of sediment characteristics from around the estuary. The comprehensiveness of these analyses varied in temporal and spatial scale. The sediments of the Homebush Bay area, for example, received considerable attention due to the significant research effort conducted preceding the 2000 Sydney Olympic Games. Thirty nine different consulting or government reports contained the word 'Homebush' or 'Olympic' in the title and most of these focused on the significant levels of sediment contamination found in the area.

5.1.1 Sediment 'in-fauna'

Hutchings et al (2013) conducted the most comprehensive analysis of fauna in Sydney Harbour. Over 3000 species of crustacea, mollusc, fish, polychaete and echinoderm species were collated from Australian Museum records, and georeferenced into 4 areas throughout the estuary. The list of species was included in that document as an appendix. While Hutchings et al. (2013) discussed sediment systems generally, the habitat

association of each taxa presented was not given. This, however, could easily be researched using the species list provided.

Beach communities in the Sydney Estuary are poorly understood. Only four peer reviewed articles investigated elements of faunal composition in that habitat. Dexter (1983, 1984) provided a holistic assessment of sediment communities in the outer beach areas of the harbour, while Jones (2003) provided a formal impact assessment of the beach dwelling amphipod *Exeodiceros fosser* in response to a 1999 oil spill. Keats (1997) provided a qualitative account of gastropod abundance on Spectacle Island, in the Parramatta River sub-catchment.

There was some indications of sediment fauna within the collated unpublished reports, but again, these were generally limited in temporal and spatial scale. Many were also dated, and released prior to, or just after, the 2000 Olympic Games. Jones and Frances (1988) found much of the infauna in the upper Parramatta was dominated by polychaete biomass. However they found more crustaceans (17 species) than any other taxa (polychaetes: 9, molluscs: 6). Homebush Bay was also found to harbour a faunal community distinct from surrounding areas; dominated by *Corophium cf. acherusicum, Arthritica helmsi, Ceratonereis aequisetis* and *Capitella spp.*.

Several studies investigated community and individual responses to contamination within sediment infaunal systems (e.g. Birch and Taylor, 2002, Dafforn et al., 2012). These are discussed in the Section 6 section of this report.

5.1.2 Sediment Microbiota

There has been recent, but limited, advances in our understanding of bacterial communities in the sediment of Sydney Harbour. So far only two papers used sequencing techniques to investigate sediment microbiota. Sun et al. (2012) and Chariton et al. (2010) found 10 091 and 4640 Operational Taxonomic Units (OTUs) respectively among several sites in the harbour. These papers described the effects of sediment contamination on these systems, and are a very useful starting point for future research on the sediment microbiota of Sydney Harbour.

5.2 Rocky Reef

Again, the most comprehensive data of sub-tidal rocky reef distribution was collected by NSW DPI.

Most of the rocky reef in Sydney Harbour is found in the lower catchment (Fig. 6), however some reef is distributed throughout the Parramatta River, Middle Harbour and Lane Cove River. The prevalence of shoreline modification in 'up-estuary' areas restricts the distribution of rocky reef to the relatively less modified outer harbour areas. These modified foreshore areas, although sometimes constructed of sandstone and other 'natural' materials, are very different to rocky reef and are discussed in section 5 of this report.

The Reef Life Survey (RLS) is non-profit organisation that organises volunteer divers to undertake SCUBA based surveys of reef site throughout the world. The organisation has several monitoring sites in Sydney Harbour including Camp Cove and the North Head Aquatic Reserve. Divers use transect methods to quantify fish and macro invertebrate abundances at each site. Surveys are organised on an ad-hoc basis. Data from each Sydney based site is available from the organisation for research purposes. Data and contact details are found at reeflifesurvey.com. This resource may represent a significant and as yet, largely untapped, data set for management purposes.

Table 3: Dive sites, number of surveys at each site, depths and time of surveys of Sydney Harbour Reef Life Survey activities. Source: RLS

Site Name	Site Latitude	Site Longitude	# Surveys	Depths	Years surveyed	LastSurveyDate
Kiribilly House	-33.85186	151.21997	2	2m	2010;	21/02/10
Georges Head	-33.83785	151.26139	2	4m;5m	2010;	24/02/10
Barmoral Bay	-33.81729	151.25331	2	3m;4m	2010;	24/02/10
Fort Denison	-33.85529	151.22484	2	2m;3m	2010;	21/02/10
Clarke Island	-33.86328	151.24196	2	2m;3m	2010;	21/02/10
Chowder Bay	-33.841655	151.253968	7	2m;3m;4m;5m;6m	2009;2010;	24/02/10
Green Point Camp Cove	-33.840111	151.277492	8	4m;5m;6m	2009;2011;2012;	19/03/12
Clifton Gardens Wharf	-33.839753	151.253504	5	2m;3m;4m;6m	2009;2011;2012;	27/10/12
Chowder Bay	-33.839495	151.25459	1	4m	2009;	28/03/09
Camp Cove middle reef	-33.839307	151.277744	9	4m;5m	2009;2011;2012;2013;	01/06/13
Camp Cove NE	-33.8388	151.27905	9	4m;5m	2009;2011;2012;	18/03/12
Inside South Head	-33.83304	151.27898	10	4m;5m;6m	2010;2011;2012;	18/03/12
Middle Head Sth 2	-33.83036	151.26378	5	5m;7m;8m	2010;2012;	17/03/12
Middle Head Sth	-33.82827	151.26574	11	6m;7m;8m;9m	2009;2011;2012;	17/03/12
The Blocks	-33.8241	151.2972	3	11m;7m;8m	2009;	30/03/09
Bradleys Heads	-33.85133	151.24823	2	2m	2010;	21/02/10
Middle Head North East	-33.8234	151.26768	13	5m;6m;7m;8m;9m	2009;2011;2012;	17/03/12
Old Mans Hat	-33.8214	151.2903	3	7m;8m;9m	2009;	30/03/09
Inside North Head	-33.81802	151.285181	20	10m;11m;16m;18m;3m;5m;6m;7m;8m;9m	2009;2010;2011;2012;	18/03/12
Grotto Point Lighthouse	-33.81848	151.26069	7	4m;5m;6m;7m	2009;	12/12/09
Quarantine Jetty	-33.81484	151.28466	3	2m;3m	2009;	27/03/09
Dobroyd Head	-33.81322	151.27238	8	10m;11m;5m;6m;8m	2009;2010;	20/02/10
Little Manly Bay	-33.808495	151.2845	2	3m;4m	2009;	13/12/09
Blue Fish Point	-33.80646	151.30526	6	10m;6m;8m;9m	2009;2011;	25/03/11
Shark Island	-33.85772	151.25629	3	2m;3m	2010;	22/02/10
Steel Point	-33.85595	151.26602	2	1m;2m	2010;	22/02/10
Berrys Bay Point	-33.84819	151.19383	2	2m	2010;	22/02/10
Shark Island SE	-33.85966	151.25916	4	3m;4m	2009;2010;	23/02/10
Neilson Bay	-33.852053	151.263956	2	5m;6m	2010;	23/02/10

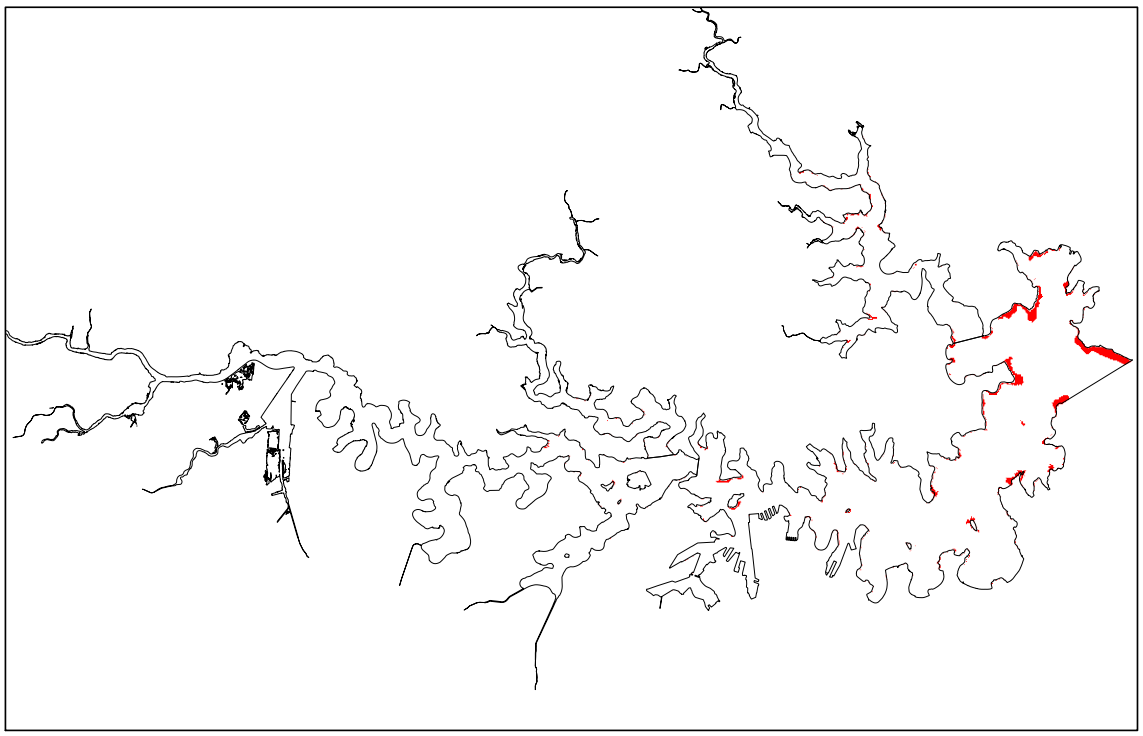

Figure 6: Distribution of Sub-tidal rocky reef (red) in the Port Jackson Sub-Catchment of Sydney Harbour. Mapping produced from data collected from NSW DPI as part of a large statewide audit of ecological assets.

5.2.1 Rocky Reef algae

Two kelp taxa dominate the sub tidal reefs of Sydney Harbour; *Sargassum spp.* and *Ecklonia spp.*. Over 16 peer reviewed articles were collated pertaining to these kelps in the harbour. They generally investigated the patterns and abundance of understory species, such as *Dictyota spp.* and *Codium spp.*, however effects on kelp by man-made structures, algal reproduction and colonisation and algal epiphytes were also investigated. There seems to be little investigation of kelp, or rocky reef in general, within the collated 'grey literature'.

Mapping was undertaken to quantify macro algae in the entire Sydney Harbour estuary by NSW DPI. It is important to note that the photographic and GIS methods used could not distinguish algal species from bare rock (West and Williams 2004). Estimates of kelp abundance in Sydney Harbour are therefore likely overestimated, given the variability of kelp cover in sub tidal reef systems. Creese et al (2009) have also comprehensively mapped 1.58 km^2 of reef habitat in Middle Harbour, where kelp was more accurately included in analyses. Almost 37% of the mapped reef was dominated by macro algae.

5.2.2 Rocky Reef fauna

Most of the published literature collated during this review investigated elements of macro algae ecology and biology. These systems support a wide variety of smaller, understory, algal communities. They also support a diverse system of bryozoans, cnidarians, annelids, molluscs, crustaceans, and fish. Connell and Glasby (1999) and Clynick et al. (2008) provided lists of taxa found during survey and experimental work in the Sydney estuary.

Table 4: Species noted during experimental and survey work in Sydney Harbour. Source: Clynick et al. (2008) and Glasby and Connell (1999)

Brown/green Filamentous complex	Connel and Glasby (1999)	*Pictilabrus laticlavius*	Clynick et al. (2008)
Rhodophyta Ceramiales complex	Connel and Glasby (1999)	*Atypichthys strigatus*	Clynick et al. (2008)
Encrusting unid.	Connel and Glasby (1999)	*Microcanthus strigatus*	Clynick et al. (2008)
Corallina o.cinals	Connel and Glasby (1999)	*Acanthaluteres vittiger*	Clynick et al. (2008)
Peyssonnelia spp.	Connel and Glasby (1999)	*Brachaluteres jacksonianus*	Clynick et al. (2008)
Sargassum spp.	Connel and Glasby (1999)	*Meuschenia trachylepis*	Clynick et al. (2008)
Zonaria sp.	Connel and Glasby (1999)	*Monocanthus chinensis*	Clynick et al. (2008)
Porifera sp. 1	Connel and Glasby (1999)	*Eubalichthys mosaicus*	Clynick et al. (2008)
Polychaeta Spirorbidae	Connel and Glasby (1999)	*Meuschenia freycineti*	Clynick et al. (2008)
Hydroides spp.	Connel and Glasby (1999)	*Unidentified juvenile*	Clynick et al. (2008)
Cirripedia Balanus trigonus	Connel and Glasby (1999)	*Monodactylus argenteus*	Clynick et al. (2008)
Bivalvia Saccostrea commercialis	Connel and Glasby (1999)	*Mugil cephalus*	Clynick et al. (2008)
Bryozoa Watersipora subtorquata	Connel and Glasby (1999)	*Upeneichthys lineatus*	Clynick et al. (2008)
Fenestrulina mutabilis	Connel and Glasby (1999)	*Upeneus tragula*	Clynick et al. (2008)
Ascidiacea Styela plicata	Connel and Glasby (1999)	*Parupeneus signatus*	Clynick et al. (2008)
Prionurus microlepidotus	Clynick et al. (2008)	*Trachinops taeniatus*	Clynick et al. (2008)
Prionurus maculatus	Clynick et al. (2008)	*Abudefduf sexfasciatus*	Clynick et al. (2008)
Apogon limenus	Clynick et al. (2008)	*Chromis nitida*	Clynick et al. (2008)
Pseudocaranx dentex	Clynick et al. (2008)	*Mecaenichthys immaculatus*	Clynick et al. (2008)
Trachurus novaezelandiae	Clynick et al. (2008)	*Parma microlepis*	Clynick et al. (2008)
Ambassis jacksoniensis	Clynick et al. (2008)	*Pomatomus saltatrix*	Clynick et al. (2008)
Cheilodactylus fuscus	Clynick et al. (2008)	*Centropogon australis*	Clynick et al. (2008)
Cheilodactylus vestitus	Clynick et al. (2008)	*Scorpis lineolate*	Clynick et al. (2008)
Chironemus marmoratus	Clynick et al. (2008)	*Diploprion bifasciatum*	Clynick et al. (2008)
Dicotylichthys punctulatus	Clynick et al. (2008)	*Acanthopagrus australis*	Clynick et al. (2008)
Enoplosus armatus	Clynick et al. (2008)	*Chrysophrys auratus*	Clynick et al. (2008)
Gerres subfasciatus	Clynick et al. (2008)	*Hippocampus whitei*	Clynick et al. (2008)
Girella tricuspidata	Clynick et al. (2008)	*Festucalex cinctus*	Clynick et al. (2008)
Kyphosus spp.	Clynick et al. (2008)	*Arothron hispidus*	Clynick et al. (2008)
Achoerodus viridus	Clynick et al. (2008)	*Enneapterygius rufopileus*	Clynick et al. (2008)
Ophthalmolepis lineolate	Clynick et al. (2008)	*Trygonoptera testacea*	Clynick et al. (2008)
Pseudolabrus guenrheri	Clynick et al. (2008)		

Sub tidal reef in Sydney Harbour, like sub tidal reef elsewhere, is generally comprised of a mosaic of flora and bare rock. This pattern is generally thought to be the result of urchin grazing.

It is also noted that over 60 % of the 586 species of fish known from Sydney Harbour are found in sub tidal rocky reef environments (Booth 2010).

There exists a paucity of studies that investigate non-algal rocky reef fauna. While the salinity and temperature patterns present in Sydney Harbour can be similar to nearby open coastal environments (where there is much more literature on rocky reef communities), there is a lack of comparison between the two areas. Stakeholder groups should be wary when drawing conclusions based on data collected in open coastal areas of Sydney; wave energy, human disturbance and substrate complexity are predicted to vary greatly between the two systems.

5.3 Seagrass

NSW DPI mapped the distribution of seagrass throughout Sydney Harbour (Fig. 7). Spatial data collated by NSW DPI included a re-examination of 1970's era photographs within a GIS framework, as well as the collation and examination of more recent orthorectified images (the data are presented in West and Laird

2004; West and Williams 2008). Additionally, West and Williams (2008) created ecological niche models using genetic algorithms to examine the potential distribution of seagrass in the harbour.

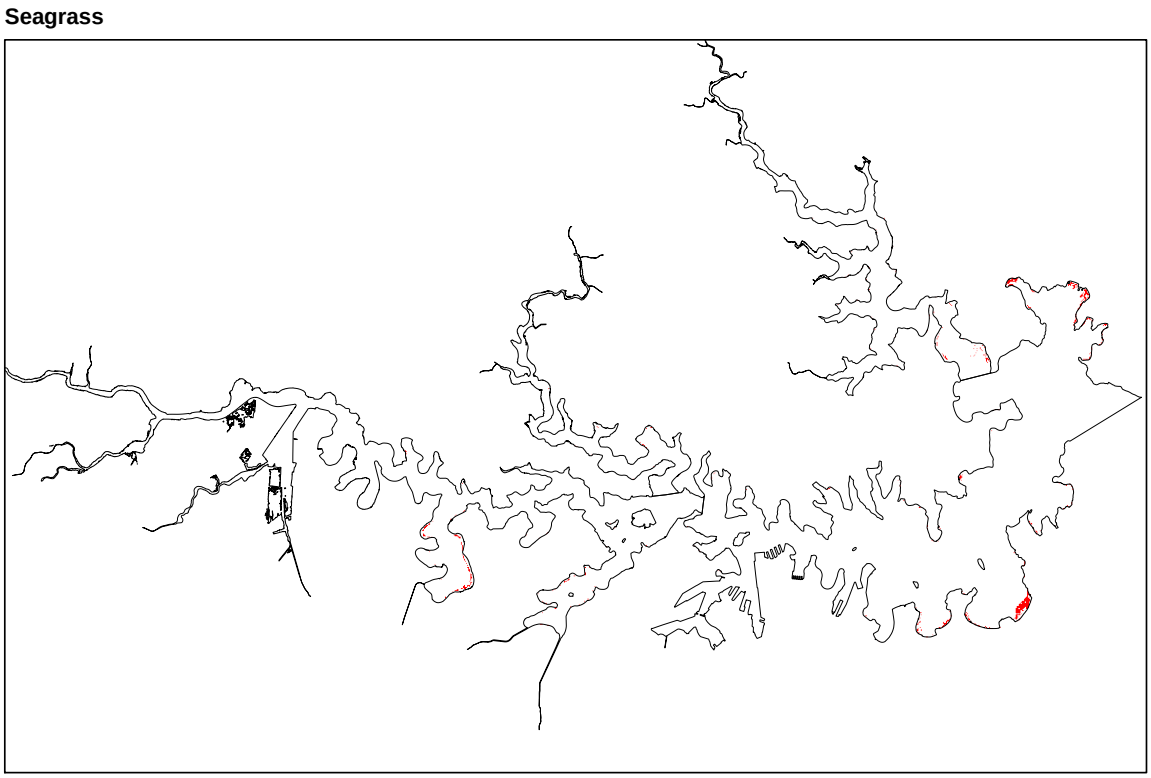

Figure 7: Area of seagrass (red) in Sydney Harbour. Source: NSW DPI (unpublished).

There is approximately 51.7 ha of seagrass in Sydney Harbour in 2000 (West and Williams 2008). Several species have been reported, including *Halophila ovalis, H. minor, H. major, H. decipiens, Posidonia australis, Zostera capricorni* and *Hetrozostera nigricaulis*. While remotely sensed imagery can be used to distinguish between seagrass taxa, it requires significant in-situ calibration. We are unaware if this has taken place in NSW waters. This is particularly important for *Posidonia australis*, a population listed as endangered under the Threatened Species Schedules of the *Fisheries Management Act 1994*. While populations of *P. australis* are known to exist in the Sydney Estuary, there was no accurate data on the distribution and abundance of this species collated.

5.4 Pelagic Systems

5.4.1 Pelagic Macrofauna

Cetaceans are a common sight in Sydney Harbour, yet we were unable to find any reference to whale or dolphin research conducted within the estuary. A research program is underway at Macquarie University to ascertain the effects of Sydney's whale watching industry on whale ecology, however no outputs from this project have been collated.

NSW DPI is undertaking the shark research program; 'Movements and biology of coastal sharks in NSW' (Peddemors et. al. 2009). The program involves the deployment of 28 acoustic listening stations to track tagged bull sharks in Sydney Harbour. Outputs from this programme are forthcoming.

5.4.2 Phytoplankton

There was little documentation on the phytoplankton in the harbour. Only two documents pertaining to harmful and potentially harmful phytoplankton were collated during this report. Ajani et al. (2001) noted outbreaks of *Alexandrium catenella, Chattonella gibosa* and *Alexandrium sp.* since European colonisation in the Parramatta River. She also noted outbreaks of the 'potentially' harmful *Scrippsiella trochoidea, Gonyaulax polygramma, Gymnodinium sanguineum, Trichodesmium sp. and Noctiluca scintillans.*

A small dataset was available from *http://researchdata.ands.org.au/phytoplankton-concentration-measurements-in-sydney-harbour-summary* that included measurements of chlorophyll in the water column at a single site in Pyrmont in response to rainfall. This data was limited, spatially and temporally, and has little utility.

Chlorophyll concentrations were also taken at several sites in the estuary during the NSW Government MER program (Roper et. al. 2011). These measurements were for the purpose of constructing an index based assessment of Sydney Harbour.

5.4.3 Zooplankton

There were no published articles on Zooplankton, nor could we find any reference to zooplankton in the 'grey literature'.

Larger pelagic invertebrates including two-spot crab *Ovalipes australiensis*, blue swimmer crab *Portunus armatus* (previously *P. pelagicus* in Australia), and mantis shrimp (family: Squillidae, several species) were consistently caught at over 100 individuals per day during the work of Liggins et al (1996), however this was the only indication of pelagic invertebrate ecology collated in this report.

McKinley et al. (2011) investigated larval fish abundances in Sydney Harbour in response to sediment contamination and the species most collected are presented in Table 5.

Table 5: The top six larval fish species collected during the work of McKinley et al 2011.

Ambassis jacksoniensis	Port Jackson glassfish
Paedogobius kimurai wide	gape paedomorphic goby
Arenigobius spp.	bridled goby spp.
Gobiopterus semivestita	transparent goby
Hyperlophus transucidus	translucent sprat
Hyperlophus vittatu	sandy sprat

5.5 Fishes in Sydney Harbour

This section comprises collated literature on both pelagic and benthic associated fishes in Sydney Harbour.

There were 32 different collated reports within the published literature that referred to fish biology or ecology in Sydney Harbour. Furthermore, 21 of the collated 'grey literature' documents contained 'fish' in the title. These documents included a number of websites, fact sheets, news articles, and other articles that detail fish species recorded by divers and fisherman. Note that these documents also refer to fishing, both commercial and recreational, which are also discussed in Section 6.4.

Liggins et al. (1996) presents a comprehensive analysis of fin fish abundance in 'by-catch' of commercial fishing operations in 1996. Here, 96 different taxa were noted (Table 6), however the abundance of these taxa were highly variable between years, and time in the fishing season.

Table 6: Fish species caught as by-catch during 1991-1992. Source: Liggins et al (1996)

Ambassis jacksoniensis	*Meuschenia freycineti*	*Sillagoflindersi*	*Loligo sp.*
Ambassis marianus	*Meuschenia scaber*	*Sillago maculata*	*Loliolus sp.*
Antennarius striatus	*Meuschenia trachylepis*	*Sillago robusta*	*Sepioteuthis australis*
Apogon sp.	*Momcanthus chinensis*	*Synaptura nigra*	*Sepia sp.*
Gronovichthys atripes	*Nelusetta ayraudi*	*Acanthopagrus australis*	*Eupyrmna stenodactyla*
Batrachomoeus dubius	*Myxus elongatus*	*Pagrus auratus*	*Sepioloida lineolata*
Centroberyx afinis	*Upeneichthys lineatus*	*Rhabdosargus sarba*	*Nototodarus gouldi*
Petroscirtes lupus	*Upeneus tragula*	*Sphyraena novaehollandiae*	
Engyprosodon grandisquamma	*Anoplocapros inermis*	*Sphyraena obtusata*	
Pseudorhombus arsius	*Pempheris multiradiata*	*Trachinocephalus myops*	
Pseudorhombus jenynsii	*Platycephalus arenarius*	*Pelates quadrilineatus*	
Foetorepus calauropomus	*Platycephalus caeruleopunctatus*	***(mixed spp.)***	
Pseudocaranx dentex	*Platycephalus fuscus*	*Optivus elongatus*	
Trachurus novaezelandiae	*Platycephalus longispinis*	*Chelidonichthys kumu*	
Seriolella brama	*Suggrundus jugosis*	*Zeus faber*	
Hyperlophus vittatus	*Plotosus lineatus*	*Alpheus spp.*	
Dicotylichthys punctulatus	*Pomatomus saltatrix*	*Paguristes spp.*	
Enoplosus armatus	*Priacanthus macracanthus*	*Macrobrachium sp.*	
Gerres subfasciatus	*Argyrosonzus hololepidotus*	*Charybdis cruciata*	
Arenigobius bifrenatus	*Centropogon australis*	*Ovalipes australiensis*	
Favonigobius exquisitus	*Notesthes robusta*	*Portunus pelagicus*	
Favonigobius tamarensis	*Scorpaena cardinalis*	*Portunus sanguinolentus*	
Favonigobus lateralis	*Atypichthys strigatus*	*Scylla serrata*	
Heterodontus portusjacksoni	*Microcanthus strigatus*	*Ibacus peronii*	
Leiognathus sp.	*Callanthias allporti*	*Mantis shrimp*	
Brachaluteres jacksonianus	*Sillago ciliata*	*Loligo chinensis*	

Ghosn et al. (2008) used recreational roving creel surveys to elucidate fish abundance and distribution during the 2007/2008 summer. Investigating fish abundance in this way is, however, restricted given recreational fishers are targeting specific species. Ghosn et al. (2008) did, however, present the size distributions and harvest rates of several harbour species targeted by recreational fishers.

The state government MER program reported on fish diversity in Sydney Harbour. During this process gill nets and seine nets were deployed in the harbour. The data from this program was used to inform an index based assessment of Sydney Harbour (Roper et. al. 2011). The derived metrics from this data (richness and other community measures) were available as appendices in that report. The data is now kept in corporate GIS databases at each of the two agencies involved; NSW DPI and NSW OEH.

Pepperell Research & Consulting Pty Ltd was commissioned by the NSW Recreational Fishing Trust to report on the historical fishing practices of early European colonisers in Sydney (Pepperell JG, (unknown date)). A comprehensive account of historical was presented in that document from anecdotal accounts.

There have been recent collections of tropical fish species in Sydney Harbour (NSW DPI , 2012). These are thought to have been transient species brought into the estuary from variability in the East Australian Current. Some of these species, however, have now established overwintering populations.

The private firm 'The Ecology Lab' was commissioned in 1991 to investigate fish abundances in the Homebush area for the Sydney Olympic Games (Olympic Coordination Authority,1996a; TEL, 1991,1992,1993). They collected over 19273 individuals and 39 different species of fish at several sites in the Homebush area over a three year period. Fish contamination studies are discussed in Section 6

McKinley et al. (2001a,b) reported on larval fish and beach fish communities from a range of sites in Sydney Harbour and compared them with 7 other NSW estuaries (McKinley et al., 2011 a,b). Sydney Harbour tended to have more diverse and more abundant fish than the other estuaries sampled.

The Sydney Institute of Marine Science produced a web based field guide that includes facts and photographs of 464 species. Life history and morphometric descriptions were included in this guide, as well as depth ranges and habitat preferences (SIMS SHRP Field Guide, *http://harbourprogram.sims.org.au/field-guide*, accessed 4/2/2014).

Similarly, the Australian Museum collated fish specimens from their Ichthyology Database and produced a list of over 586 taxa found in Sydney Harbour. Many of these were linked to a basic fact sheet or photograph (Sydney Museum, *http://australianmuseum.net.au/fishes*).

Finally, 'Underwater Sydney' a project of the not-for-profit organisation 'Underwater Earth' produced a similar website with links to common fish species found in Sydney Harbour (*http:// www.underwatersydney.org/*, accessed 20/12/2013).

5.6 Rocky Intertidal Foreshores

The Rocky intertidal areas of Sydney Harbour were examined in 38 different peer reviewed papers. Again, few 'grey literature' reports existed that examined natural Rocky Shores in the harbour. Most of the 'grey literature' in this area only described upper foreshore vegetation and were of limited use when examining natural rocky intertidal reef areas of the harbour.

The most comprehensive survey of intertidal areas in Sydney Harbour was undertaken by Chapman (2003). Here 127 taxa were identified. The diversity of species was dependant on the height on the shoreline, however there was little generality of these results and diversity at each height differed at each location in the harbour. Chapman (2003) included a species accumulation curve in her examination, and there is evidence that her sampling regime and level of replication did capture much of the diversity present on rocky shores.

The lower intertidal shores of Sydney Harbour are generally dominated by large macrophytes such as *Ecklonia spp.* or large invertebrates including the ascidian *Pyura sp.* and polychaete *Galeolaria spp.*. The mid shore is dominated by the Sydney rock oyster *Saccostrea glomerata*, however, populations of the non indigenous pacific oyster *Crassostrea gigas* can also be found scattered throughout the estuary.

Importantly, many of natural shores around Sydney Harbour have been replaced with seawalls (Fig. 8). These support a vastly different community to natural shores and are discussed in Section 6.2 of this report.

5.7 Foreshore flora

The most comprehensive mapping of foreshore flora was conducted by the NSW OEH and NSW Maritime (Fig. 8). Here a combination of Aerial Photograph Interpretation (API) and ground truth methods were employed to create a vegetation map at a 1:2000 scale. This was part of a program to prioritise property scale management objectives of NSW Maritime (Fig. 8).

Included in this mapping were the locations of 'over water' structures and 'hard construction' on the Sydney Harbour foreshore. Most of the 'natural' foreshore vegetation of Sydney is found in the upper reaches of the Middle Harbour sub catchment. A variety of coastal sandstone forests can be found in this area (Fig. 9).

NSW OEH classified 55 different canopy forming species during their reporting process (Table 8). There is almost 6386872 m^2 of Gardens and weeds around the foreshore of Sydney Harbour, more than any other vegetation type. It is only in the upper Middle Harbour sub-catchment where gardens, weeds, and hard substrate do not dominate the foreshore (Table 7).

Importantly, there were a number of unpublished consulting reports available that described the vegetation in local catchment areas. These varied in quality and scale, and were mostly qualitative assessments of urban parklands and recreational areas, however some also included vegetation species lists. Again, the Homebush Bay area had the most collated unpublished reports on local vegetation due to the construction of Sydney Olympic Park. There was relatively little 'grey literature' collated on foreshore vegetation on the southern shores of Sydney, perhaps due to the decreased coverage of flora in these areas.

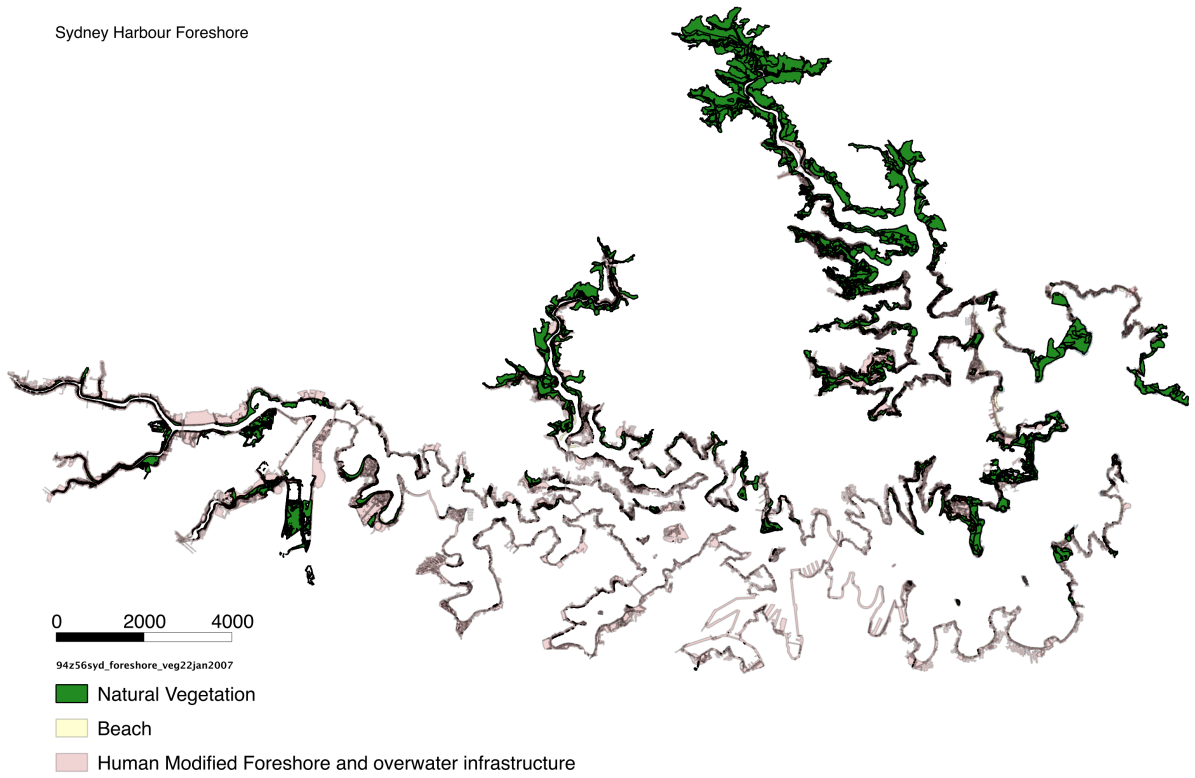

Figure 8: Natural and artificial foreshores of Sydney Harbour. Source: NSW OEH (available at *http://www.sydney.cma.nsw.gov.au/our-projects-mainmenu-149/gis-portal.html*)

Table 7: Areas of foreshore community around Sydney Harbour. Source: NSW OEH (available at *http://www.sydney.cma.nsw.gov.au/our-projects-mainmenu-149/gis-portal.html*)

	Foreshore Community	Area (m^2)
1	Beach	522910.16
2	Building/road	1323295.05
3	Coastal foredune scrub - frontal dune grassland	669.52
4	Coastal sandstone gully forest - alluvium/sandstone transition	680912.91
5	Coastal sandstone gully forest - foreshore slopes	5329802.31
6	Coastal sandstone gully forest - mesic forest	933962.33
7	Coastal sandstone gully forest - mesic understorey	1660503.27
8	Coastal sandstone gully forest - sandstone shale transition	30885.01
9	Coastal sandstone gully forest - tall	115364.46
10	Coastal sandstone gully forest - valley foreshore toe-slopes	19762.78
11	Coastal sandstone plateau heath - rock outcrop grassland	1028.91
12	Coastal sandstone plateau heath - scrub	519865.66
13	Coastal sandstone plateau heath - slopes heath/scrub	535.29
14	Coastal sandstone plateau heath - swamp	925.83
15	Coastal sandstone ridgetop woodland - dry low forest	536845.72
16	Coastal sandstone ridgetop woodland - exposed	81106.44
17	Coastal sandstone ridgetop woodland - less exposed	1740939.90
18	Coastal sandstone ridgetop woodland - scrub/heath	764751.26
19	Coastal sandstone ridgetop woodland - sheltered	61345.74
20	Estuarine fringe forest - Swamp Oak floodplain forest (EEC)	569801.66
21	Estuarine mangrove	2115119.96
22	Estuarine saltmarsh - brackish wetland	41202.35
23	Estuarine saltmarsh - Phragmites reedland	23817.90
24	Estuarine saltmarsh (EEC)	254239.17
25	Garden/weeds	6386872.48
26	Over water man made hard surface	455123.53
27	Rock	514833.83
28	Sandstone headland scrub - exposed thicket	29449.06
29	Sandstone headland scrub - foreshore	32287.60
30	Sandstone headland scrub - foreshore Allocasuarina distyla	1201.90
31	Sandstone headland scrub - non-foreshore	307518.03
32	Sandstone headland scrub - sheltered thicket	174185.15
33	Sydney turpentine ironbark forest	60534.62
34	Turf/man made hard surface	5743889.14
35	Unvegetated	2982142.47
36	Water	25312.25

Table 8: Foreshore vegetation species collated by NSW OEH. NSW OEH also maintains data on the location of communities in which these species can be found. (See Table 7, Fig. 8). Source: NSW OEH (available at *http://www.sydney.cma.nsw.gov.au/our-projects-mainmenu-149/gis-portal.html*)

1	*A. floribunda*	*Cyperus laevigatus*	*Ligustrum sinense*
2	*Acacia bipinnate parramatensis*	*Darwinia fascicularis dominants*	*Ligustrum spp.*
3	*Acacia elata*	*Dillwynia floribunda*	*Lophostemon confertus*
4	*Acacia falcata*	*Ecualyptus haemastoma*	*Melaleuca armillaris*
5	*Acacia implexa*	*Elaeocarpus reticulatus*	*Melaleuca ericifolia*
6	*Acacia longifolia*	*Epacris microphylla*	*Melaleuca linariifolia*
7	*Acacia suaviolens*	*Erythrina spp.*	*Melaleuca nodosa*
8	*Acmaena smithii*	*Eucalyptus baueriana*	*Melaleuca quinquenervia*
9	*Acmena smithii*	*Eucalyptus botryoides*	*Melaleuca styphelioides*
10	*Aegiceras corniculatum*	*Eucalyptus gummifera*	*Melealeuca spp.*
11	*Alisma plantago-aquatica*	*Eucalyptus haemastoma*	*Melia azedarach*
12	*Allocasuarina distyla*	*Eucalyptus microcorys*	*Omalanthus populifolius*
13	*Allocasuarina littoralis*	*Eucalyptus obstans*	*Palm*
14	*Allocasuarina torulosa*	*Eucalyptus paniculata*	*Pampas Grass*
15	*Allocausarina littoralis*	*Eucalyptus pilularis*	*Paspalum vaginatum*
16	*Alternanthera philoxeroides*	*Eucalyptus pilularis emergents*	*Phoenix canariensis*
17	*Angophora bakeri*	*Eucalyptus punctata*	*Phoenix canariensis occasional*
18	*Angophora costata*	*Eucalyptus resinifera*	*Phragmites australis*
19	*Angophora floribunda*	*Eucalyptus robusta*	*Phramites australis*
20	*Anredera cordifolia*	*Eucalyptus saligna*	*Pinus spp.*
21	*Arundo donax*	*Eucalyptus sieberi*	*Pittosporum undulatum*
22	*Aster subulatus*	*Eucalyptus tereticornis*	*Plantago coronopus*
23	*Atriplex prostrata*	*Eucalypus botryoides*	*Podocarpus elatus*
24	*Avicennia marina*	*Euclyptus punctata*	*Polulus nigra*
25	*B. ericifolia*	*Ficus rubiginosa*	*Polypogon monspeliensis*
26	*Bacopa monniera*	*Fimbristylis ferruginea*	*Populus nigra*
27	*Baeckea imbricata*	*foredune grass spp.*	*Portulaca oleracea*
28	*Bamboo*	*Gahnia sieberiana*	*Protasparagus aethiopicus*
29	*Bambusa*	*Gleichenia dicarpa*	*Salix babylonica*
30	*Banksia ericifolia*	*Glochidion ferdin*	*Samolus repens*
31	*Banksia integrifolia*	*Glochidion ferdinangi*	*Sarcocornia quinqueflora*
32	*Banksia serrata*	*Grevillea robusta*	*Sarococornia quinqueflora*
33	*Baumea juncea*	*Hakea teretifolia*	*Selliera radicans*
34	*Bolboschoenus caldwellii*	*Hakea territifolia*	*Senecio spp.*
35	*Bolboshoenus spp.*	*Halosarcia pergranulata*	*Senna pendula*
36	*Cabbage Palm*	*Hydrocotlye bonariensis*	*Senna spp.*
37	*Cakile edentula*	*Hydrocotyle bonariensis*	*Spergularia marina*
38	*Calllicoma serratifolia*	*Hydrocotyles bonariensis*	*Spinifex sericeus*
39	*Carpobrotus glaucescens*	*Imperata cylindrica*	*Sporobolus repens*
40	*Casuarina glauca*	*Isolepis cernua*	*Sporobolus virginicus*
41	*Ceratopetalum apetalum*	*Isolepis inundata*	*Stenotaphrum secundatum*
42	*Ceratopetalum gummiferum*	*Isolepis nodosa*	*Suaeda australis*
43	*Ceratopetalum spp.*	*Juncus acutus*	*Syncarpia glomulifera*
44	*Cinnamomum camphora Camphor Laurel*	*Juncus bufonius*	*Tetragonia tetragonoides*
45	*Cissus hypoglauca*	*Juncus kraussii*	*Triglochin striatum*
46	*Cladium procerum*	*Juncus spp. kraussii*	*Tristaniopsis lauriana*
47	*Coprosma repens*	*Kunzea ambigua*	*Tristaniopsis laurina*
48	*Cortaderia selloana*	*Lampranthus tegens*	*Typha orientalis*
49	*Corymbia gummifera*	*Lanatana camara*	*Typha spp.*
50	*Cotula coronopofolia*	*Lantana camara*	*Viminaria juncea*
51	*Crinum pedunculatum*	*Leptospermum laevigatum*	*Westringia fruticosa*
52	*Cupaniopsis anacardioides*	*Leptospermum spp.*	*Wilsonia backhousei*
53	*Cynodon dactylon*	*Ligustrum ludidum*	*A. floribunda*

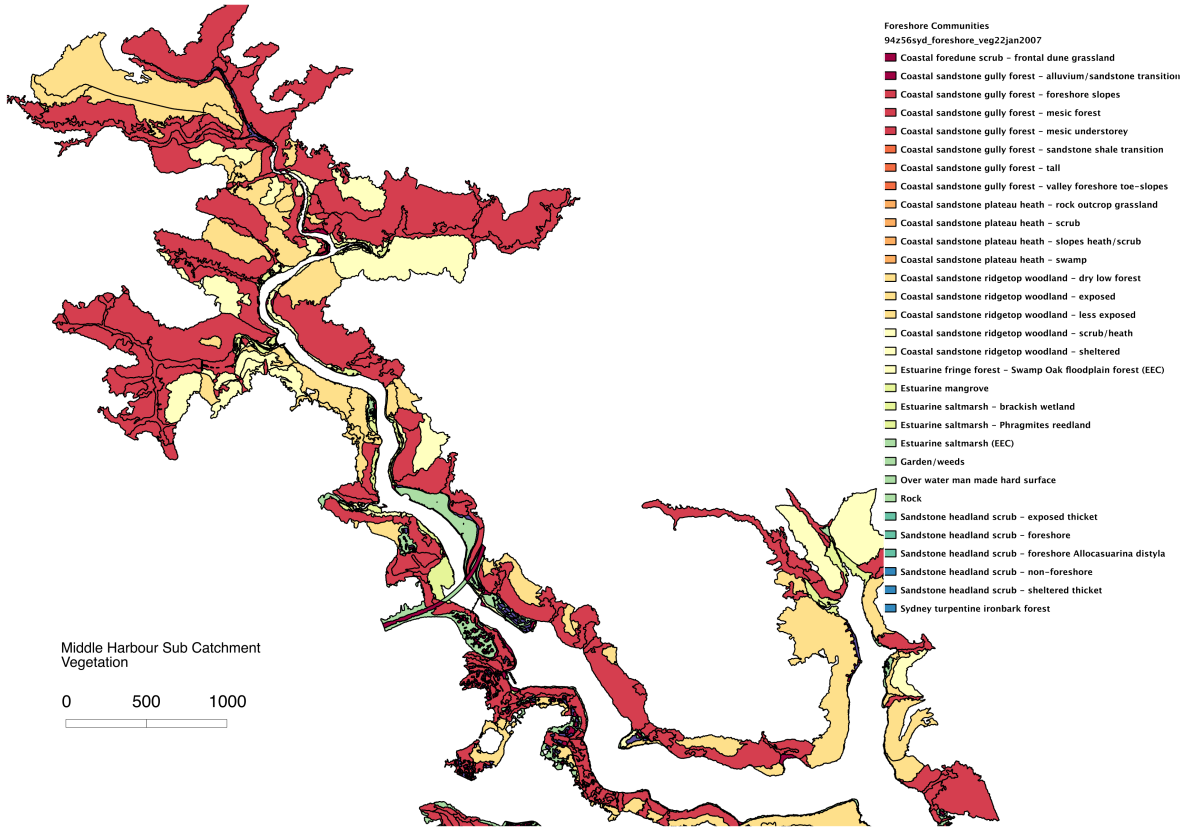

Figure 9: Distribution of estuarine foreshore vegetation in the upper Middle Harbour sub-catchment. Source: NSW OEH

5.8 Foreshore fauna

5.8.1 Avifauna

Collated data on the the avifauna of the Sydney Harbour area were generally restricted to the Parramatta River, where assessments of bird and bat fauna were undertaken as part of the lead up to the Sydney Olympic Games. Straw (1993) and The Olympic Coordination Authority (1996a,b) presented qualitative assessments of waterbird fauna in the Homebush area in the early 1990's. The Sydney Olympic Park Authority (SOPA 2007a,b,c,d) also released 'fact sheets' relating to waterbirds and bats at the parklands.

The regionally significant population of White Front Chats in the Homebush area has received particular attention. In 2007 only 11 individuals remained and the population (one of only two in the Sydney area) was predicted to go extinct. It is unclear whether this has now occurred (SOPA 2007a).

Table 9: Waterbird species observed around the Homebush Bay Waterbird Refuge created in the 1950's. Source: SOPA2007b.

Pelican	*Pelecanus conspicillatus*	Little Pied Cormorant	*Phalacrocorax melanoleucos*
Australian White Ibis	*Threskiornis molucca*	Marsh Sandpiper	*Tringa stagnatilis*
Bar-tailed Godwit	*Limosa lapponica*	Masked Lapwing	*Vanellus miles*
Black-fronted Dotterel	*Elseyornis melanops*	Nankeen Night Heron	*Nycticorax caledonicus*
Black-winged Stilt	*Himantopus himantopus*	Pacific Black Duck	*Anas superciliosa*
Chestnut Teal	*Anas castanea*	Pacific Golden Plover	*Pluvialis fulva*
Common Greenshank	*Tringa nebularia*	Pectoral Sandpiper	*Calidris melanotos*
Common Sandpiper	*Actitis hypoleucos*	Pied Cormorant	*Phalacrocorax varius*
Curlew Sandpiper	*Calidris ferruginea*	Pink-eared Duck	*Malacorhynchus membranaceus*
Darter	*Anhinga melanogaster*	Red Knot	*Calidris canutus*
Eastern Curlew	*Numenius madagascariensis*	Red-capped Plover	*Charadrius ruficapillus*
Great Egret	*Ardea alba*	Red-kneed Dotterel	*Erythrogonys cinctus*
Grey Teal	*Anas gracilis*	Red-necked Avocet	*Recurvirostra novaehollandiae*
Hoary-headed Grebe	*Poliocephalus poliocephalus*	Red-necked Stint	*Calidris ruficollis*
Latham's Snipe	*Gallinago hardwickii*	Royal Spoonbill	*Platalea regia*
Little Black Cormorant	*Phalacrocorax sulcirostris*	Ruddy Turnstone	*Arenaria interpres*
Striated Heron	*Butorides striatus*	Sharp-tailed Sandpiper	*Calidris acuminata*
White-faced Heron	*Egretta novaehollandiae*	Silver Gull	*Larus novaehollandiae*
Willie Wagtail	*Rhipidura leucophrys*		

Several local councils have also undertaken bird surveys. These were often to aid in management plans for large developments or to inform a larger environmental assessment of the area. Leichhardt Local Council, for example, compiled of list of bird species found during surveys of 15 parklands and reserves in the council area (Merops Services 2008). Similarly, the Australian Maritime Safety Authority and the NSW Environmental Protection Authority commissioned a report in 1994 that documented and mapped the locations of roosting birds in the entire Sydney estuary, however, little detail is given on the species found (NSW EPA 1994).

There are around 56 breeding pairs of Little Penguins *Eudyptula minor* found within a single colony located in the Manly area (Priddel et al., 2008). The colony was declared endangered in 1997. NPWS produced a comprehensive Recovery Plan for the colony (NPWS 2000) that also reported on the distribution, biology and ecology of the penguins.

Bat abundance and community composition in the Homebush area was also investigated by the Olympic Coordination Authority (Flannery, Parnaby and Tasker 1993) and then SOPA (Table 10, SOPA 2006a), a list of species from the area is presented in Table 10.

Table 10: Bat species found in the Homebush area. Source: SOPA 2006a

White-striped Freetail Bat	*Tadarida australis*
Goulds Wattled Bat	*Chalinolobus gouldii*
Freetail Bat	*Mormopterus sp.*
Lesser Long-eared Bat	*Nyctophilus geoffroyi*
Large Bent-wing Bat	*Miniopterus schreibersii oceanensis*
Large Forest Bat	*Vespadelus darlingtoni*
Grey-headed Flying-fox	*Pteropus poliocephalus*
Chocolate Wattled Bat	*Chalinolobus morio*
Lesser Bent-wing bat	*Miniopterus australis*
Eastern Broad-nosed Bat	*Scotorepens orion*

5.8.2 Reptiles and amphibians

Some indication of the distribution of reptiles and amphibians in the upper Parramatta River region of Sydney Harbour comes from several reports commissioned by the Olympic Coordination Authority (AMBS 1993) and then the SOPA (SOPA 2005, 2006b). Again, there was little documentation pertaining to herpatofauna in other areas of the Sydney Harbour estuary.

Table 11: Herpatofauna found in the Homebush/Newington area. Source: SOPA 2005

Myobatrachidae (Southern Frogs)	**Family Varanidae (Monitors or Goannas)**
Crinia signifera	*Varanus rosenbergi*
Heleioporus australiacus	*Varanus varius*
Limnodynastes dumerillii	**Family Scincidae (Skinks)**
Limnodynastes ornatus	Bassiana platynota Cryptoblepharus virgatus
Limnodynastes peronii	*Ctenotus robustus*
Limnodynastes tasmaniensis	*Ctenotus taeniolatus*
Paracrinia haswelli	*Cyclodomorphus michaeli*
Pseudophryne bibronii	*Egernia cunninghami*
Uperoleia laevigata	*Egernia whitii*
Family Hylidae (Tree Frogs)	*Eulamprus quoyii*
Litoria aurea	*Eulamprus tenuis*
Litoria caerulea	*Lampropholis delicata*
Litoria dentate	*Lampropholis guichenoti*
Litoria ewingii	*Saiphos equalis*
Litoria fallax	*Saproscincus mustelina*
Litoria freycineti	*Tiliqua scincoides*
Litoria lesueurii	**Family Typhlopidae (Blind Snakes)**
Litoria peronii	*Ramphotyphlops nigrescens*
Litoria phyllochroa	**Family Boidae (Pythons)**
Litoria verreauxii	*Morelia spilota*
Family Chelidae (Side-necked Turtles)	**Family Colubridae (Colubrid Snakes)**
Chelodina longicollis	*Boiga irregularis*
Family Gekkonidae (Geckos)	*Dendrelaphis punctulatus*
Diplodactylus vittatus	**Family Elapidae (Elapid snakes)**
Oedura lesueurii	*Acanthophis antarcticus*
Phyllurus platurus	*Cacophis squamulosus*
Underwoodisaurus millii	*Demansia psammophis*
Family Pygopodidae (Legless- or Snake-lizards)	*Furina diadema*
Lialis burtonis	*Hemiaspis signata*
Pygopus lepidopodus	*Notechis scutatus*
Family Agamidae (Dragons)	*Pseudechis porphyriacus*
Amphibolurus muricatus	*Pseudonaja textilis*
Physignathus lesueurii	*Rhinoplocephalus nigrescens*
Pogona barbata	*Suta spectabilis*
Rankinia diemensis	*Vermicella annulata*

5.9 Intertidal flora

5.9.1 Mangrove

Mangrove distribution was also mapped by NSW DPI (Fig. 10) using orthorectified images (West and Laird 2004).

Almost 184 ha of mangroves are found in the estuary. The highest coverage of mangroves (134 ha) is in the Parramatta River. The banks of the upper Lane Cove river, however, are also dominated by dense mangrove stands (35.9 ha). There are no reported mangroves in the main Port Jackson estuary, however some mangrove forrests can be found in the upper reaches of Middle Habrour (Fig. 10).

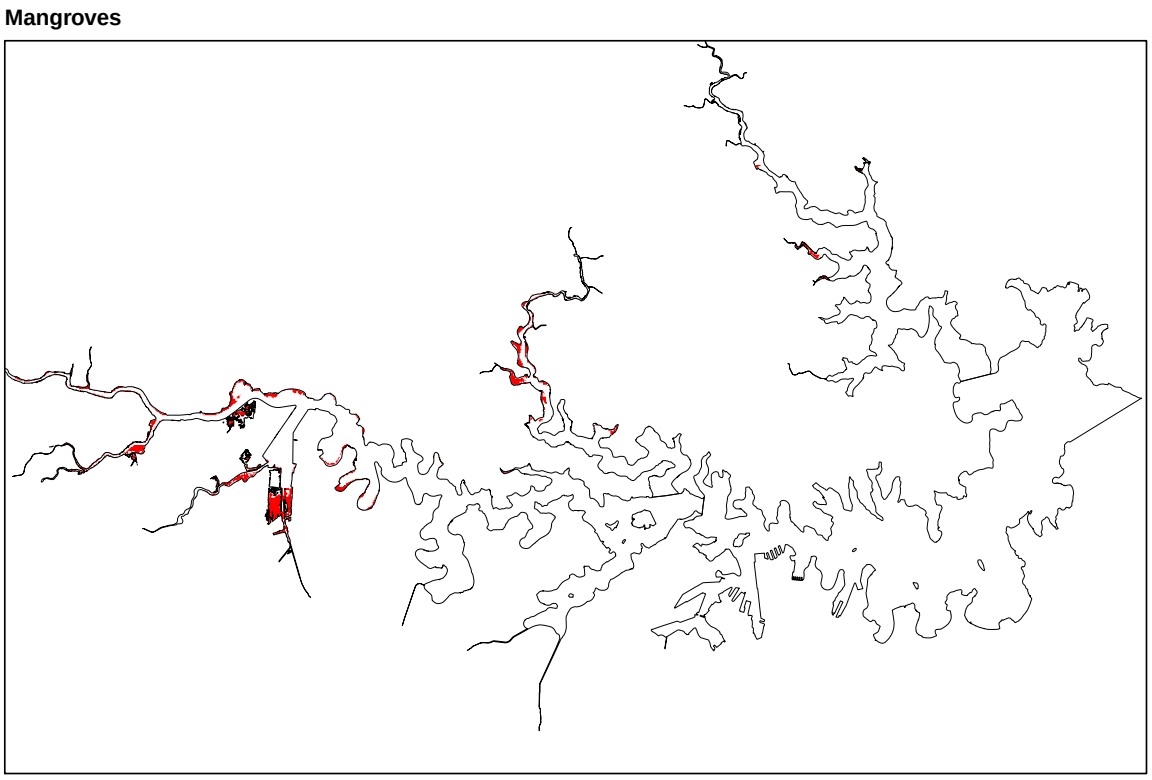

Figure 10: Distribution of Mangroves (green) in the Port Jackson Sub-Catchment of Sydney Harbour. Mapping produced from data collected from NSW DPI as part of a large statewide audit of ecological assets. Source: NSW DPI (unpublished), also presented in Creese et. al. (2009)

The abundance of mangrove has increased in the past 30 years. In the 1970's there were around 147 ha of mangrove throughout the estuary (West et al 1985). Interestingly, mangrove coverage in Sydney Harbour was around 217 ha in 1951, before decreasing to 145 ha in 1970.

The Manly Hydraulics Laboratory also conducted a separate study in 2006 for the then NSW Department of Natural Resources (MHL 2006) to map the limits of mangrove extent in NSW estuaries. This data was presented as a table of latitudes and longitudes with a brief description of where the last mangrove plant could be found in the upper reaches of the creeks and inlets to Sydney Harbour. This data is now predicted to be out of date due to variability in land use and climate in the Sydney region.

Some elements of mangrove biology and ecology are presented in several documents from both the peer reviewed, and 'grey literature'. Mangroves form the basis of many detrital food webs and so have received some empirical attention within the published literature (Ross and Underwood, 1997; Chapman, 1998; Ross, 2001; Clynick and Chapman, 2002; Melville and Burchette, 2002; Chapman et al., 2005; Tolhurst, 2009). Melville and Burtchette (2002), for example, used isozyme and allozyme analysis of *A. marina* to show that geographic distance, not sediment characteristics, determine genetic similarity of mangroves in the Sydney Harbour and Botany Bay estuaries.

Given the abundance of mangrove in the upper Parramatta River/Homebush Bay area, the taxa has also received some attention within the unpublished 'grey' literature. In 1995 the mangrove community in the upper Parramatta River was predominantly comprised of a single species *Avicennia marina*, although some stands of *A. corniculatum* were also found. Paul and Loveridge (2001) showed that many of these mangroves in the Hombush Bay area are in fact mutants, producing albino propagules. They are the first to report on this phenomena in the Sydney Region. Over 50% of the fruiting trees produced non-green propagules, indicating many of the trees are heterozygous (Paul and Loverdge 2001). Increased contamination in the area was implicated as causing these mutations.

5.9.2 Saltmarsh

There is approximately 37.3 ha of saltmarsh in the Sydney Harbour estuary (Fig. 11, Kelleway et al 2007). Currently, most saltmarsh in the estuary occurs in the upper Parramatta River, where over 23 ha can be found around Sydney Olympic Park. Just over 12 ha occurs in the Newington Nature Reserve alone (Kelleway et al 2007). Alarmingly, over 50 % of saltmarsh patches analysed by Kelleway et al (2007) were of poor quality.

Saltmarsh distribution has decreased dramatically since European Colonisation, thought to be a result of the upward spread of mangroves (Olympic Coordination Authority 1996b). Coastal saltmarsh in the Sydney basin is listed as an Endangered Ecological Community under the *Threatened Species Conservation Act 1995*.

Kelleway et al. (2007) provided the most comprehensive and recent analyses of saltmarsh distribution in the Sydney Harbour estuary. They used a combination of aerial photography and pedestrian surveys to provide detailed maps of seagrass in the catchment. Previous unpublished 'grey' literature also investigated saltmarsh distribution and composition (Hamilton 1919, Carter 1994, Olympic Coordination Authority 1996b) , however there were many instances where these analyses were qualitative and broad scale.

Figure 11: Area of saltmarsh (red) in Sydney Harbour. Source: NSW DPI (unpublished), also presented in Creese et. al. (2009) and Kelleway et. al. (2007)

Table 12: Species of Saltmarsh found in the Sydney Harbour estuary. Source: Kelleway et al (2007)

CYPERACEAE	AIZOACEAE
Baumea juncea	*Lampranthus tegens*
Isolepis nodosa	*Tetragonia tetragonioides*
GOODENIACEAE	APIACEAE
Selliera radicans	*Hydrocotyle bonariensis*
JUNCAEAE	ASTERACEAE
Juncus kraussii	*Baccharis halimifolia*
Juncus acutus	CHENOPODIACEAE
JUNCAGINACEAE	*Halosarcia pergranulata*
Triglochin striata	*subsp. pergranulata*
POACEAE	*Sarcocornia quinqueflora*
Cortaderia selloana	*Suaeda australis*
Phragmites australis	CONVOLVULACEAE
Sporobolus virginicus	*Wilsonia backhousei*
PRIMULACEAE	
Samolus repens	

Table 13: Saltmarsh distribution in each of the sub-catchment areas of Sydney Harbour. Source: Kelleway et al. (2007)

	Number	Percent Total	Total Area (ha)	Percent Total Area
Parramatta River	527	69.6	30.56	81.9
Lane Cove River	123	16.2	3.393	9.1
Sydney Harbour	15	2	0.209	0.6
Middle Harbour	78	10.3	3.109	8.3
North Harbour	14	1.9	0.036	0.1
Total	757	100	37.306	100

6 Distribution of threats, stressors, and 'community use' in Sydney Harbour

The 'Threats and Stressors' in Sydney Harbour were derived from a two day workshop held at the Sydney Institute of Marine Science in March 2013. During the workshop 13 scientists from each of the Sydney based universities, NSW DPI and NSW OEH, discussed the inclusion of these stressors for the SIMS SoH (2014) Report. The same list was also used in this report.

A comprehensive source of threats and stressor data can were found within Roper et. al. (2011), a technical report forming part of the NSW Government Monitoring, evaluation and reporting program. This report outlined an index based approach to rank NSW estuaries according to 'state'. The metrics, measured or derived, in that report included coverage of macrophytes, turbidity and fish communities among several others. The data in that report is held in corporate GIS databases at NSW OEH and NSW DPI. The quality and accuracy of the data is assessed in that report and varied across the measured variables. The Port Jackson condition index in that report was 3.8, which was similar to other estuaries in the area, including Georges River and Port Hacking. It is noted that data for macroalgae and turbidity and mangroves was absent.

6.1 Contamination

6.1.1 Heavy metals

The distribution of metallic and organometallic contaminants is fairly well characterised in Sydney Harbour, both within the published and 'grey' literature. Considerable research has been directed toward mapping sediment contaminants within Sydney Harbour (Birch and Scollen, 2003; Snowdon and Birch, 2004, Davis and Birch, 2010, 2011), and characterising the effects of contaminants on a range of flora and fauna (Dafforn et al., 2012, Roberts et al., 2008, McKinley et al., 2011, Sun et al., 2012).

Again, particular attention was directed toward the Homebush Bay area during the period leading up to, and after, the 2000 Sydney Olympic Games. These reports often focused on a particular site within the Homebush Bay area and were generally dated. Johnstone Environmental Group (1991), for example, provided one of the earliest investigations of site contamination around the Fig Tree Drive area of the Olympic Park Site. Here levels of Cadmium, Selenium and Lead exceeded the, now repealed, Clean Waters Act (1970).

Over 9 Mt of domestic, commercial and industrial waste was used to reclaim land around the Homebush area in preparation for the 2000 Olympic Games and subsequent contamination of the soils and waters around these areas have now been uncovered (Table 14, Suh et al. 2004). Metal contamination is highest in reclaimed areas of the Olympic Site, i.e. areas once estuary but filled with to a level above the high tide mark (Table 14). In the reclaimed areas of Homebush Olympic Park, metal concentrations in many samples exceed the ANZECC and ARMCANZ guideline values.

Table 14: The concentrations of heavy metals in the three types of areas in Homebush Bay. Source: Suh et al. (2004)

	Reclaimed area (n = 2382)	Landfill area (n = 1252)	Non-infilled area (n = 879)
Cu	82 (21138)	66 (5190)	30 (2436)
Pb	174 (65374)	102 (78167)0	48 (4452)
Zn	288 (83694)	231 (132394)	92 (8797)
Cr	58 (25162)	33 (2540)0	25 (2526)

Sediment contamination in Sydney Harbour is often highest in the bedded sediments and macro algae in the upper reaches of the estuary (Fig. 12). A combination of small sediment grain size, weak tidal flushing and shorter distances to point contamination sources in these areas means sediment metal contamination can be elevated to levels thought to cause adverse biological effects (Fig. 13)

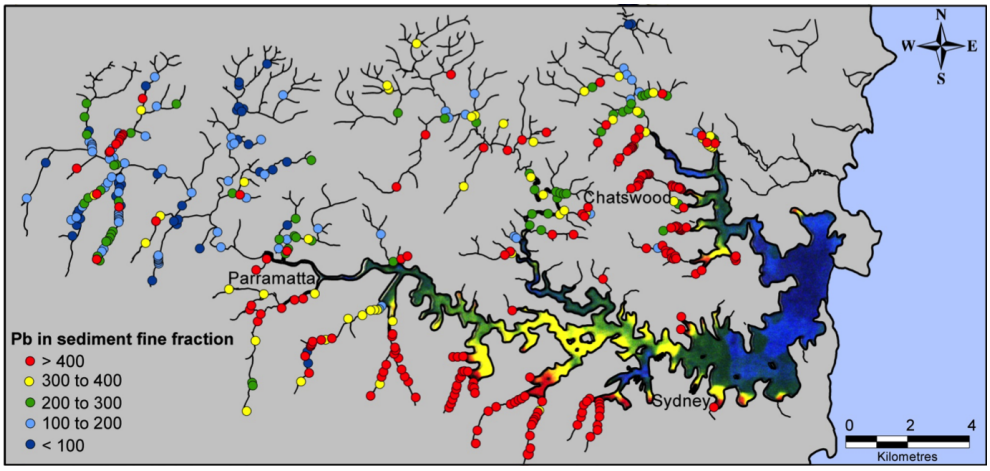

Figure 12: Distribution of Lead contamination in the Sydney Estuary. Source: Gavin Birch, University of Sydney, *supplied*

Most of the contamination in Sydney Harbour results from historical inputs (Birch and McCready, 2009), where specific industries contributed to various contamination 'hotspots' throughout the estuary (Birch and Scollen, 2003; Snowdon and Birch, 2004). Present contamination is mainly thought to be derived from catchment run-off through 'point source' stormwater drains and sewer overflows. The correlation between shoreline and catchment soil metal contaminant loads and adjacent estuarine sediment also provides strong evidence for the role of soil and particulate inputs directly into the harbour (Snowdon and Birch, 2004; Davis and Birch, 2010; Birch et al., 2011). Contaminants can also be associated with freshwater inflow during high precipitation events (Lee et al., 2011). Under these conditions (5-50 $mm.day^{-1}$), it is predicted that contaminated freshwater plumes migrate beyond the inlets and embayments of Sydney Harbour and into the main channel (Lee et al., 2011). These contaminants may exit the harbour in a dissolved state, or become attached to sediment and become bedded in the seafloor.

Sediment contamination has been found to have adverse biological effects in Sydney Harbour (Fig. 13; Birch et al., 2008; Dafforn et al., 2012; McKinley et al., 2011). Opportunistic species are often found in high abundances within or near contaminated sediment. These species include capitellid polychaetes (Dafforn et al., 2012) and gobies (McKinley et al., 2011). Further, decreased flounder growth in Sydney Harbour was linked to increased levels of tissue metal concentrations (McKinley et al. 2012). Almost 100 % of the Sydney Harbour estuary has sediment contamination levels that exceeded the Interim Sediment Quality Guideline Trigger Value concentrations; a level that requires additional investigation for any activities that may disturb the sediment. Additionally, 2, 36 and 50 % of the estuary has Copper, Zinc and Lead values that exceeds the Interim Sediment Quality Guideline High values (Fig. 13, Simpson et al., 2005; ANZECC and ARMCANZ

2000). Sediment contaminant mixtures in different parts of the harbour have also been found to be toxic to varying degrees (Table 15)

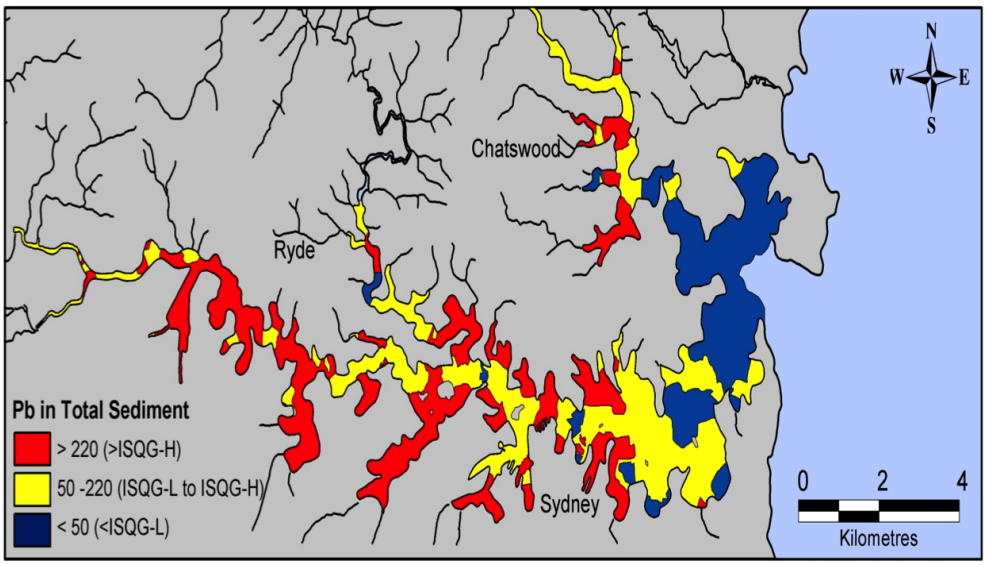

Figure 13: Sediment in Sydney Harbour where lead concentrations are at a level to cause possible biological effects on fauna. Source: Gavin Birch, University of Sydney, *supplied*

Table 15: The probability of sediment toxicity was determined for mixtures of contaminants using the mean ERM quotient (MERMQ) approach. Source: Long et al., 1998

Contaminant Category	Area
4	Central Estuary Embayments (e.g. Iron Cove, Rozelle Bay)
3	Parramatta River
	Homebush Bay
	Iron Cove
	Five Dock
	Rozelle
	Blackwattle Bays
2	Central and Lower Harbour
	Lane Cove River
	Middle Harbour
1	Harbour Entrance

6.1.2 Nutrients enrichment

There is little knowledge on the distribution of nutrient contamination under variable climate and weather conditions. We do know that freshwater flow regimes and precipitation events strongly control the input of nutrients into Sydney Harbour (Birch and Rochford, 2010, Lee et al., 2011). Under 'base flow' and weak rainfall events (< 50 mm.day^{-1}), considerable amounts of nitrogen and phosphorus are discharged into the estuary. Beck and Birch (2012b) posited that damaged and ageing sewer systems and drainage infrastructure may be the cause of discharge during 'base flow'. Birch et al., (2010) suggested that sewer overflows and discharges contribute over 50 % of the nitrogen and phosphorous loads entering the harbour.

Once the nutrients enter the Sydney estuary, their fate is also reliant on rainfall. Under high flow events (> 50 mm) the watercolumn becomes stratified and the nutrients may exit the estuary in a plume (Birch et al. 2010). Conversely, under low rainfall and 'base flow' periods, the nutrients will become incorporated into the food web (Forstner and Wittman, 1981). A very large stormwater study is currently underway through the Sydney Harbour Research Program and includes the partner investigators NSW OEH, CSIRO and the Greater Sydney Local Land Services.

Stormwater Many collated 'grey literature' documents pertained to Stormwater Management Plans, as it has become a requirement under statewide legislation for local councils to implement and manage stormwater in their LGA. We are aware of plans for the Lower and Upper Parramatta River (UPRCSMP, 2002;

LPRSWMP, 2004), The Homebush Bay Area (GHD 1999), Mid Parramatta River (Robinson GRC 1999), Subiaco Creek (SKM 2006), and the Duck River (SKM 1999). Stormwater management and current stormwater conditions were also discussed for the Hornsby shire sub-catchment in Bacon (2011). One of the most comprehensive analysis of stormwater and water quality pertained to water quality in the upper Parramatta River (Laxton and Gittens, 2008). The upper Parramatta River, Duck River, Toongabbie Creek, Darling Mills Creek, Lake Parramatta and Parramatta River above Marsden Weir were sampled monthly from 1990 to 2007. Only four stations were monitored over that time so statistical inference, modelling and prediction was difficult (and was not attempted in that report), however a full breakdown of yearly ammonia, nitrogen, phosphorous and TSS was provided.

Feacal coliforms Beachwatch and Streamwatch were established in 1994 to monitor feacal coliform levels at several harbour and open ocean beaches in the Sydney area. The programme uses membrane filtration of samples collected every six days to assess thermotolerant coliform levels throughout the estuary (Fig. 14).

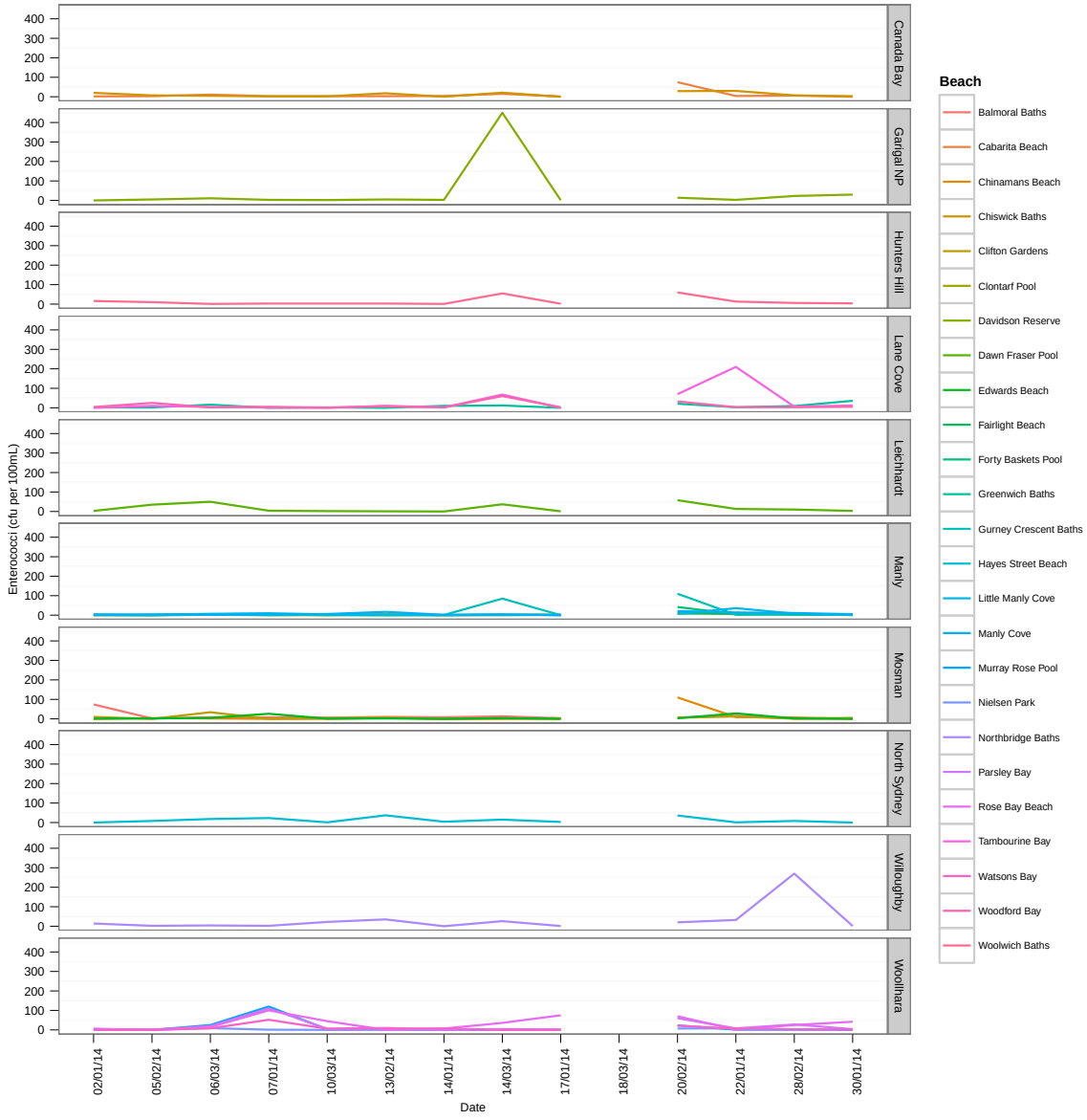

Figure 14: Thermotolerent coliform levels in each of the Sydney Harbour 'Harbourwatch' programme sites. Raw data is available from *http://www.environment.nsw.gov.au* and has been presented here a simple means at each month in 2014 Source: *http://www.environment.nsw.gov.au*

Summary reports are available from the NSW OEH website. Raw data is also available for download.

6.1.3 Debris and microplastics

There was little collated data available that pertained to debris in Sydney Harbour. NSW RMS does maintain a record of rubbish collection services in the harbour, however, this was not made available to us and no indication of its utility was given (Leslie Brix-Nielsen NSW RMS, *pers. comm.*). NSW Maritime (now NSW RMS) produced Fig. 15 that outlined the tonnage of rubbish collected over the period 1994–2004. For most parts of Sydney Harbour, over 50 tonnes of rubbish was collected during this time. Note that this figure gives no indication of effort, and so had little utility for describing differences in rubbish accumulation between locations in Sydney Harbour.

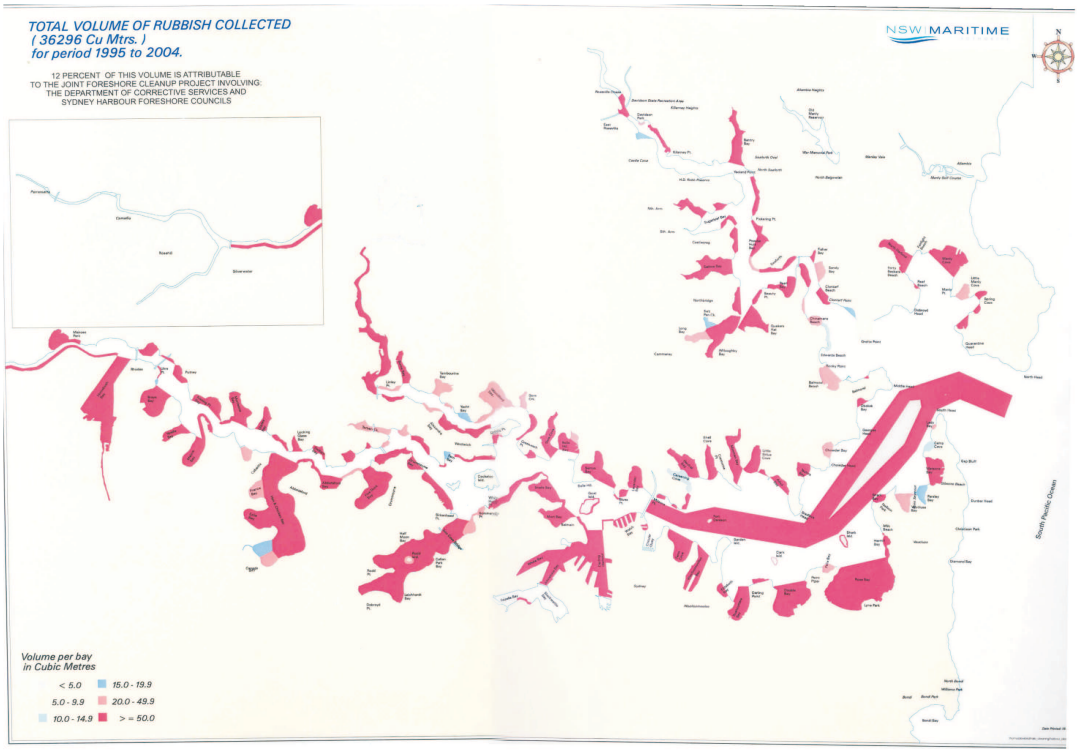

Figure 15: Volume of rubbish collected by NSW Maritime (now NSW RMS) in the period 1995-2004 in Sydney Harbour Source: NSW RMS

6.1.4 Dioxin levels in fish in Sydney Harbour

Commercial fishing in Sydney Harbour has been banned since 2006 due to concerns over dioxin levels in fin fish and invertebrates. The source of the dioxin residue in Sydney Harbour is believed to be the Homebush Bay area, which has had a long history of industrial use. Roach et al. (2008) provided a relatively recent analysis of 'dioxin like' compounds in Sydney Harbour using semi-permeable membrane devices (SPMD). Devices were deployed at several sites at increasing distances from the Homebush Bay area. All sites in the Homebush Bay area had dioxin like contaminant levels that exceeded the US EPA criteria for PCMD measurements. Sites closer to the Sydney Harbour bridge had levels of dioxin like contaminants on, or just below, the US EPA criteria. The only other estuary in the world found to have dioxin like contamination levels higher than Homebush Bay is the Houston Shipping Channel in Texas, USA.

Understanding temporal variability in dioxin like contamination was limited in this study as only a single replicate in winter, and then a single replicate in summer were deployed at each of the sites. Despite this, the levels of dioxin like contamination in the SPMDs did show marked increases (almost 3.9 fold) during the summer deployment (Roach et al. 2008). The NSW Department of Environment, Climate Change and Water (now non existent) have also sampled 25 sites in the harbour specifically for dioxin contamination. This data

is currently being prepared for publication by researchers within OEH and post-remediation monitoring is planned for late 2014. The data is not currently available to researchers outside of NSW OEH.

Dioxin like compounds are very stable over long periods of time. The distribution of these contaminants in Sydney Harbour is likely to remain constant over the long term unless they are physically removed. Extensive remediation of the most highly contaminated sediments took place in 2010. In addition, commercial fishing, was banned in 2006, and food safety advice was released for recreational fishers regarding the dangers of consuming contaminated seafood. NSW DPI have placed warning signage at major access points throughout the harbour stating that seafood caught west of the Sydney Harbour bridge should not be consumed. 'Dioxin and Recreational Fishing in the Harbour' brochures also continue to be mailed to one and three year recreational fishing licence holders (with licence renewal notices). The DPI Fishcare Volunteer Program also continues to undertake on-water advisory to promote the food safety advice. The food safety advice was also promoted on the DPI and Food Authority websites. Ghosn et al. (2010) show that, despite these warnings, almost 25.3 tonnes of fish and seafood was still caught (and presumably consumed) in areas west of the harbour bridge. Similarly, the 2014 SIMS Harbour Census (see Section 6.4) showed that, at any one time west of the harbour bridge, 24 fishing groups will generally be found. This indicates that the warnings on consuming seafood from these areas may be ineffective, particularly for some non-english speaking communities (Ghosn et al 2010).

Given the stability of the dioxin family of compounds, it is predicted that dioxin contamination is a long term environmental issue for Sydney Harbour. Further rigorous sampling regime should be conducted in the estuary to inform stakeholders of any changes in sediment dioxin levels in the estuary.

6.2 Dredging, infilling, land reclamation and artificial structures

Almost 22 % of the total 50 km^2 area of the Sydney Estuary has been reclaimed. McLoughlin et al (2000) also estimated that almost 100 Mt of material has been dredged from the Sydney Harbour estuary since European colonisation. It is almost impossible to discern the areas dredged or reclaimed due to differences in mapping throughout the years ;

> *"Some exaggerate the fill to cover the entire area of Quaternary alluvial deposits in tributary valleys. Some maps designate the areas as fill, some as reclaimed land, and some as disturbed soil, although these can mean quite different processes, with fill and disturbed soil not necessarily occurring in areas formerly wetland or part of the estuary. No map distinguishes between filling of the water body, inter-tidal mud? flats, saltmarshes inundated only at spring high tides, or low, alluvial land above all tides."* McLoughlin et al. (2000)

There are some instances where local councils commissioned reports on reclamation activities (Pyke 1995). Again, these were mostly concentrated in the Homebush Bay area, where over 9 Mt of land was reclaimed using commercial, domestic and industrial waste (Suh et al. 2004).

Over 50 % of the foreshore of Sydney Harbour has been artificially constructed. Approximately 77 km of the 322 km of original shoreline has been removed due to reclamation and infilling (Pitblado, 1978). Additionally, there are over 40 functioning marinas in the estuary. These constructions use vastly different materials to what would normally be found in subtidal and intertidal rocky reefs (Connell and Glasby 1999, Glasby 1999a, 2001) and hence support a vastly different array of flora and fauna (Clynick et al. 2008, People 2006, Marzinelli et al., 2009, 2012)

The most comprehensive analysis of foreshore construction was, again, the NSW OEH foreshore mapping project described in Section 5.7 (Fig. 8). Here fine scale 'man made surfaces' and 'over water construction' were mapped out in the same manner as foreshore vegetation (Fig. 8).

6.3 Non-indigenous species

Many Non-Indigenous Species (NIS) are found in Sydney Harbour, across all habitats and systems. Common NIS in the harbour include tunicates *Styela plicata*, the Pacific oyster *Crassostrea gigas*, tropical fish *Abudefduf*

vaigiensis, bryozoans *Membranipora membranacea*, green alga *Caulerpa taxifolia* and the saltmarsh plant *Juncus acutus*.

The most comprehensive assessment of NIS in Sydney Harbour was completed by the Australian Museum, for SPC in 2002 (AMBS 2002). Here, 57 sites in the harbour were sampled via visual surveys, epifaunal scrapings, fish poison stations, dinoflagellate sampling, grab samples, beam trawls, and shore trapping. The aim was to document where in the harbour NIS were located. AZMBS (2002) grouped species into three categories proposed by Hewitt and Martin (1996);

- Schedule 1– ABWMAC (Australian Ballast Water Management Advisory Council) target introduced pests.
- Schedule 2 – marine pest species that pose a threat to Australia.
- Schedule 3 – known or likely exotic marine species in Australian waters

Only one taxa from Schedule 1 was documented in Sydney Harbour– dinoflagellate cysts. The exact species could not, however, be identified and it is thought these cysts were *Alexandrium catenella, Alexandrium tamarense* or *Gymnodinium catenatum*.

The only species from Schedule 2 identified was the blue mussel, *Mytilus galloprovincialis*. Importantly, this species has undergone some recent genetic sequencing and the species commonly found in Sydney Harbour is now less clear, with hybridization between introduced and native mussels likely.

There were 16 schedule three species found during the survey;

- The polychetes *Euchone limnicola, Hydroides elegans* and *Pseudopolydora paucibranchiata*
- The isopods *Cirolana harfordi, Eurylana arcuata, Paracerceis sculpta* and *Sphaeroma walkeri*
- The chordates *Botrylloides leachi* and *Styela plicata*
- The chinese goby *Tridentiger trigonocephalus*
- The bryozoans *Bugula flabellata, Bugula neritina, Conopeum tenuissimum* and *Schizoporella unicornis*
- The bivalve gastropod *Theora lubrica*
- The marine plant *Caulerpa filiformis*

Another nine species were recorded in this survey that are believed to be introduced; annelids *Boccardia chilensis, Hydroides diramphus, Hydroides ezoensis*, arthropods *Caprella californica, Oratosquilla oratoria*, fish *Acentrogobius pflaumi* and the bryozoans *Bowerbankia spp., Tricellaria unicornis, Watersipora subtorquata*.

Many of these species are ubiquitous in port environments throughout the world, and Sydney Harbour has a diverse NIS community similar to many other working harbours (e.g. San Francisco). Modelling of NIS transport indicates that many species currently *not found* in Sydney Harbour, but common in ports worldwide, have an elevated chance of establishment in Sydney Harbour. These include the high profile pest species; asian shore clam *Hemigrapsus sanguineus*, chinese mitten crab *Eriocheir sinensis*, and the brown mussel *Perna perna* (Glasby and Lobb 2008). The probability of NIS introduction from the ports of Singapore, Auckland, Port Villa, Tauranga and Napier are much higher due to similar environmental variables and high rates of shipping to and from Sydney Harbour (Glasby and Lobb 2008).

The proliferation of artificial structures, increased propagule arrival rates and contamination are all posited as strong drivers of NIS colonisation, establishment and survival in Sydney Harbour (Dafforn et al. 2008).

Tropical fish have now also established 'overwintering' populations in Sydney Harbour (NSW DPI 2012). This migration of tropical species has been attributed to a southward strengthening of the East Australian Current.

While there are several peer reviewed and 'grey' literature documents that investigate NIS ecology, Spatial Distribution Models (SDMs) of any sort a lacking. This is particularly concerning for schedule one species, and notorious NIS such as *C. filliformis* that have established in the harbour.

6.4 Fishing and Aquaculture

Commercial fishing has been banned in Sydney Harbour since 2006 due to concerns over dioxin concentrations. Prior to 2006, commercial fishing in all NSW waters were examined in the 'Estuary General Fishery-Environmental Impact Assessment 2001' (NSW DPI, 2001). This document outlined the social, economic, heritage and ecological impacts of the fishery and was primarily a management document.

The commercial fishery prior to 2006 was generally described as 'artisanal' with the fishery dominated by smaller boats. NSW DPI (2001) showed that 87 different species were targeted, predominantly sea mullet, luderick, bream and school prawns. While 15 different types of fishing gear were used in the estuary, meshing and hauling nets were the most common.

NSW DPI also maintains catch records from all NSW estuarine fisheries, including Sydney Harbour prior to the closure of the fishery (Table 16). This information is freely available by request to NSW DPI.

Table 16: NSW reported commercial wild harvest of the Estuary General and Estuary Prawn Trawl fisheries for Port Jackson (Sydney Harbour and tributaries) for the period leading up to the ban on commercial fishing in 2006. Note: Commercial landings alone are not a robust indicator of abundance as landings are subject to a number of factors; Environmental, Economic, Social & Legislative Note: Data does not include commercial landings from the Abalone, Lobster or Sea Urchin & Turban Snail fisheries due to Privacy.

CLASS SPECIES	SPECIES NAME SHORT	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05	05/06
Crustaceans	blue swimmer crab	1584	2548	1365	729	999	928	1105	572	301
	mud crab	207	437	470	808	333	1666	600	458	89
	sand crab	16		5						
	crab, Unspecified	21	4				65			27
	krill		210	687	195	7250	834	6	1070	479
	nipper	50								
	eastern king prawn	5582	4489	2763	4909	3319	2405	3403	2632	1041
	greasy back prawn	633	227	494	578	40	20			
	school prawn	768	291	654	2956	87	261	1270	2686	345
	tiger prawn		73	17						
	prawn, Unspecified	284	523	95	4		58	69	371	607
	mantis shrimp	9	573	71	104	20	42		68	
	spanner crab			5						
Crustaceans Total		9153	9374	6625	10284	12048	6279	6453	7857	2889
finfish	Amberjack								10	
	anchovy	2386	434	731	1269	1983	155		2320	206
	Australian salmon	329	26	164	175	44	25	105	280	185
	barracouta			2						
	boarfish			2			2	2	2	
	bonito	43	21	462	196	26	5	22	44	
	bonito, leaping	7								
	bream black and yellowfin	14063	11217	13038	13653	12528	11758	10260	11905	7056
	bullseye, red			9		14			2	
	catfish, estuary	224	753	608	925	500	88		231	189
	catfish, unspecified	300	21	96	4					
	cobia							8	11	
	cod, estuary	6								
	cod, red rock				3					6
	cod, unspecified	4								
	dart	3				10				3
	diamondfish	40	17		39	68	5	20		35
	dory, john	56	94	57	44	43	21	3	19	4
	dory, silver			30	2					
	drummer	17	9		5	93				4
	eel, longfin River	6	5			10	22	24	8	20
	eel, pike					19			13	12
	eel, shortfin river	8		6			3	12	67	24
	eel, unspecified	5			4					
	emperor, spangled									2
	fish, unspecified estuary	3972	5450	3781	3260	2498	2547	3478	2766	1628
	fish, unspecified ocean	138	65	157	68	430	73	132	188	
	flathead, dusky	812	336	635	596	426	178	626	579	240
	flathead, sand	104	66		11	60	8			20
	flounder, unspecified	403	324	671	305	410	591	566	242	125
	flutemouth		4	3						
	garfish, river			8	7			16	11	
	garfish, sea	1903		32	1585		3	20	224	
	hairtail	105	7	2		2				
	kingfish, yellowtail	415	3	756	100	33	7	58	95	26
	latchet							3		
	leadenall	140	6	595	35	36	73		288	
	leatherjacket, black reef						34			
	leatherjacket, unspecified	723	421	686	482	395	212	221	160	75
	longtom		81							
	luderick	3169	3729	3132	3477	1538	3751	2207	823	1469
	mackerel, blue	1706	282	165	83	30	62	36	159	110
	mackerel, spotted		5				17	5		
	mackerel, unspecified	101	4		6					
	mado		116	4	39					
	moki			2						
	morwong, red	162	24	21	73	13	3	40	1	127
	morwong, rubberlip					75				
	morwong, unspecified		9							
	mullet, fantail	411	664	484	1110	1824	79	56	213	340
	mullet, pink-eye									103
	mullet, red	328	48	339	185	273	257	22	25	13

Table 16 Continued from previous page

CLASS SPECIES	SPECIES NAME SHORT	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05	05/06
	mullet, sand	28	222	10	2		73	492	188	405
	mullet, sea	35653	39534	6774	38515	11227	39521	24254	12105	1119
	mullet, unspecified	103								
	mulloway	1183	516	411	573	339	494	676	940	200
	nanata			29	1168	118	178	69	45	
	old maid	10				5				
	pigfish					1				
	pike	35	567	299	183	87	25	33	262	3
	pilchard	116	271	71	703	170	30	30	1380	186
	redfish		34							
	samson fish			332	3	9		13	42	
	sandy sprat (whitebait)		1122	802	2	586	1639		1374	
	sergeant baker	2								
	shark, angel									24
	shark, blue whaler				18					
	shark, carpet	43	8	17		59				43
	shark, fiddler	85	131	38	44	27	72			
	shark, hammerhead	212	35					39		
	shark, port jackson	16								
	shark, school	260							10	19
	shark, shovelnose		15							
	shark, unspecified	254	8	116			57		10	10
	silver biddy	6093	8150	8811	9345	10677	1471	1747	2116	2125
	snapper	6	14	212	472	148	414	274	607	286
	stingray	127	8	23	39	31			12	
	surgeonfish	29			23		9	13	9	44
	sweep				36	3				
	tailor	1383	964	1329	2138	904	89	290	490	120
	tarwhine	1681	1873	1066	1452	1257	879	343	635	48
	trevally, bigeye		24							
	trevally, black	125	96	155	157	60	11		101	
	trevally, silver	15755	6229	9329	7317	4553	1877	2625	4034	2992
	trumpeter	334	449	1238	784	720	382	185	322	49
	trumpeter, unspecified	7	4							
	tuna, bigeye					6				
	tuna, mackerel	10	50	100						
	tuna, unspecified	273	6							
	whitebait (glass fish)	1691	940	6	740	118	41	2695	322	
	whiting, king george	2		18						
	whiting, sand	3598	2643	1589	1426	1651	1950	3515	3108	2885
	whiting, school			27	85	81				302
	whiting, stout							56		
	whiting, trumpeter	4417	6108	8828	3564	3305	6124	4367	3809	3649
	whiting, unspecified			1020		10				
	wirrah	4				2				
	yellowtail	5353	3244	4064	5942	7465	4594	1878	4850	1729
Finfish Total		110973	97505	73393	102468	66997	79907	61534	57457	28257
molluscs	calamari, southern	210	5	84	101	118	30	25	41	76
	cuttlefish	1033	852	810	267	141	245	13	89	
	octopus	1008	356	1193	571	820	808	823	1000	289
	scallop		28							
	shells		11							
	squid	739	891	1248	1730	1382	931	1327	778	125
Molluscs Total		2990	2144	3335	2669	2461	2013	2189	1908	489
Grand Total		123116	109023	83353	115420	81506	88199	70176	67222	31635

NSW DPI (2001) also commented specifically on trap fishing in Sydney Harbour for yellowfin bream;

> *Current research on the trap fishery targeting yellowfin bream in Sydney Harbour (D. Ferrell, pers. comm.) has revealed fishery catch rates of 31.6 bream (all sizes), 1.5 snapper and 2.0 other species per trap lift. For every 1kg of legal sized bream, there were 0.17kg of undersized bream captured and only 0.03kg of undersized snapper. The bream included large juveniles and adults, with the smallest observed being 18 cm fork length. Among the other species, the fin fish included silver trevally, tarwhine, luderick, blue morwong, sergeant baker, various leatherjackets, red mullet, six-lined trumpeter, blind shark and boxfish. The invertebrates included octopus, blue swimmer crab, giant cuttlefish, and calamari squid.*

There is a large recreational fishery in Sydney Harbour, supported by a variety of fishing and boating clubs (see Section 8.7.3). Most of this fishery is dominated by local residents fishing from shore (Ghosn et al., 2010). This is different to the rest of the state, where recreational fisheries are dominated by boat based visitors (Steffe and Murphy 2011).

Henry (1984) provided one of the earliest comparisons of recreational and commercial fishing operations in Sydney Harbour. A 12 month sampling campaign during the years 1980–1982 was conducted and over 108 000 kg of fish were caught commercially during this time. Conversely, recreational fishers removed 164 700 kg of fish in the same period. Hence, during this period, the recreational catch exceeded the commercial catch by approximately 50 %

NSW DPI conducted the last major assessment of recreational fishing in 2007– 2008 (Ghosn et al., 2010). Almost 300 000 fishing hours were documented in the estuary, and total catch over the 3 month period was predicted to be 74 tonnes, or 225 000 fin fish, crustaceans and cephalopods (roughly 2500 animals per day). Another 293 000 individuals were thought to have been discarded. While Ghosn et al. (2008) focus on descriptive harvest statistics, it is noted that most of the harvest of kingfish (51.1 %), snapper (97 %) and tailor (76 %) were undersized. Almost 11 % of the landed yellowfin bream were also undersized. This indicates that many of the fishers were either unaware of the size limits for these species, or there appears to be a high degree of non-compliance with the fishing regulations. Further research would be required ascertain whether the small catch sizes are representative of the fish populations in the harbour more generally, caused by either anthropogenic or natural factors. This would be an extremely relevant research direction in Sydney Harbour. Importantly, kingfish and snapper are classified as 'growth overfished' and yellowfin bream are 'fully fished' in NSW as a whole (NSW Status of Stocks 2010).

Research on by-catch in the Sydney Harbour recreational fishery was limited to a single study on yellowtail kingfish (Roberts et al. 2011). Here individual fish were found to suffer 15 % mortality after being caught and released due to mechanical and physiological damage from gill hooking. Mortality rates were drastically reduced when lines were cut, rather than hooks removed. NSW DPI actively promotes two sets of guidelines on (1) Responsible Fishing and (2) Catch and Release Fishing for recreational fishing. DPI promotes both sets of guidelines through various channels including the DPI Recreational Fishing Guides, the DPI website, recreational fishing newsletters to fishers and face-to-face public advisory activities through DPI Fishcare Volunteers and Fisheries Compliance Officers.

Henry and Lyle (2003) described a national level 'phone' survey for recreational fishing participation rates and fishing effort. While not confined to Sydney Harbour, the study did parse out recreational fishing participation rates by 'area', as well as net 'fishing effort import and export'. The Sydney area was found to have the lowest participation rates of recreational fishing effort in the country (13.1 %).

The great majority of Sydney Harbour is open to recreational fishing. Small areas have been restricted from all fishing (eg Homebush Bay), spearfishing (eg Clifton Gardens and North Harbour), nets and traps (eg Pyrmont). The entire foreshore of Sydney Harbour is an inter-tidal protected area, where shore collection of invertebrates is banned. There is an Aquatic Reserve located between North Head and Dobroyd Head, however line-fishing is permitted and only spearfishing is prohibited.

In 2013 SIMS began a survey to document fine scale fisher distributions in Sydney Harbour for the purpose of quantifying risk to the harbour's ecological systems over a 20 year period. The work is ongoing, but some indication of fisher distribution is given in the, as yet, unpublished documentation on the project. The survey period covered the winter of 2013, from June–mid-September. SIMS staff have completed the summer period surveys, however this data was still unavailable for analyses. It is predicted that fishing occurrences will be much greater during this summer time period.

SIMS staff conducted boat based counts of recreational fishers on the shoreline and boats in 13 areas of the harbour, from North and South Head, to the Kissing Point Ferry Terminal in the Parramatta River (not including Middle Harbour). The number of fishers, and the observed number of rods in each fishing party that were cast (with the line in the water) were noted. This was a survey conducted to ascertain fishing effort, not total fishing, hence no questionnaires were given and no indication of catch rates, time fishing, or any other fisher related data were collected. However, all data were spatially explicit to within 30 m, allowing fine scale analyses of fisher distribution to take place. The fine scale spatial distribution and density approximation has not yet been published, however simple summary statistics from each area of the harbour are available and presented below.

Over 840 instances of shore and boat based fishing were observed during the course of 316 different surveys of the harbour (Table 17). There were a total of 476 instances of shore fishing in the harbour over the course of the surveys, and a total of 370 instances of boat fishing. It is noted that instances of shore fishing may be underestimated as many shore fishing parties consisted of several people. A better indication of shore fishing intensity is given by the number of rods cast; 879 cast fishing rods were observed along the shoreline of Harbour during the 316 surveys (Table 17). Similarly, 743 cast lines were observed from boat based fishers during the survey.

Table 17: Total fishing occurrences observed during the SIMS Harbour Survey project during the winter of 2013. we= Weekday, wk=Weekend. Source: SIMS unpublished, *supplied*

Day Type	Period	Mean (all)	Sum (all)	Mean (boat)	Sum (boat)	Mean (shore)	Sum (shore)	Mean Rods (shore)	Sum Rods (shore)	Mean Rods (boat)	Sum Rods (boat)
we	Aft	1.81	96	0.51	27	1.30	69.00	1.81	96	0.83	44.00
we	Mid	1.00	54	0.52	28	0.48	26.00	0.61	33	0.78	42.00
we	Morn	1.70	90	0.55	29	1.15	61.00	1.40	74	0.94	50.00
wk	Aft	3.13	169	0.93	50	2.20	119.00	4.46	241	1.61	87.00
wk	Mid	3.83	207	2.22	120	1.61	87.00	3.91	211	4.61	249.00
wk	Morn	4.79	230	2.42	116	2.38	114.00	4.67	224	5.65	271.00

Fishing occurrences were predictably greatest during the weekend, where 606 instances of fishing were observed, compared with 240 instances observed during the weekdays. The Manly, South Head and Chowder Bay areas of Sydney Harbour had the highest number of fishing occurrences during the weekend time periods, each with 97, 72 and 118 occurrences of fishing from land and shore observed over 3-4 survey occasions.

Table 18: Sum and mean fishing occurrences observed at different areas in Sydney Harbour during the SIMS Harbour Survey Project Winter Survey 2013. we=Weekday, wk= Weekend. Source: SIMS unpublished *supplied*

Day Type	Transect	Mean	Sum	St.Deviation
we	Chowder Bay	2	33	2
we	Darling Harbour	2	17	2
we	Drummoyne	2	17	2
we	Gladesville	2	24	2
we	Centre of Outer Harbour (Bridge)	0	4	1
we	Lane Cove	2	13	2
we	Manly	2	30	1
we	Milsons Point	2	35	3
we	Neutral Bay	1	17	1
we	Centre of Outer Harbour (Heads)	1	13	1
we	Parramatta	1	18	2
we	Rose Bay	1	8	2
we	South Head	1	11	2
wk	Chowder Bay	7	118	5
wk	Darling Harbour	3	45	3
wk	Drummoyne	3	27	3
wk	Gladesville	3	34	3
wk	Centre of Outer Harbour (Bridge)	1	9	1
wk	Lane Cove	3	49	2
wk	Manly	9	97	6
wk	Milsons Point	2	31	2
wk	Neutral Bay	1	14	1
wk	Centre of Outer Harbour (Heads)	4	49	6
wk	Parramatta	3	32	2
wk	Rose Bay	3	29	2
wk	South Head	6	72	4

6.5 Climate Change

The Sydney Coastal Councils Group (SCCG) have developed tools to understand the likely effects that climate change will have on local council resources. The group has released a series of unpublished reports detailing climate change adaption and risk in the Sydney Region that are directed towards local council stakeholders. Most described frameworks from which local governments and other council stakeholders can adapt to climate change generally (SCCG 2012a,b,c). In SCCG (2012c), for example, SCCG (in collaboration with the CSIRO), developed a model to investigate coastal inundation during '1 in 1' and '1 in 100' year storm events sunder climate change scenarios. They combine this modelling with a qualitative risk assessment to show that several councils have a much higher vulnerability to inundation due to climate change than others. Here they posited that the City of Sydney Council, Manly, and Leichardt Councils were the most vulnerable to sea level rise and coastal inundation (SCCG 2012c). Similarly, In SCCG (2012d), the group provided a framework from which local councils could develop community engagement plans and conduct various outreach activities.

It is noted in the SIMS SoH (2014) that changing climatic conditions in Sydney Harbour may lead to loss of foreshore and intertidal vegetation and changes to some natural systems. Byrne et al. (2011) showed that the development of the ubiquitous sea urchin *Heliocidaris erythrogramma*, for example, is retarded at sea temperatures predicted under climate change scenarios. This was the only collated investigation of harbour faunal response to increasing sea temperature.

Rogers et al. (2005) showed that mangrove forests may not be as susceptible to sea level rise as other foreshore vegetation, such as salt marsh and seagrass. Increases in surface elevation at sites in Sydney Harbour

were greater than the 85 year sea level trend, meaning these systems are unlikely to become inundated. This is important, as climate change scenarios predict a greater frequency of storm events. Mangroves may act as coastal defence during these storm events. Seagrass is highly dependent on light availability, and predicted increases in storm induced resuspension, modest sea level rise, and increased temperature may result in generally higher levels of turbidity that may impact this delicate system. No work has been undertaken on predicted climate change effects on Sydney Harbour's seagrass community, nor salt marsh communities, and this may be a worthwhile research direction in the near future.

It is surprising that very little research has been directed towards understanding climate change effects on the natural systems of Sydney Harbour. Improved modelling tools are needed to investigate the changing climates impact on circulation, biogeochemistry and residence times in the harbour. Additionally, modelling tools are needed to investigate the influence of rainfall and storms on a range of harbour processes. Increased rainfall, with an increase in catchment inputs and decreases in salinity in the harbour, may have detrimental effects on harbour biota. Similar detrimental effects could occur if rainfall was to decrease, with subsequent increases in evaporation and decreases in freshwater input.

There is also some evidence to suggest that the EAC is expanding southwards (Ridgway 2007). NSW DPI (2011) report that some tropical fish have established 'overwintering' populations in the estuary. If the EAC were to continue strengthening, the occurrence of species not usually found in Sydney Harbour may increase. We have little knowledge of how the current tropical species may alter the ecology of Sydney Harbour, and certainly no knowledge of the effects of further incursions from the tropical north.

6.6 Distributions of other human activities in Sydney Harbour

6.6.1 State, National and Local Government

There are 28 Local Government Areas (LGSs) with boundaries encompassing the Sydney Harbour catchment to varying degrees (Fig. 16). Spatial data on LGA boundaries is readily available from the Australian Bureau of Statistics for 2011.

Many of the councils within the estuary actively manage their estuarine resources within a Coastal Zone Catchment Management Plan (CZMP) framework. Currently, we are aware of CZMP's for the Parramatta River sub-catchment (Cardno 2012) and the Lane Cove River (BMT WBM 2012). These plans covered most of the catchment, and associated LGAs, west of the Sydney Harbour Bridge. The SCCG is undertaking a scoping study for a CZMP for the rest of the catchment east of the Sydney Harbour Bridge in 2013. These reports were largely management instruments, and developed management actions in consultation with key stakeholders (community, local and state government) to address key threats to the estuary. These documents also included a qualitative risk analysis. While very useful in a management context, these documents generally only briefly discuss catchment fauna and flora and the most comprehensive assessment of these ecological assets were provided by NSW DPI, NSW OEH and NSW RMS (discussed in the previous sections).

6.6.2 Unpowered on-water recreational usage

Here we refer to smaller vessels such as kayaks and 'stand up paddle boards', that are not generally governed by state agencies such as the NSW RMS.

Some indication of the unpowered recreational craft distribution in Sydney Harbour was given by unpublished data produced during the Sydney Institute of Marine Science Sydney Harbour Survey (2013–2014). Again, this work was ongoing and Summer data was not yet available. Table 19 summarises the results of the winter survey, however this is likely to be a gross underestimate of activity as, for each activity noted, there were often multiple people undertaking that activity. The full analysis of this data is yet to be released.

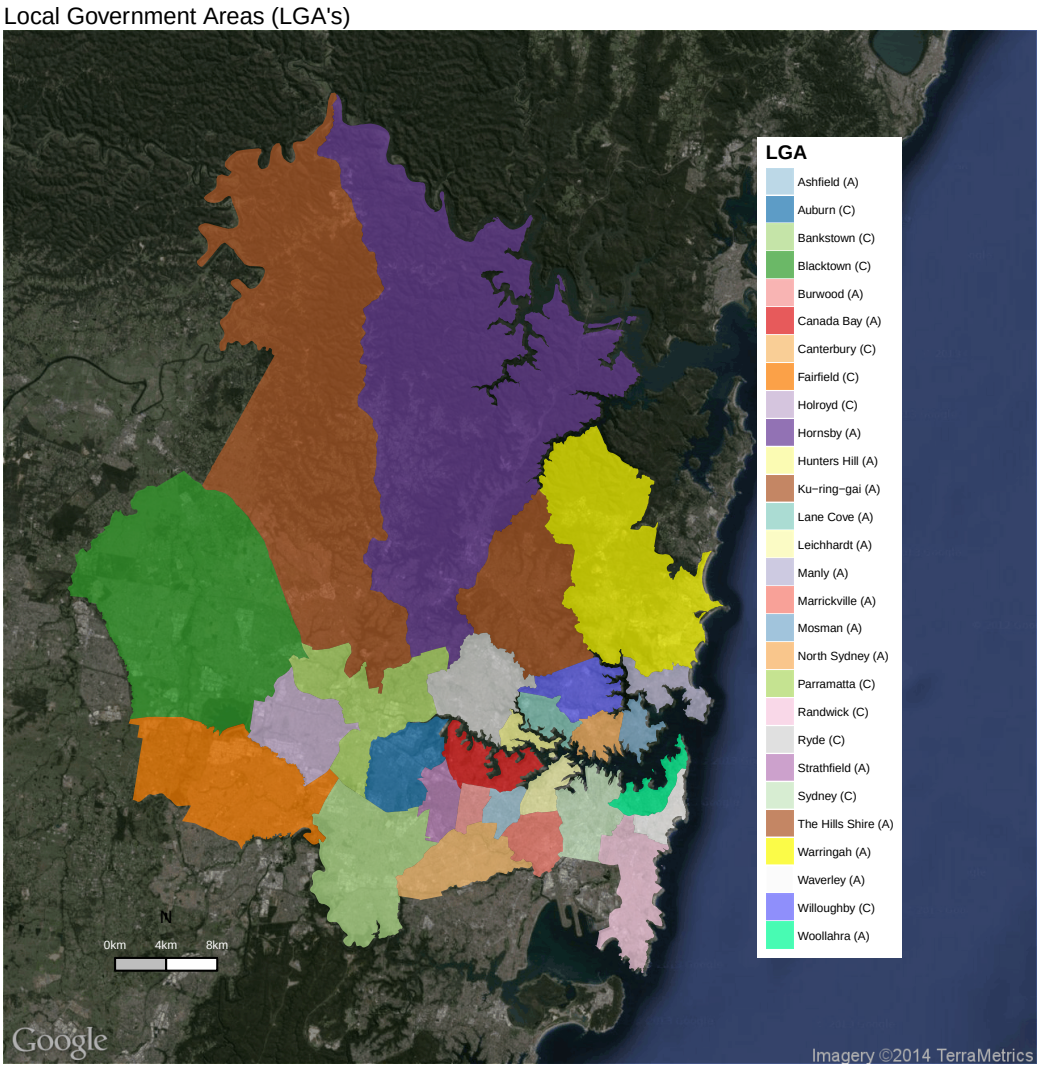

Figure 16: Local Government Areas (LGA's) in the Sydney Catchment Spatial data on LGA's, ABS Statistical Boundaries, and other government information is available from the ABS. Note Baulkham Hills is missing due to incomplete data. Source: ABS *http://www.abs.gov.au*

6.6.3 Mooring, ramp, anchoring and other boating infrastructure

The NSW RMS maintains a spatial dataset of moorings and other boating infrastructure (Fig. 18, 20, 17, 19). This includes an approximate location of each individual mooring in Sydney Harbour, as well as boating ramps and public access wharfs. Note that mooring locations are only approximate and some locations have been found to be inaccurate (Susan Norbom, NSW RMS *pers. comm.*)

Anchoring patterns were analysed in the SIMS Sydney Harbour Survey and a summary of anchor distributions throughout the harbour, across different times of day and day types is presented below (Table 20). Predictably, anchoring patterns increased during the weekend, particularly in Manly and Chowder Bay, where an average of 27 anchored vessels are found (Table 20; Manly, Midday, Weekend).

Table 19: Unpowered recreational watercraft on Sydney Harbour. These included kayaks and paddle boards, however this list does not include sailing vessels. we=Weekday, wk=Weekend. Source: SIMS Unpublished *supplied*

Transect	DayType	Period	n	Sum	Mean	Max
Chowder Bay	we	Aft	5	3.0	0.6	1.0
Chowder Bay	we	Mid	4	2.0	0.5	2.0
Chowder Bay	we	Morn	5	2.0	0.4	1.0
Chowder Bay	wk	Aft	6	1.0	0.2	1.0
Chowder Bay	wk	Mid	4	12.0	3.0	6.0
Chowder Bay	wk	Morn	6	19.0	3.2	7.0
Darling Harbour	we	Aft	4	0.0	0.0	0.0
Darling Harbour	we	Mid	3	0.0	0.0	0.0
Darling Harbour	we	Morn	4	1.0	0.2	1.0
Darling Harbour	wk	Aft	4	1.0	0.2	1.0
Darling Harbour	wk	Mid	4	2.0	0.5	2.0
Darling Harbour	wk	Morn	5	2.0	0.4	2.0
Drummoyne	we	Aft	4	2.0	0.5	1.0
Drummoyne	we	Mid	3	3.0	1.0	2.0
Drummoyne	we	Morn	4	19.0	4.8	19.0
Drummoyne	wk	Aft	4	9.0	2.2	6.0
Drummoyne	wk	Mid	3	5.0	1.7	3.0
Drummoyne	wk	Morn	3	23.0	7.7	14.0
Gladesville	we	Aft	5	4.0	0.8	4.0
Gladesville	we	Mid	2	0.0	0.0	0.0
Gladesville	we	Morn	4	1.0	0.2	1.0
Gladesville	wk	Aft	4	2.0	0.5	1.0
Gladesville	wk	Mid	3	4.0	1.3	4.0
Gladesville	wk	Morn	3	13.0	4.3	10.0
Middle of the Outer Harbour (Bridge)	we	Aft	6	1.0	0.2	1.0
Middle of the Outer Harbour (Bridge)	we	Mid	6	5.0	0.8	3.0
Middle of the Outer Harbour (Bridge)	wk	Aft	5	1.0	0.2	1.0
Middle of the Outer Harbour (Bridge)	wk	Mid	4	3.0	0.8	3.0
Lane Cove	we	Aft	2	1.0	0.5	1.0
Lane Cove	we	Mid	2	1.0	0.5	1.0
Lane Cove	we	Morn	2	1.0	0.5	1.0
Lane Cove	wk	Aft	4	8.0	2.0	3.0
Lane Cove	wk	Mid	5	4.0	0.8	3.0
Lane Cove	wk	Morn	6	31.0	5.2	10.0
Manly	we	Aft	3	4.0	1.3	2.0
Manly	we	Mid	4	7.0	1.8	2.0
Manly	we	Morn	9	10.0	1.1	3.0
Manly	wk	Aft	3	26.0	8.7	16.0
Manly	wk	Mid	2	25.0	12.5	15.0
Manly	wk	Morn	6	52.0	8.7	18.0
Milsons Point	we	Aft	5	3.0	0.6	3.0
Milsons Point	we	Mid	3	0.0	0.0	0.0
Milsons Point	we	Morn	6	3.0	0.5	1.0
Milsons Point	wk	Aft	5	0.0	0.0	0.0
Milsons Point	wk	Mid	4	1.0	0.2	1.0
Milsons Point	wk	Morn	5	4.0	0.8	1.0
Neutral Bay	we	Aft	1	0.0	0.0	0.0
Neutral Bay	we	Mid	8	10.0	1.2	3.0
Neutral Bay	we	Morn	6	1.0	0.2	1.0
Neutral Bay	wk	Aft	3	3.0	1.0	2.0
Neutral Bay	wk	Mid	4	1.0	0.2	1.0
Neutral Bay	wk	Morn	5	10.0	2.0	5.0
Middle of the Outer Harbour (Heads)	we	Aft	3	1.0	0.3	1.0
Middle of the Outer Harbour (Heads)	we	Mid	8	6.0	0.8	3.0
Middle of the Outer Harbour (Heads)	wk	Aft	2	0.0	0.0	0.0
Middle of the Outer Harbour (Heads)	wk	Mid	9	18.0	2.0	7.0
Parramatta	we	Aft	6	5.0	0.8	5.0
Parramatta	we	Mid	6	1.0	0.2	1.0
Parramatta	we	Morn	5	20.0	4.0	13.0
Parramatta	wk	Aft	6	2.0	0.3	1.0
Parramatta	wk	Mid	4	13.0	3.2	13.0
Parramatta	wk	Morn	2	4.0	2.0	4.0
Rose Bay	we	Aft	6	8.0	1.3	2.0
Rose Bay	we	Mid	3	4.0	1.3	3.0
Rose Bay	we	Morn	3	7.0	2.3	6.0
Rose Bay	wk	Aft	4	12.0	3.0	8.0
Rose Bay	wk	Mid	5	83.0	16.6	34.0
Rose Bay	wk	Morn	2	29.0	14.5	18.0
South Head	we	Aft	3	6.0	2.0	3.0
South Head	we	Mid	2	1.0	0.5	1.0
South Head	we	Morn	4	3.0	0.8	2.0
South Head	wk	Aft	4	6.0	1.5	4.0
South Head	wk	Mid	3	20.0	6.7	9.0
South Head	wk	Morn	5	21.0	4.2	7.0

Table 20: Summary of the distribution of anchoring patterns in Sydney Harbour. we=Weekday, wk=Weekend. Source: SIMS unpublished *supplied*

Transect	Day Type	Period	n	Sum	Mean	Max
Chowder Bay	we	Aft	5	1.0	0.2	1.0
Chowder Bay	we	Mid	4	4.0	1.0	4.0
Chowder Bay	we	Morn	5	3.0	0.6	2.0
Chowder Bay	wk	Aft	6	52.0	8.7	42.0
Chowder Bay	wk	Mid	4	30.0	7.5	11.0
Chowder Bay	wk	Morn	6	27.0	4.5	9.0
Darling Harbour	we	Aft	4	0.0	0.0	0.0
Darling Harbour	we	Mid	3	0.0	0.0	0.0
Darling Harbour	we	Morn	4	0.0	0.0	0.0
Darling Harbour	wk	Aft	4	0.0	0.0	0.0
Darling Harbour	wk	Mid	4	1.0	0.2	1.0
Darling Harbour	wk	Morn	5	0.0	0.0	0.0
Drummoyne	we	Aft	4	3.0	0.8	2.0
Drummoyne	we	Mid	3	0.0	0.0	0.0
Drummoyne	we	Morn	4	3.0	0.8	3.0
Drummoyne	wk	Aft	4	2.0	0.5	2.0
Drummoyne	wk	Mid	3	5.0	1.7	3.0
Drummoyne	wk	Morn	3	3.0	1.0	1.0
Gladesville	we	Aft	5	1.0	0.2	1.0
Gladesville	we	Mid	2	0.0	0.0	0.0
Gladesville	we	Morn	4	1.0	0.2	1.0
Gladesville	wk	Aft	4	2.0	0.5	1.0
Gladesville	wk	Mid	3	2.0	0.7	2.0
Gladesville	wk	Morn	3	1.0	0.3	1.0
Middle of the Outer Harbour (Bridge)	we	Aft	6	1.0	0.2	1.0
Middle of the Outer Harbour (Bridge)	we	Mid	6	0.0	0.0	0.0
Middle of the Outer Harbour (Bridge)	wk	Aft	5	1.0	0.2	1.0
Middle of the Outer Harbour (Bridge)	wk	Mid	4	3.0	0.8	2.0
Lane Cove	we	Aft	2	0.0	0.0	0.0
Lane Cove	we	Mid	2	1.0	0.5	1.0
Lane Cove	we	Morn	2	0.0	0.0	0.0
Lane Cove	wk	Aft	4	5.0	1.2	3.0
Lane Cove	wk	Mid	5	5.0	1.0	3.0
Lane Cove	wk	Morn	6	6.0	1.0	3.0
Manly	we	Aft	3	0.0	0.0	0.0
Manly	we	Mid	4	8.0	2.0	3.0
Manly	we	Morn	9	6.0	0.7	4.0
Manly	wk	Aft	3	39.0	13.0	20.0
Manly	wk	Mid	2	54.0	27.0	32.0
Manly	wk	Morn	6	34.0	5.7	14.0
Milsons Point	we	Aft	5	3.0	0.6	1.0
Milsons Point	we	Mid	3	1.0	0.3	1.0
Milsons Point	we	Morn	6	0.0	0.0	0.0
Milsons Point	wk	Aft	5	1.0	0.2	1.0
Milsons Point	wk	Mid	4	1.0	0.2	1.0
Milsons Point	wk	Morn	5	5.0	1.0	2.0
Neutral Bay	we	Aft	1	2.0	2.0	2.0
Neutral Bay	we	Mid	8	17.0	2.1	17.0
Neutral Bay	we	Morn	6	3.0	0.5	2.0
Neutral Bay	wk	Aft	3	1.0	0.3	1.0
Neutral Bay	wk	Mid	4	8.0	2.0	8.0
Neutral Bay	wk	Morn	5	4.0	0.8	4.0
Middle of the Outer Harbour (Heads)	we	Aft	3	5.0	1.7	3.0
Middle of the Outer Harbour (Heads)	we	Mid	8	5.0	0.6	2.0
Middle of the Outer Harbour (Heads)	wk	Aft	2	2.0	1.0	2.0
Middle of the Outer Harbour (Heads)	wk	Mid	9	34.0	3.8	18.0
Parramatta	we	Aft	6	0.0	0.0	0.0
Parramatta	we	Mid	6	1.0	0.2	1.0
Parramatta	we	Morn	5	0.0	0.0	0.0
Parramatta	wk	Aft	6	3.0	0.5	1.0
Parramatta	wk	Mid	4	7.0	1.8	4.0
Parramatta	wk	Morn	2	0.0	0.0	0.0
Rose Bay	we	Aft	6	2.0	0.3	1.0
Rose Bay	we	Mid	3	0.0	0.0	0.0
Rose Bay	we	Morn	3	1.0	0.3	1.0
Rose Bay	wk	Aft	4	11.0	2.8	11.0
Rose Bay	wk	Mid	5	20.0	4.0	6.0
Rose Bay	wk	Morn	2	0.0	0.0	0.0
South Head	we	Aft	3	5.0	1.7	5.0
South Head	we	Mid	2	1.0	0.5	1.0
South Head	we	Morn	4	0.0	0.0	0.0
South Head	wk	Aft	4	17.0	4.2	14.0
South Head	wk	Mid	3	16.0	5.3	10.0
South Head	wk	Morn	5	9.0	1.8	4.0

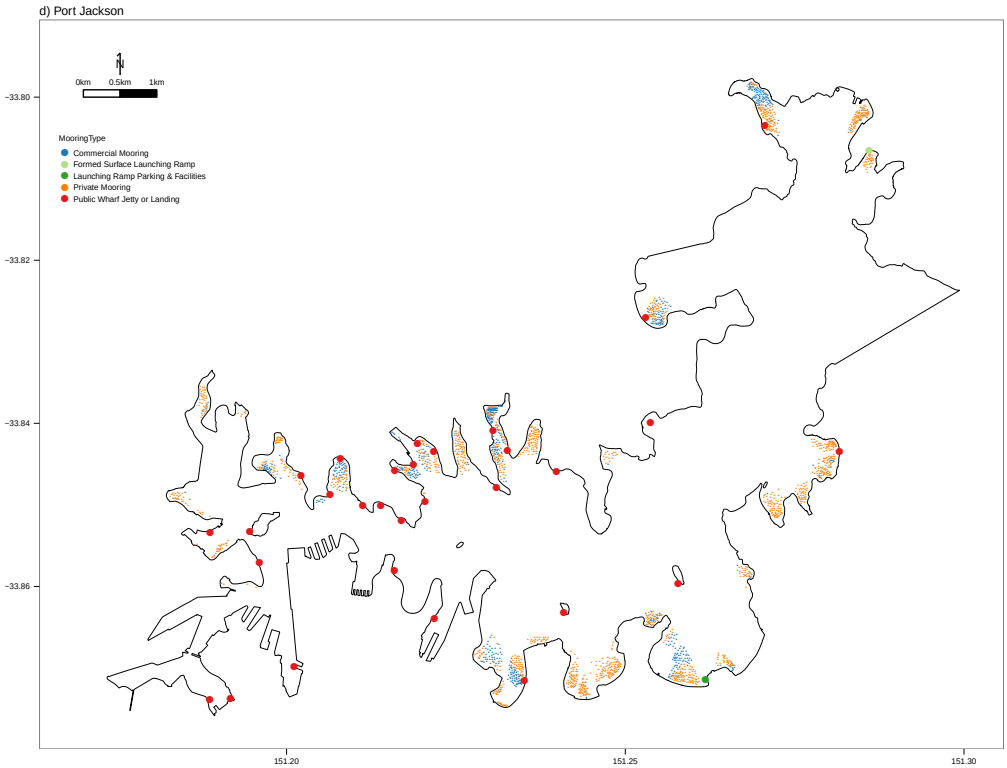

Figure 17: Boating Infrastructure in the Port Jackson sub-catchment. Source: NSW RMS

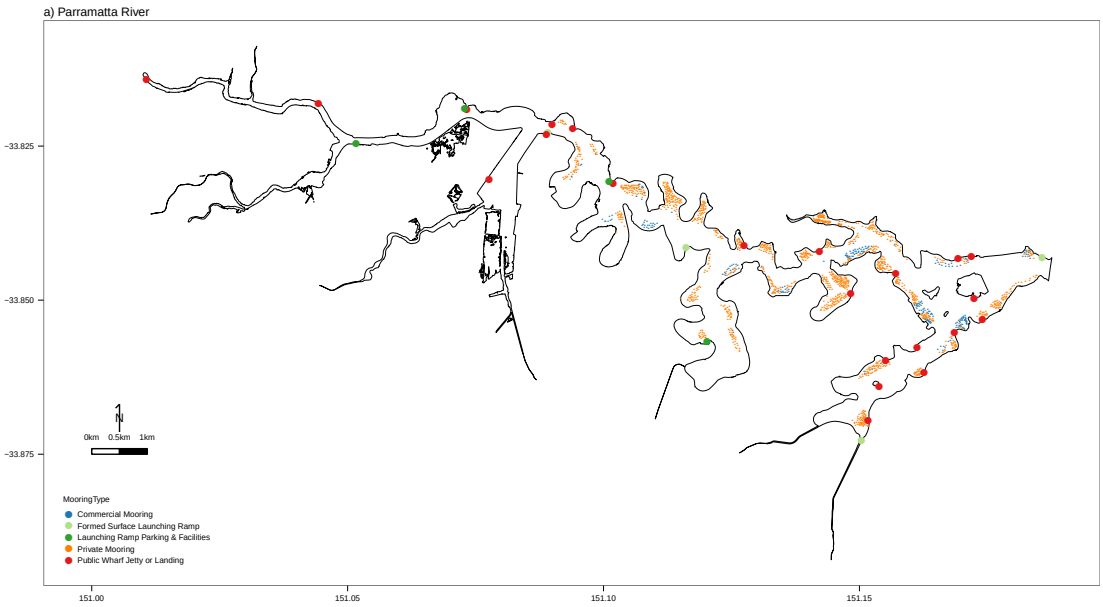

Figure 18: Boating Infrastructure in the Parramatta River sub-catchment. Source: NSW RMS

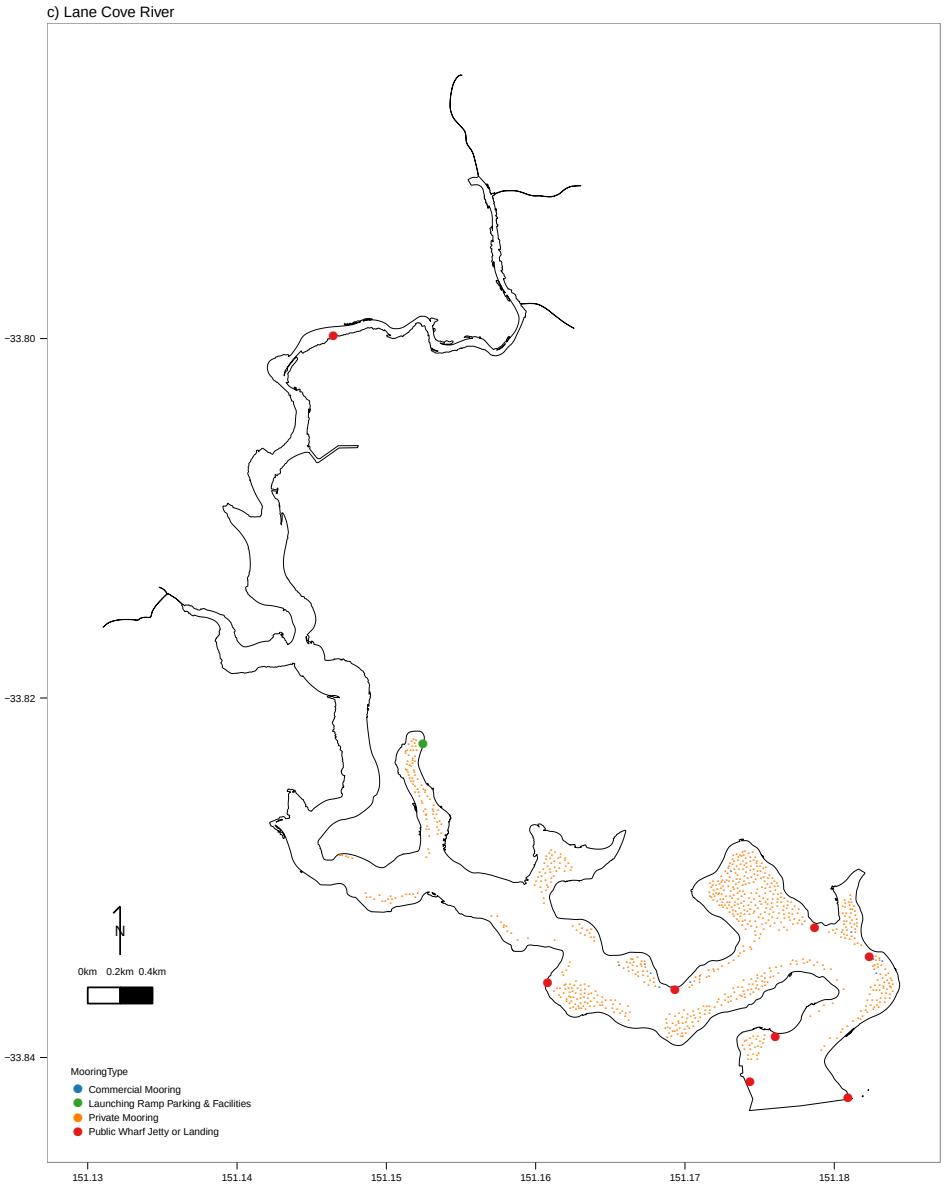

Figure 19: Boating Infrastructure in the Lane Cove River sub-catchment. Source: NSW RMS

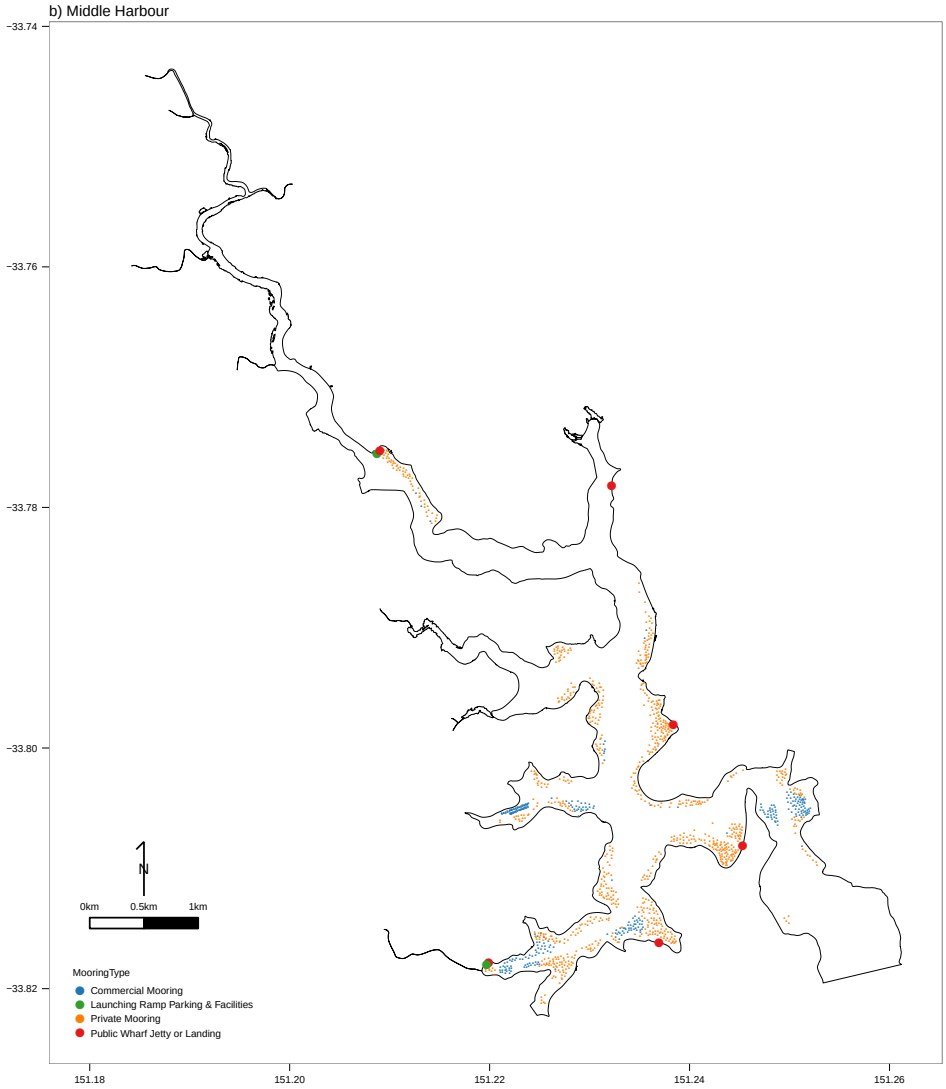

Figure 20: Boating Infrastructure in the Middle Harbour sub-catchment. Source: NSW RMS

6.6.4 Commercial shipping and ferries

The most comprehensive analysis of shipping and ferry movements was derived from the Automatic Identification System (AIS) that is required on all vessels over 12 m. Additional information could be obtained from Sydney Ports (see 8.2.1, 8.3.2, 8.10.5).

The Australian Marine Safety Authority (AMSA) maintains a database of hourly ship positions for all ships in the Australian region, including Sydney Harbour. While data for this report was obtained by direct contact with AMSA staff, the database could also be accessed through a web based portal (*https://www.operations.amsa.gov.au/Spatial/DataServices/CraftTrackingRequest*, accessed 20/3/2014). Various shipping IMO categories were measured on an hourly basis (Table 21), however could be temporally aggregated. Spatial resolution was within 10 m (AMSA *pers. comm.*, Fig. 21).

Many web based applications monitor shipping movements throughout the world (for example *www.marinetraffic.com* accessed 10/4/2-14), and data for Sydney Harbour could be easily obtained via either API based or web-scraping programs that can easily be developed.

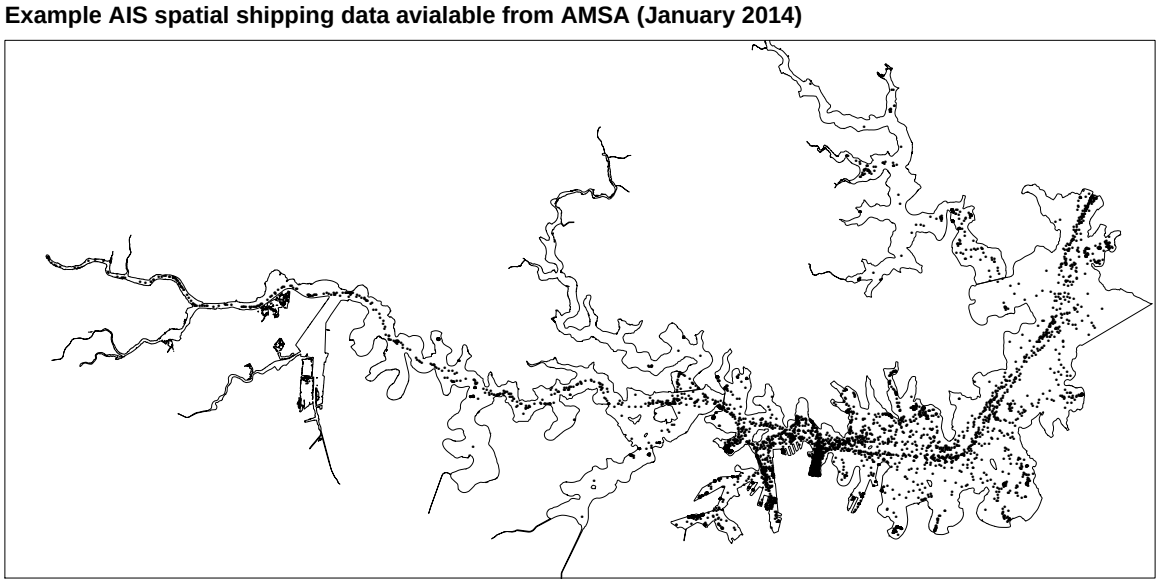

Figure 21: Example AIS information on ferry and commercial vessels over 12 m in Sydney Harbour. Points represent the position (within 10m) of a vessel every hour for the period January 1st 2014 – January 28th 2014. Point attributes include vessel speed and heading, as well as vessel type, call sign and a unique timestamp.

Table 21: IMO AIS Shipping categories measured in Sydney Harbour

IMO Shipping Category
Other - All
Tug
Sailing
Tanker - Carrying DG, HS, or MP, IMO Hazard or pollutant category A
Passenger ship - All
Pleasure craft
Passenger ship - No additional info
Engaged in military operations
HSC - All
Cargo ship - No additional info
Pilot vessel
SAR
Cargo ship - All
Tanker - All
Tanker - Carrying DG, HS, or MP, IMO Hazard or pollutant category B
Reserved
Tanker - Carrying DG, HS, or MP, IMO Hazard or pollutant category C
Other - No additional info
Tanker - No additional info
Fishing
Towing

7 Synthesis of the current knowledge of the values held by the community regarding Sydney Harbour

Sydney Harbour provides immense social, economic and ecological value for a broad range of stakeholders. It is surrounded by a large population exceeding 4.8 million residents and is an important recreational and social centre. The harbour also represents significant cultural, historic and spiritual value to the wider Australian community.

This chapter reviews the extant literature regarding the social value of the harbour, focusing on direct-use and indirect community stakeholders. We identified broad community stakeholder groups and a range of high level value categories. We concluded that there are significant gaps in the research to date, particularly relating to values by stakeholder that are specific to the harbour context.

7.0.5 Sources

This chapter has been compiled based on information gathered through meetings, discussions and documents sourced from the following departments and organisations:

- NSW Department of Primary Industries
- Office of Environment and Heritage
- Marine Estate Knowledge Panel
- Sweeney Research (conducting current community research)
- Transport NSW
- NSW Planning and Infrastructure
- Sydney Coastal Councils Group
- NSW Roads and Maritime Services
- National Parks and Wildlife Service
- Sydney Harbour Foreshore Authority
- Sydney Harbour Federation Trust
- Tourism Australia

A full list of source documents is provided in the references.

7.1 Stakeholders of the Harbour

Stakeholders are individuals or groups that have an interest in, or may be affected by, a decision or context (McGlashan and Williams, 2003). Sydney Harbour represents a unique context that is highly valuable to a wide range of stakeholders.

Stakeholder analysis is central to the understanding of social values, as different stakeholders see value in different things (Chang et al. 2012). Whilst some values are widely held (for example, access), others are of more important to a particular stakeholder group (for example, abundance of fished species).

Values may be consistent between stakeholders (shared values) or may differ in a given context (conflicting values). Effective management must understand and leverage shared values whilst managing the issues that arise from conflicting values (Jones, 2002).

In the context of Sydney Harbour, stakeholders may be classified as organisational (government and non-government) and community stakeholders.

7.1.1 Organisational stakeholders

Whilst organisational stakeholders are outside the scope of this chapter, they are a source of research and working papers that are important to the understanding of community / social values. A list of many organisational stakeholders are found in Table 22.

Table 22: Organisational stakeholders of Sydney Harbour

Sector	Organisation
Federal Government	Department of Defence
	Sydney Harbour Federation Trust
NSW Government	Department of Planning and Infrastructure
	Department of Trade and Investment
	Regional Infrastructure and Services
	Transport for NSW including RMS
	Office of Environment and Heritage
	Sydney Harbour Foreshore Authority
	Greater Sydney Local Land Services
	Sydney Olympic Park Authority
Local Government	Fourteen Local Councils
Business Sector	Boating industry
	Shipping industry
	Fishing and agriculture industry
	Tourism industry
	Diving industry
	Transport industry

7.1.2 Community Stakeholders

Community stakeholders represent the "social" in social value. The reviewed literature was generally lacking in information concerning community stakeholder groups. Some studies addressed recreational users of the harbour (Mitchell McCotter 1988), whilst others have studied a specific stakeholder group, most notably fishers (Ghosn et al 2010). Synthesis across many documents allowed a partial picture of stakeholders to be developed in this chapter. Quantitative information in particular was scarce in the case of most stakeholder groups.

Community stakeholder groups may be classified in a range of ways. Stakeholders may make direct use of the harbour, such as fishers and swimmers. Direct use is not, however, a pre-requisite for a stakeholder group; for example residents who may not physically visit the harbour but may derive value from knowing its in good condition, from the memories of childhood or from its status as an international icon.

7.1.3 Major community stakeholder groups in Sydney Harbour

Commuters Whilst a relatively small number of people commute to work on the harbour (10,000 trips to work daily by ferry in 2006), the accumulated time and experience over the course of the year is high (Transport Data Centre, 2009). Harbour commuters also represent a unique class of traveller as they enjoy high aesthetic values and their perspective is from the water back to land. The majority of harbour commuters (77 %) travel to and from the Sydney CBD.

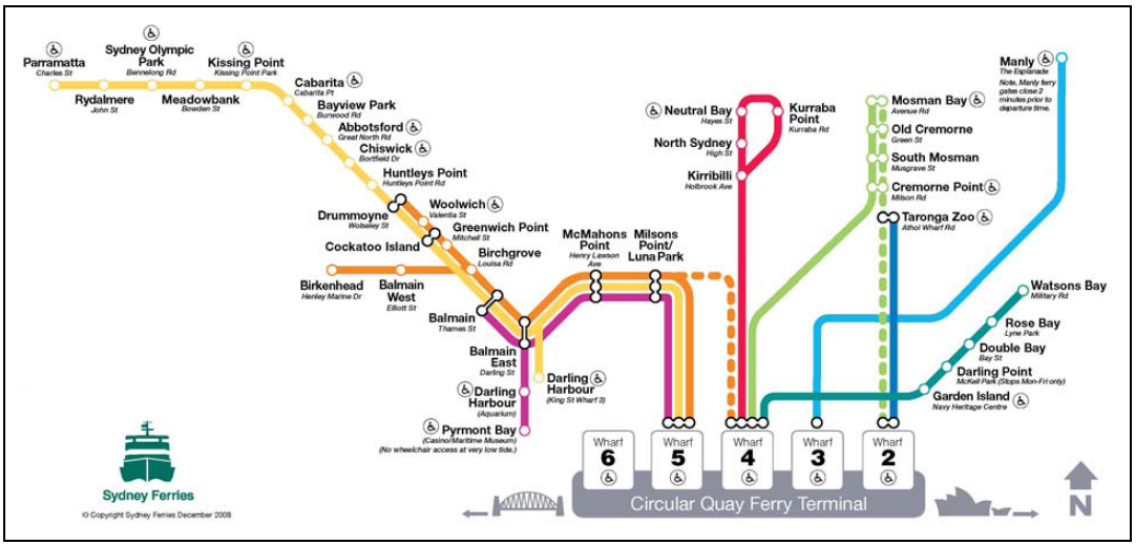

Figure 22: Ferry routes in Sydney Harbour. Source: Sydney Ferries

Commuters have four value sets (Transport for NSW, 2013)

1. Safety and enforcement
2. Safety information and customer service
3. Accessibility and supporting facilities
4. Sustainable waterway environment

Swimmers The number of swimmers that use Sydney Harbour is unknown. Sydney Harbour and Middle Harbour provide many swimming sites; 28 locations are explicitly listed in the literature (Table 23, Harbourwatch 2003).

Table 23: Swimming sites in Sydney Harbour. Source: BeachWatch 2003

Port Jackson	**Lane Cove River**
Hayes Street Beach	Tambourine Bay
Little Sirius Cove	Woodford Bay
Clifton Gardens	Woolwich Baths
Redleaf Pool	**Parramatta River**
Rose Bay Beach	Cabarita Beach
Nielsen Park	Henley Baths
Parsley Bay	Chiswick Baths
Watsons Bay	Dawn Fraser Pool
Middle Harbour	Greenwich Baths
Davidson Reserve	**North Harbour**
Gurney Crescent Baths	Forty Baskets
Sangrado Baths	Fairlight Beach
Northbridge Baths	Manly Cove
Clontarf Pool	Little Manly Cove
Chinamans Beach	
Edwards Beach	
Balmoral Baths	

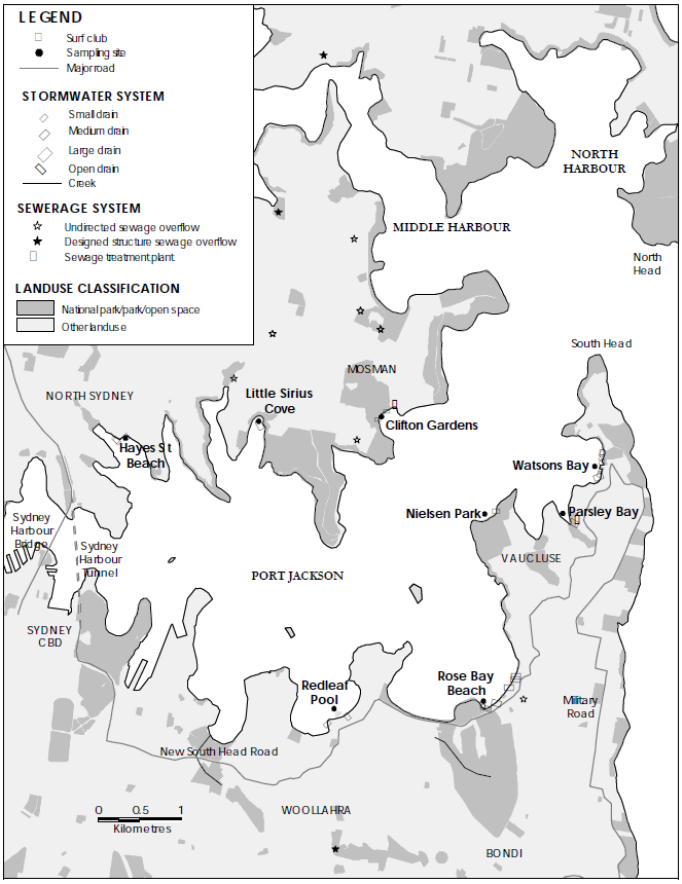

Figure 23: Swimming sites monitored by the Harbourwatch Scheme in Sydney Harbour. Source: NSW OEH

Walkers The number of people who walk on harbourside paths and tracks each year is unknown. Less than 50 % of the harbours shoreline is in a natural state. Sydney and Middle Harbours provide over 70 lookouts and 160 foreshore parks (Mitchell McCotter and Assoc. 1988; Fig. 24).

Sydney Coastal Councils Group is actively encouraging and developing walking as a recreational activity along six trunk walking routes;

- Coastal walk
- Harbour Circle walk
- Great North walk
- Federation track
- Spit to Manly walk
- Harbour to Hawkesbury track

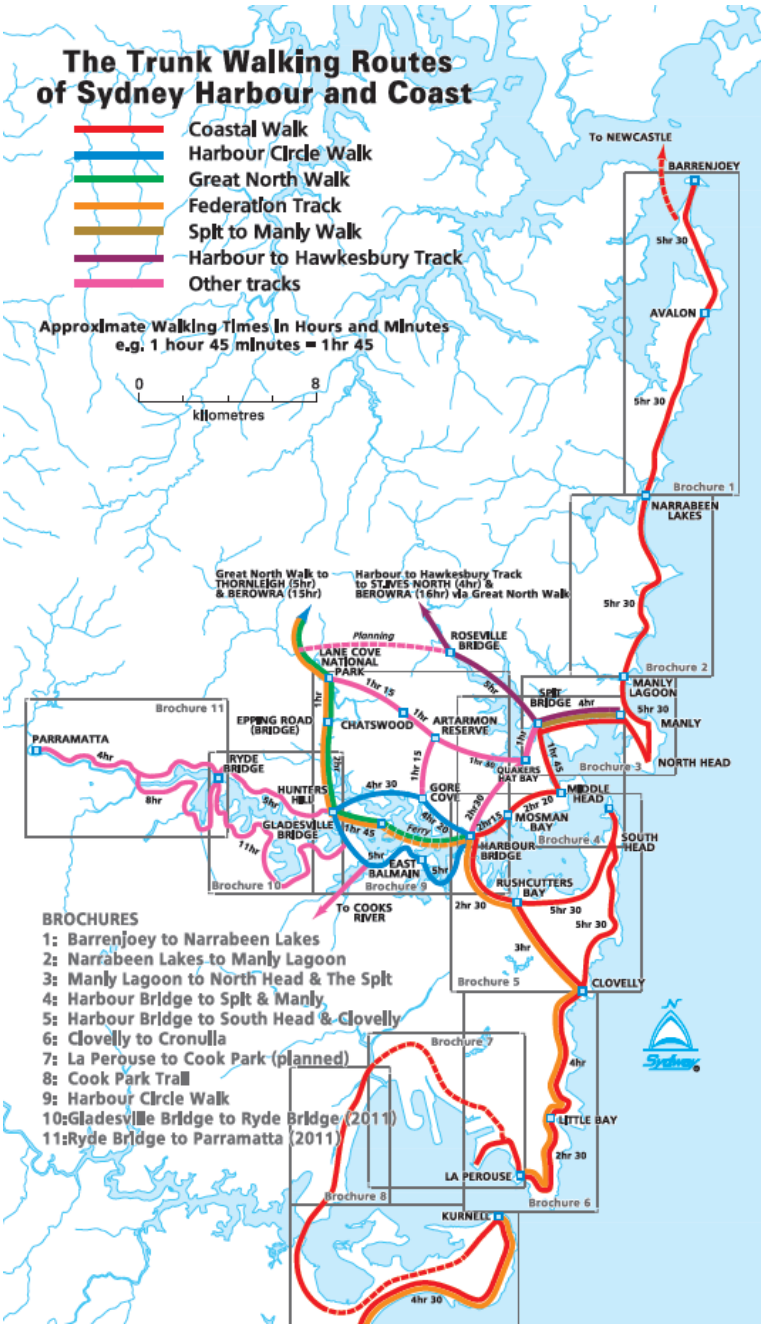

Figure 24: Walking Routes in Sydney Harbour. Source: SCCG

Fishers In 2000, NSW had an estimated 999,000 fishers (Henry and Lyle, 2003). Fishing is a popular and widespread recreational pursuit on Sydney Harbour. The great majority (96 %) of fishers on the harbour are residents of Sydney (Ghosn et al 2010). Fishing takes place in all rivers and estuaries (Fig. 25) including west of the Harbour Bridge where health warnings limit the recommended level of consumption of fishes due to pollution levels.

Sydney Harbour is heavily fished compared to other Australian estuaries (Mitchell McCotter and Assoc. 1988). Recreational fishing effort has remained relatively constant over the last 30 years, estimated at 700,000 fishing hours annually, 300,000 of which occur in summer (Mitchell McCotter and Assoc. 1988, Ghosn et al 2010). Rod and handline are the most popular fishing methods; line fishing comprises 85 % of fishing effort nationally (Henry and Lyle 2003). Nets, pots and traps represent a further 10 %. Spearfishing represents only 1 % of fishing effort. 38 % of fishing effort occurs from boats, 62 % from shore (Ghosn et al 2010).

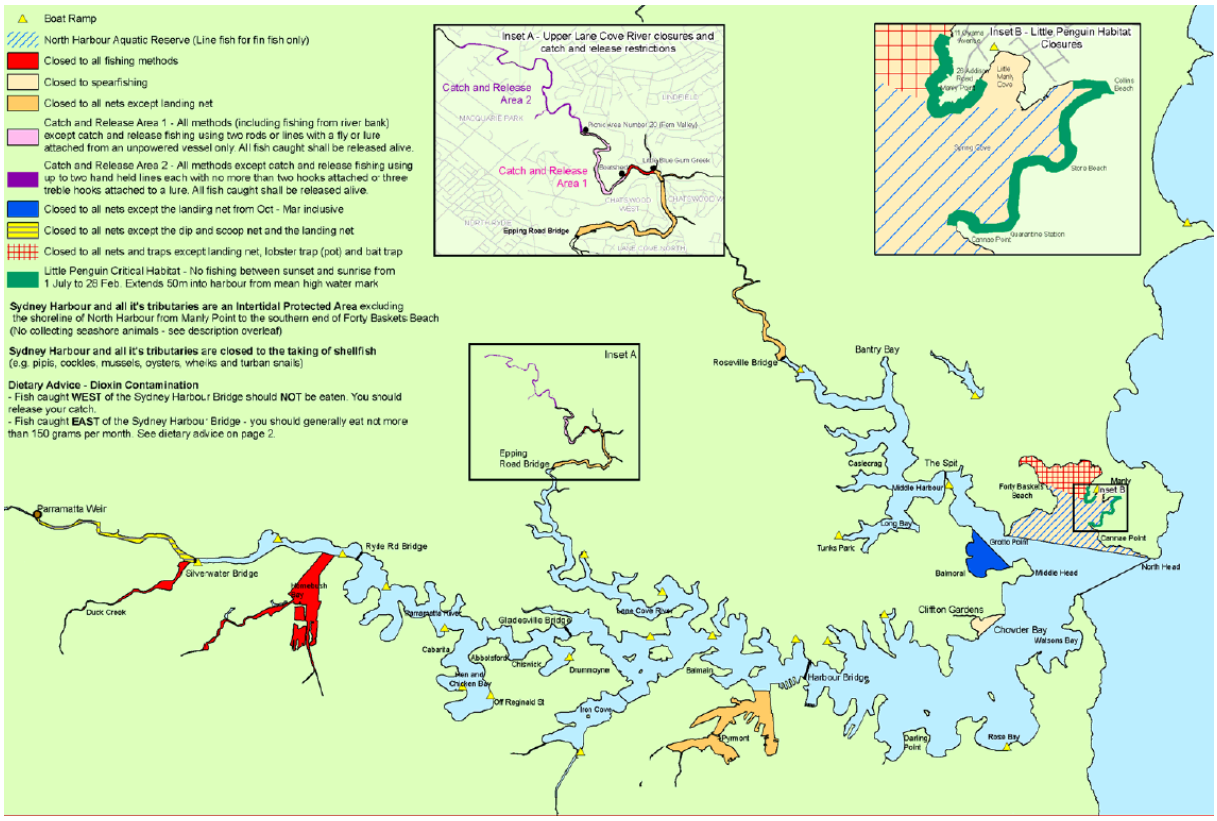

Figure 25: Recreational Fishing fact sheet for the northern Outer Harbour area.

Two studies investigated recreational fishing including fisher motivations within Sydney Harbour (Mitchell McCotter 1988) and Australia (Henry 2004). A comparison of fisher motivations between these two contexts is shown in Figure 26.

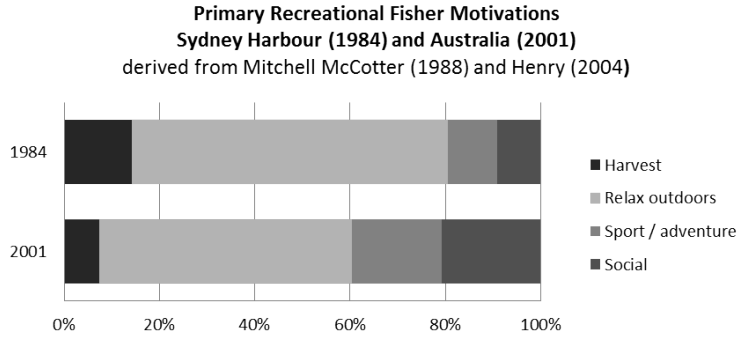

Figure 26: The motivation of recreational fishers in Sydney Harbour. Source: SIMS unpublished *supplied*.

Divers and snorkelers The diving industry estimated that there are 420,000 divers in NSW (Dive Industry Association of Australia (DIAA), *pers. comm.*). In a recent survey commissioned by DIAA, at least 25 % of residents of NSW over 18 years of age stated they participated in SCUBA diving or snorkelling (n=1007; DIAA *pers. comm.*). The number of divers and snorkelers in Sydney Harbour was unknown.

Divers may use a dive shop, dive with a club or dive with a social group. Snorkelers are a less formalised group and may overlap with swimmers, beach-goers and divers.

Divers and snorkelers frequent several bays in the harbour. Several locations such as Camp Cove, Chowder Bay and North Head are dived frequently and are busy with divers on a weekend (http://www.urgdiveclub.org.au/ accessed 1/3/14). Sixteen dive sites were listed in 1980 (Mitchell McCotter and Assoc. 1988) although new

sites have become popular in recent years. Twenty sites are currently recognised on dive reference sites (http://www.michaelmcfadyenscuba.info/news.php, http://www.urgdiveclub.org.au/ accessed 1/3/14)

- North Head Old Mans Hat
- North Head Boulders
- North Head Waterfall
- Inside South Head
- Red Indian Point (inside North Head)
- Manly Gasworks
- Fairlight
- Balmoral Baths
- Sow and Pigs Reef
- Beehive Casemate Escape Tunnel
- Chowder Bay Wharf
- Clifton Gardens
- Kirribilli Point
- Bottle and Glass Point
- Parsley Bay
- Watsons Bay Pool
- Green Point
- Camp Cove
- Middle Head South
- Obelisk Bay North

Boaters Sydney Harbour is one of the most intensively-used waterways in Australia. Recreational boating activities include sailing, kayaking, motor cruising, fishing, overnighting and attending public events such as New Years Eve fireworks.

Sydney Harbour has over 50 km^2 of navigable waterway, 15 public boat ramps, 80 public wharves, 700 private landing facilities, 5000 private moorings and 20 rowing clubs (Ghosn et al 2010, Office of Boating Safety and Maritime Affairs 2013).

There were over 220,000 recreational vessels registered in NSW in 2010 of which an estimated 17,000 use Sydney Harbour (NSW RMS, 2013).

About half of the recreational vessels in NSW are used for fishing (Henry and Lyle 2004). 80 % are less than 6m in length.

Table 24: Boat configurations in Sydney Harbour.

Open runabout	65%
Cabin runabout	12%
Punt	7%
Sail vessel	5%
Motor cruiser	4%
PWC	4%
Inflatable	1%
All other	2%

Picnickers The number of people who enjoy picnicking on the shores of Sydney Harbour is unknown. There are over 160 foreshore parks around the harbour that are accessible to picnickers containing 25 formal picnic areas (Mitchell McCotter and Assoc. 1988). These figures exclude the Parramatta River. Notable examples of picnic sites include (Capricorn Press 2003);

- Port Jackson
  - Green Point
  - Watsons Bay
  - Nielsen Park
  - Hermitage Reserve
  - Rushcutters Bay Park
  - Royal Botanic Gardens
  - Bradleys Head
  - Clifton Gardens (Sydney Harbour National Park)
- Parramatta and Lane Cove Rivers
  - Birchgrove Park
  - Goat Island
  - Cockatoo Island
  - Cabarita Park
  - Meadowbank Park
  - Gladesville Reserve
  - Clarkes Point Reserve
- Lane Cove National Park Middle and North Harbours
  - The Spit Reserve
  - Tunks Park
  - Balmoral Beach Reserve
  - Garigal National Park
  - Clontarf Reserve
  - Dobroyd Head (Sydney Harbour National Park)
  - Quarantine and Stores Beaches (Sydney Harbour National Park)

Sightseers Sydney Harbour is a popular destination for sightseeing by both local residents and visitors. Sights range from the iconic Sydney Harbour Bridge and Opera House, to more specific interests such as heritage buildings, intertidal marine life and experiencing the many lookouts around the harbour.

The brand essence of Sydney Harbour National Landscape is “Spellbinding” (Tourism Australia, 2013). Values that support this brand include seductive, sensual, sparkling, vibrant, energetic, happy, free, informal, relaxed, pristine, romantic, raw and energising.

The number of sightseers who visit Sydney Harbour each year is unknown. Whilst tourism figures are available for visitors to Sydney, there are many local and Sydney residential sightseers.

Residents (indirect) Residents may experience the harbour and its values directly as part of one of the preceding stakeholder groups or as a resident who lives near the water; or indirectly by the wider residents of Sydney who place value on knowing that *our* harbour is being looked after.

Indirect values that are important to residents may include 'option', 'bequest' and 'existence value'.

- Option value represents the knowledge that one will have the option of visiting and experiencing the harbour in future; ie that it will be protected until then.
- Bequest value reflects the importance of leaving a healthy harbour to be inherited by future generations.
- Existence value represents the comfort of knowing that the harbour is there.

7.2 Values

Values are a judgement of 'what is important in life'. They indicate that which is useful, important or of significant worth (*http://www.oxforddictionaries.com/*, accessed 15/1/14). Values in the marine context may be broadly classified as utilitarian and philosophical (Kenchington 1990)

- Utilitarian Values
  - Products and services extracted from the environment
  - Recreational amenity
  - Tourism
  - Education
- Philosophical values
  - Cultural
  - Spiritual
  - Scientific knowledge

The Sydney Regional Environment Plan (Sydney Harbour Catchment) 2005 represented community views arising from a widespread consultation process specific to Sydney Harbour and catchment. Social values were generally represented in the aims of the plan:

- Protection for an outstanding natural asset
- Heritage significance
- Healthy, sustainable environment
- Effective transport
- Rich, vibrant culture
- Accessibility
- Protection, maintenance and rehabilitation of ecological areas

Social values were also represented in a number of plans of management relating to different parts of the harbour. Local council Plans of Management, such as the McKell Park and Darling Point Reserve Plan of Management (Woolahra Council, 2013) and The Spit Reserves Plan of Management (Mosman Council, 2011) documented eight social values:

- Natural (flora, fauna, environment)
- Social / community (uses and events)

- Historical
- Aesthetic
- Cultural
- Recreational
- Scientific / educational
- Access

It is noteworthy that "natural / environmental" values and "social / community" values fell within the wider scope of social values. The community valued a healthy environment, the ability to experience nature and knowing that 'we' are looking after our natural surroundings. The community also valued the ability to socialise with others, for example at public events and picnics with family and friends. "Natural / environmental" values are documented elsewhere in this report, and will be treated in this chapter as one of the sub-categories of social value. "Socialising / sharing" with others will also be treated as a sub-category of overall community social value.

The NPWS Sydney Harbour National Park Plan of Management (2012) detailed six categories of social value:

- Landscape values
- Ecosystem values
- Cultural heritage values
- Scientific and research values
- Recreation and tourism values
- Education and interpretive values

Social values were represented in plans of management prepared by the Sydney Harbour Federation Trust (2003; Table 25).

Table 25: Social values described in Sydney Harbour Federation Trust Plans of Management

Management Plan	Social values
Woolwich Dock and Parklands	Maritime and defense history
	Open space and links to parks
	Access via land and water
	Cleaning up pollution
Cockatoo Island	History (aboriginal, convict, maritime)
	Cleaning up contamination
	Support for working harbour / apprentices
Middle Head	Conservation of bushland; biodiversity and natural ecosystems
	Open space and recreation activities
	Conservation of heritage; aboriginal and defense
	Visual amenity
	Access
	Clean runoff into the harbour
North Head	Conservation of geodiversity; flora and fauna
	Threatened species incl. bandicoots and penguins
	History (aboriginal and defense)
	Protection of the marine environment
	Access
	Amenity
	Connectivity / pathways
Camp Cove Marine Station	Preservation of historic buildings
	Access / impact of increasing traffic
	Conservation
	Future use for education / scientific purposes

The social values of Sydney Harbour are now analysed further, with particular reference to stakeholders, using the eight categories common to the Plans of Management plus a ninth category to represent functional or utilitarian value.

7.2.1 Social Values of Sydney Harbour

Functional / utilitarian value Sydney residents undertake a range of activities on the harbour in which functional or utility value is important, including travelling by ferry or water taxi, catching fish, exercising and various vocational activities (Turnbull, 2014). The harbour provides a useful service in a beautiful setting; in this respect these outdoor activities represent a blend of values for those who undertake them.

Specific examples of functional / utilitarian value in the literature include:

- Commuters –efficient, safe travel; linkages with land-based transport
- Picnickers – use of facilities including BBQs, toilets
- Residents – water quality and drainage systems; stormwater management; ecosystem services
- Swimmers – clean, safe swimming facilities; oyster risks, good nets; personal health- skin
- Fishers – extraction; harvesting edible fish and invertebrates
- Indigenous people – trade / barter of seafood; bush food
- Boaters – storage facilities, safety
- Divers – water quality, visibility, exercise
- Walkers – exercise / fitness

Some functional values are positive to one stakeholder group but negative to another. The extraction of marine life, for example, is a positive value for fishers but results in loss of amenity for snorkelers and SCUBA divers.

Aesthetic value The harbour is recognised internationally for its natural beauty (Tourism Australia 2013). Beauty and aesthetics can be combined with many other values to represent a complete experience, for example whilst walking or fishing (Ghosn et al 2010).

Sydneysiders are concerned about the "destruction of natural beauty" (Turnbull 2014). Specific examples of aesthetics / beauty value in the literature included:

- Sightseers – beautiful, sparkling, pristine waters
- Walkers – enjoying scenery / views / peace and quiet
- Residents – scenic values and visual qualities of the harbour; viewing pleasant and clean-looking water; removal of negative aesthetic impacts (rubbish, damage); peace and quiet; places for isolation, contemplation, reflection
- Divers – on-water and under-water experience; visual beauty, tranquillity

Access / convenience value Access is a value shared by many stakeholders. An integrated approach has been taken to access to the harbour, encompassing boaters, walkers, fishers and commuters (Dept of Infrastructure, Planning and Natural Resources, 2003).

Specific examples of convenience / access value in the literature include;

- Residents – access to viewing points for the harbour
- Commuters – accessibility and facilities for travel
- Picnickers – parking / road access
- Swimmers – road access to swimming facilities

- Fishers – access to boat ramps and fished (vs protected) areas
- Sightseers – multiple landscapes in one experience
- Divers – water access (boat ramps), access to natural areas for diving
- Boaters – access to on-water facilities (ramps, jetties, moorings)

Access represents a potential source of conflict between stakeholders. Boat ramp resources are limited and are busy on summer weekends, creating access conflicts between boaters, divers and fishers. Parking may also represent a source of conflict between residents, picnickers, walkers and swimmers.

Natural / environmental value NSW residents are highly engaged with their natural coastal environment. 87 % of people spend time each year at a beach or waterway and 98 % of residents often undertake environmentally-friendly behaviours (NSW OEH, 2012). Despite our high environmental values, concern for environmental issues has declined in NSW in recent years, due to the lack of a perceived dominant threat to the environment (NSW OEH, 2012). Environmental / natural values are driven primarily by a sense of concern for future generations, a long-term perspective on the conservation natural resources such as water and protection of habitats. Australia-wide, the most salient environmental concern is "environmental sustainability" (Devinney et al. 2012).

Specific examples of environment / nature value in the literature relating to Sydney Harbour include;

- Commuters – protection of marine life
- Walkers – experiencing the natural environment and wildlife
- Fishers- enjoying nature / time outdoors
- Residents – protecting natural / environmental values and assets of the harbour, islands and foreshores; geodiversity; biodiversity; addressing issues (invasive species, erosion); seeing whales and marine life
- Divers – experiencing the marine environment in its natural state

Historical / heritage value Sydney represents significant historical and heritage value, both pre- and post-European settlement. Eight historical themes were identified in the literature (Mitchell McCotter and Assoc. 1988)

Table 26: Historical themes identified in the 1988 Sydney Harbour Background Report

Theme	Heritage item examples (for full list see Mitchell McCotter & Assoc. 1988)
The indigenous population	Over 170 aboriginal sites around the harbour across four tribal groups; Gayimai, Camaraigal, Cadical and Wangal
First settlement	Macquarie Lighthouse
	Government House
	Rocks area
Industries of the port	Hornby Light and cottages at South Head
	Marine Station at Camp Cove
	Goat Island
Immigration	Customs House
	Overseas Passenger Terminal
	Quarantine Station
The threat of invasion	Signal Hill fort
	Fortifications at South Head, Dawes Point, Bradleys Head, Middle Head, Dobroyd Point and North Head
Transport	Sydney Harbour Bridge
	Pyrmont Bridge
	Glebe Island Bridge
Residential expansion	Elizabeth Bay House
	Governors Home at Cranbrook School
	Greenoaks at Darling Point
Leisure and tourism	Harbour swimming enclosures
	Structures at Clifton Gardens
	Sydney Opera House

The Sydney Catchment Regional Environmental Plan identified heritage items by area (2005):

Table 27: Heritage items by area. Source: Sydney REP

Area	No of items	Examples
Parramatta River	52	Spectacle Island Abbotsford Jetty
Sydney and Middle Harbours	85	Man OWar Steps Garden Island Precinct
Lane Cove River	2	Hunters Hill Wharf

Specific accounts of "historical / heritage" value in the literature included:

- Residents – recognition of the exceptional heritage values of the harbour, islands and foreshores; preservation of defence heritage; convict history; working harbour
- Indigenous people – appreciation of the Aboriginal history of the harbour, islands and foreshores, particularly sites of significance; preservation of middens, engravings and other relics; adequate consultation
- Walkers – ability to visit historic / heritage items
- Divers – wrecks

Educational / scientific value Educational, learning and discovery values are important to children and adults. The harbour represents "learning / discovery" value as a destination for school excursions, a place where children experience the "land / sea" interface and explore tidal areas and a place of discovery for skilled adults such as divers. "Discovering a brand new world" is an important value described by Sydney residents (Turnbull, 2014).

Whilst it is also associated with organisational stakeholders, the value of a clean, healthy, diverse harbour is also recognised by the community as a reference and outdoor laboratory for scientific research.

Specific examples of "educational / scientific" value in the literature include:

- Sightseers discovering the magical and mysterious
- Commuters exploring the harbour; access to travel information through multiple channels (mobile, web, poster)
- Residents learning about history, significant places, local environment, personal development (new skills, learn about marine life); educational experiences for children
- Divers discovering new sites, marine species, learning about an alien world, seeing nature in its healthy state

Leisure / recreational value The harbour is important in the recreational and leisure opportunities that it provides. Leisure activities take place on land, on water and at the tidal interface. Specific examples of "leisure / recreation" value in the literature included;

- Walkers – relax and unwind
- Fishers – escape, relax, unwind
- Residents – general recreational uses of the harbour; having fun on the shore and in the water
- Commuters – enjoyment of travel on the water
- Swimmers – freedom of movement and relaxation associated with swimming
- Sightseers – happy, informal, relaxed

Social / community value Despite the variety of stakeholders in Sydney Harbour, users generally value harmony between groups (Cardno 2012). Residents specifically highlight the importance of family time, sharing the beach with family and friends (Turnbull, 2014). Sydneys outdoor celebration culture makes use of the harbour for many social and community events such as New Years Eve and Australia Day.

Specific examples of "social / community" value in the literature included;

- Picnickers – time with friends and family
- Residents – ability to hold social gatherings in a local public setting; companion animals; welcoming visitors
- Fishers – companionship; time with friends and family
- Indigenous fishers – sharing food
- Divers – dive clubs that use the harbour

Cultural / spiritual / ethical value The harbour is seen as an important part of the identity of the residents of Sydney; as our way of life (Turnbull, 2014). The spiritual connection extends to passing on a healthy harbour to future generations and providing a natural environment for the benefit of charismatic wildlife such as whales and turtles.

Specific examples of "cultural / spiritual" value in the literature included;

- Residents – protection of the cultural values of the harbour; preservation of our unique identity; public art; participation in restorative volunteer activities; historic remediation; addressing unsustainable practices; animal welfare (wild animals, marine); adequate enforcement; visitors doing the right thing (rubbish); sustainable approaches to management
- Indigenous people – ceremonial occasions; sense of belonging; cultural relics and sites
- Fishers – time alone / solitude; sustainable fishing practices; legal fishing practices
- Swimmers – experience of swimming in outdoor pools; getting away from it all, freedom of movement
- Walkers – being in nature; escape; ephemeral, ever-changing landscape
- Commuters – sustainable waterways
- Divers – volunteering, citizen science; experience of "weightlessness"
- Boaters – low impact boating (invasive species, anchoring practices)

7.3 Discussion and Gaps

In general, there was a marked shortage of information in the source documents relating to the social values of Sydney Harbour. In a number of cases, documents were difficult to find (for example the 1988 Mitchell McCotter and Assoc. Background Report that took several weeks to locate) so even the small amount of information that we do have is likely to degrade over time. Social values also change over time and are context-specific so research older than a few years, or not specifically targeting Sydney Harbour, is of limited relevance.

There were no recent, comprehensive reviews of the stakeholders or the social values of Sydney Harbour. Information was either contained in documents as part of more general reviews, or was specific to a given context within the harbour such as "Fishers" or "Lane Cove River". Of the stakeholders of the harbour, fishers have received a disproportionately high level of attention in past research with two government studies that include fisher motivations (1980 and 2006). No equivalent studies were identified on other stakeholder groups despite equivalent levels of use by, for example, walkers, swimmers, divers, picnickers and boaters.

Within these limitations, some documents did represent quite good examples of social values work. The Clontarf / Bantry Bay Estuary Management Study (Manly Council 2007) provided the best example, encompassing stakeholders, social values and even conflicts in values that have to be managed. Other documents, such as the Coastal Zone Management Plans, focused heavily on the natural processes and environment with little reference to social values.

7.3.1 Maturity Model Extant Literature

The following table outlines the general level of maturity of each type of source document with respect to social values. This is a general assessment only and does not represent detailed, specific critique of every document. The table uses four levels of maturity in social values content;

- SA – (Stakeholder Analysis) – document contains a description of the community / social stakeholders and their priorities and issues
- VG – (Values in General) – document contains a high level description of the social values that are relevant to the specific context
- SV – (Stakeholder Values) – document contains an analysis of the values that are shared or conflicting across stakeholder groups
- MO – (Management Outcomes) – document proceeds to describe management outcomes that are aligned with the social values

There are three levels of assessment;

- 0– this level of maturity is not included in this type of document
- 1– this level of maturity is partly covered in this type of document
- 2 – this level of maturity is comprehensively covered in this type of document

Table 28: Sydney Harbour maturity model. Source: SIMS Unpublished

Document type	Example Reviewed	SA	VG	SV	MO
Catchment Action Plan	Hawkesbury-Nepean	1	1	0	2
Background Report: Regional Environmental Study	Sydney and Middle Harbours: Regional Environmental Study 1988	1	1	1	0
Regional Environment Plan	Sydney Harbour Catchment 2005	1	1	0	0
Marine Park Zoning Plan Report	Solitary Islands	2	1	1	1
Plan of Management	Local Councils	0	2	0	1
Management Study	Clontarf / Bantry Bay Estuary	2	1	2	2
Coastal Zone Management Plan	Lane Cove River, Parramatta River	0	1	0	0
Strategic Plan	Sydney Harbour Foreshores Trust	0	2	0	1
Development Control Plan	NSW Dept of Planning	0	1	0	1

7.3.2 Social Values by Stakeholder

An understanding of the values of different stakeholder groups, and the extent to which these values are shared or are in contrast between different stakeholders, is an important part of management and planning. Shared values can be leveraged in decision-making with little fear of community backlash, for example most stakeholders value clean water. Contrasting values must be traded off as part of any decision, for example where access is limited (who will get priority?) or where extraction of resources is valued by one group but will inhibit the experience of another group (fishing removes marine life that divers would like to see).

The following table provides a summary of the values that have been found in the literature. Caution is required in using this table as it does not represent a comprehensive study. Gaps are evident in the table, for example it is expected that boaters and picnickers would place importance on recreational and leisure values, but this is not clear in the reviewed literature. Further research is required to construct this table in a way that is accurate for the Sydney Harbour context at the current time. Ideally such a table should also represent the relative importance of each value to each stakeholder.

Table 29: Stakeholder experiences matrix

	Functional	Aesthetic	Access	Natural	Historical	Educational	Recreational	Social	Cultural
Commuters	1		1	1		1	1		1
Swimmers	1		1				1		1
Walkers	1	1		1	1		1		1
Fishers	1		1	1			1	1	1
Divers and snorkelers	1	1	1	1	1	1		1	1
Boaters	1		1						1
Picnickers	1		1					1	
Sightseers		1	1			1	1		
Residents	1	1	1	1	1	1	1	1	1

8 Synthesis of economic benefit from various types of harbour use

In this section we reviewed data, studies and other available information on the economic values of Sydney Harbour. We were unable to find any published paper on the economic value of Sydney Harbour as a whole.

The references presented in this paper were categorised into eight groups of economic values. Some were amenable to estimation of financial value; others were partially but not fully monetised or could only be quantified in terms of numbers of users or some other non-financial figures. Some were particularly difficult to quantify at all. It is important to recognise that economic values are more than only financial values. Economic values include many assets and activities that people value very highly, without quantifying or paying for them. These values can be just as important, and in some cases more important than financial values.

8.1 Eight groups of economic values researched for Sydney Harbour

The groupings of categories, used here for organising information about the economic values of Sydney Harbour are:

1. Harbour functions: ports, maritime activities, transport, Royal Australian Navy
2. Tourism and the cruising industry
3. Harbour foreshore attractions and events
4. Incremental land values close to the harbour
5. Harbour-related businesses selling retail and offering services
6. Outdoor leisure and sporting activities
7. Ecosystem service values and indicators of valuing environmental quality
8. Cultural heritage and the arts, icons and civic pride and landscape and spiritual values

Social analysis, presented in Section 7, addressed the non-market values more directly. It is important to note that the social and economic groupings of values often overlap. While the order and definitions are differently expressed, they cover a similar territory and are consistent with the economic categories. The emphasis is somewhat more on those values that are measured in some way in this section, but the importance of the less-measurable is clear in both.

8.2 Harbour Functions

8.2.1 Sydney Ports

A study of the economic impact of Sydney's port infrastructure was done in 2003 based on 2001 – 2002 figures (EconSearch, 2003). It projected revenues for 2009 – 2010 that would equal about $500 million in direct impact and $1 billion in total impact for the port (separating out the other ports in NSW) in today's dollars. Because the projections from this report are dated, these numbers are considered to be superseded now.

The most recent annual report (SPC, 2013) stated that Sydney Ports Corporation's core business focus for this year, in reference to Sydney Harbour, was on navigation and safety, pilotage, cruise, dry bulk and oil shipping, the management of cruise terminal assets at Circular Quay (Overseas Passenger Terminal) and White Bay and of dry bulk facilities at Glebe Island.

Current projects in Sydney Harbour include further developing Glebe Island as a dedicated dry bulk handling precinct and an integral part of Sydney's working harbour, once its time as an interim convention

centre is over. Upgrading the Overseas Passenger Terminal to handle larger ships and provide quicker turnaround time will include projects totalling about $49.4 million.

There were 240 cruise ship visits for the year, a compound annual growth of more than 26 % per year for the last several years. The White Bay Cruise Terminal was completed and opened with two berths; a $57 million facility. Sydney can now host three cruise ships simultaneously.

Sydney was again voted Best International Cruise Port for the eighth consecutive year in 2013. From 1 July 2013, lines pay a per passenger charge of $18 per 24 hour period, that will rise to $25 per passenger for 2014 –20 15 and $30 for 2015 – 2016.

Financial accounts were given in terms of total operations, thus including Port Botany and the smaller ports. Sydney Harbour had 522 chargeable vessel visits in 2012/13, however, Botany Bay had about three times that number. Total revenue from operating activities in 2012 – 2013 was listed as nearly $65 million, of which about $52.2 million was from port revenue and $12.8 million from rental revenue.

In last year's report, Sydney Ports Corporation stated that combined

> *our ports handle more than $61 billion worth of trade each year, contribute about $2.5 billion to the NSW economy, and generate employment for more than 17,000 people throughout the logistics chain. (Sydney Ports Corporation Annual Report, 2012 – 2013).*

8.2.2 NSW Roads and Maritime Services

NSW RMS manages a wide variety of marine and boat-related activities. It is the land owner of Sydney Harbour. It also leases facilities and provides an overview of the types of facilities covered, which include private and community boating facilities as well as commercial infrastructure (NSW RMS, *http://www.maritime.nsw.gov.au/mpd/leasing.html*, accessed 26/3/2014). Much of the Maritime information in the NSW RMS (formerly NSW Maritime) 2012 Annual Report (NSW RMS 2012) was in terms of the entirety of NSW, not just Sydney Harbour. Their website (NSW RMS, *http://www.maritime.nsw.gov.au/about/aboutus.html*, accessed 26/3/2014) provided the scope of their work in terms of area covered as well as activities.

The maintenance and upgrade of the commuter wharves in Sydney Harbour is also the responsibility of NSW RMS (NSW Transport, 2012). The annual report included mention of expenses in Sydney Harbour including for 'Sharing Sydney Harbour Access Program' grants, for the upgrading of boat ramps, and for various harbour wharfs. Other sorts of expenditures for NSW are listed without separating out those in Sydney Harbour.

NSW RMS managed projects include;

1. Berrys Bay proposed maritime precinct (marina facility, dry vessel storage, vessel workshop area, maritime businesses, retail food outlets)
2. Large visiting vessel facility, Pier 2/3 Walsh Bay
3. Sydney Cove Improvement Plan
4. Blackwattle Bay Maritime Precinct (charter vessel marina and redevelopment plans)
5. Rozelle Bay Maritime Precinct (boat repair and maintenance facility, super yacht marina, dry stack storage facility with marina, marine contracting facilities, catamaran facilities). Once complete, these projects will provide more than $ 150 million of infrastructure for the industry.
6. White Bay Cruise Terminal

8.2.3 Military installations

A number of websites described the historical importance of Sydney Harbour's fortifications for defence. Some of these sites have been converted to parklands (see below).

The Royal Australian Navy website (RAN, *https://www.navy.gov.au*, accessed 15/6/2013) described the Navy's current and historical sites around Australia, including in Sydney Harbour. The primary site is Fleet Base East (FBE) in Sydney Harbour. Today HMAS Kuttabul is the administrative centre for FBE, a precinct that includes the Garden Island dockyard and adjacent wharf facilities at nearby Woolloomooloo. Training sites and medical facilities at HMAS Penguin are active and important facilities as well.

Fleet Base East and the navy training facilities are arguably of great value to Australias military and defence system. No evidence of a monetary valuation of the Sydney Harbour military operations or its infrastructure was found.

8.2.4 Harbour transport

> *"In July, Harbour City Ferries (HCF) - a partnership between Transfield Services and Veolia Transport Australia - took over the operation of Sydney Ferries. This was done under a service contract with TfNSW designed to benefit customers with the best of private sector experience and management practices. Control of key assets and strategic decisions will remain with the NSW Government. The contract requires the operator to meet a number of performance benchmarks in key areas including safety, reliability and customer service. The contract also delivers significant improvements in value for money for taxpayers. (Transport for NSW Annual Report 2012-13)*

In 2013, this new arrangement was reported in the NSW Department of Transportation Annual Report. Some figures for the ferry services were mentioned, including increases in numbers of passengers (Table 30)

Table 30: Comparison of ferry performance indicators (source: Transport for NSW Annual Report 2012– 2013

Performance Indicator	2011-12	2012-13	Change from 2011 – 2012 to 2012 – 2013
Passenger Boardings	14768332	14943173	1.2%
Scheduled Ferry Trips	173329	174029	0.4%
Passenger Boardings / Ferry Trip	85.2	85.9	0.8%

In this report most of the extensive financial reporting is for the transport operations as a whole, including rail, buses, RMS and more. Only a few financial figures for ferries are mentioned, mostly under service group statements where total figures for expenses and revenues are less than 1 % of the total expense and revenues and the net result for the year is negative. But this now represents an oversight role of NSW Transport to the franchise-holder Harbour City Ferries.

The previous NSW Ferries Annual Report (NSW Transport, 2012) available from (http://www.harbourcityferries.com.au/ Includes information on routes, fleet and various performance indicators from the previous year. Some of the information is summarised here as an indication of scale:

Total revenue was almost $163 million, costs were almost $153 million, and operating surplus was $9.8 million in 2011– 2012 Cost per passenger journey in 2011– 2012, was $8.50. Over 14.7 million passenger journeys were recorded in 2011– 2012 About 31 % of all passenger journeys were made by people commuting to work or education, while 47 % were for sightseeing/leisure and 21 % were for private business, such as shopping, meeting friends or attending appointments Manly, which carried 5.8 million passengers, was the busiest route Inner Harbour routes accounted for 7.2 million passengers in total Parramatta River services carried almost 1.8 million passengers A total of 656 full-time equivalent staff were employed as of 30 June 2012. The websites for Manly Fast Ferries (https://www.manlyfastferry.com.au/) and Sydney Fast Ferries (http://www.sydneyfastferries.com.au/) both provide information about their operations, but not financial information as both are private companies. Harbour water taxis There are about 15 water taxi companies operating on Sydney Harbour. Their fares are considerably higher than the ferries but financial information is lacking as they are private companies.

Harbour water taxis There are around 15 water taxi companies operating on Sydney Harbour. Their fares are considerably higher than ferry services but financial information is lacking as they are private companies.

8.3 Tourism and Cruising industry

8.3.1 Tourism

'Destination NSW' provided annual data on tourism including numbers of visitors, their preferred activities and their expenditure (Destination NSW, 2013). Data was provided for both national (day-trippers and overnight) and international cruises. Sydney was judged to be Australias leading gateway, and the most popular destination for overseas visitors. It also stated whether the prime motivation of the visitors was holiday/pleasure, visiting friends and relatives, business or other. The total revenue that tourism brings to Sydney was $13.5 billion in 2012. It was not possible to separate out how much of the visitors time and money was spent directly on activities in, on and around the Harbour.

The city received 10.5 million visitors in 2012 (City of Sydney, 2013), and visitor direct expenditure contributed over $5 billion to the cities economy (City of Sydney, 2013). It is predicted that tourism supports over 10, 000 businesses in the city (City of Sydney, 2013). More than 6.8 per cent of the LGA workforce is employed in the citys tourism industry; an estimated 26,700 people.

'Destination NSW' website also linked to 'Tourism NSW' website, an archive of older documents from the tourism sector (*www.destinationNSW.com.au*, accessed 25/5/2013). These included older documents on the economic value of the tourism sector, with comparisons to other sectors and international data.

Deloitte Access Economics website (*http://www.deloitteaccesseconomics.com.au/tourism*, accessed 1/3/2014) provided periodic updates with long term trends in tourism overall.

Websites promoting tourism in Sydney generally listed things to do and some sites also rank them. For example, on the website 'Top things to do in Sydney' (*www.sydney100.com*, accessed 26/3/2014), the top 10 activities listed all involved Sydney Harbour .

'Trip Advisor', a widely used travel planner that provides user submitted information and reviews (*www.tripadvisor.com.au*, accessed 26/3/2014) listed Sydney Harbour as number 1 of 183 attractions in Sydney. These rankings are based on travellers reviews.

The company 'TNS Australia' compiled a report (TNS Australia, 2011) that reported which sites were the best in terms of "performance" in drawing visitors. The report gave no economic figures. It does state "Darling Harbour and the Rocks see highest performance" indicating the importance of sites on or near the harbour. Also five of the six full-page pictures in the report were of the Harbour.

A recent study on the ongoing Darling Harbour redevelopment (Darling Harbour Live, 2013) focused on tourism. The fact that the region directly borders on the Sydney Harbour waterfront is explicitly stated; the Waterfront, on the edge of Cockle Bay will become a new civic space. The Darling Harbour redevelopment website (*www.darlingharbourlive.com.au*, accessed 26/3/2014) also gave an estimate for incremental revenue to be expected. It projected a future annual economic benefit for NSW of $200 million/year and 4,000 jobs.

Barrowclough reported (Barrowclough, 2011) that Australia's comparative advantage in tourism lay largely in Australia's unique experiences, particularly wildlife and outdoor activities and ecotourism.

In a report on Australian tourism (BDA Marketing Planning, (no date)) 'aquatic wildlife experiences' topped the list of thematic appeals, averaging 50 % appeal. 'Non-aquatic wildlife' and 'beach/coastal/harbour' scored 41 % each, and were ranked #2 and #3.

In another report, BDA Marketing Planning (2012) suggested that Sydney is well-placed to emphasise the arts by developing a promenade of international significance linking the Art Gallery of NSW, the Botanic Gardens, the Opera House, Circular Quay, MCA Australia, The Rocks, Walsh Bay and Barangaroo. The harbour was not mentioned, yet all but the first of those destinations are located on the harbour waterfront.

The Destination NSW website (*www.destinationnsw.com.au*, accessed 20/5/2014) often refers to Sydney as the "Harbour City" in articles such as "Sydney FC to showcase our Harbour city in Japan" and "Vivid Sydney lights up Harbour City".

8.3.2 Cruising Industry

In its submission to the Barangaroo Review, 'Carnival Australia' (Carnival Australia, 2011) presented summary statistics on the growth and value of the cruise industry, declaring it the best performing part of the tourism industry, with an estimated annual growth in the market of 24 % from 2005 – 2013. It projected that one million passengers would be cruising from Australia by 2015. The report also stated that cruising contributed $221 million to the NSW economy based on the 2007–8 data and projects it to be more than $660 million in 2011.

'Carnival Australia' states also states;

> *An Access Economics report prepared in 2009 but based on 2007–2008 data found cruising contributed $1.2 billion to the Australian economy*

and that

> *Based on current growth patterns, there is every reason to believe that cruising now contributes at least $3 billion to the national economy. (Carnival Australia, 2011)*

'Cruise Lines International Association Australasia' (CLIAA, 2012) produced an industry report for 2012 that summarises the industry more globally and Australia's place in it.

Sydney Ports Corporation website included a section on cruising (*http://www.sydneyports.com.au/port_operations/cruising, accessed20/5/2014*). It stated that 259 cruise ship visits are scheduled for 2013 – 2014, more than double that of 119 in 2009 – 2010. It also cited the opening of the new $57 million cruise facility at White Bay in April 2013.

'Cruise Down Under' (AEC Group Ltd, 2013) reported that the total output of the Australian cruise shipping industry in 2012–2013 was $2.06 billion, including direct expenditure of $1.23 billion. This was a 20.6 % increase from 2011– 2012, when total output was estimated at $1.71 billion. The figures for Sydney Harbour showed a direct expenditure in Sydney by the cruise ship industry in 2012– 2013 of $1.0247 billion.

8.4 Major events on Sydney Harbour and its foreshore

In a NSW state planning document (NSW 2021, 2013) it is stated that tourism and events were a $28 billion a year business and support more than 162,500 jobs across the State. Here tourism and special events were cited together, and the data is for all of NSW.

Tourism research suggests that NSW is

> *Well-placed to capture benefits from events and festivals, with Sydney recognised in 2010 and 2011 as the best festival and event city in the world (BDA, 2012, International Festival and Events Association 2012)*

but does not give financial estimates.

Some results of special events are cited in media releases from the office of the Minister for Tourism. In one, for example (Souris, 2012) the NSW Events Calendar was estimated to generate more than $600 million in annual revenue for NSW.

In a media report on the fireworks for New Years Eve in 2013 – 2014, (City of Sydney, 2014), Lord Mayor Clover Moore said the event's world-famous fireworks displays attracted more than 1.6 million people to the harbour foreshore. The event generated an economic boost of about $156 million for local businesses. NSW Roads and Maritime Services Annual Report for 2012 (NSW RMS 2012) states that New Years Eve on Sydney Harbour celebrations annually attracted an estimated 2500 to 3000 spectator vessels.

According to a Destination NSW media release, *Last year the Sydney Festival attracted more than 500,000 people with more than 120,000 tickets sold to paid events, including more than 33,000 people who attended*

events in Western Sydney. In 2012, it injected almost $57 million into our economy, (Destination NSW 2014).

8.5 Land values and real estate prices close to harbour

8.5.1 Higher residential land and/or real estate prices

Government data on quarterly real estate sales, reported in NSW Rent and Sales Reports, are issued regularly and provided sales and rent data (*http://www.housing.nsw.gov.au/About%2BUs/Reports%2BPlans%2Band%2BPapers/Rent%2Band%2BSales%2BReports/*, accessed 20/5/2014)) on LGAs (Local Government Areas) that break down to large concentric rings around the centre of Sydney.

Ideally data on land or real estate prices for areas closest to the harbour would be compared to similar places further away. Data on real estate prices, however, are not reported on the basis of proximity to the Harbour.

To some extent, this evaluation was completed in the work on valuing Sydney's beaches (Anning, 2013), where values of 'views' were calculated along with tourist days spent at the studied beaches.

LGA-level data can be used, however, to compare the median prices for the 'Inner Ring' to the median prices of all the suburbs adjacent to the harbour. If combined with the areas of the LGAs, this may give a rough indication of incremental value of proximity to the Harbour compared to proximity to the CBD.

Since 2012, Australian Bureau of Statistics (ABS), has started using a more refined system of geographical boundaries, called 'Statistical Areas'. On the ABS website (*www.abs.gov.au*, accessed 20/5/2014) it is possible to construct maps of these areas by selecting levels and some data as well, mostly demographic, produced in census taking, but no real estate or land values. Discussion with NSW Land and Property Information, NSW (NSW LPI, *pers. comm.*) made clear that NSW LPI does not use the new ABS system of Statistical Areas. NSW LPI could construct a database of land values around the harbour that could be compared with land prices in Sydney generally, but that would require writing a program to extract the data properly and the cost would be high (e.g. a medium search of 10,000 records would cost about $45,000). It is not clear what could be done between government departments.

NSW LPI has digital cadastral databases (*http://www.lpi.nsw.gov.au/mapping_and_imagery/cadastral_data*, accessed 20/5/2014). Two in particular, "Hydrology features including the coastline and drainage patterns" and "Domestic Waterfront Precinct" may be of use in creating a map of incremental real estate values.

NSW LPI also provides tables with some land values for representative property (both residential and commercial) based on a few suburbs and representative properties. It might be possible to get the data to construct tables that would include all the suburbs that are adjacent to Sydney Harbour and numbers of properties in each and also for median land prices for each category for Sydney. This would give rough estimates for comparison and estimating the incremental value for real estate close to the harbour.

'RPdata' (*www.myrp.com.au*, accessed 20/5/2014) also supplies extensive sales data. 'RPdata' appeared to have more information about hedonic values of real estate, which might make possible the separation of values due to characteristics of houses vs. characteristics of neighbourhoods, in particular proximity to the harbour. Again, the question might be the expense of getting the information vs. the usefulness of it.

> *"Perhaps the most exciting methodological development is the introduction of hedonic price indexes to the Australian market. This approach to price index construction controls for compositional change by obtaining information on housing characteristics (e.g. bedrooms, bathrooms, land size, suburb, etc.)." (www.myrp.com.au, Rismark Daily Home Value Index)*

8.5.2 Higher commercial land and/or real estate prices

Commercial real estate is very complicated and very extensive. The amount of data needed would be daunting, unless the data from NSW LPI, cited above could be made available in a format suitable for making a comparison.

'RPdata' (*www.myrp.com.au*, accessed 20/5/2014) also supplies commercial real estate rental data.

8.6 Harbour attractions and businesses selling retail and offering services

The distinction between attractions and icons is somewhat arbitrary, but not all attractions are icons. Most harbour attractions such as Luna Park, Taronga Zoo, all the activities in Darling Harbour and The Star are commercial or, in some cases, mixed commercial and government enterprises. Taronga Zoo received around half of its total income of about $83 million in 2011 – 2012 from admission, trading sales and franchise revenues (Taronga Conservation Society of Australia, 2013). Its site on the harbour foreshore, with dramatic views, adds amenity value, making it particularly valuable for both domestic and tourists visitors. There are many commercial businesses that benefit from proximity to the harbour, but data on such private businesses are 'commercial in confidence'. Where studies of a class of businesses have been done, good data may be available, however we were unable to find such data.

A listing of such businesses may include;

- Water taxis and limousines
- Marinas and commercial dock businesses
- Boating related businesses: Boat mooring rental fees; sales of fuel, maintenance contracts; Boat sales, repairs, parts etc. (25 boat dealers in Sydney are listed on *www.boatsonline.com.au*, accessed 20/5/2014)
- Fishing related businesses, bait and tackle shops; fishing gear sales
- Other water sport related businesses, sales and rentals of kayaks canoes; stand-up paddle (SUP) boards; scuba gear
- Sailing, scuba and kayak schools and trips
- Harbour organised activities and trips including wind, history and dinner cruises, SIMS ecology cruises; whale watch trips; fast thrill boats
- Boats to charter for numbers from under 36 passengers to over 800
- Seaplane sight-seeing flights and commuter flights
- Harbour-side dining businesses

There are websites for commercial companies offering all of the above. For example, 'Sydney Harbour Escapes' website (http://*www.sydneyharbourescapes.com.au/boat-fleets/view-all-charter-boat-fleets*, accessed 20/5/2014) offered almost 28 small boats, 22 medium sized and 16 that can take between 70 and 800 guests and claims to only offer boats from companies screened for quality and reliability. Charter rates are also posted, but not overall market figures although 'Sydney Harbour Escapes' may have figures for the industry.

8.7 Outdoor and sporting activities on and around the harbour

> *This outstanding environment is an extremely popular venue: the Boating Industry Association (BIA) estimated ten years ago that more than one million people use Sydney Harbour for water-based recreation activities each year.(Access UTS, 2004)*

This confirms that boaters have leisure/ recreation and social/ community values through recreational use of the harbour, and social clubs that offer services and access related to maritime uses.

The Transport for NSW Sydney Harbour Boat Storage Strategy 2013 states that in 2012 there were 217,000 recreational vessel registrations of which 8 % within Sydney Harbour, registrations growing at 2.9 % since 1999 and trend forecast to 2026. (page 3). The rising trend in recreational vehicle registration and ownership confirms boater values for leisure/ recreation or social/ community.

8.7.1 Boating

There are about 10,000 storage spaces for Sydney Harbour, but 17,000 recreational vessels, so many boats are stored in Sydney's streets. A monthly berth east of the Sydney Harbour Bridge now costs on average $2600, up from $1900 a decade ago. The problem of boat storage is likely to continue as boat registrations in NSW are predicted to go from the present 219,000 to 335,000 by 2026 (Hasham, 2013). NSW RMS has now completed a draft Boat Storage Strategy for Sydney Harbour which has provided guidance on the development of new 'off water' storage solutions, as well as a range of options for current and future 'on water' storage solutions (NSW RMS 2013).

In recent years there were over 40 private marinas (Widmer and Underwood, 2004), over 4,700 private moorings and about 570 private berthing pens or jetties and 14 rowing clubs with boat shed access (Williams, 2009 quoted in Ghosn et al, 2010).

NSW Maritime has produced the report 'Boat Ownership and Storage: Growth Forecasts to 2026' that covered the whole of NSW but also broke some of the data down into regions (NSW Maritime, 2010). It showed 19,128 recreational and commercial boats operating in Sydney Harbour out of a total of 228,643 in all NSW. With 18,011 recreational boats, Sydney Harbour accounted for only 8 % of the recreational boats in NSW but the 1084 commercial boats amounted to 20 % of NSWs commercial fleet. The report also forecasted boat growth and the need for more on-water boat storage, but did not include any financial data.

8.7.2 Boating and other clubs on Sydney Harbour

NSW has 90 sailing clubs, according to the website of 'Clubs of Australia' (*www.clubsofaustralia.com.au*, accessed 20/5/2014); about 30 of them on Sydney Harbour. A web search for boating clubs on the harbour comes up with more than 40 by name, including dragon boat racing clubs.

These clubs generally charge membership fees, may have restaurants and bars, and some have retail sales or offer other services. No study of their economic value has been found, but it would be considerable.

8.7.3 Recreational fishers from boats and from land – Sydney Harbour fishing survey

Fishing World magazine reported favourably on a survey done of recreational fishers in the summer of 2008 by NSW DPI in an article entitled 'Fishos favour Sydney Harbour' (Fishing World, 2010).

The recreational fishing survey found (Ghosn et al, 2010) that over 300,000 hours of fishing was done in the harbour over the summer of 2008 and over 32 different fish species were caught. The survey covered the area west of the Sydney Harbour Bridge, including the Parramatta and Lane Cove Rivers and east of the Bridge, including North and Middle harbours.

The weight of fish caught could be multiplied by a retail price per kilogram of fish, but that would undervalue the enjoyment recreational fishers get from their fishing. On a purely cost basis it would be cheaper to go out and buy fish.

8.7.4 Expenditure by recreational fishers

The Australian Bureau of Agricultural and Resource Economics (ABARE) stated that 5 million Australians report that they have engaged in recreational fishing at least once a year and the total amounts spent in pursuit of recreational fishing activities are substantial. These figures appear to be based on the Henry report, an extensive survey of recreational fishing in Australia, published in 2003 based on surveys conducted in 2000

– 2001 (Henry and Lyle, 2003). NSW DPI estimated that 1 million people engage in recreational fishing in NSW waters each year (NSW DPI, 2008).

A report on the expenditure of recreational fishers in NSW (McIlgorm and Pepperel, 2013) made more recent estimates as part of a study into methodologies for such estimates. This study covered NSW in four regions, with an estimated 491,232 recreational fishers based in the greater Sydney region out of a total of 776,496 for NSW-based on adult fishers.

The expenditure survey above was based on the residence of the respondents and not the location of expenditure (McIlgorm and Pepperel, 2013). An estimated 51.5 % of the Sydney region anglers fished elsewhere in NSW. Expenses per trip for NSW anglers included $162.59 for travel, lodging, entertainment etc and $87.47 for fishing equipment expenses for a total of $250.07 per trip (average of 1.5 days/trip). Other reports suggested similar or smaller amounts with Sydney day fishers spending around $100/day (2003 figures, 2012 dollar equivalent would be about $128/day; Dominion Consulting Pty Ltd, 2003).

McIlgorm and Pepperel (2013) do not give value of expenditure on recreational fishing in Sydney Harbour, but given the results of the summer survey of recreational fishers in Sydney Harbour, where 96 % of the fishers were local day-fishers and most of the fishing is from shore (Ghosn et al. 2010), it is very likely that the average expenditure for fishing in Sydney Harbour would be considerably lower than the $250/trip average for Sydney fishers, roughly half of whom were estimated to have travelled to other parts of NSW to fish.

8.7.5 Swimming at harbour beaches

A web search looking for total numbers of swimming beaches in Sydney Harbour reveals upwards of 50 names (see also Section 7.1.3). A total count seems hard to find, but the point is clear: Sydney Harbour offers a very large number of beaches for swimming, but the number of swimmers or swimmer-days seems to be unknown. Under the category of ecosystem services, there is a category of valuing swimmable water (Table 31). If the number of swimmer-days in the harbour was known, and a reasonable value per swimming in one day found, a value could be estimated.

8.7.6 Snorkelling and SCUBA diving

> *Sydney is home to several hotspots that veteran pipe-breathers reckon are among some of the best snorkelling sites in the country. (Time Out, http://www.au.timeout.com/sydney/sports/features/6735/sydneys-top-5-snorkelling-spots, accessed 26/3/14)*

> *There are over 500 species of sea life in the harbour including seadragons, cuttlefish, seahorses, octopi, blue swimmer crabs, pygmy leatherjackets, Port Jackson sharks, starfish, blue groper and many many more. (Weekend Notes, http://www.weekendnotes.com/sydneys-best-beaches\-for-snorkelling, accessed 26/3/14)*

Several harbour beaches are among the top recommended spots including Clontarf, Balmoral, Chowder Bay, Manly Cove and Little Manly Beach, Chinamans Beach, Bare Island and Congwong Beach, Camp Cove as well as ocean beaches.

Scuba diving in the ocean off Sydney, but also in Sydney Harbour, is highly praised by divers. Advertisements and individual websites indicate the popularity of the estuary for diving. There are around a dozen dive shops in Sydney and one individual site lists 14 dive sites within the Harbour (Micheal MacFadyan's Scuba, *www.michealmacfadyansscuba.info*, accessed 22/4/2014)

In a poll taken for the Dive Industry Association of Australia (Dive Industry Association of Australia (DIAA), *pers. comm.* See Section 7.1) 6 % said they scuba dive and 25 % said they snorkel. Since there are most likely overlap between the two groups, the implication would be that 25 % of the residents of NSW either scuba dive or snorkel or both. Additional data on usage have not been found.

8.7.7 Picnicking and walking at harbour-side parks, and walking trails

The Sydney Harbour National Park Draft Plan of Management (NSW Environment, Climate Change and Water NPWS, 2010) made statements implying that there is a link between the park and financial revenues, and between the park areas and values that are important to people. Unfortunately, it did not provide economic values or quantitative measures for any of these.

There are reports every two years on annual visits to NSW NPWS managed parks (Roy Morgan Research, 2013). They mostly gave state statistics, but some of the information is broken down by selected individual parks. Sydney Harbour National Park received 1.098 million domestic visitors in 2012. Lane Cove National Park (along Lane Cove River, 973000 visitors in 2012) and Garigal National Park (at the upper reaches of Middle Harbour, 388000 visitors in 2012) are partly within the Sydney Harbour area.

The Sydney Coastal Councils Group website Walking Coastal Sydney gave a comprehensive description and maps for coastal walks (Fig. 24.

A National Parks and Wildlife Service visitor survey (NPWS 2005) in several park areas showed that 71 % of visitors travelled less than half an hour to reach the park, suggesting parks around Sydney Harbour may be generally frequented by locals. Travel costs would therefore not adequately value these areas.

At time of writing, we are not aware of any social surveys and valuation studies for use of the parks around Sydney Harbour, although a number are reported for NSW generally. Social valuation of the harbour and areas bordering on the harbour is treated under the social values chapter of this report.

8.8 Ecosystem service values

A large number of studies have been conducted recently using the concept of 'ecosystem services' to value specific natural resources. These are generally based on the work of Costanza et. al., (1997). Similar studies from around the world have compiled regional and national data to come up with syntheses of methods and estimated values of these resources. Some studies have also focused on valuing coastal and ocean resources including an overview by Ledoux and Turner (2002) where 58 studies were listed from various countries, but none from Australia. Despite the popularity of these types of analyses for natural resources around the world, none have been completed for the Sydney Harbour estuary.

A valuation of estuarine systems in Australia more generally has been conducted (Blackwell, 2005). These results were considered preliminary. Figures (updated to 2012 $) are shown in Table 31.

Table 31: Micro-assessment, valuing Australian estuaries (Blackwell, 2005 updated to 2012 A$). WTP: WIllingness to Pay, CS=Consumer Surplus

Ecoservice	WTP	CS	Market Value	SUM
	(in 2012 $.km^2)			
Protection	156308			156308
Water quality	658940			658940
Recreational boating		39146		39146
Fishable water	2149577			2149577
Swimmable water	1700086			1700086
Fish conservation	208056			208056
Food, fisheries			4126	4126
Recreational fishing			24691	24691
Port services			4174	4174
Total for study estuaries, value per km2	4872967	39146	32990	4945103

Using these figures the total value of ecosystem services for Sydney Harbour would be over $175 million/year. Using the Constanza et al. (1997) figures (for the whole Sydney estuary) would give a value of about $150 million/year. These figures are only indicative.

Many studies were done in recent years investigating the economic evaluation of ecosystem services. Some examples included applying ecosystem services as a common language for ecosystem- based management (Granek et al., 2010) identifying some of the controversies in defining the contributions to human well-being from functioning ecosystems (Costanza et al., 2010), valuing ecosystem services in terms of ecological risks

and returns (Abson and Termansen, 2011) and arguing for a more comprehensive multicriteria assessment dialogue and processes (Turner et al., 2010, Schmitt and Brugere, 2013). These papers are not further discussed here but are listed in the appendix.

8.9 Biodiversity values, endemism

Given the diversity of Sydney harbour's marine life, biodiversity values are likely to be high and worth investigating. Attempts to value the biodiversity of Sydney Harbour have not been found.

An example of a valuation of biodiversity relative to marine leisure and recreation industries was attempted in the UK in Lyme Bay, an area where fishing, diving and wildlife watching are important (Rees et. al. 2010), using both monetary and, to some extent, non-monetary measures. The authors commented on the difficulty of adequately representing non-monetary values:

There is still an issue of how to value the irreplaceable and fundamental supporting and regulatory functions of marine biodiversity and its intrinsic value when set against competing economic interests in marine spatial planning. This issue will continue to underpin the case that is made for designating marine protected areas on scientific criteria alone regardless of monetary values. (Rees et al, 2010)

Such a study would be a worthwhile investment for the Sydney Harbour estuary.

8.10 Indicators of valuing environmental quality in NSW

The gap between value and price, which is sometimes called 'consumer surplus', is relevant to discussions of how residents value environmental quality (Baker and Ruting, 2014). Many environmental qualities are not priced, but people show that they value environmental qualities in other ways.

8.10.1 Valuing cleaner harbour water

'Economic and Financial Evaluations for the Sewerage Overflow Licensing Project' (ACIL, 1996) was conducted as part of Sydney Waters investigations into reducing sewerage overflows into the Sydney Harbour and elsewhere in the Greater Sydney region. A study of willingness to pay for different degrees of cleaner water was carried out and resulted in large values equivalent to around $50 million to $75 million per year in 2012 dollars. These estimates would be a marginal value for increasing the water quality from the state it was in 1996 to hypothetically improved states.

From 1998 – 2001, Sydney Water spent around $466 million for the North Side Storage Tunnel that stores wastewater and stormwater and transfers it to North Head wastewater treatment plant and protects the Harbour (*http://www.sydneywater.com.au/SW/water-the-environment/how-we-manage\-sydney-s-water/\wastewater-network/northside-storage-tunnel/index.htm*, accessed 16 June 2013). An auditor's report stated:

> *Results speak for themselves with Sydney Harbour being cleaner than it has been for a generation. Evidence of this improvement has been widely reported and is demonstrated by the re-emergence of rock oyster colonies along the foreshores as far inland as Lane Cove and even the return of whales to the inner harbour. (NSW Auditor General, July 2003)*

In addition, between 2007 and 2012, Sydney Water spent around $250 – $300 million on the part of the 'Sewer Fix Program' that affected Sydney Harbour (Hall, 2010). Additionally, in the early 1990's, more funds were spent on the 'Clean Waters Program' to protect the beaches and the harbour, as well as other areas. It is apparently difficult for Sydney Water to separate out how much of the funds spent affected the harbour water quality and how much was for water quality in the Hawkesbury-Nepean catchment and for ocean beaches (Sydney Water staff, *pers. comm.*).

It is noted that future improvements in harbour water quality may depend more on controlling stormwater runoff into the harbour than on more reduction in sewer overflow reduction. Stormwater was rated by some

as the major problem affecting harbour water quality now (Sydney Water staff, 2013, *pers. comm.* see also Section 6)

8.10.2 Civic Pride in a cleaner environment enticing charismatic animals (whales)

Television and newspaper coverage (Robinson, 2010) of whales coming into the harbour and the excitement this caused is an indication of a kind of civic pride that Sydney Harbour has become clean enough to entice such giant, charismatic wildlife (Power, 2013).

8.10.3 Volunteer Environmental Labour

The Sydney Metropolitan Catchment Management Authority (now merged and incorporated into NSW Local Land Services) reported that environmental volunteering in the Sydney Metropolitan region in 2009 totalled an equivalent value of $5.4 million in hours worked (CMA Sydney Metropolitan, now an archived website). The 2010 annual report stated that more than 17 000 Bushcare volunteers participated in on-ground environmental work across Sydney in 2009 (SMCMA, 2011). It is difficult to say how much of this can be attributed to Sydney Harbour, but clearly, a proportion of it will be.

8.10.4 Clean-up Australia Day activities in harbour walks, beaches and in water

In its Annual Report of 2010 – 2011 (SMCMA, 2011) the (then) Sydney Metropolitan Catchment Management Authority cited the history of 'Clean Up Australia Day', that started in Sydney Harbour.

> *In 1989, Ian Kiernan initiated the first Clean up Sydney Harbour recruiting an unexpected and almost overwhelming 40,000 volunteers.*

The event grew into 'Clean Up Australia Day', starting in 1990 with 300,000 volunteers, and in 1993 it became a global event with 30 million people in 80 countries participating.

The Review of Operations for 2012 – 2013 (Clean Up Australia, 2013) states its income as $1.4 million from corporate sponsorship, donations, in-kind contributions and revenue from activities.

8.10.5 Regulations relative to boat discharges and water quality

Part of the move to clean up Sydney Harbour included placing restrictions on boat discharges and on chemicals painted on hulls to reduce damage from fouling. In effect, these represent another kind of willingness to pay for water quality in that these regulations are largely adhered to and considered reasonable (See Sydney Ports website, *http://www.sydneyports.com.au/community/recreation*, accessed 20/5/2014).

8.10.6 Sydney Harbour Catchment Water Quality Improvement Plan

> *The Sydney Metropolitan Catchment Management Authority (SMCMA) is leading a project to develop a Sydney Harbour Catchment Water Quality Improvement Plan (WQIP). The development of the Plan will involve several steps over the next 3 years and will require partnership support from the local councils and government agencies which manage land draining into Sydney Harbour. (SMCMA, 2011)*

8.11 Other Landscape values, icons, arts and cultural heritage

8.11.1 Landscape values

In February 2013, Sydney Harbour was declared an official National Landscape, a title that it shares with 15 other landscapes in Australia. These are promoted as part of a campaign titled the best destinations to experience Australia's outstanding nature and culture. It is impressive that Australia's largest city, with a population of over four million people, can be considered a prime destination to experience nature. That is part of the appeal and importance of the harbour and its foreshores.

The National Landscape website (*http://www.australia.com/nationallandscapes/sydney-harbour.aspx*, accessed 6/6/2013) describes Sydney Harbour as one of the most environmentally diverse landscapes in the world. These landscape and outdoor values are real, but attempts to quantify them at this point for Sydney Harbour have not been found.

8.11.2 Harbour Icons

The Opera House Ticket sales, contributions to businesses, employment and estimates of iconic and experiential value of the Sydney Opera House are made in the Deloite report 'How do you evaluate an icon? The Sydney Opera House: economic, cultural and digital value' (Deloite Touche Tohmatsu , 2013).

According to this report, the Opera House contributed $775 million to the Australian economy from ticket sales, onsite bars, shops, and restaurants. A further $113 million is generated indirectly through supply chains from other sectors and 8,439 full-time jobs directly.

Sydney Harbour Bridge On the website for Commonwealth of Australia, National Heritage Places, the listing for Sydney Harbour Bridge (*http://www.environment.gov.au/system/files/pages/4e0363fc-9214\-4825-af2a-d685e379cab2/files/national-heritage-harbour-bridge.pdf*, accessed 20/5/2014) gave a comprehensive list of values that are very difficult to quantify but clearly of high value.

NSW Roads and Maritime Services also reported on an event commemorating the 80th anniversary of the bridge opening, citing 3500 people attending and 22,000 visits to an online guest book. (NSW Roads and Maritime Annual Report, 2013).

8.11.3 Arts and cultural heritage

The arts, tourism and special events The arts, and an appreciation of cultural values, are not generally valued in an economic way, but bits and pieces are available. In a study by BDA Market Planning, described as New research to help Australian tourism reach its potential for Tourism Australia (*http://www.tourism.australia.com/documents/Statistics/Research_130624_CDP6pagesummary.pdf*, accessed 20/5/2014) international culture and heritage visitors were said to spend an average of $6,280 per trip compared to the other international visitors average of $3,832 per trip.

In another example from the same tourism study (BDA Marketing Development, 2012) the estimate was made that a six-month run of a first-time musical production generates $20 million in direct visitor expenditure.

The 'La Traviata Handa Opera', which was held on a specially-built stage over the water brought in $20 million to the NSW economy. (*http://www.destinationnsw.com.au/news-and-media/media-releases/three-more-years-of-handa-opera*, accessed 20/5/2013). This, and a number of other major events, were listed in the estimates provided by 'Destination NSW' media releases (*http:/www.destinationnsw.com.au/news-and-media/category/media-releases*, accessed 20/5/2014)

Obviously these estimates say little or nothing about the total value of arts and culture for residents and tourists, but the Walsh Bay redevelopment study focuses on the arts in venues on Sydney Harbour.

Walsh Bay redevelopment, arts and heritage In the Walsh Bay Master Plan (Souris Media Release, 2013) comments included reference to *"a fantastic harbour foreshore precinct," "stunning harbour views," "Sydneys beautiful harbour"* and *"the precincts unique maritime heritage."*

The Walsh Bay Master Plan (NSW Public Works, 2013) focused on the natural qualities above, as well as developing an "Arts and cultural ribbon" around Sydney Harbour and the CBD and emphasising the historical links, *"maximising the interface with the water"* and *"passive recreation along the foreshore."*

Cockatoo Island as a venue for the arts and events Cockatoo Island is described as an extraordinary heritage setting on the harbour (Souris Media Release, 2013). Cockatoo Island has been a prison, an industrial school and a shipyard. It is now a major venue with a program of activities including temporary events, festivals, art shows and concerts as well as camping, swimming, overnight stays and temporary moorings.

Historical values and special indigenous values Sydney Harbour Foreshore Authority plays an important role in protecting and managing historical sites including The Rocks and Darling Harbour. They maintain a heritage register and produce publications about heritage areas such as 'The stories we could tell, Darling Harbour' (Sydney Harbour Foreshore Authority, 2010). The Rocks is very much a tourist draw due to its history, whereas Darling Harbour has been so transformed that its history is hard to see, but it is hugely successful as a leisure and entertainment district. The Sydney Harbour National Park Draft Plan of Management (NSW DECCW, 2010; Sydney Harbour National Park Plan of Management 2012) stated that Sydney Harbour contains an extensive collection of historic sites representing thirty two of the thirty four NSW State Heritage themes.

The Plan of Management for Sydney Harbour National Park (NSW Office of Environment and Heritage, 2012) lists the environment, education and research, tourism and recreation values as part of cultural heritage values. It emphasises the importance of historical buildings, and aspects of history including migration, defence, quarantine, harbour protection and conservation, recreation, suburban expansion and industry.

The plan also describes some sites of importance historically to Aboriginal peoples and specifically mentions Aboriginal ties to the harbour:

> *The strong ongoing association between Aboriginal people and the park is highlighted by the gazettal in 2005 of two Guringai Resting (Aboriginal) Places within the park at North Head and at Reef Beach. [The 3rd Key Project in the plan is to] work in partnership with the Aboriginal people of Sydney, and other stakeholders, to develop and expand programs to interpret both traditional and contemporary Aboriginal culture throughout Sydney Harbour (NSW OEH, 2012)*

Sydney Harbour Federation Trust, protecting heritage and environmental values Sydney Harbour Federation Trust is a self-funding agency set up by the Australian Government to rehabilitate for public use former Defence and other Commonwealth lands around Sydney Harbour. The Trust works on sites that have significant heritage and environmental values (Austraian Government Directory website (*http://www.directory.gov.au/directoryea0_lf99_120.organizationalUnit&83a79cf2-405c-4a26-a52c-\f7823ef866ea*, accessed 20/5/2014).

The Sydney Harbour Federation Trust website (*http://www.harbourtrust.gov.au*, accessed 20/5/2014) included a map of the main areas where it works (Snapper Island, Cockatoo Island, Woolwich Dock and Parklands, Platypus Neutral Bay, Chowder Bay, Georges Heights, Middle Head, Marine Biological Station, North Head Sanctuary Manly and Macquarie Light station.)

In addition to improving and maintaining foreshore areas, the Trust leases a number of buildings for restaurants, schools, artist's studios and more. These tenants pay rent to the Trust which was listed as $10.5 million in 2012 – 13. Revenue from overnight accommodations is around $22.4 million. Almost 375,000 people visited Cockatoo Island, mostly for two major events, the Biennale and the 'Red Bull X-Fighters' World Grand Tour Final, with over 200,000 for the 2012 Biennale alone.

8.12 Identified risks and potential benefits

8.12.1 Environmental risks and benefits

A number of economic risks arise from environmental threats to the ecology of Sydney Harbour. These include such things as water pollution, invasive species, warming and increasingly acid waters caused by climate change. There are economic implications to the environmental status of Sydney Harbour in terms of the provision of ecosystem services. These include both potential economic losses and potential gains. Risks were addressed in section 6 of this report.

The potential for benefits coming from restoration of ecosystem functioning would also depend on rigorous scientific analysis. Some possible restoration projects that could have quantifiable economic benefits would include restoration of sea grasses, of oyster beds and of kelp forests, all of which could have benefits as fish nurseries. Removal of contaminated sediment and exotic species might also. These issues are treated more comprehensively in the environmental sections of this report, although possibilities for economic valuation will exist when bio-physical parameters are known. Removal of contaminated sediment and exotic species might also provide economic benefits.

8.12.2 Economic adjustments from halting commercial fishing in 2006

When the NSW government banned commercial fishing in the harbour in 2006 it used $5.8 million from the Environmental Trust to buy out licences (Davis, 2010). Calculations based on the payout suggest that the annual value of fish caught in Sydney Harbour was about half a million dollars a year in current dollars. There are also indications that the annual harvest was on a decreasing trend (ACIL Economics, *unpublished*).

More current summary statistics from 2006 – 2007 show the value of estuary general catch for all of NSW as $20.8 million, and $3.9 million for prawn trawl. This was the year of the closing of commercial fishing in Sydney Harbour (*http://www.dpi.nsw.gov.au/fisheries/commercial/catch-statistics#Want-to-know-more?*, accessed 2/2/2014).

The economic losses from closing the Harbour to commercial fishing are not known. If the commercial fishing effort was all displaced to other areas and continued as before, bringing in similar value of fish and providing the same incomes and not negatively effecting other fishers in the area where the Harbour fishers subsequently fished, then the result was an economic adjustment but not an economic loss.

Because the Harbour was closed to commercial fishing for the reason of contamination, and not, for instance because it was rezoned to what would be taken to be a higher value use such as a protected area for fish to breed, that former fishing area is a total loss to commercial fishing. But it was not closed to recreational fishers, and there is evidence in fishing magazines from the time that recreational fishers were very happy with the closure because they benefited in terms of improved catch. There is some concern that recreational fishers may, in some cases, have consumed too much contaminated fish, but there is no evidence of negative health effects so it is impossible to say if they exist. If there are no negative health effects, then the transfer of fish catch from commercial to recreational fishers is not necessarily an economic loss either, but a transfer of benefits from one group of users to another.

8.12.3 Health risks of recreational fishers consuming catch from Sydney Harbour

The NSW Food Authority strongly suggests limiting consumption of fish caught in Sydney Harbour (NSW Food Authority website, 2009 last update). Another report gives a good brief description of the extent of contamination in the harbour and the resulting loss of fishing and danger of consuming fish (McGrath, 2012).

There are indications that these recommendations are not fully followed (Ghosn et al, 2010) but the extent of consumption is unknown. Therefore the health implications of this are not known, nor are economic costs in terms of loss of work or medical costs, if any. If it was shown that contaminated fish were being eaten, that would lower the economic value of the fish caught.

8.12.4 Health risks of swimming in Sydney Harbour

Environment NSW, in its Beachwatch program, monitors quality of water for swimming in the Sydney (and other) regions and posts daily updates (*http://www.environment.nsw.gov.au/sob/index.htm*, accessed 20/5/2014). The site stated as a general precaution, swimming in Sydney Harbour should be avoided for up to three days following rainfall or for as long as stormwater is present.

The health risks of swimming in Sydney Harbour, according to the NSW Beachwatch website (NSW Environment, Swimming illness, *no date*) include pathogens (bacteria, viruses and protozoa) which can easily enter the ears, eyes, nose and mouth of swimmers. The skin is also directly exposed to infectious agents and chemicals through swimming, playing or working in polluted waters. No estimates of the economic costs of health issues arising from a stormwater polluted harbour have been found, however there may be some projections made by Sydney Water Inc.

8.12.5 Claims of illness and/or infection from SH waters

There are occasional signs of other health risks as well. Again from the SMH, an article titled 'Killer bugs lurk in harbour' described *Staphylococcus* infections from bacteria in waterways and particularly of two examples of infections that led to loss of toes in one case and a foot in the second (Cubby and Lockwood, 2009).

There was a listing of databases available at NSW Land and Property Information, which included a Beachwatch and Harbourwatch Bacteriological Database at the NSW Spatial Data Catalogue (*https://sdi.nsw.gov.au/nswsdi/catalog/main/home.page* accessed 10/3/2014) that could be a source of additional information over time.

In general, Sydney Harbours beaches nearest to the Heads and the ocean are rated the best, and those upriver somewhat less. Overall count of health problems caused by exposure to polluted water in Sydney Harbour does not seem to be available judging by negative responses to requests to both NSW Environment and Health departments.

8.13 Environmental values used for planning - estuaries adjacent to cities

8.13.1 Australian examples of using economic assessments of social preferences for environmental values applied to planning

Queensland estuary health, methodology study Windle and Rolfe (2004) examined community attitudes about economic development in an estuary vs. preservation of environmental values in the Fitzroy River. The estuary acts as a buffer between the outflow from the Fitzroy river basin, the second largest river system in Australia (approximately 142 645 km^2) and the marine waters of the world heritage listed Great Barrier Reef Marine Park. However, it focuses largely on determining appropriate methodologies for use of choice modelling with different questionnaires on willingness to pay, testing various formulations of questions looking for consistency and differences in estimation results.

> *The other contribution of this paper is to extend the case studies in natural resource valuation to include values for the protection of river estuaries. Assessing these values is important because estuaries are a key environmental asset in Australia. Although there have been a number of CM [choice modelling] studies in Australia focusing on water resource issues, this is the first to focus on protection values for estuaries. Case studies of this kind help to build a database of valuation exercises that can be sourced in benefit transfer exercises. (Windle and Rolf, 2004, emphasis added.)*

Queensland- estuary health, valuation survey Windle and Rolfe (2005) aimed to elicit non-use values held for protecting the environmental health of the Fitzroy River estuary in central Queensland. This estuary is affected by an annual discharge of suspended sediment of approximately 2 635 000 tonnes, mostly due to rangelands grazing in the Fitzroy River Basin region (main land use activity).

People were found to be willing to pay AUS$3.21 per household per year for a 20-year period for a 1 % increase in the area of the Fitzroy River estuary that is in good condition. A value of AUS$674,100 for each 1 % improvement in the area of the Fitzroy River estuary in good environmental health was found for the state level.

Tasmania catchment natural resources Kragt and Bennett (2009) sought to estimate the values that Tasmanian households hold for protecting natural resources in the George catchment in north-eastern Tasmania using a choice modelling survey in three towns.

> *The study focused on three environmental attributes: area of healthy seagrass beds in the George Bay, rare native animal and plant species, and native riverside vegetation. Respondents from the full sample were found to be, on average, willing to pay AUS$0.11 for a hectare increase in seagrass area, $3.57 for a kilometre increase in native riverside vegetation and $8.42 for the protection of each rare native animal and plant species.*

Queensland river water quality Robinson et al. (2002) used a citizens jury approach and choice experiment method to address the water quality issues due to nutrient enrichment in the Bremer River. A jury of 23 individuals was convened for two full days, and exposed to intensive scientific information from experts. Participants were paid a nominal fee. Opinion of scientific experts, as well as the community, was sought to identify and determine the appropriateness of the attributes to be included in the choice sets as well as to test a survey design. The appropriate levels that these could be offered to survey respondents and the plausibility of the financial attribute and its acceptance by respondents, was assessed through a focus group of eight people who were members of the Rural Consultative Committee supported by the local council

> *Results show that there is considerable scope for benefit for citizens from an improvement in the water quality of the Bremer River (WTP [willingness to pay] between $21 and $87 per household/year).*

Western Australia recreational fishing Raguragavan et al. (2010) used a travel cost method to determine the value of recreational fishing in all of the eight major fishing regions and 48 fishing sites in Western Australia.

> *Welfare measures were estimated for the different fish types, a 100% increase in catch rates, and site access values. The monetary value of a fish caught by recreational fishers in Western Australia (WA) ranged from $2.28 for butter fish to $15.94 for prize fish. For a 100% increase in the expected catch rates, anglers, on average, would be willing to pay from about $14.88 for table fish to $31.41 for prize fish. The mean access values or welfare losses from site closure amounted to $3.81 per trip across all anglers and $5.61 for anglers who actually fished in the affected site. The aggregate annual access value of fishing sites in WA was estimated at $20.38 million.*

Queensland, Moreton Bay - wetlands Clousten (2003) valued the ecological benefits (habitat provision, water quality), use benefits (fishing and recreation), and non-use values of wetlands Moreton Bay, Queensland.

Three approaches for assessing non-market values (direct linkage models, revealed preference and stated preference models) were reviewed with respect to their ability to capture ecological value. An alternative biophysical approach of energy analysis was also considered. Environmental values of the wetlands included the contribution of approximately one-third of primary productivity in the Bay, providing habitat for a wide range of dependent species and a diverse fauna with a relatively large number of endemic species. Economic values of the wetlands include both direct and indirect use values (fishing, recreation, water quality improvements and storm buffering) and non-use values such as the value in preserving the environment for future generations (bequest value) and the existence of vulnerable animals such as turtles and dugongs, which one may never expect to see. If consumers are willing to pay to preserve these animals, this is also a valid economic value.

The results indicate that the provision of different types of information influences willingness to pay. However, willingness to pay when provided with ecological information is not significantly different from willingness to pay when provided with other information. As it was not possible from the research undertaken to state that the contingent valuation method can capture ecological value, an alternative approach is proposed to link ecological and economic values. It is argued that ecologists and economists need to develop common aims and scales of assessment. Further, communication between the two disciplines can be enhanced through the use of agreed indicator terms. Through an iterative approach it should then be possible to understand the linkages between changes in indicators of ecosystem values and indicators of economic value. "

There are studies on environmental values of estuaries and adjacent land including, for example where both ecosystem services and human use are considered (Johnston et al. 2002). Value is strictly in terms of recreation, not economics, and not particularly associated with cities. Again, the focus is largely on valuation techniques.

Study methods included: hedonic pricing; travel cost; a valuation of the estuarine system as an input to productivity of bird and fish populations; and a contingent valuation survey. Between them, the studies estimated the values associated with property in proximity of the system; recreational activities; willingness to pay to preserve the system; and the value of the system as an input to bird and fish populations. The authors found that the different methodologies resulted in very different valuation estimates. For instance, the contingent valuation study yielded a positive value for farmland, while the hedonic approach yielded a negative one. The total benefit associated with a 10% increase in water quality as measured using the travel cost method was $1,299,854, and the total annual consumer surplus associated with swimming, fishing, boating, and bird and wildlife viewing was $27,272,806. The hedonic study showed that property in proximity to preserved open space had an increase in value of 12.8% or more, and property in proximity to farmland was 13.3% less valuable.

Similarly, Ko (2009) looked at ecosystem services provided by the Galveston Bay in the State of Texas. These include flood mitigation, water quality, habitat provisions, commercial fishing and recreation (including recreational fishing). The results concluded that flood mitigation services provided by the wetland were valued at $5,800 per acre (= $14,325 $/ha in United States dollar, 2007). Restoration cost of the Galveston Bay is estimated at $6,000 per acre (= $14,820 $/ha US dollar, 2007). The non-use value of the Galveston Bay wetlands was estimated at $5.77 billion (US dollar, 2007).

There are many studies worldwide where ecosystem services are valued for past or future improvements in water quality for various benefits in terms beach going, boating, fishing, tourism and so forth. Most are regional and for specific, limited values.

8.13.2 Studies of environmental values in estuaries with major cities

There were very few studies where economic activities that took place on or around water bodies adjacent to major cities were valued as environmental benefits or where environmental, social and economic values were considered together for a city and waterbody combination. One of the few studies found, however, evaluated the various functions of the San Francisco Bay in relation to a large number of economic activities, including some that could be quantified and some that could not (Battelle Memorial Institute for National Oceanic and Atmospheric Administration, 2008)

In this study, the research team identified possible environmental values in the literature, both for economic methodology of evaluating environmental services and for those focusing on specific aspects of San Francisco Bay. A list of environmental values was evaluated by experts and then proposed to local stakeholders. A final list was assembled and information available summarised. The environmental values included direct uses, indirect uses and non-use and intrinsic values.

The direct use values were defined as goods and services directly consumed by users, from fishing to mining. The indirect use values were: the benefits arising from ecological and aquatic systems or ecosystem services. The non-use values were; option (possibility of future use), existence (cultural, aesthetic, spiritual)

and bequest (stewardship, heritage and legacy) values. Finally, the intrinsic value was that organisms have a worth of their own regardless of usefulness to humans.

Most of the report was dedicated to direct use values. The non-use and intrinsic values were defined in general terms, but no attempt to quantify them or relate them specifically to the SF Bay was made.

Quantitative assessments were given for most of the values, some in monetary terms and some in physical numbers (marinas and boat slips, birds and gray whales migrating, tons of wastewater discharged and drinking water desalinated, megawatts of power generated). No quantification was given for subsistence fishing, scientific research, education or non-use and intrinsic values. The values that were quantified in monetary terms were not totalled.

This report was nevertheless considered valuable as the sole report found of its kind, attempting to do a full valuation of the environmental values, very broadly defined, of an estuary associated with a major city. Such a report would be a valuable asset to managers and stakeholders of Sydney Harbour.

9 Conclusions

Sydney Harbour is a complex waterway that sits within Australias largest city. The interaction of intense commercial and recreational activity and the great diversity of species and habitats found in the estuary will need to be managed carefully into the future. Prior to the implantation of any management plan is the need to asses our current knowledge of the system and identify research gaps.

The natural systems of Sydney Harbour are varied. Seagrass, mangroves, salt marsh and natural rocky reef sit amongst seawalls, wharves and marinas. The great diversity of plants and animals are threatened by a notoriously contaminated seafloor, communities are altered by the addition of seawalls and we have almost no knowledge of the effects of non-indigenous species in natural systems. Further, we very little knowledge of the historical and contemporary recreational fishing practices, distribution, and effort in the harbour. While we know that climate change predictions will lead to warming in the Sydney area, this report also compiles surprisingly little research of the potential consequences of this. The findings in the preceding pages should make for a useful guide to directing future research effort and funds.

In conducting this review, it is apparent that managers have not historically recognised the importance of social values in the majority of plans and research relating to Sydney Harbour. Contemporary management plans have, however, now been enacted that do contain statements highlighting the importance of understanding the social and economic values of Sydney Harbour's natural systems. 'Sharing Sydney Harbour', for example, is the NSW Government's vision for managing the future of Sydney Harbour (Transport for NSW, *pers. comm.*). Having consulted a wide range of Harbour users the vision is;

> *'... [To take] wise and comprehensive care of the Harbour as a natural asset belonging to future generations, and sharing the Harbour with nature and for all human activities...' (Sharing Sydney Harbour Regional Action Plan 2000)*

Four themes underpin the vision, giving Sydney its unique character among the great harbour cities of the world.

1. Natural harbour - a healthy sustainable environment on land and water
2. Urban harbour - a high quality urban environment
3. Working harbour- a prosperous, working waterfront and effective transport corridor
4. People's harbour - a culturally rich, accessible, active place for people

Also, The Sydney Harbour Regional Environmental Plan (Sydney Harbour Catchment) 2005 recognises the areas social, economic and environmental values.

"Sydney Harbour, including Parramatta River and its tributaries, is a major natural, cultural, recreational and commercial asset for both Sydneysiders and visitors alike. The continuing growth and importance of Sydney has resulted in increasing pressures on the harbour and its foreshores."

"The Harbour REP aims to establish a balance between promoting a prosperous working harbour, maintaining a healthy and sustainable waterway environment and promoting recreational access to the foreshore and waterways."

Recognition of the harbour's economic benefits have been largely ignored in the literature or simply recognised as a 'given'. Recent priorities, as described in the NSW Government's strategic plan (Dept of Premier and Cabinet 2011) include 'putting the customer at the centre' and giving community a say in decisions affecting their lives. We conclude that there are significant gaps in the research to date, particularly relating to values by stakeholders that are specific to the harbour context. Two of the five strategies in NSW 2021 place priority on the customer or community. A thorough assessment of social values, including analysis of customers or stakeholders, the values that these stakeholders share and the potential issues that may arise from contrasting values is an essential part of accomplishing these strategic goals.

Ecological Risk Assessment (ERA) and Spatial Management and Prioritisation are tools by which complex natural resources can be effectively managed. A recommendation of the NSW Independent Scientific Audit of Marine Parks was to manage marine resources within a Risk Assessment framework. Undertaking such a project for the Sydney Harbour estuary is a large task, however a multidisciplinary, multiagency team based at SIMS has started such a project. This work is ongoing, and will require significantly more investment of time and funding before completion. New data relating recreational and commercial use, nutrient inflow, habitat quality and current management practices are, however, being collected, or are planned to be collected in the coming years.

This report goes someway to addressing our current knowledge of Sydney Harbour, and can be used to guide future research into the areas that will help managers and stakeholders better manage this complex waterway. The scientific community will need to contribute much to the future of Sydney Harbour, as any management of this valuable resource will need to be scientifically robust, transparent and credible.

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