SUMMARY OF ECOLOGICAL INFORMATION

FOR THE

WALLIS LAKE POTENTIAL RAMSAR SITE

FINAL DRAFT REPORT

OCTOBER, 2010

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ACKNOWLEDGEMENTS

I wish to acknowledge the assistance and support of Peter Scanes, Department of Environment and Climate Change; Tim Glasby, Department of Industry and Investment; Prue Tucker and Isabelle Strachan, Great Lakes Council.

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GLOSSARY

Acceptable change: variation will allow the component or process to which it refers to be sustained

Assessment: the identification of the status of, and threats to, wetlands as a basis for the collection of more specific information through monitoring activities (Resolution VIII.6, 8th Conference of Parties to the Ramsar Convention)

Attributes: biological diversity and unique cultural and heritage features; these lead to uses or derivations of products, but they may also have intrinsic, unquantifiable importance (Annex A to Resolution VI.1, 6th Conference of Parties to the Ramsar Convention)

Baseline: condition at a starting point, usually the time of listing

Benchmark: a pre-determined state, based on the values to be protected, to be achieved or maintained

Benefits: as they relate to Ramsar wetlands and to ecological character and change in that character, are the benefits that people receive from ecosystems (Resolution IX.1, 9th Conference of Parties)

Change in ecological character: the human-induced adverse alteration of any ecosystem component, process, and/or ecosystem benefit/service (Resolution IX.1, 9th Conference of Parties)

Components: physical, chemical and biological constituents (from large scale, such as habitat, to small scale, such as genes)

Driver: direct or indirect human forces of change; examples include laws, institutional arrangements, river basin management, and water allocation etc. or natural aspects of a wetland ecosystem such as natural hydrology, climate, and geomorphology

Ecological character: the combination of the ecosystem components, processes and benefits/services that characterise the wetland at a given point in time (Resolution IX.1 Annex A, 9th Conference of Parties)

Ecological condition: the health or quality of a site —- a comparative assessment, analysis and value-based judgment

Ecosystem: a dynamic complex of living (including human) communities and the nonliving environment interacting as a functional unit which provides, inter alia, benefits to people

Ecosystem services: are benefits that people receive or obtain from an ecosystem; the types of ecosystem services are:

- provisioning (food, water)
- regulating (flood control)
- cultural (spiritual, recreational)
- supporting (nutrient cycling, ecological value)

Ecological Character Description: a report of the living and non-living components and how they interact, the natural variability of the wetland, and the limits of acceptable change

Eutrophic: having a high level of nutrients, typically compounds containing nitrogen or phosphorus

Functions: activities or actions that occur naturally in wetlands as a product of interactions between ecosystem structure and processes, and include flood water control; nutrient, sediment and contaminant retention; food web support; shoreline stabilisation and erosion controls; storm protection; and stabilisation of local climatic conditions, particularly rainfall and temperature

Mesotrophic: having moderate levels of nutrients, typically compounds containing nitrogen or phosphorus

Monitoring: systematically observing and measuring conditions in order to assess any changes

Oligotrophic: having very low levels of nutrients nutrients, typically compounds containing nitrogen or phosphorus

Processes: changes or reactions — physical, chemical or biological — that occur naturally

Shorebirds: birds frequent the shores of coastal, estuarine and inland water bodies, including wetlands; also known as waders

Tidal prism: the change in the volume of water covering an area, such as a wetland, between a low tide and subsequent high tide

Values: the perceived benefits to society, either direct or indirect, that result from wetland functions; these values include human welfare, environmental quality and wildlife support (Annex A to Resolution VI.1, 6th Conference of Parties)

Wetlands: areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres

Wise use: sustainable utilisation that is compatible with the maintenance of the natural properties of an ecosystem 116 Ecological character description

ABBREVIATIONS

ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agricultural and Resource Management Council of Australia and New Zealand
BOM	Bureau of Meteorology, Commonwealth of Australia
CAMBA	China—Australia Migratory Bird Agreement
CMS	Convention for the Conservation of Migratory Species (Bonn)
CoP	Conference of the [Contracting] Parties
DECC	Department of Environment and Climate Change NSW
DEWHA	Department of Environment, Water and Heritage, Australia
DIPNR	Department of Infrastructure, Planning and Natural Resources, NSW
DO	dissolved oxygen
DPI	Department of Primary Industries
DSE	Department of Sustainability and Environment, Victoria
EPBC Act	*Environmental Protection and Biodiversity Conservation Act 1999*
I&I	Department of Industry and Investment, NSW
IUCN	International Union for the Conservation of Nature
IBCA	Integrated Biodiversity Conservation Assessment
JAMBA	Japan—Australia Migratory Bird Agreement
LAC	limit of acceptable change
mAHD	elevation in metres relative to the Australian Height Datum
MHL	Manly Hydraulic Laboratory
MPA	Marine Parks Authority, NSW
NLWRA	National Land and Water Resources Audit
NPWS	National Parks and Wildlife Service, NSW
NSW	New South Wales
SAV	submerged aquatic vegetation
SEPP	State Environmental Planning Policy
TSC Act	*Threatened Species Act 1995* (NSW)

SUMMARY

Designation for Wallis Lake as a Wetland of International Importance is being sought under the Ramsar Convention.

The Wallis Lake site is in near-pristine condition and contains the largest area of seagrasses of any NSW estuary, the most recent estimate being 3190 hectares, which constitutes 35% of the total seagrass in NSW.

Of the five seagrass species present two are at the limits of their distribution, *Posidonia australis* at the north and *Halodule tridentata* at the south. Although most seagrass species in NSW constitute protected ecological community, *Posidonia australis* has been identified as *endangered* in five NSW estuaries south of Wallis Lake. The other species, *Halodule tridentata*, which is relatively widespread (although patchy) in the southern basin of Wallis Lake has not been recorded from any other NSW lake or estuary.

Wallis Lake also contains the second largest area of saltmarsh after Port Stephens, although the area of saltmarsh mapped in the southern basin during 2009 was less than had been mapped in the same area in 2002.

Wallis Lake has well over 100 species of fish; 55 species of invertebrates and three species of sea turtles of which two species are threatened and eight are protected. The north of the site receives transient tropical species under the strong marine influences during summer and autumn, while occasional freshwater species occur at the southern end.

The southern basin of Wallis Lake is unique compared to other coastal lakes and lagoons in New South Wales in that it contains a relatively diverse assemblage of at least twelve species of sponges, many of which are undescribed and new to science.

Abundances of some of these sponges, however, were shown to be reduced between 2007 and 2009 compared to previous years and many individuals showed signs of stress. As the sponges are associated with seagrass and macroalgal meadows and represent the best or only example of such unique assemblages in the bioregion it is important to understand their requirements for survival throughout their life cycles and to afford the best protection possible.

Water quality in Wallis Lake is high but the key threat to the survival of the sponges is likely to be deterioration of water quality through increased sediment loading, which would directly affect the physiology and feeding efficiency of filter feeding sponges. Indirect effects of sedimentation on the sponges include reduced light penetration of the water column, leading to loss of aquatic vegetation. This highlights not only the fragile nature of these species, but the need to conserve the associated habitat.

Ramsar listing would assist future management decisions regarding Wallis Lake and provide vital protection for these unique ecosystems.

1. INTRODUCTION

This summary of the literature documenting the ecological character of Wallis Lake, for a proposed amendment to the Myall Lakes Ramsar site, was prepared for the Department of Environment and Climate Change NSW (DECC) (Table 1) following the *National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands* (DEWHA 2007).

1.1 BRIEF DESCRIPTION OF THE SITE

Wallis Lake is a wave-dominated coastal barrier lake that extends from its entrance to the sea at Forster-Tuncurry, approximately 18kms south to Charlotte Bay, Pacific Palms. The lake entrance is located 107km north of Newcastle, on the mid-north coast of New South Wales.

The site described comprises the central and southern basins of Wallis Lake extending from Wallis Island south to Pacific Palms and covers a water area of 74.81km^2. It includes some of the islands within the lake currently listed as Nature Reserve or National Park. The site forms part of the Wallis Lake Catchment that comprises a 40.89km long estuary and covers a total water area of approximately 92km^2.

The central and southern basins comprise a relatively healthy coastal wetland rich in biodiversity and complex variety of habitats. The most prominent habitat in Wallis Lake consists of a coastal estuarine lake and its associated habitats of seagrass and macrophyte beds, intertidal sand and mud flats, rocky habitat, sponge gardens, islands and coffee rock. Mangroves and saltmarsh border a large part of the lake and cabbage trees and littoral rainforest, which are distinctive to the area, line parts of the shoreline. A number of species that occur in this area are at the limit of their distribution and some species are found exclusively in Wallis Lake and have not been recorded at other locations.

Site Name	Wallis Lake Central and Southern Basins
Location	Mid-north coast NSW, extending northwards from Pacific Palms, approximately 18km south of Forster and 93km north of Newcastle
Area	74,810ha
Geographical Co-ordinates	$32^0 14' S$ to $32^0 20' S$ $152^0 29' E$ to $152^0 31' 30'' E$ and $32^0 12' 02'' S$ to $32^0 12' 64'' S$ $152^0 29' E$ to $152^0 31' 50'' E$
Management Authority	Department of Environment and Climate Change
Status of Description	This is the preliminary document

Name of Compilers	Suzanne Fiebig*, April McKay *pacific blue design - Marine Ecologist Produced for the Department of Environment and Climate Change
Date of Compilation	June, 2010
Reference for Ramsar Information Sheet	NONE AS YET
Reference for Management Plan	NONE AS YET

1.2 STATEMENT OF PURPOSE

The following document forms a summary of the ecological information available for the central and southern basins of Wallis Lake. This will provide a baseline for a description of the ecological character of the site. This will be available for submission with a proposal to have the nearby Myall Lakes Ramsar site amended to include Wallis Lake. It will also in turn form the benchmark for management planning and actions, including site monitoring to detect negative impacts.

The legal objectives of an ecological character description are to:

- Assist in implementing Australia's obligations under the Ramsar Convention, as stated in Schedule 6 (Managing wetlands of international importance) of the Environment Protection and Biodiversity Conservation Regulations 2000 (with):
- Describe and maintain the ecological character of declared Ramsar wetlands in Australia
- Formulate and implement planning that promotes:
  - conservation of the wetland
  - wise and sustainable use of the wetland for the benefit of humanity in a way that is compatible with maintenance of the natural properties of the ecosystem
- Assist in fulfilling Australia's obligation under the Ramsar Convention to arrange to be informed at the earliest possible time if the ecological character of any wetland in its territory and included in the Ramsar List has changed, is changing or is likely to change as a result of technological developments, pollution or other human interference
- Supplement the description of the ecological character contained in the Ramsar Information Sheet submitted to the Ramsar Convention for each listed wetland, and collectively, form an official record of the ecological character of the site
- Assist the administration of the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) 1, particularly to:
  - determine whether an action has, will have or is likely to have a significant impact on a declared Ramsar wetland in contravention of sections 16 and17B of the EPBC Act, or
  - assess the impacts that actions referred to the Minister under Part 7 of the EPBC Act have had, or will have on a declared Ramsar wetland.

- Assist other relevant NSW planning or impact assessment legislation such as the Environmental Planning and Assessment Act 1979
- Assist any person considering taking an action that may impact on a declared Ramsar wetland whether to refer the action to the Minister under Part 7 of the EPBC Act for assessment and approval
- Inform members of the public who are interested generally in declared Ramsar wetlands to understand and value the wetlands

[1] http://scaleplus.law.gov.au/html/pasteact/3/3295/top.htm

From the perspective of management planning and action, the ecological character description forms the reference for:

- Development and implementation of a management plan designed to maintain the ecological character of the site
- Design and implementation of monitoring programs to detect change in ecological character and to assess the effectiveness of management actions
- Regular evaluation of the results of the monitoring program to assist in site management.

1.3 RELEVANT LEGISLATION AND TREATIES

The Ramsar Convention on Wetlands is an intergovernmental treaty signed in Ramsar, Iran, in 1971, The Conventions' mission statement is "… the conservation and wise use of all wetlands through local, regional and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world". Australia addresses its obligations under the *Biodiversity Conservation Act 1999* (EPBC Act), the Environment Protection and Biodiversity Conservational Regulations 2000, and national, state and territory and local government wetland policies and natural resource management programmes.

The following NSW legislation and policies currently protect Wallis Lake:

- *National Parks and Wildlife Act 1974* (NPW Act)
- *Threatened Species Conservation Act 1995* (TSC Act)
- *Environmental Planning and Assessment Act 1979*
- *Water Management Act 2000*
- *Fisheries Management Act 1994* (FM Act)
- State Environment Planning Policy 71 – coastal protection (SEPP 71), which applies to coastal waters immediately adjacent to coastal wetlands
- State Environment Planning Policy 14 – coastal wetlands (SEPP 14), which applies to coastal waters immediately adjacent to wetlands
- *Protection of Environment Operations Act 2000.*

Migratory shorebirds use the East Asian-Australasian Flyway, which stretches from New Zealand and Australia, through South-East Asia, China and Japan, and north to Siberia and Alaska. International legislation that protects these birds includes the:

- Agreement between the Government of Australia and the Government of Japan for the Protection of Migratory Birds in Danger of Extinction and their Environment (JAMBA)[2]
- Agreement between the Government of Australia and the Government of the People's Republic of China for the Protection of Migratory Birds and their Environment (CAMBA)[3]

[2]http://www.austlii.edu.au/au/other/dfat/treaties/1981/6.html

[3]http://www.austlii.edu.au/au/other/dfat/treaties/1988/22.html

1.4 HOW TO USE THIS REPORT

This report has been compiled as a basis to meet the requirements of the Ramsar Convention that requires presentation of:

- A general description of the site
- Services provided by the site
- Components and processes within the site
- Definition of the main characteristics of the site
- Setting of limits to change for the main characters and nomination of indicators to measure change.

An inventory of the physical, chemical and biological components of the site is found in Sections 2, 3 and 4.

Section 5 provides a summary of how these components work together to produce the unique character of the central and southern basins of Wallis Lake.

Sections 6, 7 and 8 provide guidance on limits of acceptable change, threats and monitoring for the site.

Knowledge gaps for the site are listed in Section 9.

Important messages about the site are outlined in Section 10.

2. GENERAL DESCRIPTION

2.1 ECOLOGICAL CHARACTER

The Wallis Lake site is part of a large coastal estuary, with other wetland types, either directly connected (such as seagrass and macrophyte beds, associated sponge gardens, saltmarsh and mangroves) or located nearby (swamp sclerophyll forest, littoral rainforest). The following discussion focuses on the subtidal and fringing habitats but recognizes that the supporting terrestrial habitat is very much linked with the whole ecosystem.

The site has a strong marine influence through its connection to the sea via the entrance at Forster-Tuncurry but the estuary is connected to the greater catchment by four major rivers, the Wallamba, Coolongolook, Wallingat and Wang Wauk. The northern parts of the site are more heavily influenced by the marine parameters than in the south. As part of the marine wetland type, coffee rock, sandy and rocky shorelines fringe the islands within the site and provide a range of habitats for aquatic fauna.

The southern and central basins are nearly pristine in condition with oligotrophic, clear waters and low nutrient and chlorophyll concentrations. Saltmarshes line sections of the lake and seagrass beds thrive under these conditions and dominate the shallow parts of the lakebed. In the southern basin, macrophyte beds also flourish. Associated with these beds is a diverse array of sponge and ascidian beds that have not been studied extensively and are poorly understood.

Although the already known fish and invertebrate fauna of the lake attracts tourists and fishers alike, the outstanding diversity of Wallis Lake lies in the sponge beds and may define its character in relation to other similar coastal lagoons in NSW. Wallis Lake has more than double the number of sponge species of other lakes, most of which are new to science.

The importance of the delicate ecological balance of Wallis Lake and its surrounding catchment cannot be underestimated. The sponges have recently shown a decrease in species numbers and abundance, highlighting the need to ‘tread carefully’ in terms of protecting and managing our site and its resources. Many of the wetlands and aquatic fauna are threatened on state, national or international levels. Human access, introduced species, landuse and climate changes can jeopardize the ecological character of Wallis Lake so the best knowledge, understanding and protective management should be put in practice to preserve this pristine area.

2.2 LOCATION AND REGIONAL CONTEXT

The centre of the proposed Ramsar amended site in Wallis Lake lies at a geographic position of longitude $152^0 30' 36''$ E and latitude $32^0 17' 24''$ S, approximately 12km south of Forster-Tuncurry and 5.5km north of Pacific Palms, 97km north-east of Newcastle on the mid-north coast of NSW. It is situated between the eastern coastal dunes of Seven Mile Beach, including Booti Booti National Park, and the hills of the Wallingat National Park and State Forest to the west.

Wallis Lake comprises part of the ACIUCN 1986 Lower East Coast Geographic Region and the NSW North Coast Biogeographic Region. It also forms part of the Manning Shelf Interim Marine and Coastal Region. In terms of climatic area, Wallis Lake has a temperate climate with a hot summer and uniform rainfall (BOM 1981, 1988) and low tidal range.

The site covers an area of 74.81km^2 in the central and southern basins of Wallis Lake with the surrounding land owned by National Parks, Crown Lands and private stakeholders. The body of the lake below the mean high tide water level falls under the jurisdiction of the Crown Lands Department. Some of the islands within Wallis Lake are partly or wholly privately owned, whilst others including those within the site are designated National Park or Nature Reserve.

The southern end of the site at Pacific Palms is located approximately 12km north of the end of the current Myall Lakes Ramsar site. With Smiths Lake, Booti Booti and Wallingat National Parks located between or bordering the sites, the region comprises multiple ecosystems that are unique in terms of the range of species and habitats within aquatic, wetland and terrestrial environments. The site is unique compared to other coastal lakes and lagoons in New South Wales in that it contains a relatively diverse assemblage of sponges, many of which are undescribed and new to science. It also contains a number of species at the limit of their range of distribution, some of which are not otherwise found in NSW.

Due to the increasing population and pressure as a top holiday destination for boating and fishing enthusiasts, the natural diversity of Wallis Lake provides the surrounding townships with a diverse range of recreational opportunities.

2.3 AREA COVERED BY THIS DESCRIPTION

The Wallis Lake site includes the central and southern basins extending from Yahoo Island in the north of the central basin approximately 11.5km southwards to Charlotte Bay and Pacific Palms Recreation Club along the southern and eastern borders of the southern basin. The site covers a water area of 74.81km^2. It also includes a 500m strip of coffee rock ledge along the north-eastern shoreline of Wallis Island, which, while not connected to the main site, provides unique habitat to protected species. Islands within the site include Yahoo, Snake, Little Snake, Pelican, Black Rocks, Earps and Booti.

Although the boundaries of the site may not be the definite boundaries for the Ramsar site submission, the site has been chosen to include the best currently

documented examples of unique assemblages, habitat and biodiversity within Wallis Lake. As such, the area includes the sponge beds, macroalgal and seagrass meadows of the southern basin, the *Posidonia* and other seagrass beds of the northern central basin, the habitat of the protected estuary cod along the coffee rock ledges of north-eastern Wallis Island, the pelican rookeries on the sand islands of the northern central basin, and the fringing saltmarshes and littoral and lowland rainforest and swamp oak floodplain forest in the catchment adjacent to the lake*.

* The sand islands and terrestrial flora and fauna are not covered in detail in this report as these are beyond the scope of the project at this stage.

2.4 THE CATCHMENT

The Wallis Lake Catchment covers an area of approximately 1,292.2km^2 and a total water area of 91.24 km^2 including the lake and its tributaries to the tidal limit (Table 2.4.1), (Wallis Lake Estuary Management Committee 2005, GLC 2009). It consists of seven sub-catchments including Wallis Lake and four river systems which discharge into the lake. Wallis Lake itself is a large, shallow estuary characterized morphologically as a wave-dominated coastal barrier lagoon (West *et al.* 1985, Creese *et al.* 2009). It has an average depth of 1.8m, is constricted at the entrance by sand from adjacent beaches and is kept permanently open to the ocean with the assistance of the flow from the estuary and by two man-made breakwaters, constructed in 1966 (Adam, 1986, GLC 2009, Roper *et al.* 2009). Tidal exchange between the ocean and the estuary occurs twice daily at the entrance area of the lake but the time taken for waters to completely exchange varies from 1 day to1 week in the lower part of the estuary to greater than two months in the southern basin of the lake and the upper reaches of the rivers (Great Lakes Catchment Management Steering Committee 2001).

The sub-catchments are based on the major drainage networks in the Wallis Lake catchment. These consist of the Wallamba River, Lower Wallamba River, Wang Wauk, Coolongolook, Wallingat, Wallis and Minimbah sub-catchments (Figure 2.4.1 Source: GLC 2009). The four main river systems are the Wallamba River, Coolongolook River, Wang Wauk River and Wallingat River, which together drain the total catchment area. The two Wallamba sub-catchments drain the northern-most third of the catchment (429.5km^2); the Wang Wauk and Coolongolook sub-catchments drain a further 30% (389.6km^2); while the Wallingat River sub-catchment drains 13% (173.1km^2). Of these, the Wallamba, Wang Wauk and Coolongolook River sub-catchments are the most modified for agricultural purposes while the Wallingat, with 72% (124km^2) of the catchment private native forest, state forest or National Park, is the least modified. Wallis Lake itself and its foreshore drains a further 15% (177.8km^2) and the Minimbah sand bed aquifer drains the remaining 9% (122.1km^2) of the catchment area (GLC 2009).

The total catchment covers an area extending over three local government boundaries. This includes the Great Lakes Council (65%); the Greater Taree City Council (30%)to the north; and the Gloucester Shire Council (5%) to the west. Wallis

Lake, Minimbah sand beds, Coolongolook, Wallingat and most of the Wang Wauk sub-catchments lie within the Great Lakes Council area. The Wallamba River, Lower Wallamba River and parts of the Wang Wauk River sub-catchments fall within the Greater Taree City Council area. Grazing lands west of here belong to the Gloucester Shire Council area. (GLC 2009).

The catchment plays a critical role in maintaining the water quality of the site in Wallis Lake. Although much of the catchment of Wallis Lake is cleared or partially cleared agricultural land, extensive areas including the Wallingat National Park and Wallingat State Forest to the west of the site have been protected from clearing or development (Adam 1986).

The site receives most of its drainage from the southern and western sub-catchment of Wallis Lake and it falls entirely within the Great Lakes Council area (Figures 2.4.1, 2.4.2 & 2.4.3. Source: GLC 2009). The dominant land uses of this sub-catchment include protected vegetation in National Parks (31%); forestry in State Forests (38%); rural residential (21%); unimproved pasture (6%); roads (2%); and urban land (2%), as shown in Table 2.4.2 (GLC 2009).

Table 2.4.1: Summary of Wallis Lake Catchment Area and Lake Habitats*

Description	Size
Estuary Length	40.89 km
Estuary Width	10.46 km
Perimeter	227.88 km
Catchment Area	1,292.2km^2
Water Area	91.24 km²
Central Basin	74.81 km²
Intertidal Flats	1.30 km²
Seagrass	30.79 km^2
Mangrove and Saltmarsh	5.25 km²
Tidal Sand Banks	2.78 km²
Rocky Reef	0.08 km²
Channel	5.98 km²
Bedrock	0.00 km²
Floodplain	0.00 km²
Bedrock Perimeter	14.85 km

* Based on National Land & Water Resources Audit (NLWRA) 2001and Estuary Management Committee, 2005

* hppt://www.ozcoasts.org.au/indicators/beach_erosion.jsp

Table 2.4.2: Land use in the Wallis Lake southern and western sub-catchments (Source: GLC 2009)

Description of land use	% Cover	Area (ha)
Forest	38	1,967
Protected Vegetation	31	1,605
Rural Residential	21	1,087
Unimproved Pasture	6	311
Roads	2	104
Urban Land	2	104
Total	**100**	**5,176**

Figure 2.4.1: Location of Wallis Lake within the Great Lakes in the Hunter-Central Rivers region, just north of the Myall Lakes and Smiths Lake catchments. The various sub-catchments of Wallis Lake catchment are also shown. (GLC 2009)

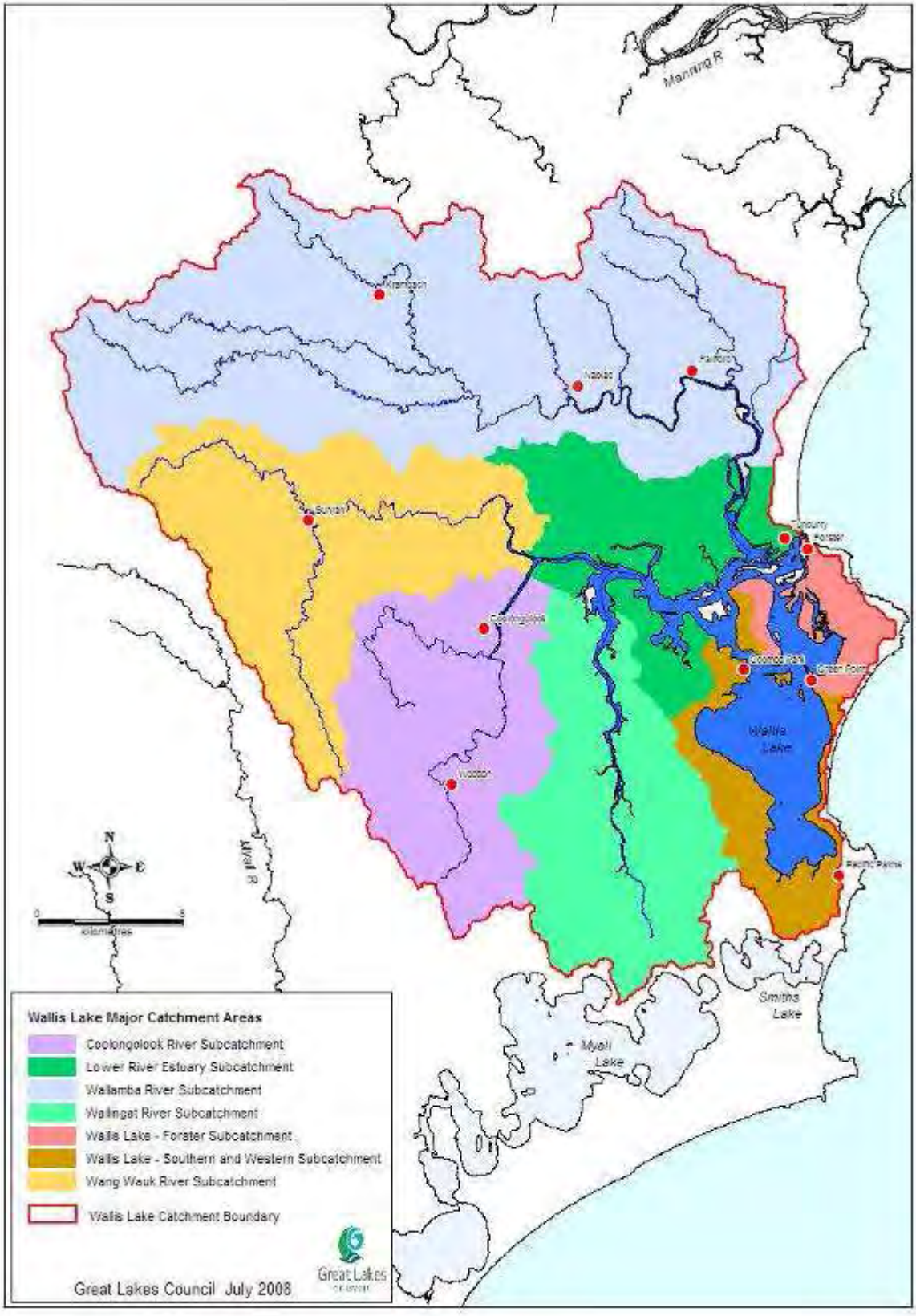


Figure 2.4.2: Local government jurisdictions within the Wallis Lake catchment: Great Lakes local government area, Greater Taree City local government area and Gloucester Shire local government area. (Source: GLC 2009)

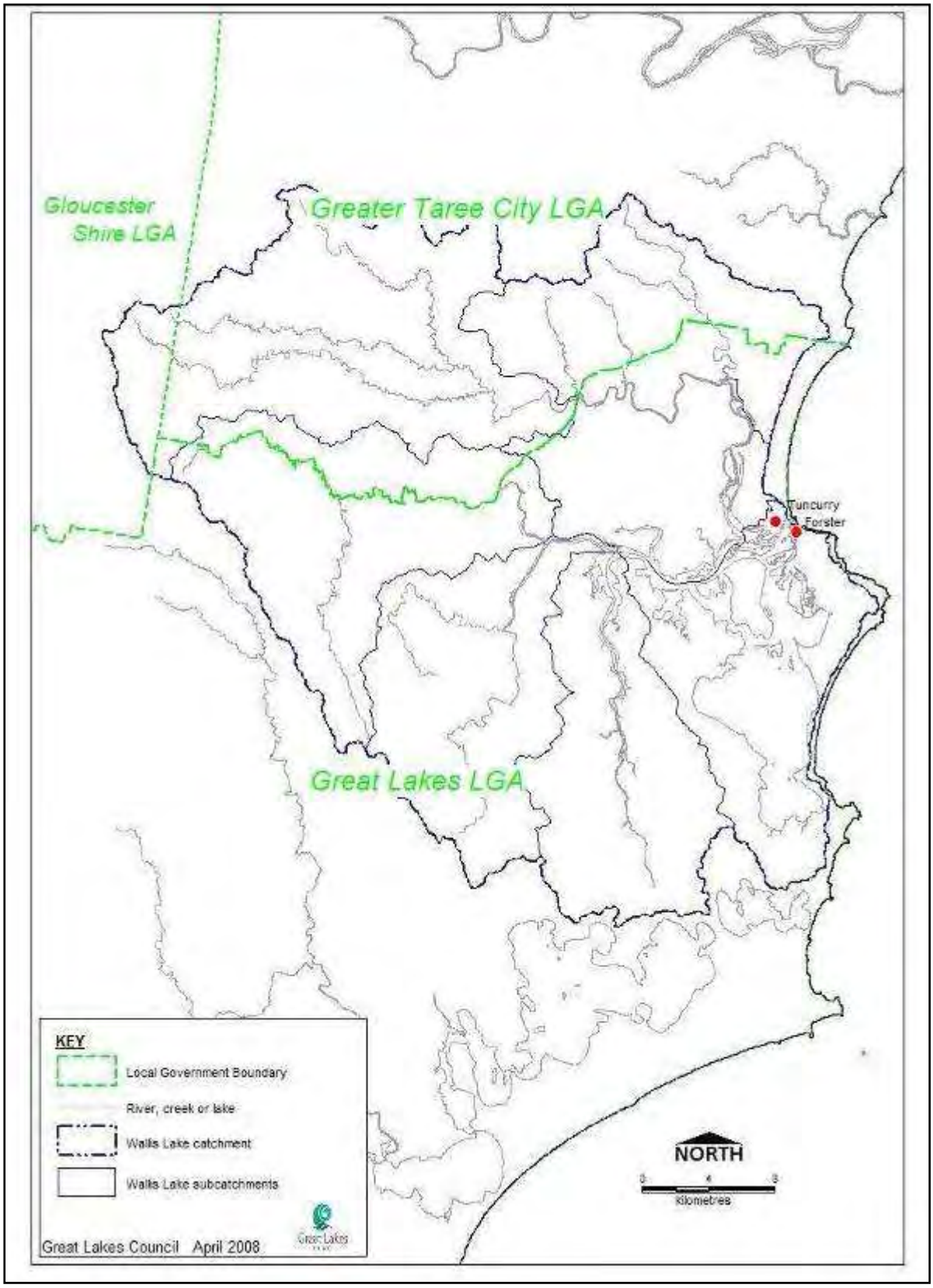
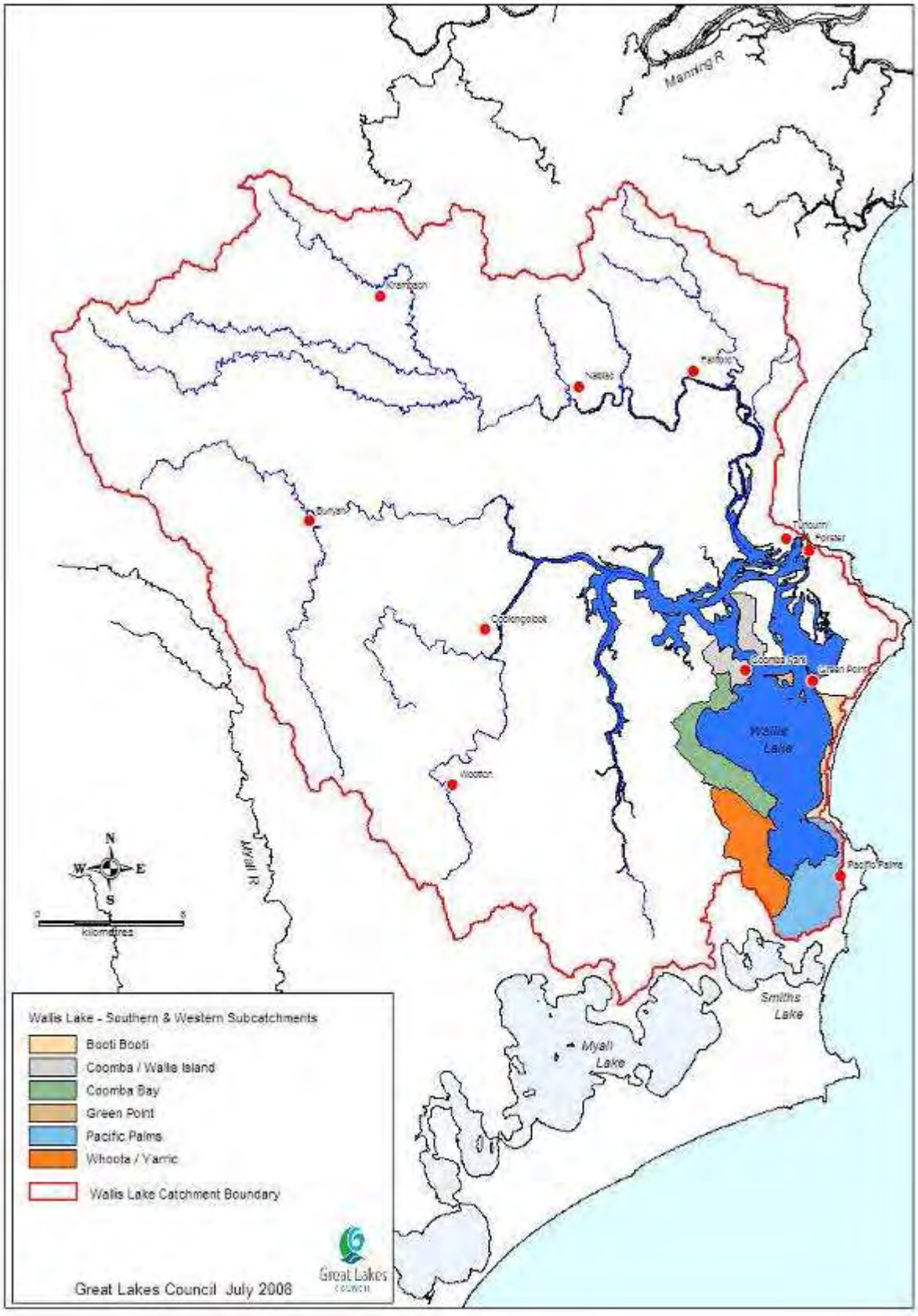


Figure 2.4.3: The southern and western sub-catchments of Wallis Lake (GLC 2009).



2.5 LAND TENURE

The proposed Wallis Lake southern and central basin Ramsar site is bordered on the western side by freehold land and a portion of Wallingat State Forest. To the west of this is Bachelor State Forest, which borders the upper catchment of the Cooloongolok River and is managed by Forests NSW. The eastern side of the lake is bordered largely by Booti Booti National Park with some interspersed freehold land.

The National Parks and nature reserves within the lake, bordering the eastern part of the lake and adjacent to the western boundary are protected under the NPW Act and managed by DECC. Waters adjacent to the site are also protected under SEPP 14 – coastal wetlands and SEPP 71 – coastal protection.

The remaining boundaries adjoin freehold land and Crown Land reserve. Much of the freehold land has been cleared for agricultural grazing activities and includes salt marsh areas.

Management of the proposed Ramsar site is consistent under the management objectives of the NPW Act for the conservation and wise use of wetlands. The objectives for managing National Parks in NSW directly protects and conserves the values for which the Ramsar site listing is proposed and aims to maintain the components, processes and services that define the ecological character of the site.

Land use practices of the surrounding catchment greatly influence water quality in the lakes system, however, and potentially threaten the ecological character of the site.

2.6 RAMSAR CRITERIA

This report, which forms the basis of an Ecological Character Description, proposes that the Wallis Lake southern and central basin site meets the criteria required for Ramsar listing. Under the current 2005 Ramsar criteria, this site meets Criteria 1, 2, 3 and 4.

Criterion 1: A wetland should be considered internationally important if it contains a representative, rare or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.

The wetland should be considered internationally important based on the presence of a rare and unique example of sponge communities found within the southern drainage basin.

Twelve species of sponge have been found in the southern basin of Wallis Lake which is shown to have the largest sponge diversity out of 20 coastal lakes and lagoons in NSW (Barnes 2009). Of these twelve species four are known only from Wallis Lake and most of the other species have been recorded from only a few other

lakes. Only two of the species have been tentatively identified to species level and those remaining are so far undescribed and new to science (Barnes 2010).

In addition to these unique sponges the southern basin contains a species of seagrass previously unrecorded in NSW, *Halodule tridentata*. Not only could Wallis Lake be the first recorded location for this species in NSW but also the southernmost area of its distribution on the eastern Australian coast. This species has only recorded from Queensland in the past but is widely distributed in the southern part of Wallis, typically scattered amongst dense beds of *Zostera capricorni* (Glasby & van den Broek 2010)).

Booti Booti National Park also has additional wetland types, for example swamp sclerophyll and littoral rainforest.

Criterion 2: A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.

The sponge communities of Wallis Lake comprise an example of a vulnerable community although these are not currently leglislated under any protective act. This is partly due to the fact that most of these species are new to science and little is known of their life histories. Studies in Wallis Lake over the past decade have shown that populations may vary over time and recent records show decreased numbers in some species. This may be cause for concern and the need for research to understand what threatens their populations and what requirements and limits are needed for population sustainability.

A newly recorded species of seagrass has recently been identified in Wallis Lake. The southern basin supports extensive beds of multispecific seagrasses, which are listed as vulnerable communities under the FM Act (1994). These include *Halodule tridentata,* only recently identified as occurring here in Wallis Lake. As this is the only identified location on the east coast of Australia south of Queensland Wallis Lake may also be the southernmost limit for the distribution of this species (Glasby & van den Broek 2010). This makes it vulnerable to both localized and more widespread environmental changes.

The northern half of the central basin and Wallis Lake supports extensive beds of *Posidonia australis* that occur here at the northernmost limit of its distribution in Australia. The very best examples occur along the western shoreline of Yahoo Island. *Posidonia* is known to be vulnerable to human activities and endangered populations have been determined in six more southern NSW estuaries (FM Act 2009) so careful management and protection for this species is important.

Criterion 3: A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.

The sponge communities of Wallis Lake comprise at least twelve species and as the assemblages here are far more diverse than in other similar coastal lakes (Barnes

2009) this wetland is extremely important for maintaining the biological diversity of this North Coast Biogeographic Region.

Furthermore these sponge communities coexist with the extensive macroalgal and seagrass beds including *Halodule tridentata* in the southern basin wetland and while the exact importance of the relationship between these communities is unknown it is potentially very high.

The Wallis Lake wetland supports at least two species of seagrass that are at the limits of their distribution. As at least one of these species is potentially threatened and as the limits are one to the north and one to the south, this means that the area is particularly vulnerable to any ecological changes and is of critical importance to maintaining biodiversity.

The Wallis Lake site also supports at least one threatened fish species, seven protected fish species, one endangered and two protected marine reptile species and at least five endangered or protected ecological communities including saltmarsh and seagrass. Furthermore there are at least two mangrove species, six saltmarsh species, 223 bird species and more than 100 fish species reported for the site. It also supports many species in the extensive and highly diverse surrounding terrestrial habitats.

In addition, the terrestrial ecosystems immediately adjacent to the Wallis Lake site include the endangered swamp oak forest, littoral rain forest and swamp sclerophyll forest.

Criterion 4: A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage of their life cycle, or provides refuge during adverse conditions.

Little is known to date about the critical stages of distribution of the sponges from the southern basin wetland and where knowledge is limited it is vital to proceed with caution to preserve what already exists. At least one of the sponge species has diminished in population density during the last two monitoring periods, from unknown causes, which may be related to natural conditions, climate change, sedimentation of the lake or its lifecycle. Until further studies can bring more certainty to the causes, utmost care should be exercised in management of the sponge communities.

The northern area of the central basin, particularly the coffee rock ledges along Wallis Island, supports protected species such as juvenile to adult stages of estuary cod, possibly juvenile black cod and syngnathids. Syngnathids such as White's seahorse, tiger pipefish and hairy pipefish are found in the protected seagrass habitat in both the northern and southern areas of the site.

2.7 ECOSYSTEM TYPES

2.7.1 WETLAND HABITATS

The main wetland habitats within the site are listed and described below and shown in Figure 2.7.1. These consist of both subtidal and supratidal habitats. This description focuses on the aquatic habitats, however, as the terrestrial habitats are beyond the scope of this study.

2.7.1.1 SUBTIDAL HABITATS

Seagrasss and Macrophyte Beds

Subtidal lagoon habitats within the southern basin include 1,643.2 hectares of seagrasss beds comprising at least five species of seagrass: *Zostera capricorni*, *Posidonia australis, Halodule tridentata, Halophila ovalis* and *Ruppia megacarpa. Posidonia australis* (Figure 2.8.1a), a protected species that has recently been proposed as an *endangered ecological community* in a number of estuaries in NSW (Fisheries Scientific Committee, 2009), occurs at the northern end of the southern-central basin and is in almost pristine condition along the south-western shores of Yahoo Island. *Halodule tridentata* (Figure 2.8.1b) occurs here at the southernmost limit of its distribution along the eastern coast of Australia and is the first confirmed record for NSW (Glasby & van den Broek 2010). The seagrass communities in Wallis Lake are of great importance as habitat and account for 35% of the total seagrass in the Hunter Central Rivers region and 20% of the total seagrass in the entire state of NSW (Creese et al. 2009). Seagrasses play a vital role in nutrient cycling within the lagoon, providing habitat structure, acting as both nursery grounds and sheltering fish and invertebrate communities, and stabilizing the substratum.

The southern end of the lake also supports macrophyte beds of the aquatic charophyte, *Lamphrothamnium* sp.. These are scattered throughout the southern basin, with concentrated patches in some areas (after Glasby & van den Broek 2010). Macrophytes play a similar role to the seagrass beds in providing structure and habitat, particularly for a diverse range of sponges, some of which are unknown outside Wallis Lake.

Sponge Gardens

The southern basin of Wallis Lake is unique in terms of diversity of invertebrates because it supports a highly diverse assemblage of estuarine sponges, almost twice as many species as any other NSW coastal lake. *Dysidea* sp., *Raspaillia* sp., a species of *Haliclona* and a species of *Halichondria* have only been recorded in Wallis Lake (Barnes 2009). Of the twelve species so far reported from the southern basin of Wallis Lake, only *Chondrilla* c.f. *australiensis* and *Aplysilla* c.f. *sulphurea* could be tentatively identified to species. The others have not yet been scientifically described and are likely to be new to science. Other sponges include *Suberites* sp. and *Mycale* sp. The ascidians *Styela plicata* and *Eudostoma laysani* are also associated with the sponge gardens.

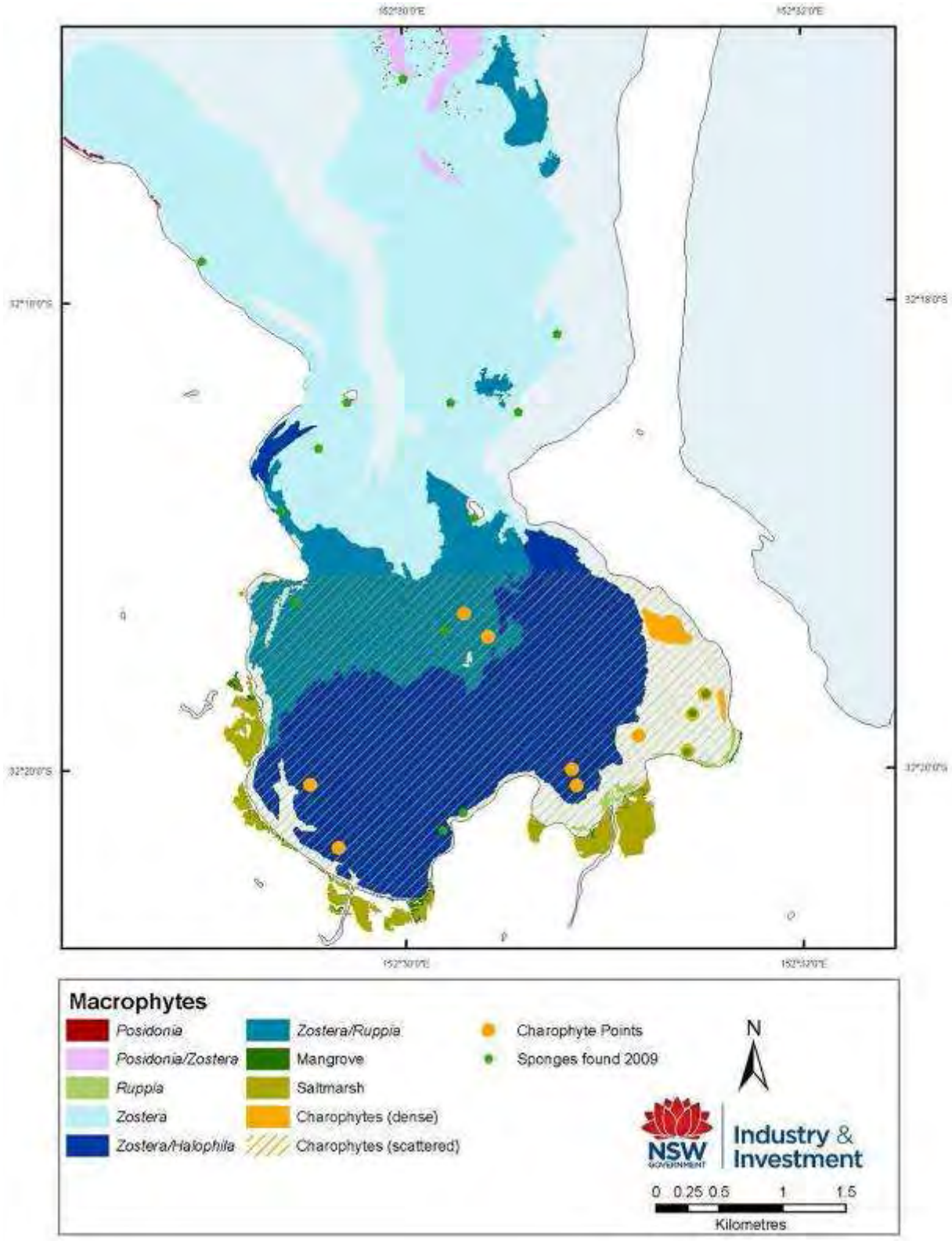


Figure 2.7.1: Wallis Lake Site Wetland Habitat Map (Glasby & van den Broek 2010)

Coffee Rock

Coffee rock is a rock-like formation of compacted, indurated sand comprised of humus and iron oxide components along the island foreshores. It can be brittle and may not be very stable substrate. Along the foreshore of north-eastern Wallis Island a 500m strip of coffee rock provides an excellent example of rocky habitat with a range of ledges and crevices for macrophytes to grow on and fish and invertebrates to feed and shelter within. The coffee rock provides habitat to a range of protected species including estuary cod, tiger pipefish, hairy pipefish and White's seahorse. It possibly also provides habitat to the threatened juvenile black cod.

2.7.1.2 SUPRATIDAL HABITATS

Saltmarsh

The saltmarsh in the entire catchment has been estimated at approximately 4km^2 (West *et al.* 1985) but this may be in decline as the area of saltmarsh in the southern basin of Wallis Lake was estimated at 69.1 ha in 2002, but just 43.8 ha in 2010 (Glasby & van den Broek 2010). Although the variation in estimate may partially be accounted for by differences in survey methods, this is cause for concern because it is known as vulnerable to human disturbances.

The saltmarsh in Wallis Lake is unusual in NSW because it is mostly fronted directly by the lagoon itself and not by mangroves, which is more common in other lake systems (Adams 1986). Pools are not so common amongst the marsh but when present may become hypersaline in summer and fresh after heavy rain. The saltmarsh in the site provides mostly edge habitat to fish and aquatic invertebrates, and it supports numerous flora and bird species.

Mangroves

Mangroves species in the Wallis Lake catchment consist of the grey mangrove, *Avicennia marina* and the river mangrove, Aegiceras corniculatum. Within the site mangroves occur along the edges of the saltmarsh, within the saltmarsh itself and edging the lake. These are scattered in distribution but nevertheless provide habitat for a range of invertebrates and juvenile fish. On Booti Island both species are found above the current tidal limit in crevices among rocks (Adam 1986). Mangroves have been mapped together with the saltmarsh in Table 1, because of its scattered distribution and association, but the total area of mangroves within the catchment is likely to be in the order of 1.25km^2.

Rocky Islands

These include Earps and Booti Islands and are rocky all the way down to well-below low tide level. These islands support mangroves and the fringing rocky subtidal areas support macroalgal species such as *Hormosira banksii* and *Codium spongiosum;* sponges, ascidians, and numerous fish, mollusc and crab species.

Sand Islands

Some of the islands within the site are used extensively as rookeries, particularly for the pelicans on Pelican Island and Snake Island in the central basin. Black swans, cormorants and terns often roost alongside the pelicans.

Littoral rainforest

An important feature of the area is the littoral rainforest, of which there exist only around 1,000 ha in the whole of NSW. The Great Lakes has a concentration of these stands (Clough 1979, Warren 1985) and this is of biogeographical interest as a number of rainforest species reach the southern limit of their distribution in this region. Cabbage tree palms (Livingstonia australis) are prominent to the south east of the lake around Pacific Palms and these may be replacement of rainforest under swampy conditions (Adams 1986).

2.8 WETLAND TYPES

The Wallis Lake site includes 10 representative wetland types as defined by the Ramsar Convention classification system (Table 2.8.1: Wallis Lake Wetland Types and Appendix 1). These wetland types are broadly categorized into four major groups based on salinity and ecological connection. The different groups do not function entirely as separate systems but all influence each other to some extent while at the same time maintaining the unique characteristics of the group. These groups have similar functions and will form the basis of discussion of ecological components and processes throughout this summary of ecological information.

Table 2.8.1: Wallis Lake Wetland Types

Group	Ramsar wetland types
1. Marine Coast	A, B, D, E
2. Mangroves and Intertidal Flats	F, G, H, I, M
3. Brackish Waters	J
4. Rivers, Creeks and Streams	H, I, J, M

Group 1: Marine Coast

Ramsar wetland types: A, B, D, E

Estimated area: Unknown

Where found: The entrance, channels and islands of Wallis Lake, including Wallis, Yahoo, Little Snake, Snake, Pelican, Earps and Booti Islands. Also includes the central and southern basins.

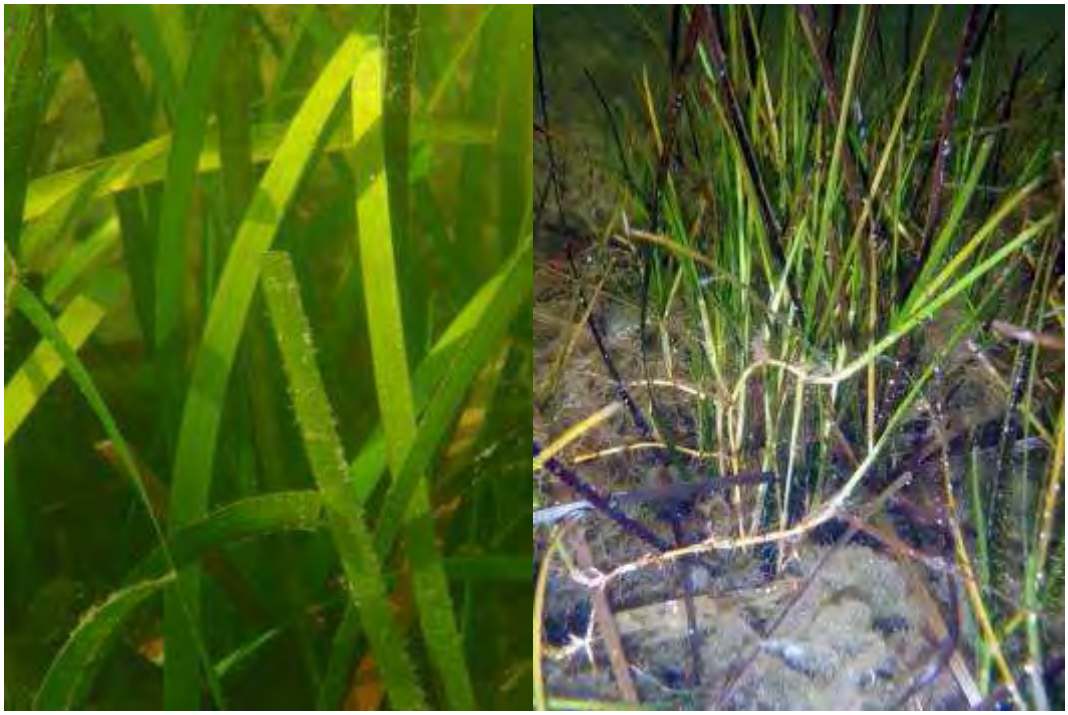
Description: Strongly influenced by oceanic tides, marine waters enter the lake through hydrological connection via the channels. Habitats include the seagrass (Figures 2.8.1 & 2.8.3) and macrophyte beds, coffee rock ledges and sponge gardens along Wallis and Yahoo Islands; rocky shores of Earps and Booti Islands and Talambar and Deepwater Points; sand spits associated with Pelican Island; and other seagrass and macrophyte beds of Wallis Lake

Key ecological components and processes: Clear, clean waters provide good conditions for growth of seagrass and charophytes and associated sponge gardens. Rocky and sandy shores, spits and islands provide significant habitat for shorebirds including the little tern, pied oystercatcher and pelicans for breeding and feeding.

Key cultural components and processes: Fishing and recreational boating

Key threats: Loss of habitat and changed vegetation types due to clearing, disturbance by human intrusion, predation and competition by introduced species.

Figure 2.8.1: Examples of (a) *Posidonia australis* and (b) *Halodule tridentata* in Wallis Lake (Photographs: I. Strachan; T. Glasby)



a) b)

Group 2: Mangroves and saltmarsh

Ramsar wetland types: F, G, H, I, M

Estimated area: Unknown

Where found: fringing the Wallis Lake wetland site along some of the islands in both the central and southern basins and at the entrance to Wallis Creek

Description: Intertidal sand and mudflats occur in Charlotte Bay and in the vicinity of Pelican and Yahoo Islands. Mangroves and saltmarsh are found in Charlotte Bay at the Wallis Creek entrance and along the western edge of the southern basin; northern Yahoo Island; central-eastern and southern Wallis Island.

Key ecological components and processes: Intertidal habitats are important to wading and migratory shorebirds as feeding habitat and provide roosting habitat at high tide.

Key cultural components and processes: Important for maintaining fishery productivity

Key threats: Loss of habitat and changed vegetation types due to clearing, disturbance by human intrusion, grazing by agricultural livestock, predation and competition by introduced species.

Group 3: Brackish waters

Ramsar wetland types: J

Estimated area: Unknown

Where found: Southern basin of Wallis Lake

Description: The southern basin can be brackish at times, as salinity drops following high rainfall events and heavy flows of freshwater runoff from the catchment.

Key ecological components and processes: Maintenance of hydrological processes and nutrient cycling; habitat for fish and invertebrate fauna (different species to those under greater marine influence) as part of their life cycles as shown in Figure 2.8.2; waterbird habitat.

Key cultural components and processes: Recreational and commercial fishing; recreational boating

Key threats: Loss of habitat and changed vegetation types due to increased loads of nutrients and sediments from catchment clearing, algal blooms, disturbance from human intrusion, predation and competition by introduced species.

Group 4: Rivers, creeks and streams

Ramsar wetland types: H, I, J, M

Estimated area: Unknown

Where found: Wallis Creek

Description: A relatively small creek, but the only one within the site, and takes in the catchment from Charlotte Bay village and Pacific Palms area.

Key ecological components and processes: Wallis Creek provides freshwater inflow into the lakes system. The creek is relatively small, however, and does not have a great influence on salinity of waters entering the creek from the southern basin.

Key cultural components and processes: Recreational fishery

Key threats: Loss of riparian vegetation and in-stream vegetation and increased loads of nutrients and sediments from catchment clearing, algal blooms, disturbance by human intrusion, predation and competition by introduced species, changed flow patterns from changed rainfall patterns.

Figure 2.8.2: Estuarine sponges and diverse benthic algae in Wallis Lake. Top: Healthy clear-water ecosystems around Earps Island, showing estuarine sponges and diverse benthic algae. These areas adjoin diverse and healthy seagrass, algae and macrophyte beds; Middle: The brilliant blue sponge Suberites sp. occurs almost exclusively on seagrass and macrophyte beds near Talambar Point; Bottom: The bright green alga Codium spongiosum is susceptible to smothering by sediments (Source: DECC)

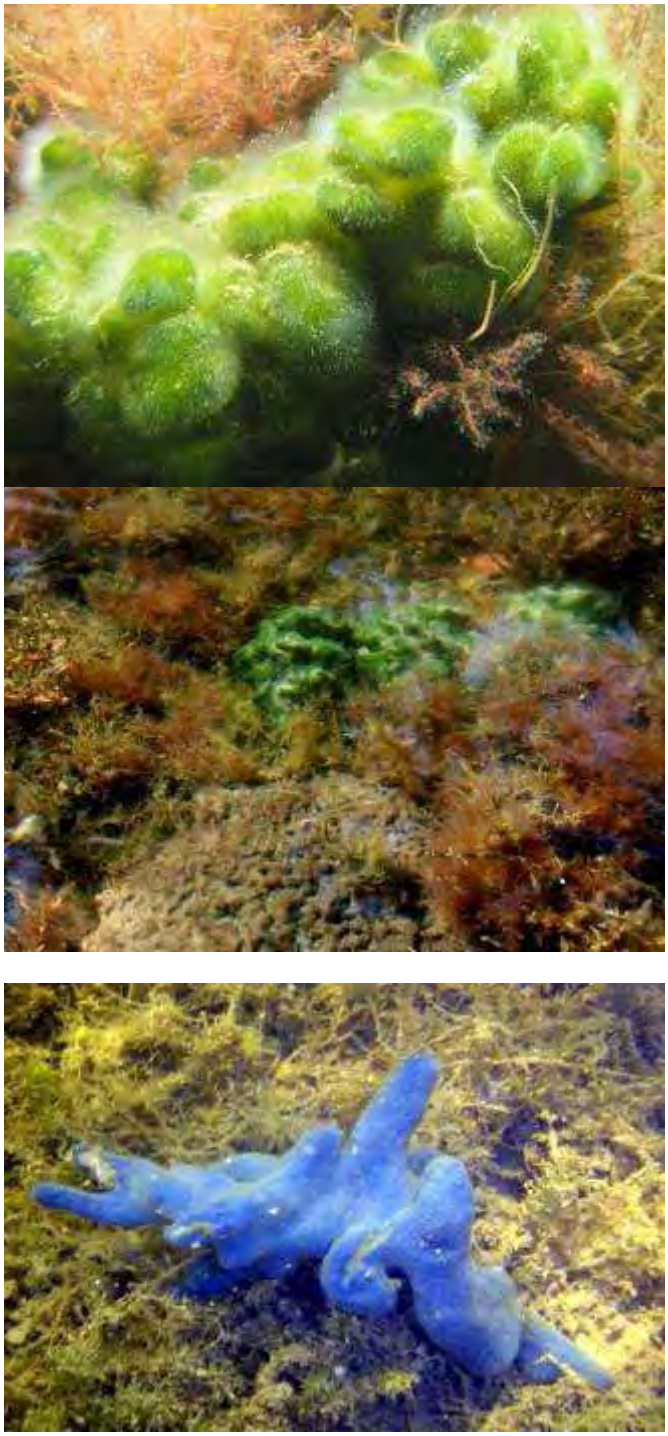
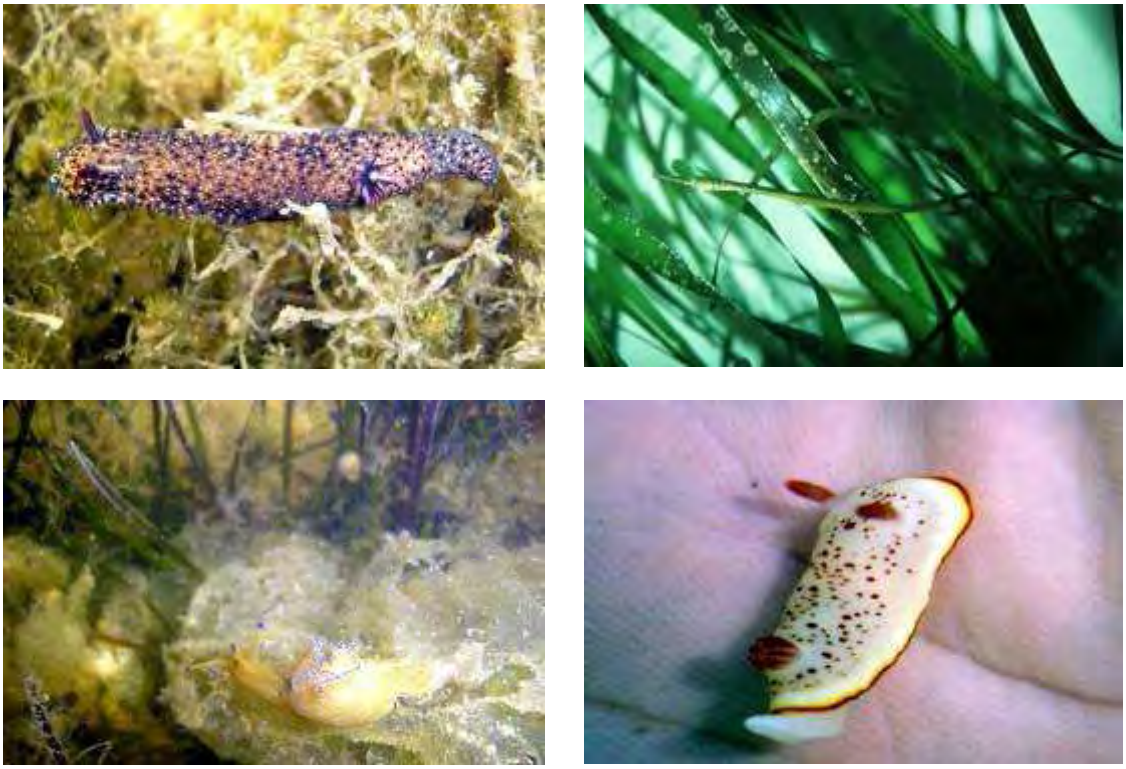


Figure 2.8.3: Biodiversity in Wallis Lake. Top right: Pipefish; Top left, bottom right: Colourful nudibranchs, and naked-gilled sea slugs; Bottom left: Sea hares (Aplysia sp.) live in the seagrass and macrophyte beds (Source: DECC).



3. ECOSYSTEM SERVICES AND BENEFITS

3.1 SUPPORTING SERVICES

Ecosystem support services pulls together many fundamental ecosystem processes that are essential to the maintenance of a sustainable ecosystem including primary production, nutrient cycling, habitat, food provision, breeding and nursery areas ecological connectivity and maintenance of food webs (DECC 2008).

3.2 REGULATING SERVICES

Retains sediments and associated nutrients

The southern and central basins of Wallis Lake act as a trap for sediments, organic matter and nutrients. Hydrographic modelling conducted in 2008 (GLC 2009) show that the mean residence (tidal flushing) time for these areas of the lake can be quite long (1 day-2 months).

The major sources of sediment to the section of Wallis Lake covered in this report are from eroded areas of the catchment, urbanisation, land clearing and farming practices (GLC 2009). Re-suspension of these sediments through human use and unfavourable wind conditions can continue to have light inhibiting effects on the macrophytes that live within the lake.

Due to the slow tidal flushing of the southern lake, sediments and their associated nutrients are able to settle out of the water column. These nutrients are taken up by plants and algae and for the most part remain in the nutrient cycling within the water body.

However it should be noted that because of slow tidal flushing and long retention times, coastal lakes are sensitive to high nutrient loads and sedimentation which jepoardises these highly diverse ecosystems (GLC 2009).

Recycles nutrients

It is documented in the literature that saline water bodies are limited by nitrogen, whilst freshwater systems are phosphorus limited. Studies of nutrient cycling within the main body of Wallis Lake show that the lake has a denitrification efficiency of almost 100%, recycling most of the nitrogen falling to the sediments (Smith & Heggie 2003). This shows the capability of the lake to assimilate the current nutrient loads into its internal processes without providing stress to the system. However if the nutrient loads were to increase, it is likely that the nutrient cycles occurring within the lake would not be able to cope.

Flood control

The wide shallow nature of the lake intercepts and stores stormwater, changing sharp peak runoff to slower discharges over a longer timeframe. As flood damage is

usually produced by the peak flows, the lake reduces peak flows and provides a certain level of flood protection (DECC 2008).

Water Quality

The southern basin of Wallis Lake has been classified as being of 'high conservation value' or near pristine state (GLC 2009). It supports a wide variety of seagrass, healthy algae, brackish water plant (macrophyte) and sponge communities that are dependent on clear, clean water with very low nutrient loads (GLC 2009).

It is widely reported that increased land use and removal of vegetation results in increased amounts of sediment and nutrients washed into the waterways. Sediments reduce the light availability to plants including seagrasses and the recently discovered sponges and nutrients promote the growth of fast growing nuisance algae that also smothers and reduces light availability and penetration.

The main body of Wallis Lake and in particular the southern basin, has comparatively little urban development in the catchment immediately surrounding. The lake supports a variety and density of aquatic plants that serve to trap and stabilise sediments and utilise and recycle nutrients resulting in clean, clear water.

3.3 PROVISIONING SERVICES

Food and Commercial fisheries

Up to 51 commercial fishers operate in Wallis Lake, supporting a valuable commercial fishing industry including oyster farming. Wallis Lake achieves the highest production of Sydney rock oysters in the state of NSW, with a total of 2,773,842 dozen oysters produced in the 2008/2009 season (I&I 2010). This amounts to 42.4% of the state's production.

The economic value of Wallis Lake's commercial oyster production reached $14,822,211 in the 2008/2009 year (I&I 2010).

The annual catch of other species caught in the lake are approximately 360 tonnes per year. The species of most significant commercial interest include; sea mullet (*Mugil cephalus*), luderick (*Girella tricuspidata*), dusky flathead (*Platycephalus fuscus*), sand whiting (*Sillago ciliata*), yellow fin bream (*Acanthopagrus australis*), blue swimmer crabs (*Portunus pelagicus*), and a number of prawn species.

The value of the commercial fishing industry to the region is estimated at approximately $22 million per annum, making it one of the largest industries after tourism.

3.4 CULTURAL SERVICES

Recreation and tourism

Tourism in the Great Lakes is the "life blood" of the local economy. The Great Lakes area is within a relatively short distance to large population centres such as

Newcastle and Sydney and offers a range of activities in our natural environment. The 'pristine' nature of our waterways, beaches and hinterlands attract the tourists to this area. It is estimated that around 100, 000 people visit the Great Lakes each year, contributing $125 million annually to the local economy.

The popular activities conducted in the area surrounding Wallis Lake include boating (power boats, sailing boats, kayaks), recreational fishing, swimming, bushwalking, cycling, picnicking, bird watching, and general aesthetic enjoyment. The facilities that support these activities are boat ramps and associated facilities, wharves, camping grounds, toilets, picnic areas, roads and pathways, playgrounds and interpretative signage.

The major recreational activities are described below:

Boating

Powerboats and sailing are the two predominant forms of boating that occurs on Wallis Lake. There is a sailing club located on the foreshore of the eastern side of the main lake body that holds regular events, and the area is open for the public to use. It is also a popular place for picnics and recreational use.

Powerboats are more dominant on the lake and are used for fishing and water sports. During peak visitor season their numbers increase dramatically.

Fishing

Recreational fishing is extremely popular within Wallis Lake, however there is no data to quantify the volume of catch taken by recreational fishers. Species targeted within the lake include, bream, flathead, leather jacket and mullet. Traps for blue swimmer crabs and prawn netting also occur in the lake.

3.5 CULTURAL HERITAGE

Aboriginal heritage

The traditional custodians of the Wallis Lake area are the Worimi people, whose lands ranged from the Tuncurry area in the north, to Newcastle in the south and Gloucester in the west. Their lifestyle was supported by a rich abundance of coastal foods provided by lakes, rivers, ocean and diversity of wetlands that is evident through middens, campsites and burials.

The entire coastal area including Wallis Lake remains important to the Worimi people for traditional foods and learning, recreation and spiritual values, sacred sites and maintaining connection to country.

Historical heritage

Land clearing began in the Wallis Lake catchment for timber resources and pastoral lands in the early 1800's, and is recognised as being one of the earliest catchment areas to be exploited in this manner (GLC 2009). By around 1850's the Australian Agricultural Company abandoned their claim for the coastal strip that started the

allocation of land grants between 1856 and 1875. These land grants were the beginning of the shipbuilding and fishing industry in Forster Tuncurry (GLC 2009). By the mid 1970's around 44% of the Wallis Lake catchment had been cleared of its native vegetation (GLC 2009, Wallis Lake Catchment Plan Steering Committee 2003, Webb *et al.* 1999).

In 1884 around 700 oyster leases had been formally established on approx 5.5km of Wallis Lake foreshore (GLC 2009).

4. ECOLOGICAL COMPONENTS AND PROCESSES

4.1 PHYSICAL PROCESSES

The physical components and processes of the Wallis Lake site include climate, geology and geomorphology. These are key drivers of the overall system as they determine the conditions and the setting for all other components and processes. Due to their influence on other components and processes a change in character of these ecosystem drivers will likely cause a change in character of all other components and processes.

4.1.1 CLIMATE

The Wallis Lake estuary has a warm temperate climate with a strong marine sub-tropical influence. It has high humidity and rainfall and does not have stark daily or seasonal contrasts.

Precipitation - Average annual rainfall measured 1218.6mm with an annual median of 1207.4mm (Forster Post Office BoM Station 60013). Monthly averages and medians are shown in the table (Table 4.1.1.1) below. The wettest month is March and the driest month is September.

Table 4.1.1.1: Average and median annual rainfall for Forster (1896 – 2009)

Mnth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Av. (mm)	107.3	118.4	150.2	128.5	116	117	87.4	72.4	67.6	78.4	80.7	92.4	1218.6
Med. (mm)	91.5	92.5	116.5	96.8	107.4	92.4	59.5	51.4	45.5	58.1	70.0	76.5	1207.4

Temperature - The temperature data with the closest resemblance of conditions to Wallis Lake estuary is that from Nelson Bay (BOM Station 61054). Average temperatures range between 11^0-30^0C in summer and 5^0-24^0C in winter. There are occasional days of light to medium frost in the catchment. Mean daily maximum and minimum temperatures for Nelson Bay and for Forster (BoM Station 60013) are shown in the tables (Tables 4.1.1.2 and 4.1.1.3) below:

Table 4.1.1.2: Mean maximum and minimum temperature for Nelson Bay (1914-1972)

Mnth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr Av
Max T ^{0}C	27.5	27.0	26.1	23.8	21.1	18.6	17.6	18.9	21.3	22.8	23.5	25.7	23.1
Min T ^{0}C	17.3	17.7	16.4	13.7	11.0	8.8	7.7	8.4	10.2	12.5	14.6	16.5	12.9

Table 4.1.1.3: Mean maximum and minimum temperature for Forster (1999-2009)

Mnth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr Av
Max T 0C	26.3	26.3	25.3	23.5	21.0	18.9	18.2	19.2	21.4	23.3	25.2	26.3	22.6
Min T 0C	19.5	19.5	17.6	15.1	12.0	9.8	8.6	9.4	11.7	13.9	16.0	18.1	14.2

Evaporation- Average evaporation data from a standard Class A pan with bird guard is available for the BOM for Taree Station 60030. For the period 1979-1997, average annual evaporation was 1383mm. Average monthly evaporation data are shown in the table (Table 4.1.1.4) below:

Table 4.1.1.4: Average evaporation rate for Taree (1979 – 1997)

Mnth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Evapn	171	141	129	96	64	53	62	84	113	142	154	173	1373

Wind- Prevailing summer winds are from the north-east, bringing moist air and winds of 10-20km/hr. Westerly winds, not as common, are hot and dry, usually 10-20km/hr but up to 50km/hr. Autumn winds are south-easterly bringing coastal rain. Winter winds are from the west and south-west, bringing cool air.

Changes in climate have the potential to threaten the character of the site by altered rainfall volumes and patterns, increased threat of more storms with high winds, raised sea level and increased water and air temperatures.

4.1.2 GEOLOGY

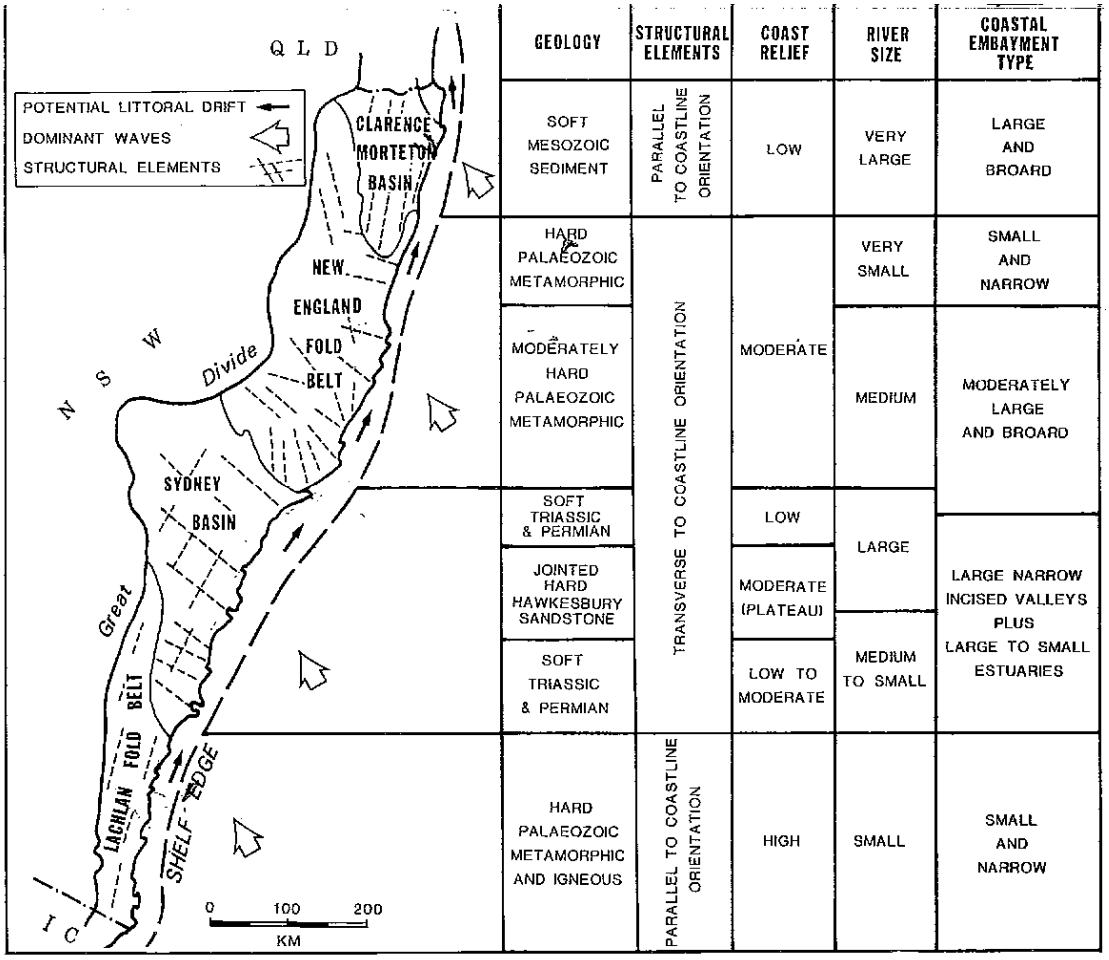
Situated within the New England fold belt (Fig 4.1.2.1), the site which forms the main Wallis Lake area is a barrier lake system with Carboniferous sedimentary rock hills and ridges forming the western foreshore and a more recent (Quaternary) dune system forming the eastern foreshore barrier between the lake and the ocean (Webb *et al*. 1999, Meleo 2009).

During the last ice age (120,000 - 18,000 years ago), sea level fell to approximately 120m below the present level. The coastal floodplain extended some 25km eastward of the present shoreline. At the end of the ice age when sea level began to rise again, sediments deposited on the inner shelf were transported landward to form barrier beach/dune complexes, with catchment materials ‘trapped’ behind coastal embayments, ultimately forming the modern-day floodplains and coastal rivers and lakes.

In the Forster area, the rising sea level and consequent formation of the 7 Mile Beach barrier complex created an impoundment, forming the main lake area behind the barrier of sand between Cape Hawke and Booti Booti. North of Cape Hawke, the sand from the previous ice ages formed a series of beach dunes which prograded eastwards all the way to Hallidays Point. The present sea level was attained

approximately 6,500 years ago and the lake entrance and islands formed by meandering of the rivers and entrance channels (Webb *et al.* 1999).

Figure 4.1.2.1: Geology of NSW east of the Great Divide (Source: Chapman *et al*. 1982)



4.1.3 GEOMORPHOLOGY

There are four main geomophological features associated with the Wallis Lake estuary: the entrance/island area, the main Wallis Lake area, the Wallamba River catchment and the Coolongolook River system including the Wang Wauk, Coolongollok and Wallingat Rivers.

The entrance/island area consists of sand islands and coastal dunes intersected by the meanders of past entrance channels, marine delta deposits and the results of channel dredging. The soils are sandy, permeable and of low fertility.

The main Wallis Lake area, between the sedimentary rock western shoreline with its loamy yellow earths and podsols and the more recent eastern barrier sand dunes of the eastern shoreline has soils of low fertility. The podsols are highly erodible when disturbed.

The Wallamba River catchment covers a third of the total catchment, and consists of broken sedimentary rock hills and valleys upstream of the estuary with loamy yellow earths and podsols. The lower catchment is dominated by fluvial and estuarine sand and silt deposits from the estuary and coastal plain.

The Coolongolook River system includes more than a third of the total catchment. The Wang Wauk sub-catchment is similar to the upper Wallamba sub-catchment but the Coolongolook and Wallingat Rivers occupy steeper valleys between sedimentary rock ridges and their lower estuarine sections are drowned river valleys (Webb *et al.* 1999).

Soils, Sedimentation and Erosion

Sediments are transported throughout the marine environment via the hydrological cycle and are influenced by catchment land use and climate. The tides and currents that occur in the marine environment allow accretion and erosion of sediment in different locations, which affects habitat location and quality.

Wallis Lake is a relatively immature barrier estuary with relatively low sediment infilling because the rivers are in close proximity to the mouth of the estuary and the catchment is relatively small with hard catchment rock and an initially deep basin (Meleo 2009). The estuary is made up of a combination of marine and fluvial deposits, which are relatively recent, eroded and deposited in the last 20,000 years. Non-consolidated Quaternary sand deposits are dominant landscapes in the area (beaches, dunes, back barriers, coastal lowlands/floodplains). Marine deposits and delta movement are high at the entrance to the estuary but not in the southern basin of the lake, where fine fluvial sediments are mixed with and overlie reworked coastal sands. Based on modelling fluvial sediments entering Wallis Lake estuary are around 11,000m^3 per year of which 20% would be deposited on the lake bed, a rate of 0.05mm per year averaged over the entire lake. However in the southern basin deposition rate could exceed 0.2mm per year (Webb *et al.* 1999). Direct sediment inputs to the southern basin mainly occur from Wallis Creek, with sediments trapped in the seagrasses and deposited over the lower lake. Sediments deposited along the foreshore are transported to deeper waters by wind, waves and currents.

In the catchment adjacent to the lake low fertility catchment soils have developed from the sedimentary rocks that in turn developed from acidic volcanic bedrock. Characteristic soil types have developed on the flat ridge tops, the flat coastal lowlands and hill slopes. Shallow loamy yellow earths have developed on ridge crests, which are mostly covered with forests, and are of low fertility and moderately erodible if disturbed, but moderately resistant to erosion in forested areas (Bass 1985). Yellow podsolic soils have developed from sedimentary rocks that are poor in alkalinity and of low fertility. These occur on hill slopes and topsoils are poorly aggregated and easily detached when wet. Erosion can be severe in exposed soils but only moderate to low erosion usually occurs in grazing areas, most of which are in the upper catchment.

4.1.4 HYDROLOGY

Tidal regime and flows

Ocean tides at the entrance to Wallis Lake estuary consist of the normal ocean astronomic tide plus localized impacts from the ocean bed, storms, waves, currents and water temperature variations. There are two tides each day with a mean range of approximately 1.05m, a mean neap range of 0.75m and a mean spring range of around 1.35m. Maximum range is less than 2.0m. Variations from the predicted tide can exceed 0.5m during major storm events, as shown below in Table 4.1.4.1 (Webb *et al.* 1999).

Table 4.1.4.1: Tidal Ranges and Mean Phase Lag in Wallis Lake

Gauge Location	Ocean	Entrance	Islands	Main Lake	Wallamba River	Coolongolook River	Wang Wauk River	Wallingat River
Gauge No. (MHL,1998)	**0**	**1**	**7**	**17**	**32**	**25**	**26**	**23**
Mean Spring Range (m)	1.32	1.068	0.241	0.147	0.321	0.145	0.145	0.156
Mean Range (m)	1.049	0.861	0.196	0.122	0.269	0.125	0.124	0.134
Mean Neap Range (m)	0.779	0.654	0.15	0.097	0.217	0.105	0.103	0.113
Mean Phase Lag (min)	0	4	74	214	191	209	209	230

There is a big drop in tidal range between the entrance and the rest of the estuary. The main lake has a tidal range of 10-15% of the ocean tide, which is associated with the tidal lag time behind the ocean tide. Lag time is greater than 3 hours in the central and southern basins of the lake, which is associated with shallow water effects within the estuary entrance (Webb *et al.* 1999). As these effects restrict flows and limit the capacity of the tide to fill the lake during a tidal cycle, the lake acts as a large reservoir which drains or fills through the narrow entrance, only partially filling when ocean tide is high and partially emptying when ocean tide is low, i.e. 3 hours after the minimum ocean tide. Peak flows occur when the water level differences between the lake and the ocean are at their greatest, i.e. at peak high water and bottom low water. Peak flows are higher for flooding tides than for ebbing tides. This is the result of shallow water and frictional effects that affect low tides more than high tides. The low tides then become longer with smaller peaks in flow, and the high tides shorter with larger peaks in magnitude.

Tidal Flow Distribution, Flushing, Exchange and Balance

Tidal flows between the entrance and the main lake are greater than flows into the tributaries, as there is much more storage area available in the lake. As it flows into

the lake, more tidal flow passes to the west of Wallis Island than to the east. During a mean springtide the channels from the entrance to Wallis Lake have peak tidal velocities of 0.2m/s – 0.8m/s, with 1.4m/s at the entrance. At the southern end of the lake peak spring tidal velocity is 0.01m/s. Movement of water within in the lake caused by wind generated currents produces much higher peak velocities, up to 0.5m/s at the surface.

The degree of tidal flushing is given by a *tidal prism ratio,* which is a ratio between the estimated mean tidal prism at specific locations within the estuary and the upstream volume of the estuary at low tide level. The ratio indicates the degree of tidal flushing i.e. volume of water moving in compared to remaining volume at that location. At the entrance to the lake there is complete flushing, but otherwise the exchange of tidal waters is dependent on mixing and dispersion rates, however the ratio gives an indication of tidal exchange and interaction between tidal movement and water quality. Tidal prism ratios are consistently 7-9% throughout the Wallis estuary (see Table 4.1.4.2), which is higher than for a larger lake estuary (typically 5-10%) because the rivers are less affected by lake storage effects. Large lakes have an increased potential to act as sinks for pollutants which enter the waterways and settle, rather than being flushed from the system by tidal flows or flooding.

Table 4.1.4.2: Tidal Prism Ratios in Wallis Lake (Source: Webb *et al.* 1999)

Location	Mean Tidal Prism (Mm^3)	Low Tide Volume (Mm^3)	Tidal Prism Ratio
Ocean Entrance	11.2	160	0.07
East-West Wallis Is.	7	100	0.07
Lake (Green Pt to Coomba Park)	5.7	75	0.08
Coolongolook River at Entrance	1.6	20	0.08
Wallamba River at Entrance	1.3	15	0.09

The rate at which estuary waters are exchanged with ocean waters depends on degree of tidal flushing and on mixing rates between catchment inflows and ocean waters. Mixing depends on water densities, flow velocities, channel shape, substrate, storage, wind-generated currents among other things.

The flow rates for 100% tidal exchange are estimated as <1 week for eastern Wallis Island; 2 weeks for the lower lake (Coomba Park to Green Point); and >2 months for the southern basin near Booti Booti (Stn 18).

Water Balance consists of tidal inflows and outflows through the entrance, catchment runoff and precipitation and evaporation directly from the estuary, as shown below in Table 4.1.4.3 (Webb *et al.* 1999). Direct runoff into the catchment as

drainage or groundwater is less than 10% of total inflow to the lake but does come from the foreshore area in the south and west of the lake that is underlaid by sedimentary rocks. Volume into the estuary balances volume out of the estuary, with a volume of 8,250,000 megalitres per year, which means that around 95% of all waters entering and leaving the estuary are tidal flows.

Table 4.1.4.3: Average Annual Water Balance Estimate for Wallis Lake (Source: Webb *et al.* 1999)

Water Balance Component	Volume In (ML)	Volume Out (ML)
Entrance Flows	**7 850 000**	**8 160 000**
Fluvial Runoff (Surface and Groundwater) comprising the following	**300 000**	
Wang Wauk River	50 000	
Wallamaba River	135 000	
Coolongolook	40 000	
Wallingat River	35 000	
Lake Area	10 000	
Entrance Island Area	30 000	
Direct Rainfall	**100 000**	
Evaporation		**90 000**
TOTAL	**8 250 000**	**8 250 000**

Climate Change Effects

It remains unclear as to whether overall changes to the balance of water in Wallis Lake would occur as the result of climate change as any rise in ocean water levels may be exacerbated or minimized by changes in storm activity and rainfall in the region.

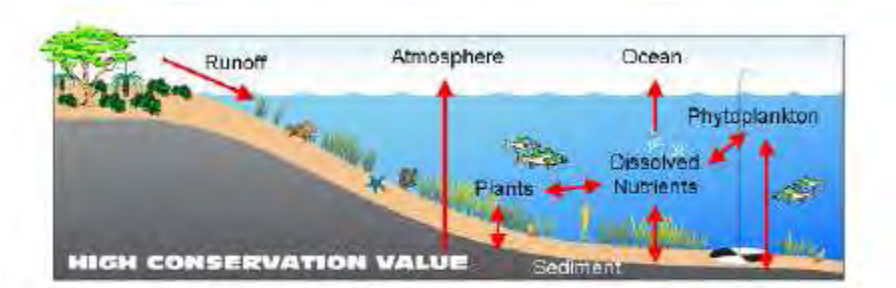
4.2 BIOGEOCHEMICAL PROCESSES

Nutrient Components

Nutrients in the water column are important for survival and growth of organisms and are affected by the nutrient cycling processes in the lake. These processes involve biological (plant and bacterial) activity, and are affected by light and nutrient

availability, temperature and sedimentation. A diagram of the complex network of processes occurring in the water column is shown below in Fig 4.2.1.

Figure 4.2.1: Nutrient Cycling Processes in Wallis Lake (Source: DECC)



Nitrogen and Phosphorus

Nutrients are primarily sourced from catchment runoff, but rainfall and decaying plants are also contributors. Loss of nutrients occurs through tidal outflow to the ocean, burial in sediments and, for nitrogen, denitrification to produce nitrogen gas, which is then lost to the atmosphere. Aquatic plants take up nitrogen and phosphorus in order to grow. Both nutrients must be available and can limit growth if in short supply. Wallis Lake is thought to be nitrogen limited but Myall Lakes may be phosphorous limited.

Nitrogen and phosphorus are found in many forms in water but exist in three major categories: as dissolved inorganic, dissolved organic and particulate (Table 4.2.1). The sum of these is the total nutrient pool, i.e. total nitrogen (TN) and total phosphorus (TP). Depending on the form it is in, the nutrient may play a large part in stimulating rapid 'nuisance' plant growth. In dissolved inorganic forms (DIN, DIP) both nitrogen and phosphorous are very *active* in stimulating rapid algal growth if other conditions such as temperature, light and salinity are favourable (GLC 2009).

Table 4.2.1: Forms of nitrogen and phosphorus that can be found in coastal lakes and river estuary waters, and their likely short-term bioavailability to stimulate algal growth (Source: GLC 2009).

Category	Description	Bioavailability
Dissolved inorganic	Chemically bound to carbon, and include urea and amino acids	Immediate
Dissolved organic	Commonly derived from some animal or plant product, which may be living, dead, fragmented, excreted (urine, faeces) or exuded (mucus, enzymes, etc.)	Depends on the compound, e.g. brown tannin stains from tea-tree swamps are completely inactive dissolved organics Reactivity not known for many compounds
Particulate	Constitutes a solid fragment, which can be some animal or plant product such as fish flesh, leaf fragments and algal cells; or non-living particles such as soil	Not immediately

Benthic seagrass, charophyte and other macrophyte plant growth in Wallis Lake is controlled by the amount of light that penetrates through the water column, which in turn is affected by water clarity, bathymetry and the stability of the lake bed. Too many nutrients, sediments and algae in the water can block light from reaching the benthic plants, which have a suitable depth range and grow in areas that are not subject to wave action.

Only the immediate sub-catchment impacts the southern and central basins in terms of nutrients or sediments from the wider catchment. This is due to the hydrological separation of southern Wallis from the inputs of the major rivers, and the relatively small south-western sub-catchment with abundant natural vegetation surrounding the southern bays. Models of nutrient loads from the surrounding sub-catchment estimate total nitrogen (80kg/m^2/yr), total phosphorus (4kg/m^2/yr) and total sediments (10kg/m^2/yr) as shown in the table below (Table 4.2.2).

Table 4.2.2: Nutrient loads from the catchment case study areas (kg/km^2/yr) (Source: GLC 2009).

	Total Nitrogen	Total phosphorus	Total suspended solids
Piper'sBay	762.0	73.0	270.0
Coomba Bay	113.0	4.7	2.3
Southern Bay	78.0	3.8	9.6

Sediments and Water Stratification

Sediments, which wash into the estuary from the catchment, are suspended in the water column in the short-term (days), but eventually settle to the bottom. Wind-induced currents and waves can stir these up and so the sediments are prone to resuspension over months to years, making the water column turbid and reducing light penetration to benthic plants. This results in deterioration of the seagrass/ macrophyte habitat and loss of the associated fish and invertebrate fauna associated with the habitat.

Lower levels of nutrient runoff favour slow-growing macrobenthic plants such as seagrasses. Excess nutrients from catchment runoff stimulate excessive growth of free-floating and microscopically small phytoplankton in the water column; epiphytic algae which grows on the seagrass; and macrobenthic algae which grows alongside the seagrass. The effects are murky water and shading from the sunlight, which results in accelerated loss of seagrass and build-ups of decaying plant matter in the water.

Seagrass decays as part of a natural cycle and is essential to nutrient recycling, however, in small amounts over time. Excessive amounts of decaying matter strips oxygen from the water and sediments, which can be lethal to fish and invertebrates.

Water stratification in the upper estuary can also prevent exchange of oxygen between deeper waters and the surface. When combined with algal blooms and excess organic matter in the catchment it can result in deoxygenation of the water and massive fish kills.

Wallis Creek at the southern end of the lake has been shown to be generally well-mixed, with little evidence of water stratification and only small differences between surface and bottom water temperatures and salinities Studies have shown dissolved oxygen levels close to saturation (100%) with supersaturation of water (116%) at 4m depth in the central basin (Table 4.2.3) (Smith & Heggie 2003).

Table 4.2.3: Water Column Profiles in Wallis Lake (numbers in brackets are from the 2000 winter survey) (Source: Smith & Heggie 2003).

	Depth (m)	Temperature ^{0}C	Salinity ppt	DO (%)
Wallis Creek	0	25.94 (14.7)	32.31 (33.84)	103.7 (93.5)
	0.8	25.84 (15.1)	32.32 (34.30)	97.4 (95.6)
	1.4	25.86 (15.2)	32.32 (34.35)	96.7 (95.5)
Central Basin	4.0	23.64 (14.8)	33.51 (31.30)	111.6 (75.1)

Nutrient Concentrations

Denitrification efficiency (the efficiency with which microbial reactions in the sediments convert N fixed in plant material into N_2 gas) is high within the Wallis Lake site, with studies showing 100% at all sampled sites (Table 4.2.4), (Geoscience Australia 2003). This means there is limited recycling of ammonia from the sediments to the overlying water, where it could contribute to phototrophic growth. This indicates that there is little risk of eutrophication and deterioration in water quality.

Table 4.2.4: Average Bottom Water Nutrient Concentrations for Wallis Lake (2000 and 2003) (Source: Smith & Heggie 2003)

Site	NH_4	PO_4	NO_x	SiO_4	Date
PipersCk	6.67	0.22	0.36	40.9	Feb 2003
Wallis Ck	0.34	0.35	0.06	6.3	Feb 2003
Central Basin	0.87	0.37	0.07	4.4	Feb 2003
PipersCk	0.58	0.02	0.06	1.02	June 2000
Wallis Ck	0.53	0.04	0.08	0.8	June 2000
Central Basin	0.39	0.02	0.20	0.3	June 2000

Carbon loading

Diatomaceous organic matter may represent half to most of the carbon input into the sediment in Wallis Creek as shown by carbon flux measurements (Smith & Heggie, 2003) and seagrass detritus also accounts for organic carbon sediment input. Denitrification efficiency is high (100%). In the central basin diatomaceous carbon (TCO_2) fluxes to the sediments possibly increase during summer, however denitrification efficiency only slightly decreases. Despite the increase in carbon loading denitrification efficiency of the site is also near 100%, indicating that most of the nitrogen falling to the sediments is recycled as biologically unavailable nitrogen gas. This poses no risk to water quality, which is good at this site.

Salinity

Salinity of marine waters is generally around 35 parts per thousand (ppt). In the Wallis Lake central basin salinity varies from around 35-38ppt, fluctuating as a result of rainfall from the catchment. At the southern end it tends to be fresher as it has less marine influence and more influence from runoff from the southern and western sub-catchments, with salinity variations from 31to 33ppt.

Water Quality in Wallis Lake: Chlorophyll-a and Turbidity

Chlorophyll-a concentrations and water clarity have been shown to be the best indicators of water quality because these are the only indicators directly linking catchment disturbance with estuary condition (DECC 2008). Nutrients stimulate microalgal growth in the water and sediments reduce water clarity, resulting in reduced light to benthic seagrasses and macroalgae. Measurement of concentrations of chlorophyll-a, the main pigment in all plants including algae, is a way of estimating the amount of microalgae in water samples, expressed as µg/L.

Turbidity gives a measure of water clarity and is a measure of the amount of light scattered by particles in the water, expressed as nephelometric turbidity units (NTU). Secchi depth is a measure of light transmission through the water and is affected by particles in the water and by colour of the water. This is measured by the depth at which a standard black and white secchi disk lowered into the water becomes invisible to an observer above the disk. Decreases in water clarity are early indicators of stress in estuarine ecology.

Increases in algae and decreases in water clarity are early indicators of stress in estuarine ecology. Modelling links water clarity with depth to which seagrass survives, therefore together with measuring changes in the extent of the seagrass, these variables are used as prime indicators of estuarine condition. Studies have shown that southern Wallis Lake has relatively low chlorophyll-a (1.43µg/L) and low turbidity (0.9 NTU) compared to other places in the catchment (Figs 4.2.2 & 4.2.3) (GLC 2009). In combination with secchi depths and seagrass depth limits in excess of 3m this indicates that the ecological condition of the site is healthy.

Figure 4.2.2: A conceptual diagram of the effects of chlorophyll a and water clarity on water quality (GLC 2009)

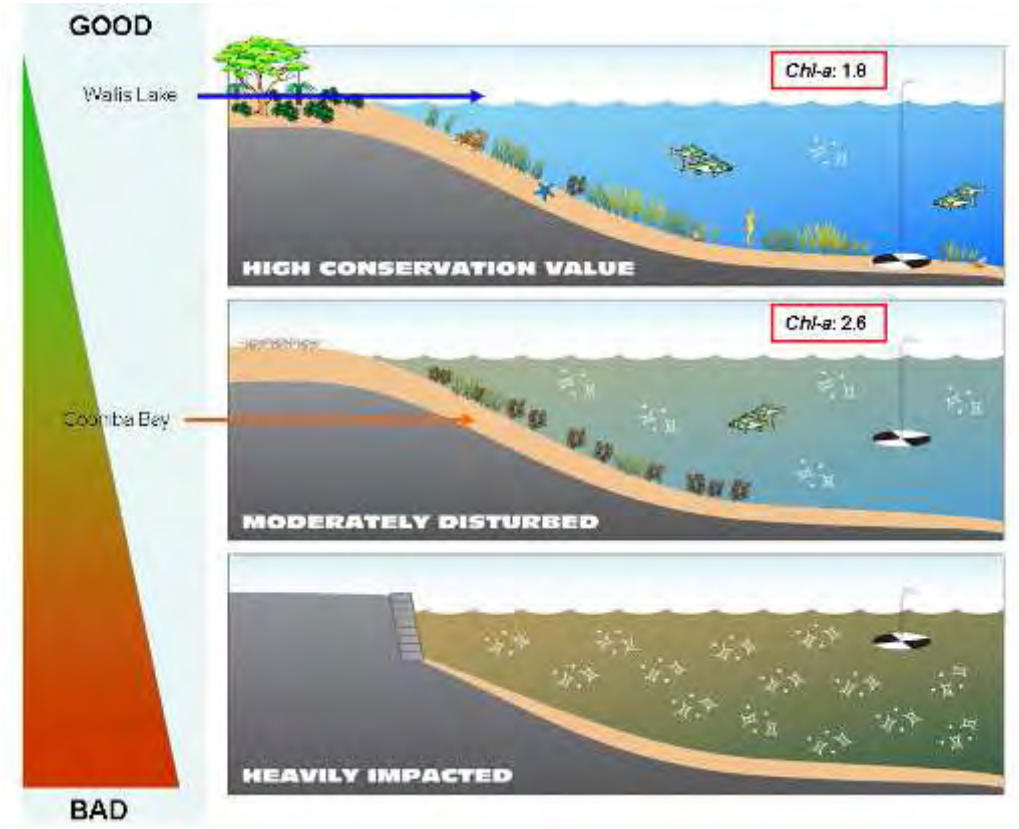


Figure 4.2.3: Mean chlorophyll-a concentrations (µg/L) recorded in Wallis Lake estuary by DECC Waters and Catchment Science in 2006/07 (GLC 2009).

4.3 BIOLOGICAL COMPONENTS AND PROCESSES

4.3.1 FLORA

This summary of available ecological information includes information on the submerged aquatic vegetation and fringing saltmarsh communities within the proposed Ramsar site (Table 4.3.1). The extent of submerged aquatic vegetation, saltmarsh and mangroves has been mapped by NSW Department of Industry and Investment (I&I) (Creese *et al.* 2009). The extent and distribution of terrestrial vegetation communities is beyond the scope of this current study, and as such there is at present a knowledge gap.

4.3.1.1 SUBMERGED AQUATIC VEGETATION (WETLANDS GROUP 1)

Main taxa and distribution

Submerged aquatic vegetation assemblages are very dynamic in space and time and can vary between seasons and years, or after stressful events. The aquatic vegetation communities within the Wallis Lake site reflect the slight changes in salinity within the lakes system. In general marine seagrasses and algae are found throughout the ecosystem, but some species show preference for areas of high salinity. By comparison, the freshwater macrophytes occur only in areas of lower salinity.

In the northern part of the site the dominant submerged aquatic vegetation is *Zostera capricorni*, followed by *Posidonia australis* and *Halophila ovalis,* which is often mixed amongst the beds with the other species. *Halophila ovalis* is opportunistic and often a primary colonizing species, stabilizing the edges of dynamic channels, following which *Zostera* and other species colonize. *Posidonia* forms large beds fringing Yahoo Island, where it is in almost pristine condition and along eastern Wallis Island, but also occurs in large patches or beds in other shallow areas of the site.

Large brown algal seaweed species, such as *Sargassum* spp. and *Cystoseira trinodis* are widely spread species occurring along submerged coffee rock, fringing rocky shorelines or wherever there are holdfasts to aid anchoring to the substratum. These are often intermingled with seagrasses and on soft bottoms where cockles, oysters or other molluscs may serve as holdfasts. These occur throughout the site where light is not limiting, usually to a depth of around 3m. Other seaweed species common to the site are *Padina* sp. and *Dictyota dichotoma*.

Seagrasses fringe the foreshores and shallow substratum of the southern basin, and the entrance to and throughout Wallis Creek. Some seagrass beds are monospecific but most are a mix of species including *Zostera capricorni*, *Halodule tridentata, Halophila ovalis* and *Ruppia megacarpa.*

The charophyte *Lamphrothamnium* sp. is also found in dense monospecific patches in the south, but is more commonly mixed amongst the seagrass beds. The marine brown alga, Neptune's necklace, *Hormosira banksii* is found fringing rocky foreshores and islands in the southern basin.

Temporal Change

Seagrass and macrophyte beds within the southern basin covered an area of 1,643.2 hectares and in the whole Wallis Lake catchment an area of approximately 31.9km^2 in 2010. Studies indicate a slight overall increase in seagrass distribution over recent years although determining methods have changed (West 1985; Creese *et al*. 2009). Of the total seagrass area in 2010, 3.98 hectares were mapped as small and patchy beds of *Posidonia australis* beds, mostly in the vicinity of Whoota on the western shore in the central-southern basin. This showed a considerable increase since 2002 when just 0.64 hectares were mapped in the same area (Glasby & van den Broek 2010). The increase was due to size increases of the *Posidonia* beds along the western shoreline and increased numbers of small patches in the central region. Similarly, possible size increases in *Posidonia* beds were observed along Wallis Island and in Paling Fence Bay, along the western shoreline of Wallis Lake between 2003-2008 (S. Fiebig, personal observations).

Seasonal variations in *Zostera capricorni* and *Ruppia megacarpa* between spring/summer and autumn/winter in Charlotte Bay in 2005-2006 showed increased growth and cover during spring/summer and reduced cover over the autumn/winter months but no change in the scale or position of the seagrass beds (Fiebig 2007). Similarly, increased growth in spring was observed in *Zostera capricorni* along Wallis Island, with a decrease over winter (S. Fiebig, personal observations).

Threats

With its dependence on clear waters for sufficient light penetration for photosynthesis, the greatest threat to submerged aquatic vegetation is increased water turbidity.

Consequence of Loss

The consequences of loss of seagrass and macrophytes within the site are significant on both biogeographical levels, and on an economic level. Seagrass and macrophyte beds and seaweeds support many aquatic and avian food webs, provide shelter and nursery grounds for vertebrate and invertebrate aquatic species, stabilize the substratum and are important in recycling nutrients in the lake. Loss would lead to depletion of fish habitat and fish resources and a collapse of the fishery in Wallis Lake. This would have economic repercussions in terms of commercial fishing, tourism and employment within the Great Lakes shire.

Table 4.3.1: Dominant submerged aquatic vegetation in Wallis Lake

Taxa	Life-Form	Occurrence
Zostera capricorni	Perennial seagrass	Widespread throughout site
Halodule tridentata	Perennial seagrass	Mixes with *Zostera* in southern basin
Halophila ovalis	Perennial seagrass	Widespread, colonizing bare areas
Posidonia australis	Perennial seagrass	Northern part of site, around Yahoo and Wallis, central basin
Ruppia megacarpa	Perennial - Angiosperm	Southern end of site
Lamprothamnium sp.	Ephemeral – green algae	Southern end of site
Sargassum spp.	Ephemeral – brown algae	Widespread
Cystoseira trinodis	Ephemeral – brown algae	Widespread
Padina sp.	Ephemeral – brown algae	Colonises rocky areas
Dictyota dichotoma	Ephemeral – brown algae	Colonises rocky areas
Hormosira banksii	Ephemeral – brown algae	Colonises rocky shorelines at Deepwater & Talambar Points and Booti Is.

4.3.1.2 MANGROVES AND SALTMARSHES (WETLANDS GROUP 2)

Mangroves and saltmarshes occur along the margins of the lake and islands, especially in the south of the site around and to the west of Charlotte Bay. The two mangrove species present are the grey mangrove, *Avicennia marina* and the river mangrove*, Aegiceras corniculatum.* Within the site mangroves occur along the edges of the saltmarsh, within the saltmarsh itself and edging the lake. These are scattered in distribution and are present with swamp oak, *Casuarina glauca* and the common reed *Phragmites australis*. On Booti Island both mangrove species are found above the current tidal limit in crevices among rocks (Adam 1986).

The saltmarshes at Charlotte Bay are dominated by *Sarcocornia quinqueflora; Suaeda australis and Sporobolus virginicus,* alongside the neighbouring maritime sedge, *Juncus kraussi* (Table 4.3.2, Fiebig 2007).

Table 4.3.2: Dominant species of the Charlotte Bay saltmarsh wetland

Saltmarsh Family	Species
Juncaeae	*Juncus krausii*
Chenopodiaceae	*Sarcicornia quinqueflora*
	Suaeda australis
Poaceae	*Sporobolus virginicus*
	Phragmites australis
Primulaceae	*Samolus repens*

The saltmarsh in Wallis Lake is unusual in NSW because it is mostly fronted directly by the lagoon itself and not by mangroves, which is more common in other lake systems (Adams 1986). Pools are not so common amongst the marsh but when present may become hypersaline in summer and fresh after heavy rain.

Ecological significance

The saltmarsh and mangroves within the site provide mostly edge habitat to fish and aquatic invertebrates, particularly crabs and molluscs, and support numerous flora and bird species.

Threats and Loss

The saltmarsh and mangroves are threatened by human disturbances such as site clearing and grazing by livestock.

Mangroves have been mapped together with the saltmarsh in habitat distribution maps of Wallis Lake due to scattered distribution and association with the saltmarsh. The total area of mangroves within the catchment is likely to be in the order of 1.25km^2 but the actual site area is unknown. The saltmarsh in the catchment has been estimated at approximately 4km^2 (West *et al.* 1985) but may be in decline as the area in the southern basin of Wallis Lake was estimated at 69.1 ha in 2002, but just 43.8 ha in 2010. This possible decline will be further investigated when macrophytes in all of Wallis Lake are mapped by I&I NSW in late 2010 using high resolution digital imagery captured in mid 2010. At this stage it is not possible to determine whether the estimated decline may actually be a consequence of different mapping techniques used in 2002 and 2010 (Glasby & van den Broek 2010).

4.3.2 ENDANGERED AND PROTECTED ECOLOGICAL COMMUNITIES

Coastal saltmarsh constitutes an endangered ecological community under the TSC Act (1995)(see Table 4.3.3). The presence of a Ramsar site will assist with management and protection of this wetland type.

Posidonia australis constitutes a protected ecological community under the FM Act (1994). However, protection of this species was recently proposed for upgrading to *endangered populations* in a number of estuaries in NSW (Fisheries Scientific Committee 2009). This does not include the Wallis Lake site. However, as *Posidonia* occurs at its northern-most limit in Wallis Lake loss of this or any of the other seagrass species would decrease the limit of distribution of these species within the biogeographic region and within Australia.

Zostera capricorni and *Halodule tridentata* are also classified as protected ecological community. Until recently *Halodule tridentata* was misidentified as *Zostera capricorni* and has only just been recognized as a separate species. The occurrence of *Halodule tridentata* in Wallis Lake is important because it is the first record in NSW and the southernmost limit of its distribution along the east coast of Australia (Glasby & van den Broek 2010). Similar to *Posidonia*, loss of these species in Wallis Lake would not only decrease the distribution limit in *Halodule tridentate* but would significantly undermine our target to maintain ecological integrity and biodiversity.

Table 4.3.3: Endangered ecological communities in the Wallis Lake site

Ecological Community	Landscape Position	Vegetation Class
Coastal saltmarsh	Intertidal flats	Saltmarshes; mangrove swamps
Littoral rainforest	**Outside of scope of this project, but present**	
Swamp oak coastal floodplain forest	**Outside of scope of this project, but present**	
Swamp sclerophyll forest on coastal floodplains	**Outside of scope of this project, but present**	

4.3.3 PRIMARY PRODUCTION AND FOOD WEBS

Primary production is the conversion of sunlight and nutrients to carbon and energy by plants, which will then sustain all ecosystems on Earth. Significant disruptions to these fundamental processes have great potential to disrupt many higher order ecosystems.

There are no known studies or measurements available on primary production and food webs in the Wallis Lake site. However, the evidence showing that the potential Ramsar wetland is in near pristine condition, supporting a diverse and apparently healthy aquatic ecosystem suggests that fundamental ecosystem processes are still functioning in a near to natural state.

4.3.4 FAUNA

4.3.4.1 MARINE, ESTUARINE AND BRACKISH WETLANDS (GROUPS 1, 2, 3)

INVERTEBRATES

Macroinvertebrates are believed to play critical structural and functional roles in nutrient cycling and the food web in aquatic ecosystems, but there is limited information for the Wallis Lake site. This is a knowledge gap.

Species abundance

Species lists from various studies show that at least 55 invertebrate species occupy the southern basin (Fiebig 2007, Barnes 2010, Glasby & van den Broek 2010), some of which have not been fully identified, but species numbers might be a lot higher (Appendix 2). These include species from ten phyla including crustaceans (crabs, prawns and shrimp); molluscs bivalves, gastropods and cephalopods); porifera (sponges); cnidarians (sea anemones); echinoderms (brittle stars); chordates (tunicates); bryozoans (lace corals); polychaetes (bristle worms); nematodes (nematode worms) and nemerteans (nemertean worms).

Aquatic invertebrates such as crustaceans, molluscs and polychaete worms are very important sources of food for many aquatic and terrestrial species, including fish and shorebirds. For fishermen, only two of these phyla and seven species are of interest. These comprise the crustaceans, of which mud crabs, blue swimmer crabs, school prawns, greasyback prawns and king prawns occur in the southern site, and mollusca, of which octopus and cuttlefish have been sampled within the site. Fishermen target these species with traps or nets. Prawns are usually caught in the deeper channels. The blue swimmer crab fishing industry is very important in Wallis Lake, with crabs comprising the second highest catch from the lake in terms of biomass, which is the highest out of any estuary in NSW.

A study within Charlotte Bay showed habitat preference by invertebrate species, with most species occurring in mangroves (26 species); followed by seagrass beds (24 species); rocky shores (22 species); terrestrial woody debris (16 species); macrophyte and algal (14 species); and soft non-vegetated habitat (13 species) (Fiebig 2007, Appendix 2). Many of the same species were represented across all habitats. Abundance of individuals has not been studied but may range from hundreds to thousands per square metre in the substrate.

Biodiversity

Species biodiversity indices indicate that invertebrate fauna is similar to other NSW coastal lakes. However, of all the invertebrate taxa represented, the sponges of Wallis Lake may be the most unique to our biogeographical region. The southern basin of Wallis Lake is unique in terms of diversity of invertebrates because it supports a highly diverse assemblage of estuarine sponges, with 12 species, which is almost twice as many species as any other NSW coastal lake. *Dysidea* sp., *Raspaillia* sp., *Haliclona* sp. and *Halichondria* sp. have only been recorded in Wallis Lake (Barnes 2009). Of the twelve species so far reported, only two species (*Chondrilla* c.f.

australiensis and *Aplysilla* c.f. *sulphurea*) could be tentatively identified to species. The others have not yet been scientifically described and are likely to be new to science. Other sponges include *Suberites* sp. and *Mycale* sp. The ascidians *Styela plicata* and *Eudostoma laysani* are also associated with the sponge gardens.

Threats to survival

Although the sponges are diverse in terms of species, abundances of some species (e.g. *Suberites* sp.) were reduced in 2009 compared to previous years and individuals were typically small. Many showed signs of stress. The likely key threat to the ongoing survival of these species is deterioration of water quality through increased sediment loading. This is likely to have both direct effects on the physiology and feeding efficiency of filter feeding sponges and indirect effects by reducing or changing the distribution of seagrass and algal meadows on which the sponges are closely associated (Barnes 2010).

FISH

Taxa and distribution

Wallis Lake supports well over 100 species of fish of which 54 species were recorded in the southern basin in recent studies (Appendix 2).

Around 15 species of those are of commercial interest. The dusky flathead; yellowfin bream; tarwhine; luderick; trumpeter and sand whiting; leather jacket; tailor and sole are table species, while flat-tail, sand and sea mullet; silver biddy; garfish and catfish are mostly caught to bait traps or lines.

At the southern end of the site other species include the southern eagle ray; sparsely spotted stingaree and common stingaree; frogfish; fortescues; numerous gobies; perchlets; hardyheads; toadfish; diamond fish; glassfish; both estuarine and striped catfish; gudgeon; herring and puffer fish. As these species are quite diverse they occupy a range of ecological niches. The habitats of the site utilised by 26 species of fish in Charlotte Bay were recorded and included seagrass beds and woody debris (16 species in each); non-vegetated areas over bare soft substrate (11); mangrove habitat (7); rocky shore habitat (6); and macrophyte and algal habitat (5) (Fiebig 2007).

The fish fauna of the coffee rock habitat of north-eastern Wallis Island comes under greater marine influence from tides due to its closer proximity to the entrance of the lake. The fauna list contains 101 confirmed species and expands that of the southern area. It includes the estuary cod and juvenile black cod also potentially inhabitat the area. Other species include catfish, pineapple fish, old wives, mado, moray eels, goatfish and a variety of wrasse. In summer and autumn a number of species of tropical butterfly fish, Moorish idols, damselfish and angelfish that have travelled south along the eastern Australian current reside in the coffee rock habitat.

Threatened and Protected Species

There are no threatened species recorded in the site but the crevices and overhangs of the coffee rock alongside the channel of north-eastern Wallis Island provides good

potential habitat for juvenile black cod, *Epinephelus damaelii*, listed as vulnerable under the FM Act. In addition there are at least seven species in the site listed as protected under the FM Act. A population of estuary cod, *Epinephelus coioides,* inhabits the coffee rock and the adjacent channel along Wallis Island. The other six species belong to the family Syngnathidae and include White's seahorse, *Hippocampus whitei;* Mollison's pipefish, *Mitotichthys mollisoni*; and the brushtail pipefish, *Leptoichthys fistularis* in the southern basin. In the northern part of the site White's seahorse, the protected tiger pipefish, *Filicampus tigris;* the spotted pipefish, *Stigmatopora argus* and the hairy pipefish, *Urocampus carinorostris,* have been found in the *Zostera* and *Posidonia* seagrass beds and along the coffee rock.

Biodiversity

Biodiversity indices from Glasby *et al.*'s (2010) study show that fish diversity in southern Wallis Lake is similar to other comparable NSW estuaries. All fish species have been recorded in other NSW coastal lakes and most are known to have a wide distribution within NSW. The one exception is the crimson-tipped gudgeon *Butis butis* that was recorded from the Wallamba River in 1996/97. This species is a tropical brackish water gudgeon with a previously recorded southernmost distribution in the Richmond River, Ballina (Glasby & van den Broek 2010).

COMMERCIAL FISHING AND AQUACULTURE

Biomass and numbers

Forty-nine species of fish or invertebrates were caught by commercial fishers in Wallis Lake during the 2008-2009 financial year (Appendix 4a). Sea mullet (*Mugil cephalus*) were the most significant catch (by weight) followed by blue swimmer crabs, flathead and whiting. Prawns and mud crabs were also important commercial catches. The biomass of commercially caught finfish in Wallis Lake, averaged over all the fishing business in the last 6 years, is comparable to the typical catch from other NSW estuaries and lakes (Appendix 4b). Wallis Lake, however, supports more commercial fishing businesses (51) than the average for a NSW estuary; it has the fifth largest number of fishing businesses of any NSW estuary and the second largest overall catch (349,125.3kg) after the Clarence River estuary.

Culture of oysters is an important commercial industry with Wallis Lake producing 2, 773,842 dozen oysters in the 2008/2009 season, far exceeding production of all other NSW estuaries. The economic value of Wallis Lake's commercial oyster production reached $14,822,211 in the 2008/2009 year, which makes it the main industry for the Great Lakes Region. Oyster production is not carried out within the main site but it is conducted along the north-eastern side of Wallis Island adjacent to the coffee rock zone.

Threats

There are no annual catch statistics for recreational fishing in Wallis Lake, except for during fishing competitions, so there is a knowledge gap regarding overall catch from the lake. The concern is that increased fishing pressure from tourism and the closure of fishing to Marine Sanctuary zones and other estuaries to either or both commercial and recreational fishing will result in unsustainable fishing and

diminished biomass or catch per unit effort in Wallis Lake or the site (Frost 2006).

Aquaculture has modified the catchment in other areas of Wallis Lake and contributes to sedimentation and increased pollutants in the lake. Oyster racks, however, provide habitat to fish and other species that settle there, but the overall effect on the Wallis Lake site is not known.

REPTILES

Green turtles are regularly observed in Wallis Lake, especially along the northeast coffee rock ledges of Wallis Island, feeding on *Zostera* seagrass or resting on the substrate. At least one hawksbill turtle has also been recorded (S. Fiebig, personal observations) in the vicinity. Loggerhead turtles are residents of reefs along the coast and also have the potential to enter the Wallis Lake site.

Threatened and Protected Species

All sea turtles are protected species under the EPBC Act (1999) and most are also listed under the TSC Act (1995). The green turtle, *Chelonia mydas*, is listed as *vulnerable* under the TSC Act and the EPBC Act; the Hawksbill turtle is *vulnerable* (EPBC Act) but is not listed under the TSC Act; and the loggerhead turtle, *Caretta caretta,* is listed as *endangered* under both the TSC Act (1995) and the EPBC Act (1999).

Threats to Survival

The greatest potential threats are habitat loss through dredging within the estuary combined with loss of or reduction in seagrass habitat; and impact or death from collisions with boats and damage from motors.

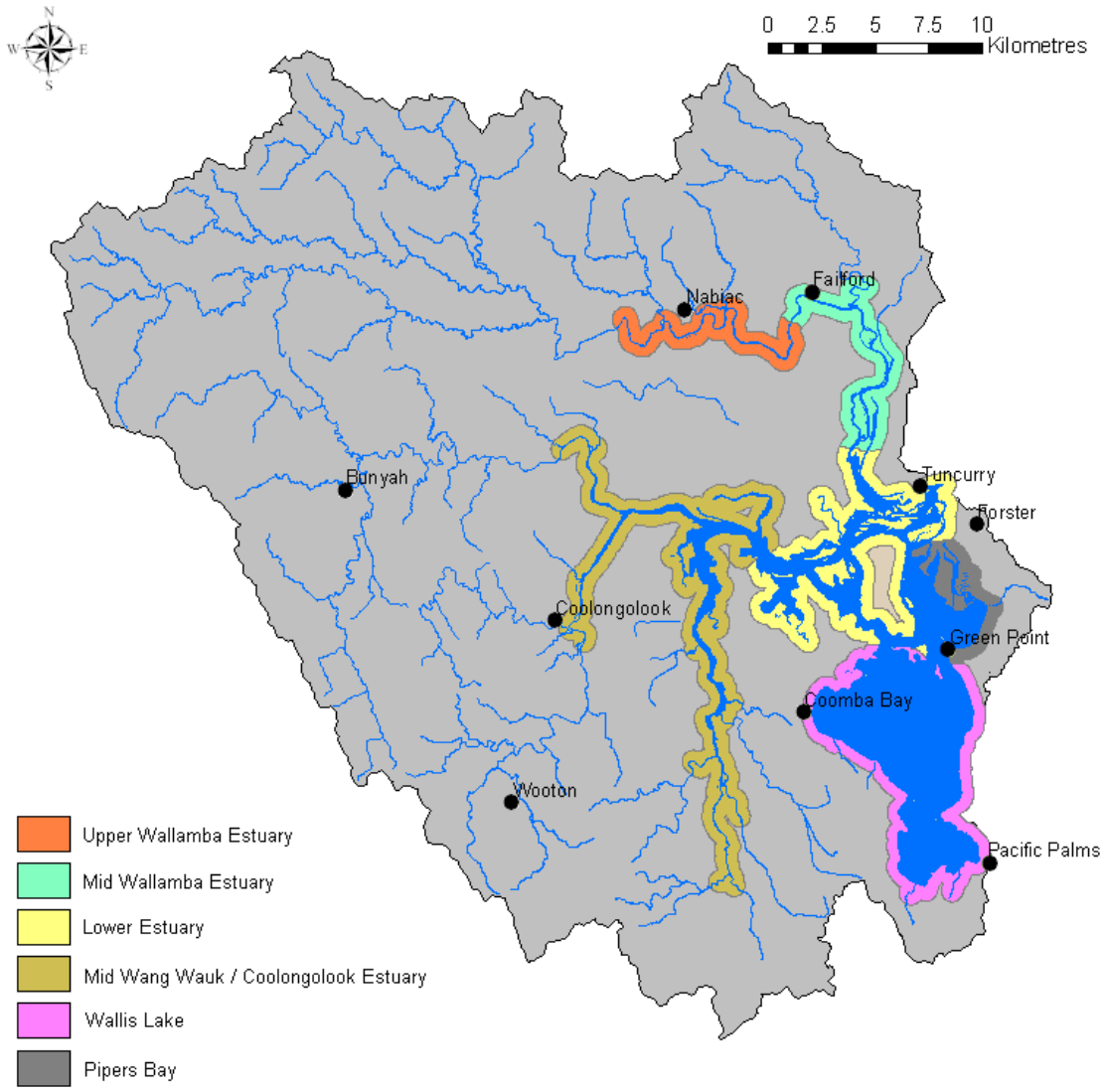
4.3.5 CONNECTIVITY

Connectivity describes the interconnectedness of ecosystem types, both within the potential Ramsar site and between the Ramsar site and external areas.

The Wallis Lake site has a range of wetland ecosystems that have excellent connectivity. As the scope of this project does not extend beyond the water, there are few anthropogenic barriers within the site and aquatic connectivity is not impeded by weirs or other unnatural barriers. In addition, the potential Ramsar site links further expanses of undisturbed native vegetation in the Booti Booti and Wallingat National Parks to the east and west, and to the north the extension of a healthy estuarine system. This enhances connectivity between the proposed Ramsar site and external ecosystems.

The presence of further healthy wetlands associated with Wallis Island immediately to the north and adjacent to the site provides added connectivity for a wide range of shorebirds and waterbirds.

Figure 4.3.5.1: Zones in the Wallis Lake estuary showing the connectivity of the waterways (Source: GLC 2009)



5. CRITICAL ECOLOGICAL COMPONENTS, SERVICES AND PROCESSES

5.1 CONCEPTUAL ECOLOGICAL MODELS

Conceptual models are abstractions or simplifications of the real world that portray the dominant components and processes. Typically, models define relationships among states (components of the ecosystem) and transitions (processes that change the state). These relationships are the basis on which to predict changes in ecological character over time depending on trajectories of, or perturbations to, key processes. Ecological models are excellent tools for generating questions about system behaviour and guiding decision making for planning and management. In addition, models document and record major assumptions and current understanding of the system.

Primarily the nature of Wallis Lake is determined by climate (through precipitation, evaporation and transpiration) that influences surface and groundwater flows, and hydrology and hydrological variability. Geomorphology determines the size, shape and location, water sources, physicochemical properties and soils as well. These natural drivers are strongly affected by human activities such as land use and water diversion. Human interventions are considered as system drivers in this report.

Conceptual models have been prepared based on models developed for an adjacent Ramsar wetland (Myall Lakes) by DECC. These models describe the main influences that drivers have on the services provides by Wallis Lake. Like the Myall Lakes model, those services are defined as:

- Ecosystem support – including threatended species and communities, critical habitat and refuges for birds and nursery areas for fish
- Recreation – primary contact: swimming, secondary contact: boating.

The black arrows in the models represent the main pathways for ecosystem change resulting from alterations in drivers.

Figure 5.1.1: Conceptual Model – Brackish Wetlands Group 3 Wetland type

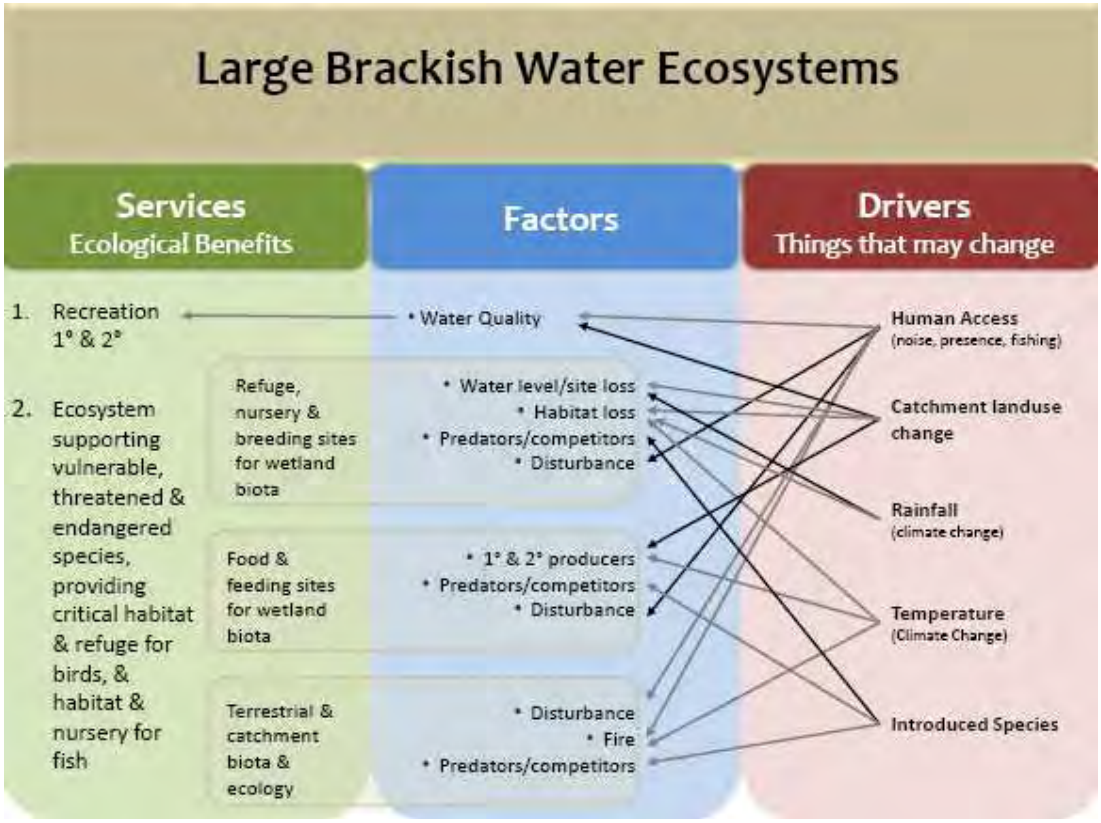


Figure 5.1.2: Conceptual Model – Mangroves and Intertidal Flats Group 2 Wetland type

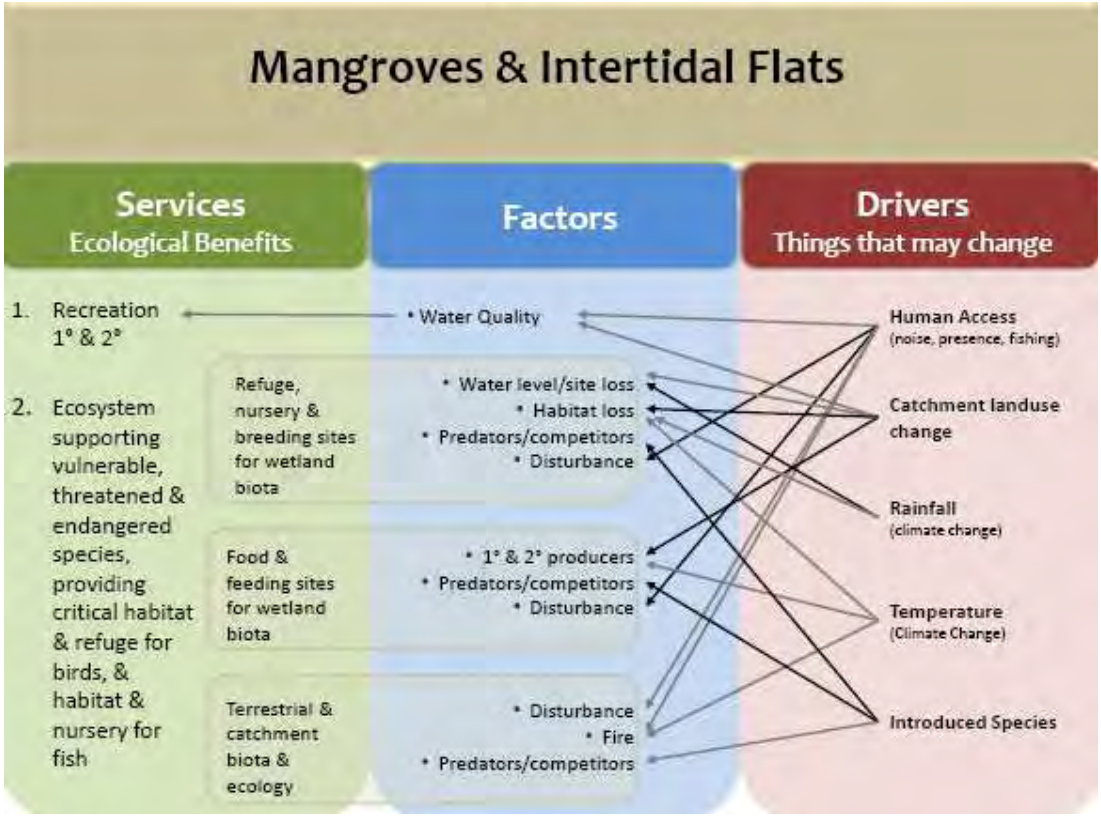


Figure 5.1.3: Conceptual Model – Islands Group 1 Marine Coast

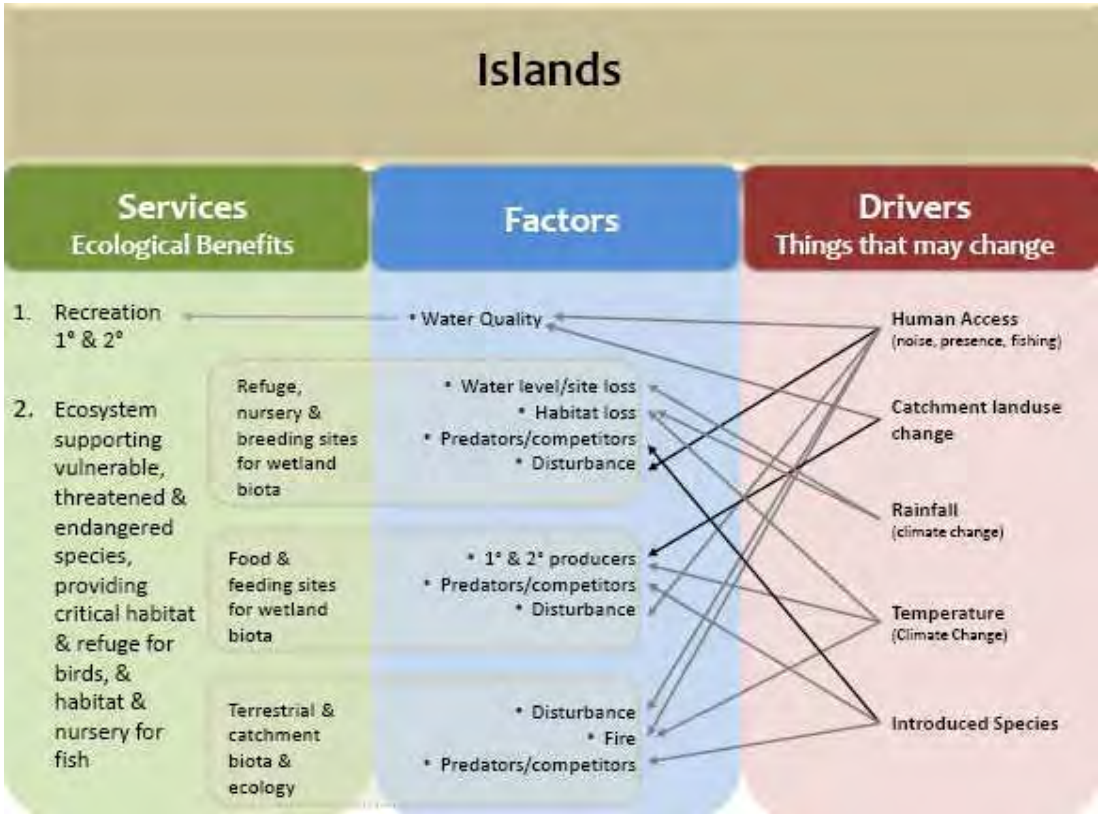
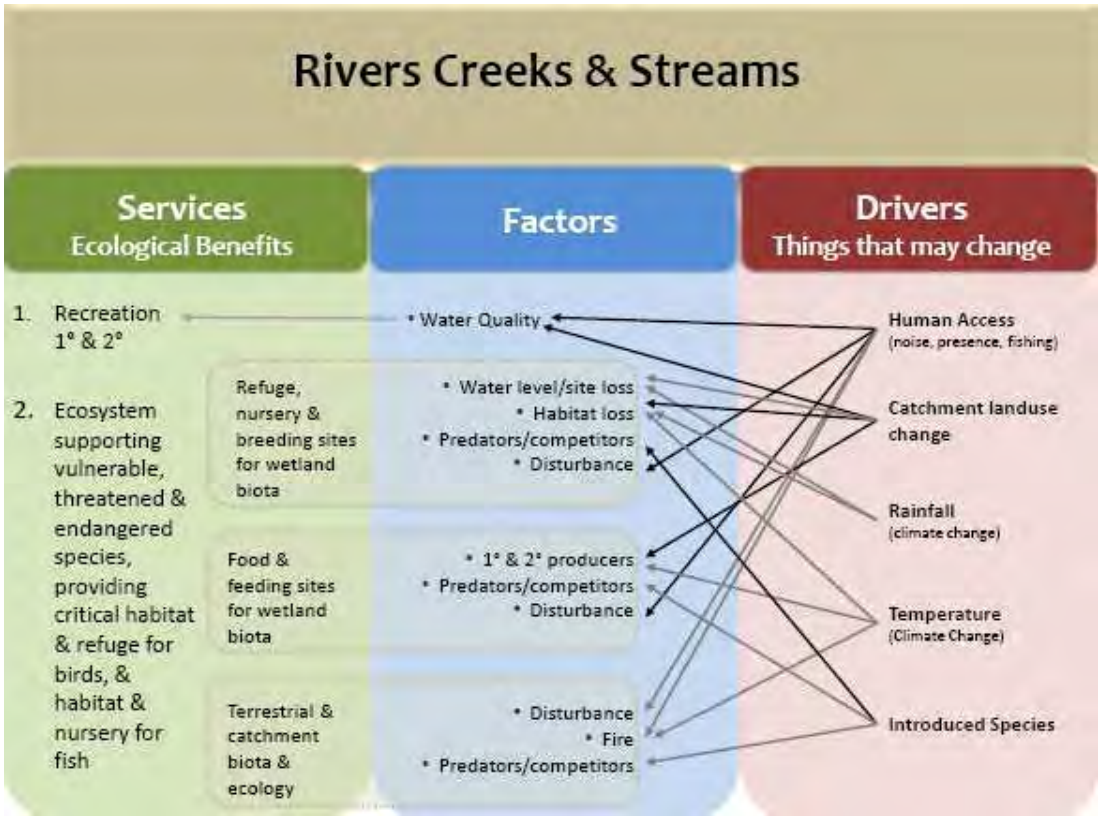


Figure 5.1.4: Conceptual Model – Rivers Creeks & Streams Group 4



5.2 DRIVER AND STRESSOR ECOLOGICAL MODELS

The purpose of this section is to describe how driver, stressor, or outcome conceptual models have been used to define the critical processes and components of Wallis Lake.

In order to reduce the complexity of the interacting habitats and wetland types, a set of identifiers have been defines for the area. Change in ecological character is a fundamental alteration of these identifiers.

To establish the identifiers, conceptual models were developed for each of the wetland types/groups the models in section 5 take the primary linkages identified in black and add detail to the process pathways, allowing the determination of the identifiers of ecological character, and of the processes that affect those characters.

Critical processes are those that provide or support the unique characters of the lake. In the following conceptual diagrams, the indicators of these unique characters are highlighted in the dark shaded boxes and the critical processes are those that influence the indicators. Negative influence can be seen as threats to the character (as per the diagrams) and positive influences are those that protect and maintain the character. The diagrams also indicate the appropriate levels in the system at which to determine and assess limits of acceptable change that are indicated by the letters LAC on the diagram.

5.2.1 KEY CHARACTERS OF WETLAND GROUPS 1-4 (LARGE MARINE TO BRACKISH WATER ECOSYSTEMS, RIVERS CREEKS AND STREAMS, MANGROVES & INTERTIDAL FLATS)

Table 5.2.1.1: Key Characters of Wetland Groups 1-5

Key Character	Indicators
Extensive macrophyte beds	Extent of macrophyte
Extensive seagrass beds	Extent of seagrass
Varying water levels	Variation in water level evident within natural range
Saline to brackish water	Salinity
Shallow water	Depth
Oligotrophic, clear water aquatic plant dominated ecology	Chlorophyll a, water clarity
Provision of habitat and food for birds and fish	Bird roosting, breeding and feeding sites, abundance of birds, abundance of fish
Supports threatened, vulnerable and protected species	Presence of threatened, vulnerable and protected species
Recreational attraction	Algal blooms general amenity

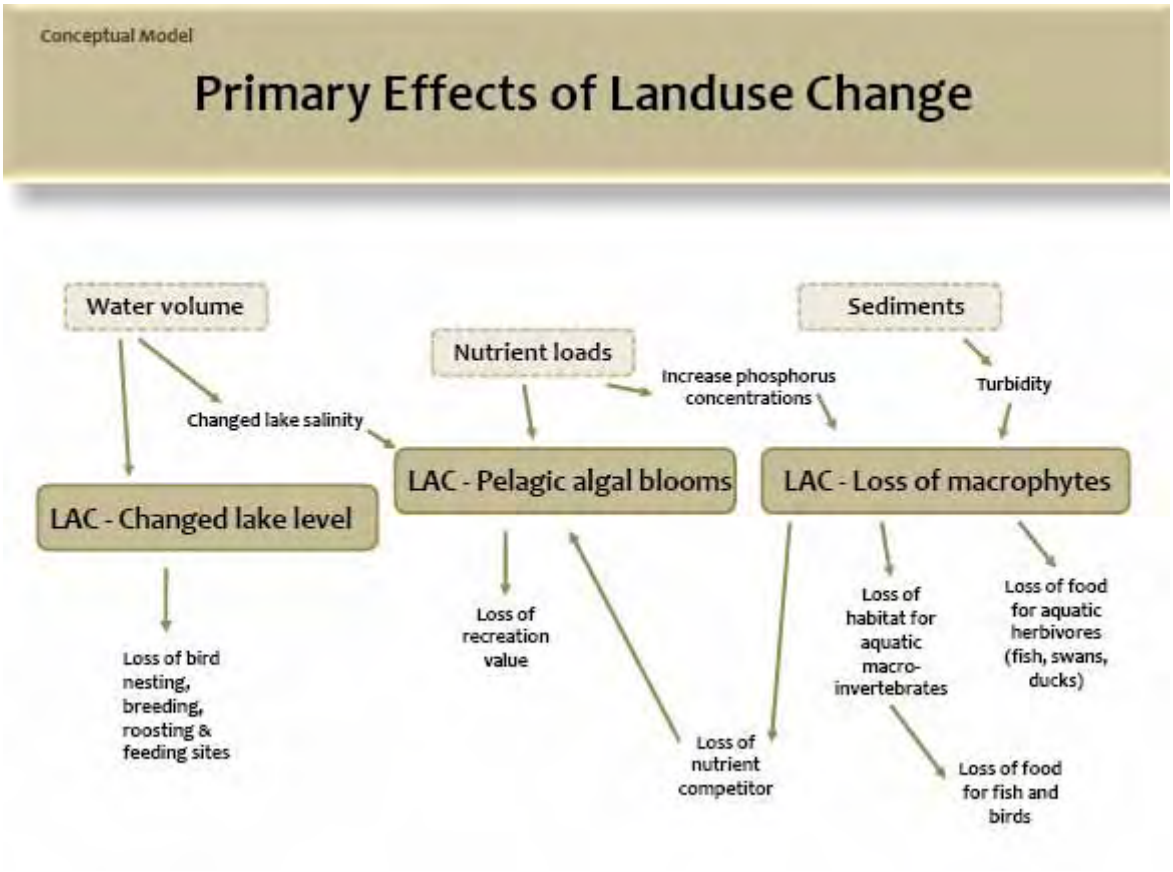
Macrophyte & seagrass beds, and oligotrophic water

The extensive seagrass and macrophyte beds are the dominant characteristics of southern Wallis Lake basin. The high densities of these plants are attributed to the clear water that makes up the lake body, and is reflective of a catchment that is relatively undisturbed.

Low sediment and nutrient inputs from the catchment ensure that clear water allows plant communities to grow at depth, where light can penetrate through the water column. The presence of the plant communities stabilise sediments that do make it into the system and, and recycle the nutrients. These processes keep the clarity of the water high, and ensure algal blooms and turbid waters do not threaten the plants and the associated faunal communities.

Increases in sediment and nutrient inputs as a result of land use changes will certainly threaten these communities by decreasing the amount of light penetration (turbidity) and smothering from algal blooms (nutrients). Re-suspension of sediments through recreational activities, also pose a threat to these critical communities.

Figure 5.2.1.1: Critical process interruptions resulting from landuse changes

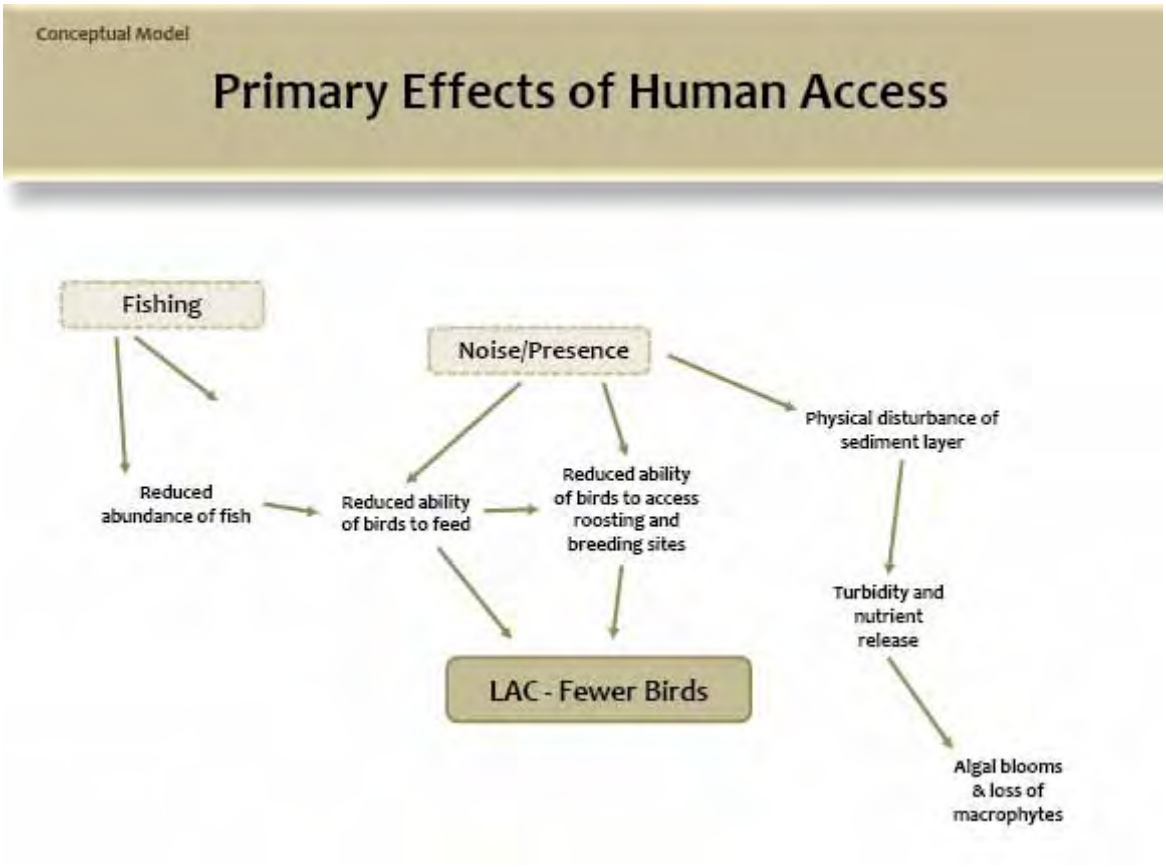


Varying water levels, shallow waters and brackish/marine continuum

Wallis Lake exchanges tidal water with the ocean, however the flush times vary from 1 day to 2 months. During times of high rainfall salinity levels drop in the southern area of the lake. During periods of drought, salinity levels rise.

The varying water levels are essential to the maintenance of the fringing wetlands. The existing regimes are maintained by critical processes such as changing lake levels in response to tidal movement and variable rainfall, and sufficient inflow from rainfall to keep salinity levels low.

Figure 5.2.1.2: Critical process interruptions resulting from recreation



Habitat for birds and fish; threatened, vulnerable and protected species

These characters are underpinned by a wide range of critical processes encompassing provision of suitable habitat and site availability, access to and suitability of food, small levels of disturbance and interactions with predators and competitors.

Catchment and Terrestrial Biota

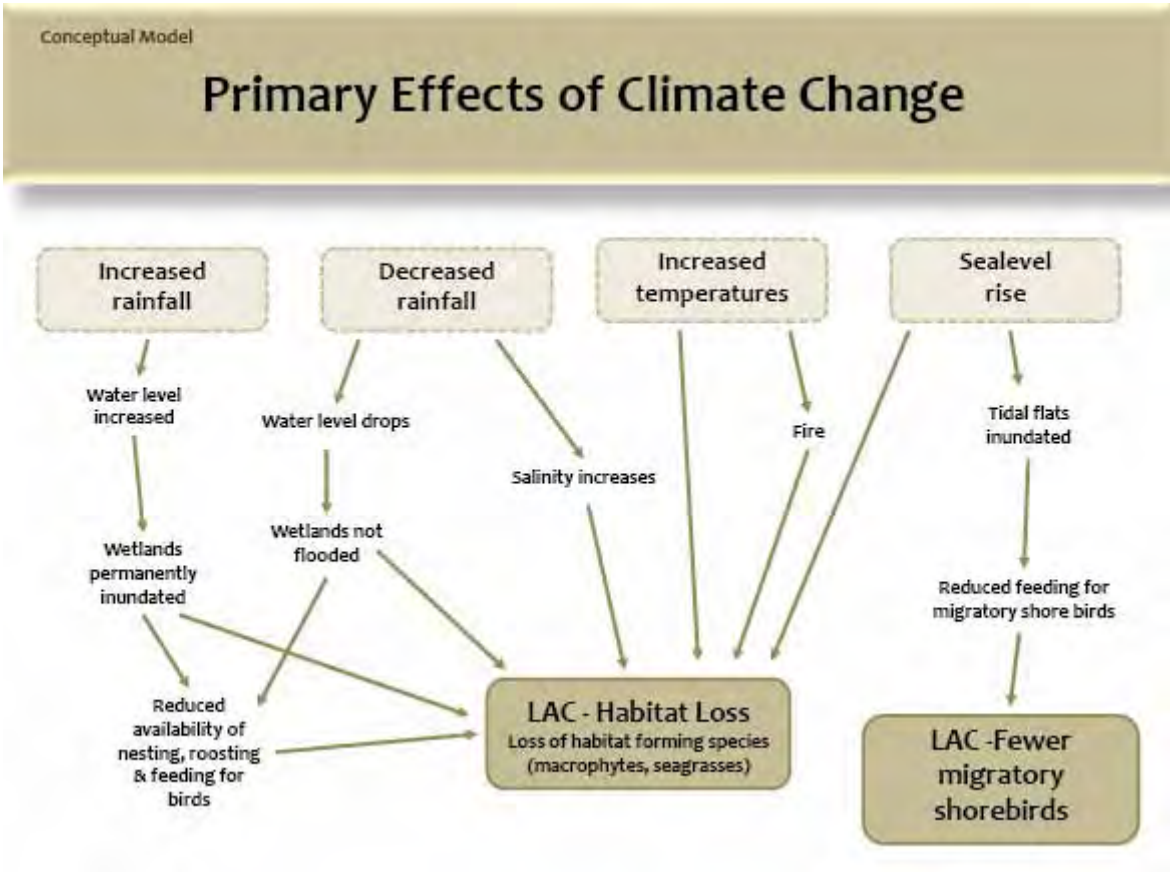
The presence of intact vegetation throughout the Wallis Lake catchment conveys a number of benefits to the site (Figures 5.1.1-5.1.4). It provides protection from the effects of catchment disturbance (changed nutrient and sediment inputs, direct loss of habitat) and reduces the potential impact of introduced species. It also ensures that natural inputs of food chain components such as carbon and dissolved organics

to the waterways are maintained and that there is a wide variety of habitat available to native fauna. The intact vegetation is also valuable in its own right, supporting a wide array of threatened and non-threatened native flora and fauna.

Recreation

Wallis Lake attracts recreation in the form of its pristine nature, fishing (abundance of fish) and clean water (clarity and oligotrophic status). The critical processes supporting this character are those that support those attractions.

Figure 5.2.1.3: Critical process interruptions resulting from climate change



6. LIMITS OF ACCEPTABLE CHANGE

The concept of limits of acceptable change (LACs) is used to identify and set limits within which change may be tolerated (Ramsar Convention 1993). It may be applied to the long-term or operational objectives. Once these limits are exceeded there will be a need for immediate remedial action.

As a signatory to the Ramsar Convention, Australia is obliged to manage its Ramsar sites in order to maintain the ecological character of each site. The LACs provide thresholds of critical components or processes of the wetlands that can be used to indicate when and by how much the ecological character of a site has changed. This information can help site managers to determine limitations to activities, monitor the site, and take action to maintain ecological character. Furthermore, it is expected to inform the Ramsar Secretariat if the ecological character of a Ramsar wetland is changing or is likely to change as a result of technological development, pollution or other human interference (Article 3.2).

It is essential to have the knowledge and available data and information to assess the range of natural variations in order to set LACs for the components and processes under consideration. This is particularly important for Australian wetlands that have a large range of natural variability. However, due to the lack of long-term monitoring programs for this Ramsar site, the information and data available for setting the LACs for most of the ecosystem components, processes and services presented in the previous sections are less than ideal. For some components and processes detailed information is available through the CCI (GLC 2009). For most others, relevant research, information from other similar sites, national and state guidelines and standards, and knowledge of site managers have been relied on when considering the site-specific characteristics. As a result, some of the given LACs should be interpreted as interim.

Another difficulty in setting definite LACs for some ecosystem components and processes is that changes are not often caused by site abundance of migrant shorebirds are known to be highly variable. This may reflect annual changes in habitat availability elsewhere, variation in climatic conditions, annual variation in the period of peak migration, or annual fluctuations in sizes of shorebird populations. In this case, exceedance of the LACs may send false alerts to wetland and park managers, but this was considered to be a realistic and precautionary approach, especially for endangered species.

The conceptual models in section 5 allow identification of the critical system components that define the unique character of the Myall Lakes Ramsar site, the key variables for which LACs should be set, and the origins of pressures on those components. In most cases those variables are ecological outcomes rather than stressors or drivers. This is because in the vast majority of cases the underlying theory and process understanding to allow prediction of outcome from stressor information is absent, so setting LACs at the stressor level is either tokenistic, misleading or valueless. The situation is different for some stressors relating to

macrophytes and algal growth in the Myall lakes as a consequence of the detailed research and modelling done as part of the CCI program. In this case there is reasonable information to suggest trigger values for some stressors that might lead to exceeding LACs in ecological outcomes relating to macrophytes and algal growth.

The LACs determined for the Wallis Lake site are set out in Table 6.1.

Table 6.1: Limits of acceptable change for critical components and processes

Key Character	**Indicator**	**Baseline condition and range of natural variation where known**	**Interim LACs Short term (1-5 yrs)**	**Interim LACs Long term (10-20yrs)**
Protect Threatened Ecological Communities –	Extensive seagrass beds - Extent of cover -Number of epiphytes and Condition	Distribution maps in 1985 and 2009 Distribution study in 2005-6 to assess seasonal changes Condition study 2005-2006	No net change in areas of vegetation cover	No net change in area of communities
	Extensive macrophyte beds -Extent of submerged aquatic plants in the lake -Degree of siltation -Condition	Distribution map to be made in late 2010 Distribution study in 2005-6 to assess seasonal changes Condition study 2005-2006	No net change in areas of vegetation cover Condition average or better	No net change in area of communities Condition average or better
	Saltmarsh Area and cover	Surveys in 1985 and 2009 indicate reduction in area	No reduction in area	No net change in area of community
	Mangroves	Knowledge gap – mapping needed separate to saltmarsh area	No net change in area of community	No net change in area of community
	Coffee Rock Area and condition	Knowledge gap – mapping needed	No change in area No change in condition due to human impact, e.g. trampling and boats	No net change in area
	Sponge gardens	Knowledge gap – mapping needed But known to be associated with seagrass and macrophyte beds so need further mapping outside of these habitats Numbers decreasing and 1 species absent in 2009/10 survey	Knowledge gap	No net reduction in species or numbers

Key Character	Indicator	Baseline condition and range of natural variation where known	Interim LACs Short term (1-5 yrs)	Interim LACs Long term (10-20yrs)
Marine grading into brackish	Marine exchange	The tidal prism from the entrance is 7-9%, which indicates that a larger volume of seawater enters the southern basin than in larger lakes	No change from current exchange	No change from current exchange
	Freshwater inputs	Contribution of freshwater to the lake via the catchment and Wallis Creek is <10%	As the lake is unregulated the freshwater inflows follow a natural pattern during normal and wet conditions	No net change in the timing, duration and frequency of freshwater inputs
Shallow 0-1.8m average with channels to 5m	Water Depth		No change from present	No change from present
Oligotrophic, clear water	Chlorophyll a	As per ANZECC guidelines, 80th percentiles of reference data were calculated to provide a trigger value (GLC 2008)	Annual mean concentrations should not exceed 1.8µg/L	Annual mean concentrations should not exceed 1.8µg/L
	Turbidity	As per ANZECC guidelines, 80th percentiles of reference data were calculated to provide a trigger value (GLC 2008)	Annual mean concentrations should not exceed 1NTU	Annual mean concentrations should not exceed 1NTU
	Secchi Depth	Secchi depth is an additional measure of water clarity. Secchi depths are in excess of 3m	Annual mean Secchi depth should not be less than 3m	Annual mean Secchi depth should not be less than 3m
	External nutrient loads	External nutrient loads govern nutrient availability for plankton growth. Present values are: TN 80kg/m2/yr TP 4 kg/m2/yr TS 10kg/m2/yr	No change from present	No change from present
Provides habitat and food for birds and fish	Migratory shorebirds -numbers of species recorded at site annually?	Knowledge gap	Numbers of migratory shorebirds show substantial variation between years and observed differences are hard to interpret	No net reduction in the number of shorebird species

Key Character	**Indicator**	**Baseline condition and range of natural variation where known**	**Interim LACs Short term (1-5 yrs)**	**Interim LACs Long term (10-20yrs)**
	Migratory shorebirds	Knowledge gap	Knowledge gap	No net reduction in waterbird numbers over 10 years
	Invertebrates Sponges	Knowledge gap – intensive study needed to estimate total number of species and their temporal change Baseline study of 12 species recorded 2009	>20% change in numbers of species per class for > 2 years Knowledge gap	No net loss of species No net loss of species
	Fish species	At least 100 species identified around Wallis Island coffee rock an 54 species recorded at the Southern Basin	Knowledge gap	No net loss of species
Supports threatened (endangered & vulnerable) and protected species	Threatened and protected species -number and distribution -population size	Known are: 1 threatened fish and 1 threatened turtle; and 7 protected fish and 2 protected turtle species but population sizes unknown Sponges should be protected – knowledge gap	No net reduction in population size and no net loss of habitat	No net reduction in population size and no net loss of habitat

7. THREATS TO KEY CHARACTERS OF THE WALLIS LAKE SITE

The primary threats to ecological character of the Wallis Lake site are human access, catchment landuse change, climate change and introduced species. The pathways of impact of these threats for each wetland group are presented in section 5. Detailed threat pathways are shown in the diagrams in section 5.1. Threats to key characters of the Ramsar site for wetland groups 1-4 are summarised in Tables 7.1

Table7.1: Threats to key characters of wetland groups 1-4

Key Character	Indicators	Threatening Driver	Threatening Factor
Threatened Ecological Communities – Seagrass beds	Extent of segrass beds	Landuse change Human access	Excess nutrients Poor water clarity Disturbance
Macrophyte beds	Extent of macrophyte beds	Landuse change Human access	Excess nutrients Poor water quality Disturbance
Saltmarsh and Mangroves	Area and cover	Landuse change Human access Introduced species	Agricultural livestock Clearing and Loss of habitat Changed vegetation types Disturbance Predation and Competition
Coffee Rock	Area and condition	Landuse change Human access	Direct loss of habitat Disturbance and damage
Sponge Gardens	Number of species and individuals	Landuse change Human access Climate change	Sedimentation Disturbance Altered rainfall Sedimentation
Marine water grading to brackish	Salinity	Climate change	Altered rainfall
Shallow	Depth	Climate change	Altered rainfall
Oligotrophic, clear water	Chlorophyll a Water clarity	Landuse change	Excess nutrients Excess sediment input from catchment
Provision of habitat and food for fish and birds	Abundance of fish Bird roosting, breeding & feeding sites Abundance of birds	Landuse change Climate change Human access Introduced species	Direct loss of habitat (clearing) Loss of macrophytes Changed vegetation types Disturbance Predation and competition

Key Character	Indicators	Threatening Driver	Threatening Factor
Supports threatened, vulnerable and protected species	Presence of endangered, vulnerable and protected species	Landuse change Climate change Human access Introduced species	Direct loss of habitat (clearing) Loss of macrophytes Changed vegetation types Disturbance Predation and competition
Recreational attraction	Algal bloom General amenity	Landuse change Climate change Human access	Excess nutrients Loss of habitat and wildlife Loss of habitat and wildlife

8. MONITORING

The key characters of the Ramsar site were defined earlier, along with suitable indicators. Table 8.1 below indicates the type of monitoring that should be done to track changes in the character along with priorities. Existing programs are indicated by an asterix (*).

Table 8.1: Monitoring programs for wetland groups 1-4

Key Character	Indicators	Monitoring Programme	Priority
Threatened Ecological Communities – Seagrass beds	Extent of segrass beds	Survey extent of seagrass beds in summer and winter every 3rd year	H
Macrophyte beds	Extent of macrophyte beds	Survey extent of macrophyte beds in summer and winter every 3rd year	M
Saltmarsh and Mangroves	Area and cover	Survey extent of saltmarsh and mangroves every 3rd year	H
Coffee Rock	Area and condition	Survey extent and condition of coffee rock annually - every summer	H
Sponge Gardens	Number of species and individuals	Survey abundance and species of sponge every six months until further knowledge for management becomes clear	H
Marine water grading to brackish	Salinity	Continuous salinity logging measurements	L
Shallow	Depth	Bathymetric surveys	L
Oligotrophic, clear water	Chlorophyll a Water clarity	Monitoring of chlorophyll a and water clarity in summer	H
Provision of habitat and food for fish and birds	Abundance of fish Bird roosting, breeding & feeding sites Abundance of birds	Fish surveys every 3 years Bird Surveys annually for 3 years	M M
Supports threatened, vulnerable and protected species	Presence of endangered, vulnerable and protected species	Threatened species surveys every season over 1 year then reassess depending on knowledge gained	M
Recreational attraction	Algal bloom General amenity	Visitor census	M

9. KNOWLEDGE GAPS

Knowledge gaps have been highlighted through this report. They primarily relate to a lack of systematic surveys of the distribution and abundance of aquatic and terrestrial flora and fauna and, in particular, temporal variations in abundances and distributions. The fundamental knowledge gaps for the Myall Lakes Ramsar site are described below.

- A standardised and consistent map of vegetation showing the distribution of vegetation communities and endangered ecological communities is lacking. Remote sensing or aerial photos of vegetation types and distributions, together with ground truthing, are recommended.
- Annual waterbird survey, including distributions, abundance and identification of nesting, roosting and feeding sites and food resources, is needed. Additionally, bird surveys are required around high boating areas as well as non-boating areas to discern if there are differences in the bird communities.
- Fish survey is incomplete.
- There is limited information about the wetland types and their distribution, extent, composition and temporal change (inundation records) across Wallis Lake. Remote sensing or aerial photos of the sites over time can greatly enhance the current knowledge of the distribution and dynamics of the wetlands.
- Targeted surveys of threatened flora and fauna species are needed to assess the population trends, conservation status and efficiency of recovery efforts. These surveys can also increase regional and local public awareness of the importance of Wallis Lake.
- It is expected that the Wallis Lake site is abundant with aquatic invertebrates such as crustaceans, molluscs and macroinvertebrates, providing an important food source for waterbirds. However, there is limited quantitative information about their distribution, diversity, and abundance. The aquatic invertebrates could be sampled at the same time as annual waterbird survey.
- There is little information on the abundance, distribution and seasonal variation in the sponge gardens. It is recommended that initial annual seasonal studies are conducted to gather baseline information and identification of sponges, as well as identifying connections and relationships to existing communities such as seagrasses.
- There is very little data relating to the amount of fish taken from the lake through recreational fishing. It is also unknown how this changes during peak visitor seasons where recreational fishing efforts are dramatically increased. Detailed studies on the effects of fishing efforts on fish populations will provide considerable background information on fish communities within the lake.

- It is believed that the large number of oyster leases provide habitat for many species within the lake. However there has been virtually no research into the types and numbers of species that use these areas for food and shelter, and what that means for commercial and recreational fishing within the lake.

10. IMPORTANT COMMUNICATION, EDUCATION AND PUBLIC AWARENESS MESSAGES

As a result of recent studies, Wallis Lake has been classified as being of high conservation value and near pristine state (GLC 2009). Wetland and ecosystem types include; large brackish lake system, creeks and streams, saltmarsh, mangroves, rocky and sandy shores, extensive seagrass and macrophyte beds, and sponge gardens.

Wallis Lake is also important as a tourist destination as it offers a wide variety of water sports including boating (kayaking, sailing), water skiing/wake boarding, fishing and swimming. The areas around the foreshore also offer camping, bushwalking, picnicking, sightseeing and bird watching. The tourism industry injects approx $125 million per year into the local economy.

Wallis Lake contributes significantly to the local economy through the commercial fishing and oyster industry is estimated to value $22 million per annum. Around 130 species of fish and invertebrates are found in Wallis Lake of which at least 50 species are of economic or recreational value.

Wallis Lake is also known to support two endangered species and five threatened ecological communities.

Wallis Lake contains Aboriginal and historic heritage sites. There are Aboriginal cultural and spiritual connections to the landscapes in and around Wallis Lake.

Wallis Lake is home to around 20% of the total seagrass communities in NSW and is considered to be the northern most distribution limit of *Posidonia australis.* A new seagrass has been discovered in Wallis in recent times (*Halodule tridentata*) and is considered to be at its southern most distribution limit in Wallis Lake. Where these two spatial boundaries meet highlights the importance of maintaining the ecological status of Wallis Lake. Associated with the seagrass beds are the recently discovered (and some unidentified) marine sponges that have been found in the main body of Wallis Lake. Again this showcases the unique qualities of the lake in being able to support and maintain these ecosystems and its need for protection.

In addition to having a relationship to the sponges, the seagrass and macrophyte beds provide important habitat for fish and invertebrates, and food for waterbirds.

The extensive wetlands, forested areas and coastal shores, including islands, provide important roosting, nesting and foraging sites for both migratory and resident birds.

Key communication messages concerning threats that impact on the ecological character of Wallis Lake include:

- Catchment land uses can alter nutrient and sediment loads in the waterways, change the hydrological regime, cause loss of macrophytes and seagrass and cause loss of fauna and their habitats.
- Weeds and pests cause loss of native flora, fauna and their habitats.

- Climate change may impact on Wallis Lake through a range of effects including sea level rise, temperature change, change in precipitation patterns and increased atmospheric carbon dioxide.
- Inappropriate activities including recreation, seagrass and macrophyte damage from powerboats, commercial fishing causing disturbance or loss of habitats and disturbance or loss of fauna.

There is no single agency that manages the entirety of Wallis Lake, however all those involved in management components of the lake should promote these key messages:

- The important ecological values of Wallis Lake, including its biodiversity, ecological communities and water quality status.
- The importance of promoting appropriate and responsible recreation, and monitoring/managing the impact of recreation.
- The importance of promoting responsible commercial fishing and managing and monitoring the impact of commercial fishing.
- The need to consider the risks of climate change in the development of strategies relating to Wallis Lake.
- The importance of Wallis Lake as a Aboriginal cultural heritage site and historic heritage values.

Within the catchment surrounding Wallis Lake, key communication messages include:

- The need to manage changes in land use activities and to reduce the impact of existing activities that impact on water quality through sedimentation, nutrient loads and altered hydrology.
- The need to monitor the occurrence of plant and animal pests that may impact on the land use and catchment management and ensure their control.

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APPENDICES

Appendix 1: Ramsar wetland type classification

(http://www.environment.gov.au/index.html)
Under the Ramsar Convention, wetland types have been defined to provide a very broad framework to aid rapid identification of the main wetland habitats represented at each Ramsar site. Wetland type is identified for each site on the relevant Ramsar Information Sheet.
The codes used to define wetland types for Ramsar sites are based upon the Ramsar Classification System for Wetland Type as approved by Recommendation 4.7 and amended by Resolutions VI.5 and VII.11 of the Conference of the Contracting Parties.

Marine/Coastal Wetlands
A — Permanent shallow marine waters in most cases less than six metres deep at low tide; includes sea bays and straits.
B — Marine subtidal aquatic beds; includes kelp beds, sea-grass beds, tropical marine meadows.
C — Coral reefs.
D — Rocky marine shores; includes rocky offshore islands, sea cliffs.
E — Sand, shingle or pebble shores; includes sand bars, spits and sandy islets; includes dune systems and humid dune slacks.
F — Estuarine waters; permanent water of estuaries and estuarine systems of deltas.
G — Intertidal mud, sand or salt flats.
H — Intertidal marshes; includes salt marshes, salt meadows, saltings, raised salt marshes; includes tidal brackish and freshwater marshes.
I — Intertidal forested wetlands; includes mangrove swamps, nipah swamps and tidal freshwater swamp forests.
J — Coastal brackish/saline lagoons; brackish to saline lagoons with at least one relatively narrow connection to the sea.
K — Coastal freshwater lagoons; includes freshwater delta lagoons.
Zk(a) - Karst and other subterranean hydrological systems, marine/coastal

Appendix 2: Species Lists

Appendix 2a: Aquatic Species Lists

Appendix 2ai: Fish species of Wallis Lake (Source: Glasby and van den Broek 2010)

Species name	Common Name
*Ambassis jacksoniensis	Glassfish
*Redigobius macrostoma	Large-mouth goby
*Pseudogobius olorum	Swan River Goby
Plotosus lineatus	Striped catfish
*Gobiopterus semivestita	Glass Goby
Pseudomugil signifer	Southern blue-eye
*Pelates sexlineatus	Eastern striped trumpeter
*Afurcagobius tamarensis	Tamar River goby
*Gerres subfasciatus	Silver biddy
*Liza argentea	Flat-tail mullet
*Arenigobius frenatus	Half-bridled goby
*Atherinosoma microstoma	Small mouthed hardyhead
*Centropogon australis	Eastern fortescue
*Siphamia roseigaster	Silver siphonfish
Philypnodon grandiceps	Flathead gudgeon
*Favonigobius exquisitus	Exquisite sand Goby
*Acanthopagrus australis	Yellow fin bream
*Favonigobius lateralis	Long finned Goby
*Rhabdosargus sarba	Tarwhine
*Arenigobius bifrenatus	Bridled Goby
*Meuschenia trachylepis	Variable leatherjacket
*Mugil cephalus	Striped mullet
*Myxus elongates	Sand mullet
*Sillago ciliata	Sand whiting
*Siphamia cephalotes	Little siphonfish
Urocampus carinirostris	Hairy pipefish
*Girella tricuspidata	Luderick
*Atherinomorus vaigiensis	Ogilbys hardyhead
*Ambassis marianus	Estuary perchlet
*Tetractenos hamiltoni	Common toadfish
*Monodactylus argenteus	Silver batfish
Hyperlophus vittatus	Sandy Sprat
*Bathygobius krefftii	Kreffts goby
*Monacanthus chinensis	Fan-belly Leatherjacket
*Herklotsichthys castelnaui	Southern Herring
Siganus nebulosus	Happy moment
Petroscirtes lupus	Brown sabretooth blenny
Pandaka lidwilli	Dwarf goby
*Platycephalus fuscus	Dusky flathead
Monacanthidae juvenile	Leatherjacket juvenile
Pseudorhombus arsius	Large toothed flounder

*Synaptura nigra	Black sole
*Cryptocentrus critatus	Oyster goby
Torquigener pleurogramma	Weeping toad
*Hyporhamphus regularis	River garfish
Pseudorhombus jenynsii	Small-toothed flounder
Sphyraena obtusata	Striped sea pike
*Arenigobius spp	Goby
Mugilogobius palidus	Mangrove goby
Tylosurus gavialoides	Stout longtom
*Cnidoglanis macrocephalus	Estuary catfish
Meuschenia freycineti	Six-spined leatherjacket
Paramonacanthus otisensis	Dusky leatherjacket
*Tetractenos glaber	Smooth toadfish
Glossogobius biocellatus	Goby
*Pomatomus saltatrix	Tailor
*Hippocampus whitei	Whites seahorse
Marilyna pleurosticta	Banded puffer
*Sillago maculata	Trumpeter whiting
Lethrinus genivittatus	Lancer
Scobinichthys granulatus	Rough leatherjacket
Vanacampus margaritifer	Mother of pearl pipefish
Engraulis australis	Australian anchovy
Galaxias maculates	Common jollytail
*Philypnodon spp.	Dwarf flathead gudgeon
Tetradontidae juvenile	Toadfish juvenile
*Batrachomoeus dubius	Frogfish
Butis butis	Crimson-tipped gudgeon
Dasyatis fluviorum	Estuary stingray
Callionymus limiceps	Rough headed dragonet
Caranx spp	Trevally
Dinolestes lewini	Longfin Pike
Gambusia holbrooki	Gambusia
Gobiidae species	Goby
Mugilogobius spp	Goby
Scatophagus argus	Spotted scat
Anguilla reinhardtii	Long-finned eel
Antennarius striatus	
Atypichthys strigatus	Australian mado
Chelidonichthys kumu	Red gurnard
Cristiceps australis	Crested weedfish
Dasyatis spp	Stingray
Dicotylichthys punctulatus	Three-bar porcupinefish
Enoplosus armatus	Old wife
Gobiidae juvenile	Goby juvenile
Leptoscarus vaigiensis	Seagrass parrotfish
Lutjanus fulviflammus	Black spot snapper
Notesthes robusta	Bullrout

Parkraemeria ornate	Ornate goby
Pegasus volitans	Slender seamoth
Platycephalus caeruleopuncatatus	Blue-spot flathead
Pseudogobius sp	Blue spot goby
*Repomucenus calcaratus	Spotted stinkfish
Scomberoides lysan	Queenfish
Stigmatopora nigra	Wide body pipefish
Upeneus tragula	Bar-tail goatfish

* found in the southern basin

Appendix 2aii: Invertebrate Species of Wallis Lake (Source: Glasby and van den Broek 2010)

Species name	**Common Name**
Palaemon sp. (debilis)	Shrimp
*Macrobrachium intermedium	Long-armed shrimp
Acetes sibogae australis	Swarming shrimp
Chlorotocella spinicaudus	Slender beaked shrimp
*Penaeus plebejus	King prawn
*Metapenaeus macleayi	School prawn
*Latreutes pygmaeus	Hump-backed shrimp
*Idiosepius notoides	Southern pygmy squid
Mysidia spp	Opposum shrimp
Penaeus esculentus	Tiger prawn
Metapenaeus bennettae	Greasyback prawn
Alpheus richardsoni	Shrimp
*Palaemon spp.	Weed shrimp
Hymenosoma hodgkini	Spider crab
Macrobrachium cf novaehollandiae	Long-armed shrimp
Grapsidae spp.	crab
*Portunus pelagicus	Blue swimmer crab
Juvenile Squid	Juvenile Squid
Euprymna tasmanica	Dumpling Squid
Thalamita spp.	Sand crab
Xanthidae spp.	Stone crab
Amarinus spp	Spider crab
Latreutes Type 1	Shrimp
Caridina maccullochi	Shrimp
Hippolytidae	shrimp
Pandalidae	Shrimp
*Sepiidae spp	cuttlefish
Alpheus spp.	Shrimp
Loliolus noctiluca	Inshore squid
Metapenaeus spp	Penaeid prawn
Penaeus spp	Penaeid prawn

* found in the southern basin

Appendix 2aiii: Taxa caught in Wallis Lake but not in other comparable lakes in NSW (Source: Glasby pers. comm.)

Species	Common name
Alpheus richardsoni	Shrimp
Butis butis	Crimson-tipped gudgeon
Callionymus limiceps	Rough headed dragonet
Caridina maccullochi	Shrimp
Chlorotocella spinicaudus	Slender beaked shrimp
Euprymna tasmanica	Dumpling Squid
Hymenosoma hodgkini	Spider crab
Loliolus noctiluca	Inshore squid
Metapenaeus spp	Penaeid prawn
Mugilogobius palidus	Mangrove goby
Notesthes robusta	Bullrout
Palaemon debilis	Slender beaked Shrimp
Pandaka lidwilli	Dwarf goby
Parkraemeria ornata	Ornate goby
Pegasus volitans	Slender seamoth
Penaeus spp	Penaeid prawn
Plotosus lineatus	Striped catfish
Scomberoides lysan	Queenfish

Appendix 2aiv: Fish Species and their Habitat Preferences in Charlotte Bay, Southern Basin Wallis Lake (Fiebig 2007).

Common Name	Species	Habitat where observed					
		Seagrass Beds	Non-vegetated Soft Substrate	*Chara* and Macroalgae	Mangroves	Rocky Shore	Woody Debris
Mollison's Pipefish	*Mitotichthys mollisoni*	P					
Brushtail Pipefish	*Leptoichthys fistularis*					P	
Common Stingaree	*Urolophus testaceus*		P				
Sparsely Spotted Stingaree	*Urolophus paucimaculatus*	P					
Eagle Ray	*Myliobatis australis*	P					
Yellowfin Bream	*Acanthopagrus australis*	P	P			P	P
Tarwhine	*Rhabdosargus sarba*	P				P	P
Luderick	*Girella tricuspidata*	P		P			P
Silverbiddy	*Gerres subfasciatus/ ovatus*	P			P	P	P
Sea Mullet	*Mugil cepahalus*		P				P
River Garfish	*Hyporhamphus regularis*	P					P
Sand Whiting	*Sillago ciliata*		P				P
Trumpeter	*Pelates quadrilineatus*		P				P
Sandy Sprat	*Hyperlophus vittatus*		P				P
Stripey	*Microcanthus strigatus*		P				
Smooth Toadfish	*Tetractenos glaber*	P	P		P		P
3-Bar Porcupine Fish	*Dicotylichthys punctulatus*						P
White-flecked Puffer Fish	*Arothron hispidus*			P			P
Flathead Goby	*Callogobius depressus*	P	P		P		P
unidentified Gobies				P			
Perchlets (Agassiz's Glass Fish)	*Velambassis jacksoniensis*	P			P	P	P
Dusky flathead	*Platycephalus fuscus*	P	P		P		P
Fan-bellied Leather Jacket	*Moncanthus chinensis*	P		P			
Striped Catfish	*Plotosus lineatus*	P	P				
Estuary Catfish	*Cnidoglanis macrocephalus*			P		P	P
Diamond fish	*Mondodactylus argenteus*	P			P		
Larval and juvenile fish		P			P		

Appendix 2av: Invertebrate Species and their Habitat Preferences in Charlotte Bay, Southern Basin of Wallis Lake (Fiebig 2007)

Common Name	Species	Habitat where observed					
		Seagrass Beds	Non-vegetated Soft Substrate	*Chara* and Macroalgae	Mangroves	Rocky Shore	Woody Debris
Phylum Crustacea							
Mud Crabs	*Scylla serrata*	P	P	P			P
Blue Swimmer Crabs	*Portunus pelagicus*						
Grapsid Crab	Family Grapsidae					P	P
Pagurid Hermit Crab	Family Paguridae	P	P		P		
Greasyback Prawn	*Metapenaeus bennettae*	P					
School Prawn	*Metapenaeus macleayi*						
Carid Shrimp	*Macrobrachium intermedium*	P		P	P		P
Mysids		P		P			
Amphipods	*Ligia australiensis*	P		P	P	P	P
Isopods		P		P	P	P	P
Phylum Mollusca							
Bivalves - Sydney Rock Oyster	*Saccostrea commercialis*				P	P	P
Mussel	*Mytilus edulis*				P	P	P
Gastropods - Sea Hare	*Aplysia oculifera*	P	P				
Nudibranch	*Dendrodoris gunnamatta*	P					
Large Whelk	*Pyrazus ebininus*	P	P	P	P		
Small Whelk	*Velacumantus australis*	P	P	P	P		
Tent Shell	*Australium tentoriforme*				P		
Tortoiseshell Limpet	Cellana tramoserica				P		
Periwinkle	*Austrocochlea constricta*				P	P	P
Black Periwinkle	*Nerita attramentosa*				P	P	
Top Shell	*Thalotia comtessei*				P		
Morula	*Morula maarginalba*				P	P	
Mulberry Whelk	*Nassarius particeps*				P		P
Striped-mouth Conniwink	*Bembicium nanum*				P	P	
Octopus	*Octopus cyanea*	P	P	P			
Pylum Porifera - Sponges							P
Orange Sponge		P			P	P	P
Yellow Sponge		P			P		P
Blue Finger Sponge	*Suberites sp.*	P	P	P		P	
Phylum Cnidaria - Sea Anemones							
Green Anemone	*Cnidopus verater*					P	P
Phylum Echinodermata - Ophiuroidea							
Brittle Star sp. 1						P	
Brittle Star sp. 2						P	
Brittle Star sp. 3						P	
Phylum Chordata - Tunicates							
Stalked tunicate			P				
Species 2	*cf. Pyura sacciformis*	P	P	P			
Phylum Bryozoa							
Bryozoan	*cf. Membranipoa membranacea*	P			P		P
Phylum Polychaeta - Polychaete worms							
Serpulidae - Spirorbid tube worms	*Spirorbis* sp.	P		P	P	P	P
Sabellidae - tube worm	Family Sabellidae	P	P		P	P	P
Syllidae	Family Syllidae	P			P	P	
Aphroditidae	Family Aphroditidae	P		P	P	P	
Nereidae	Family Nereidae	P	P		P	P	
Phylum Nematoda							
Nematode worm		P	P	P	P	P	
Phylum Nemertea							
Nemertean worm		P	P	P	P	P	

Appendix 2avi: Aquatic Plant Species List, Charlotte Bay (Fiebig 2007)

Common Name	Species
Seagrasses	
Eelgrass	*Zostera capricornia*
Sea Tassel	*Ruppia megacarpa*
Paddleweed	*Halophila ovalis*
Algae	
Green Algae	
Stonewort	*Lamprothamnium sp.*
Chaetomorpha	*Chaetomorpha sp.*
Green Guts (snot)	*Enteromorpha sp.*
Mermaid's Wineglass	*Acetabularia calyculus*
Sea Lettuce	*Ulva sp.*
Turf Algae	
Codium	*Codium fragile*
Red Algae	
Gracilaria	*Gracilaria sp.*
Laurencia	*Laurencia sp.*
Hypnea	*Hypnea sp.*
Brown Algae	
Sargassum	*Sargassum sp.*
Cockleweed	*Cystoseira trinodis*
Funnel Weed	*Padina elegans*
Irridescent Blue Dictyota	*Dictyota dichotoma*
Neptune's Necklace	*Hormosira banksii*
Saltmarsh Species	
Spiky Rush Sedge	*Juncus krausii*
Samphire	*Sarcicornia quinqueflora*
succulent	*Suaeda australis*
grass	*Sporobolus virginicus*
Mangrove Species	
Grey mangrove	*Avicennia marina*
Terrestrial Species	
Swampy oak	*Casuarina glauca*

Appendix 3: Terrestrial Species Lists

Source: NPWS Atlas of NSW Wildlife (as at 20 June 2010)

Appendix 3a: Bird Species The list below is a record of birds since 1980 for the whole of the Great Lakes LGA.

Aves	Scientific Name	Common Name	Legal Status
Acanthizidae			
	Acanthiza chrysorrhoa	Yellow-rumped Thornbill	P
	Acanthiza lineata	Striated Thornbill	P
	Acanthiza nana	Yellow Thornbill	P
	Acanthiza pusilla	Brown Thornbill	P
	Gerygone albogularis	White-throated Gerygone	P
	Gerygone mouki	Brown Gerygone	P
	Sericornis citreogularis	Yellow-throated Scrubwren	P
	Sericornis frontalis	White-browed Scrubwren	P
	Sericornis magnirostra	Large-billed Scrubwren	P
Accipitridae			
	Accipiter cirrocephalus	Collared Sparrowhawk	P
	Accipiter fasciatus	Brown Goshawk	P
	Aviceda subcristata	Pacific Baza	P
	Circus approximans	Swamp Harrier	P
	Elanus axillaris	Black-shouldered Kite	P
	Haliaeetus leucogaster	White-bellied Sea-Eagle	P
	Haliastur indus	Brahminy Kite	P
	Haliastur sphenurus	Whistling Kite	P
	Hieraaetus morphnoides	Little Eagle	V
	Pandion haliaetus	Osprey	V
Acrocephalidae			
	Acrocephalus australis	Australian Reed-Warbler	P
Aegothelidae			
	Aegotheles cristatus	Australian Owlet-nightjar	P
Alcedinidae			
	Ceyx azureus	Azure Kingfisher	P
	Dacelo novaeguineae	Laughing Kookaburra	P
	Todiramphus sanctus	Sacred Kingfisher	P
Anatidae			
	Anas castanea	Chestnut Teal	P
	Anas gracilis	Grey Teal	P
	Anas superciliosa	Pacific Black Duck	P
	Aythya australis	**Hardhead**	**P**
	Chenonetta jubata	Australian Wood Duck	P
	Cygnus atratus	Black Swan	P
Anhingidae			
	Anhinga novaehollandiae	Australasian Darter	P
Apodidae			
	Hirundapus caudacutus	White-throated Needletail	P

Ardeidae			
	Ardea ibis	Cattle Egret	P
	Ardea intermedia	Intermediate Egret	P
	Ardea modesta	Eastern Great Egret	P
	Ardea pacifica	White-necked Heron	P
	Botaurus poiciloptilus	Australasian Bittern	V
	Butorides striatus	Striated Heron	P
	Egretta garzetta	Little Egret	P
	Egretta novaehollandiae	White-faced Heron	P
	Egretta sacra	Eastern Reef Egret	P
	Ixobrychus flavicollis	Black Bittern	V
	Nycticorax caledonicus	Nankeen Night Heron	P
Artamidae			
	Artamus cyanopterus	Dusky Woodswallow	P
	Artamus leucorynchus	White-breasted Woodswallow	P
	Artamus superciliosus	White-browed Woodswallow	P
	Cracticus nigrogularis	Pied Butcherbird	P
	Cracticus tibicen	Australian Magpie	P
	Cracticus torquatus	Grey Butcherbird	P
	Strepera graculina	Pied Currawong	P
Burhinidae			
	Esacus neglectus	Beach Stone-curlew	E4A
Cacatuidae			
	Cacatua galerita	Sulphur-crested Cockatoo	P
	Cacatua sanguinea	Little Corella	P
	Calyptorhynchus funereus	Yellow-tailed Black-Cockatoo	P
	Calyptorhynchus lathami	Glossy Black-Cockatoo	V
	Eolophus roseicapillus	Galah	P
Campephagidae			
	Coracina novaehollandiae	Black-faced Cuckoo-shrike	P
	Coracina tenuirostris	Cicadabird	P
Centropodidae			
	Centropus phasianinus	Pheasant Coucal	P
Charadriidae			
	Charadrius bicinctus	Double-banded Plover	P
	Charadrius mongolus	Lesser Sand-plover	V
	Charadrius ruficapillus	Red-capped Plover	P
	Elseyornis melanops	Black-fronted Dotterel	P
	Pluvialis fulva	Pacific Golden Plover	P
	Pluvialis squatarola	Grey Plover	P
	Vanellus miles	Masked Lapwing	P
Ciconiidae			
	Ephippiorhynchus	Black-necked Stork	E1
Cisticolidae			
	Cisticola exilis	Golden-headed Cisticola	P
Climacteridae			
	Cormobates leucophaea	White-throated Treecreeper	P

Columbidae			
	Columba leucomela	White-headed Pigeon	P
	Columba livia*	Rock Dove	U
	Geopelia humeralis	Bar-shouldered Dove	P
	Geopelia striata	Peaceful Dove	P
	Lopholaimus antarcticus	Topknot Pigeon	P
	Macropygia amboinensis	Brown Cuckoo-Dove	P
	Ocyphaps lophotes	Crested Pigeon	P
	Phaps chalcoptera	Common Bronzewing	P
	Phaps elegans	Brush Bronzewing	P
	Streptopelia chinensis*	Spotted Turtle-Dove	U
Coraciidae			
	Eurystomus orientalis	Dollarbird	P
Corvidae			
	Corvus coronoides	Australian Raven	P
	Corvus orru	Torresian Crow	P
	Corvus tasmanicus	Forest Raven	P
Cuculidae			
	Cacomantis flabelliformis	Fan-tailed Cuckoo	P
	Cacomantis pallidus	Pallid Cuckoo	P
	Cacomantis variolosus	Brush Cuckoo	P
	Chalcites basalis	Horsfield's Bronze-Cuckoo	P
	Chalcites lucidus	Shining Bronze-Cuckoo	P
	Eudynamys orientalis	Eastern Koel	P
	Scythrops	Channel-billed Cuckoo	P
Dicruridae			
	Dicrurus bracteatus	Spangled Drongo	P
Diomedeidae			
	Thalassarche	Yellow-nosed Albatross	P
	Thalassarche melanophris	Black-browed Albatross	V
Estrildidae			
	Neochmia temporalis	Red-browed Finch	P
	Taeniopygia bichenovii	Double-barred Finch	P
Falconidae			
	Falco berigora	Brown Falcon	P
	Falco cenchroides	Nankeen Kestrel	P
	Falco longipennis	Australian Hobby	P
	Falco peregrinus	Peregrine Falcon	P
Haematopodidae			
	Haematopus fuliginosus	Sooty Oystercatcher	V
	Haematopus longirostris	Pied Oystercatcher	E1
Hirundinidae			
	Hirundo neoxena	Welcome Swallow	P
	Petrochelidon nigricans	Tree Martin	P
Laridae			
	Chlidonias hybrida	Whiskered Tern	P
	Chroicocephalus	Silver Gull	P

	Gelochelidon nilotica	Gull-billed Tern	P
	Hydroprogne caspia	Caspian Tern	P
	Sterna albifrons	Little Tern	E1
	Sterna hirundo	Common Tern	P
	Thalasseus bergii	Crested Tern	P
Maluridae			
	Malurus cyaneus	Superb Fairy-wren	P
	Malurus lamberti	Variegated Fairy-wren	P
	Malurus melanocephalus	Red-backed Fairy-wren	P
	Stipiturus malachurus	Southern Emu-wren	P
Megaluridae			
	Cincloramphus cruralis	Brown Songlark	P
	Megalurus timoriensis	Tawny Grassbird	P
Megapodiidae			
	Alectura lathami	Australian Brush-turkey	P
Meliphagidae			
	Acanthorhynchus	Eastern Spinebill	P
	Anthochaera carunculata	Red Wattlebird	P
	Anthochaera chrysoptera	Little Wattlebird	P
	Entomyzon cyanotis	Blue-faced Honeyeater	P
	Epthianura albifrons	White-fronted Chat	V
	Gliciphila melanops	Tawny-crowned Honeyeater	P
	Lichenostomus chrysops	Yellow-faced Honeyeater	P
	Lichenostomus fuscus	Fuscous Honeyeater	P
	Lichenostomus leucotis	White-eared Honeyeater	P
	Lichmera indistincta	Brown Honeyeater	P
	Manorina melanocephala	Noisy Miner	P
	Meliphaga lewinii	Lewin's Honeyeater	P
	Myzomela sanguinolenta	Scarlet Honeyeater	P
	Philemon citreogularis	Little Friarbird	P
	Philemon corniculatus	Noisy Friarbird	P
	Phylidonyris niger	White-cheeked Honeyeater	P
	Phylidonyris	New Holland Honeyeater	P
	Phylidonyris pyrrhoptera	Crescent Honeyeater	P
	Plectorhyncha lanceolata	Striped Honeyeater	P
Meropidae			
	Merops ornatus	Rainbow Bee-eater	P
Monarchidae			
	Grallina cyanoleuca	Magpie-lark	P
	Monarcha melanopsis	Black-faced Monarch	P
	Myiagra rubecula	Leaden Flycatcher	P
Motacillidae			
	Anthus novaeseelandiae	Australian Pipit	P
Nectariniidae			
	Dicaeum hirundinaceum	Mistletoebird	P
Neosittidae			
	Daphoenositta	Varied Sittella	V

Oceanitidae			
	Oceanites oceanicus	Wilson's Storm-Petrel	P
Oriolidae			
	Oriolus sagittatus	Olive-backed Oriole	P
	Sphecotheres vieilloti	Australasian Figbird	P
Pachycephalidae			
	Colluricincla harmonica	Grey Shrike-thrush	P
	Falcunculus frontatus	Eastern Shrike-tit	P
	Pachycephala pectoralis	Golden Whistler	P
	Pachycephala rufiventris	Rufous Whistler	P
Pardalotidae			
	Pardalotus punctatus	Spotted Pardalote	P
	Pardalotus striatus	Striated Pardalote	P
Passeridae			
	Passer domesticus*	House Sparrow	U
Pelecanidae			
	Pelecanus conspicillatus	Australian Pelican	P
Petroicidae			
	Eopsaltria australis	Eastern Yellow Robin	P
	Microeca fascinans	Jacky Winter	P
	Petroica rosea	Rose Robin	P
Phalacrocoracidae			
	Microcarbo melanoleucos	Little Pied Cormorant	P
	Phalacrocorax carbo	Great Cormorant	P
	Phalacrocorax sulcirostris	Little Black Cormorant	P
	Phalacrocorax varius	Pied Cormorant	P
Phasianidae			
	Coturnix pectoralis	Stubble Quail	P
	Coturnix ypsilophora	Brown Quail	P
	Pavo cristatus*	Indian Peafowl	U
Podargidae			
	Podargus strigoides	Tawny Frogmouth	P
Podicipedidae			
	Tachybaptus	Australasian Grebe	P
Procellariidae			
	Pachyptila turtur	Fairy Prion	P
	Pelecanoides urinatrix	Common Diving-Petrel	P
	Puffinus gavia	Fluttering Shearwater	P
	Puffinus huttoni	Hutton's Shearwater	P
Psittacidae			
	Alisterus scapularis	Australian King-Parrot	P
	Glossopsitta concinna	Musk Lorikeet	P
	Glossopsitta pusilla	Little Lorikeet	V
	Lathamus discolor	Swift Parrot	E1
	Melopsittacus undulatus	Budgerigar	P
	Platycercus eximius	Eastern Rosella	P
	Psephotus haematonotus	Red-rumped Parrot	P

	Trichoglossus	Scaly-breasted Lorikeet	P
	Trichoglossus	Rainbow Lorikeet	P
Psophodidae			
	Psophodes olivaceus	Eastern Whipbird	P
Ptilonorhynchidae			
	Ailuroedus crassirostris	Green Catbird	P
	Ptilonorhynchus violaceus	Satin Bowerbird	P
	Sericulus chrysocephalus	Regent Bowerbird	P
Rallidae			
	Fulica atra	Eurasian Coot	P
	Gallinula tenebrosa	Dusky Moorhen	P
	Gallirallus philippensis	Buff-banded Rail	P
	Lewinia pectoralis	Lewin's Rail	P
	Porphyrio porphyrio	Purple Swamphen	P
Recurvirostridae			
	Himantopus himantopus	Black-winged Stilt	P
Rhipiduridae			
	Rhipidura albiscapa	Grey Fantail	P
	Rhipidura leucophrys	Willie Wagtail	P
	Rhipidura rufifrons	Rufous Fantail	P
Scolopacidae			
	Actitis hypoleucos	Common Sandpiper	P
	Arenaria interpres	Ruddy Turnstone	P
	Calidris acuminata	Sharp-tailed Sandpiper	P
	Calidris canutus	Red Knot	P
	Calidris ferruginea	Curlew Sandpiper	P
	Calidris ruficollis	Red-necked Stint	P
	Calidris tenuirostris	Great Knot	V
	Gallinago hardwickii	Latham's Snipe	P
	Limosa lapponica	Bar-tailed Godwit	P
	Limosa limosa	Black-tailed Godwit	V
	Numenius	Eastern Curlew	P
	Numenius phaeopus	Whimbrel	P
	Tringa brevipes	Grey-tailed Tattler	P
	Tringa incana	Wandering Tattler	P
	Tringa nebularia	Common Greenshank	P
	Tringa stagnatilis	Marsh Sandpiper	P
	Xenus cinereus	Terek Sandpiper	V
Spheniscidae			
	Eudyptula minor	Little Penguin	P
Stercorcariidae			
	Stercorarius pomarinus	Pomarine Jaeger	P
Strigidae			
	Ninox novaeseelandiae	Southern Boobook	P
	Ninox strenua	Powerful Owl	V
Sturnidae			
	Sturnus tristis*	Common Myna	U

	Sturnus vulgaris*	Common Starling	U
Sulidae			
	Morus serrator	Australasian Gannet	P
Threskiornithidae			
	Platalea regia	Royal Spoonbill	P
	Threskiornis molucca	Australian White Ibis	P
	Threskiornis spinicollis	Straw-necked Ibis	P
Timaliidae			
	Zosterops lateralis	Silvereye	P
Turdidae			
	Zoothera heinei	Russet-tailed Thrush	P
Tytonidae			
	Tyto javanica	Eastern Barn Owl	P
	Tyto novaehollandiae	Masked Owl	V

Appendix 3b: Vertebrate fauna excluding bird and fish species

Mammalia	**Scientific Name**	**Common Name**	**Legal Status**
Canidae			
	Canis lupus familiaris*	Dog	U
	Canis lupus*	Dingo, domestic dog	U
	Vulpes vulpes*	Fox	U
Cervidae			
	Cervus sp.*	Unidentified Deer	U
Dasyuridae			
	Antechinus flavipes	Yellow-footed Antechinus	P
	Antechinus stuartii	Brown Antechinus	P
	Antechinus swainsonii	Dusky Antechinus	P
	Dasyurus maculatus	Spotted-tailed Quoll	V
Delphinidae			
	Tursiops truncatus	Bottlenose Dolphin	P
Emballonuridae			
	Saccolaimus flaviventris	Yellow-bellied Sheathtail-bat	V
Equidae			
	Equus caballus*	Horse	U
Felidae			
	Felis catus*	Cat	U
Leporidae			
	Lepus capensis*	Brown Hare	U
	Oryctolagus cuniculus*	Rabbit	U
Macropodidae			
	Macropus giganteus	Eastern Grey Kangaroo	P
	Macropus rufogriseus	Red-necked Wallaby	P
	Wallabia bicolor	Swamp Wallaby	P
Molossidae			
	Mormopterus	Eastern Freetail-bat	V
	Tadarida australis	White-striped Freetail-bat	P

Muridae			
	Hydromys chrysogaster	Water-rat	P
	Mus musculus		U
	Mus musculus*	House Mouse	U
	Pseudomys	Eastern Chestnut Mouse	V
	Pseudomys	New Holland Mouse	P
	Rattus fuscipes	Bush Rat	P
	Rattus lutreolus	Swamp Rat	P
	Rattus rattus*	Black Rat	U
Otariidae			
	Seal sp.	Unidentified Seal	P
Peramelidae			
	Isoodon macrourus	Northern Brown Bandicoot	P
	Perameles nasuta	Long-nosed Bandicoot	P
Petauridae			
	Petaurus breviceps	Sugar Glider	P
	Petaurus norfolcensis	Squirrel Glider	V
Phalangeridae			
	Trichosurus sp.	brushtail possum	P
	Trichosurus vulpecula	Common Brushtail Possum	P
Phascolarctidae			
	Phascolarctos cinereus	Koala	V
Pseudocheiridae			
	Pseudocheirus peregrinus	Common Ringtail Possum	P
Pteropodidae			
	Pteropus poliocephalus	Grey-headed Flying-fox	V
Rhinolophidae			
	Rhinolophus megaphyllus	Eastern Horseshoe-bat	P
Tachyglossidae			
	Tachyglossus aculeatus	Short-beaked Echidna	P
Vespertilionidae			
	Chalinolobus gouldii	Gould's Wattled Bat	P
	Chalinolobus morio	Chocolate Wattled Bat	P
	Falsistrellus tasmaniensis	Eastern False Pipistrelle	V
	Miniopterus australis	Little Bentwing-bat	V
	Miniopterus schreibersii	Eastern Bentwing-bat	V
	Myotis macropus	Southern Myotis	V
	Nyctophilus geoffroyi	Lesser Long-eared Bat	P
	Nyctophilus gouldi	Gould's Long-eared Bat	P
	Nyctophilus sp.	long-eared bat	P
	Scoteanax rueppellii	Greater Broad-nosed Bat	V
	Scotorepens orion	Eastern Broad-nosed Bat	P
	Vespadelus darlingtoni	Large Forest Bat	P
	Vespadelus pumilus	Eastern Forest Bat	P
	Vespadelus regulus	Southern Forest Bat	P
	Vespadelus troughtoni	Eastern Cave Bat	V
	Vespadelus vulturnus	Little Forest Bat	P

Vombatidae			
	Vombatus ursinus	Common Wombat	P
Reptilia	**Scientific Name**	**Common Name**	**Legal Status**
Agamidae			
	Amphibolurus muricatus	Jacky Lizard	P
Chelidae			
	Chelodina longicollis	Eastern Snake-necked Turtle	P
Colubridae			
	Dendrelaphis punctulatus	Common Tree Snake	P
Dermochelyidae			
	Dermochelys coriacea	Leathery Turtle	V
Elapidae			
	Cryptophis nigrescens	Eastern Small-eyed Snake	P
	Hemiaspis signata	Black-bellied Swamp Snake	P
	Pseudechis porphyriacus	Red-bellied Black Snake	P
	Pseudonaja textilis	Eastern Brown Snake	P
Scincidae			
	Bellatorias major	Land Mullet	P
	Calyptotis ruficauda	Red-tailed Calyptotis	P
	Ctenotus robustus	Robust Ctenotus	P
	Ctenotus taeniolatus	Copper-tailed Skink	P
	Lampropholis delicata	Dark-flecked Garden Sunskink	P
	Lampropholis guichenoti	Pale-flecked Garden Sunskink	P
	Saiphos equalis	Three-toed Skink	P
	Tiliqua scincoides	Eastern Blue-tongue	P
Varanidae			
	Varanus varius	Lace Monitor	P
Amphibia	**Scientific Name**	**Common Name**	**Legal Status**
Hylidae			
	Litoria caerulea	Green Tree Frog	P
	Litoria dentata	Bleating Tree Frog	P
	Litoria fallax	Eastern Dwarf Tree Frog	P
	Litoria gracilenta	Dainty Green Tree Frog	P
	Litoria jervisiensis	Jervis Bay Tree Frog	P
	Litoria nasuta	**Rocket Frog**	**P**
	Litoria peronii	Peron's Tree Frog	P
	Litoria tyleri	Tyler's Tree Frog	P
Myobatrachidae			
	Crinia signifera	Common Eastern Froglet	P
	Crinia tinnula	Wallum Froglet	V
	Limnodynastes dumerilii	Eastern Banjo Frog	P
	Limnodynastes peronii	Brown-striped Frog	P
	Limnodynastes	Spotted Grass Frog	P
	Uperoleia fusca	Dusky Toadlet	P

	Uperoleia laevigata	Smooth Toadlet	P

Appendix 3c: Flora

Plants	Scientific Name	Common Name	Legal Status
Acanthaceae			
	Pseuderanthemum	Pastel Flower	U
Adiantaceae			
	Adiantum aethiopicum	Common Maidenhair	P13
	Adiantum formosum	Giant Maidenhair	P13
	Adiantum hispidulum	Rough Maidenhair	P13
	Pellaea falcata	Sickle Fern	U
	Pellaea paradoxa		U
Agavaceae			
	Yucca aloifolia*	Spanish Bayonet	U
Aizoaceae			
	Carpobrotus glaucescens	Pigface	U
	Tetragonia tetragonioides	New Zealand Spinach	U
Amaranthaceae			
	Alternanthera denticulata	Lesser Joyweed	U
Amaryllidaceae			
	Crinum pedunculatum	Swamp Lily	U
Anthericaceae			
	Caesia parviflora	Pale Grass-lily	U
	Sowerbaea juncea	Vanilla Plant	U
Aphanopetalaceae			
	Aphanopetalum	Gum Vine	U
Apiaceae			
	Actinotus helianthi	Flannel Flower	P13
	Centella asiatica	Indian Pennywort	U
	Cyclospermum	Slender Celery	U
	Hydrocotyle bonariensis*		U
	Hydrocotyle laxiflora	Stinking Pennywort	U
	Hydrocotyle peduncularis	A Pennywort	U
	Hydrocotyle spp.*		U
	Platysace ericoides		U
	Platysace lanceolata	Shrubby Platysace	U
	Xanthosia pilosa	Woolly Xanthosia	U
Apocynaceae			
	Asclepias curassavica*	Blood Flower	U
	Cynanchum carnosum		U
	Cynanchum elegans	White-flowered Wax Plant	E1
	Gomphocarpus	Narrow-leaved Cotton Bush	U
	Marsdenia rostrata	Milk Vine	U
	Parsonsia straminea	Common Silkpod	U
	Parsonsia velutina		U

	Tylophora barbata	Bearded Tylophora	U
	Tylophora paniculata	Thin-leaved Tylophora	U
Araceae			
	Alocasia brisbanensis	Cunjevoi	U
	Gymnostachys anceps	Settler's Twine	U
Araliaceae			
	Polyscias elegans	Celery Wood	U
	Polyscias sambucifolia	Elderberry Panax	U
	Polyscias sambucifolia		U
	Schefflera actinophylla*	Umbrella Tree	U
Arecaceae			
	Livistona australis	Cabbage Palm	P13
Asparagaceae			
	Asparagus aethiopicus*	Asparagus Fern	U
	Asparagus asparagoides*	Bridal Creeper	U
Aspleniaceae			
	Asplenium australasicum	Bird's Nest Fern	P13
Asteraceae			
	Ageratina adenophora*	Crofton Weed	U
	Arctotheca calendula*	Capeweed	U
	Aster subulatus*	Wild Aster	U
	Bidens pilosa*	Cobbler's Pegs	U
	Bidens subalternans*	Greater Beggar's Ticks	U
	Carthamus lanatus*	Saffron Thistle	U
	Cassinia aculeata	Dolly Bush	U
	Chrysanthemoides	Bitou Bush	U
	Chrysanthemoides		U
	Cirsium vulgare*	Spear Thistle	U
	Conyza bonariensis*	Flaxleaf Fleabane	U
	Conyza spp.*	A Fleabane	U
	Conyza sumatrensis*	Tall fleabane	U
	Coreopsis lanceolata*	Coreopsis	U
	Crassocephalum	Thickhead	U
	Delairea odorata*	Cape Ivy	U
	Enydra fluctuans		U
	Erechtites valerianifolia*	Brazilian Fireweed	U
	Euchiton spp.	A Cudweed	U
	Galinsoga parviflora*	Potato Weed	U
	Gamochaeta antillana*		U
	Gamochaeta spicata*	Cudweed	U
	Gamochaeta spp.*		U
	Hypochaeris glabra*	Smooth Catsear	U
	Hypochaeris radicata*	Catsear	U
	Leptinella longipes		U
	Olearia nernstii		U
	Olearia viscidula	Wallaby Weed	U
	Ozothamnus diosmifolius	White Dogwood	U

	Senecio	Fireweed	U
	Senecio pinnatifolius var.		U
	Sigesbeckia orientalis	Indian Weed	U
	Soliva sessilis*	Bindyi	U
	Sonchus oleraceus*	Common Sowthistle	U
	Taraxacum officinale*	Dandelion	U
Basellaceae			
	Anredera cordifolia*	Madeira Vine	U
Bignoniaceae			
	Pandorea pandorana	Wonga Wonga Vine	U
	Pandorea pandorana	Wonga Wonga Vine	U
Blandfordiaceae			
	Blandfordia grandiflora	Christmas Bells	P13
Blechnaceae			
	Blechnum cartilagineum	Gristle Fern	U
	Blechnum indicum	Swamp Water Fern	U
	Doodia aspera	Prickly Rasp Fern	U
Brassicaceae			
	Capsella bursa-pastoris*	Shepherd's Purse	U
	Lepidium africanum*	Common Peppercress	U
Cactaceae			
	Opuntia monacantha*	Drooping Pear	U
Campanulaceae			
	Wahlenbergia gracilis	Sprawling Bluebell	U
Capparaceae			
	Capparis arborea	Native Pomegranate	U
	Capparis sarmentosa		U
Caprifoliaceae			
	Lonicera japonica*	Japanese Honeysuckle	U
Caryophyllaceae			
	Stellaria media*	Common Chickweed	U
Casuarinaceae			
	Allocasuarina littoralis	Black She-Oak	U
	Allocasuarina simulans	Nabiac Casuarina	V
	Allocasuarina torulosa	Forest Oak	U
	Casuarina equisetifolia	Coastal She-oak	U
	Casuarina glauca	Swamp Oak	U
Celastraceae			
	Elaeodendron australe		U
	Elaeodendron australe		U
	Maytenus silvestris	Narrow-leaved Orangebark	U
Chenopodiaceae			
	Atriplex prostrata*		U
	Sarcocornia quinqueflora		U
	Suaeda australis		U
Clusiaceae			
	Hypericum gramineum	Small St John's Wort	U

Colchicaceae			
	Burchardia umbellata	Milkmaids	U
Commelinaceae			
	Aneilema acuminatum		U
	Commelina cyanea	Native Wandering Jew	U
Convolvulaceae			
	Dichondra repens	Kidney Weed	U
	Ipomoea cairica*		U
	Polymeria calycina		U
Cornaceae			
	Alangium villosum subsp.	Muskwood	U
Crassulaceae			
	Bryophyllum delagoense*	Mother of millions	U
Cyperaceae			
	Baumea articulata	Jointed Twig-rush	U
	Baumea juncea		U
	Baumea muelleri		U
	Baumea rubiginosa		U
	Baumea spp.		U
	Baumea teretifolia		U
	Carex appressa	Tall Sedge	U
	Carex longebrachiata		U
	Caustis flexuosa	Curly Wig	P13
	Caustis pentandra	Thick Twist Rush	P13
	Caustis recurvata		P13
	Caustis recurvata var.		P13
	Chorizandra cymbaria		U
	Chorizandra	Roundhead Bristle-sedge	U
	Cyperus difformis	Dirty Dora	U
	Cyperus eglobosus		U
	Cyperus enervis		U
	Cyperus eragrostis*	Umbrella Sedge	U
	Cyperus gracilis	Slender Flat-sedge	U
	Cyperus sphaeroideus		U
	Cyperus spp.		U
	Eleocharis equisetina		U
	Eleocharis sphacelata	Tall Spike Rush	U
	Fimbristylis dichotoma	Common Fringe-sedge	U
	Gahnia aspera	Rough Saw-sedge	U
	Gahnia clarkei	Tall Saw-sedge	U
	Gahnia melanocarpa	Black Fruit Saw-sedge	U
	Gahnia radula		U
	Gahnia sieberiana	Red-fruit Saw-sedge	P13
	Isolepis inundata	Club-rush	U
	Lepidosperma laterale	Variable Sword-sedge	U
	Lepironia articulata		U
	Schoenoplectus		U

	Schoenoplectus validus		U
	Schoenus brevifolius		U
	Schoenus ericetorum		U
	Schoenus turbinatus		U
	Tricostularia pauciflora		U
Davalliaceae			
	Davallia solida var.	Hare's Foot Fern	U
Dennstaedtiaceae			
	Histiopteris incisa	Bat's Wing Fern	U
	Hypolepis glandulifera	Downy Ground Fern	U
	Hypolepis muelleri	Harsh Ground Fern	U
	Pteridium esculentum	Bracken	U
Dicksoniaceae			
	Calochlaena dubia	Rainbow Fern	U
Dilleniaceae			
	Hibbertia acicularis		U
	Hibbertia aspera	Rough Guinea Flower	U
	Hibbertia aspera subsp.		U
	Hibbertia dentata	Twining Guinea Flower	U
	Hibbertia empetrifolia		U
	Hibbertia fasciculata		U
	Hibbertia linearis		U
	Hibbertia obtusifolia	Hoary guinea flower, Grey	U
	Hibbertia scandens	Climbing Guinea Flower	U
	Hibbertia serpyllifolia	Hairy Guinea Flower	U
Dioscoreaceae			
	Dioscorea transversa	Native Yam	U
Droseraceae			
	Drosera spatulata		U
Dryopteridaceae			
	Lastreopsis decomposita	Trim Shield Fern	U
Ebenaceae			
	Diospyros australis	Black Plum	U
Elaeocarpaceae			
	Elaeocarpus obovatus	Hard Quandong	U
	Elaeocarpus reticulatus	Blueberry Ash	U
	Tetratheca ericifolia		U
Ericaceae			
	Astroloma pinifolium	Pine Heath	U
	Brachyloma daphnoides	Daphne Heath	U
	Brachyloma scortechinii		U
	Epacris microphylla	Coral Heath	U
	Epacris obtusifolia	Blunt-leaf Heath	U
	Epacris pulchella	Wallum Heath	U
	Leucopogon deformis		U
	Leucopogon ericoides	Pink Beard-heath	U
	Leucopogon juniperinus	Prickly Beard-heath	U

	Leucopogon lanceolatus		U
	Leucopogon lanceolatus		U
	Leucopogon		U
	Leucopogon parviflorus	Coastal Beard-heath	U
	Leucopogon virgatus		U
	Monotoca elliptica	Tree Broom-heath	U
	Monotoca scoparia		U
	Sprengelia incarnata	Pink Swamp Heath	P13
	Sprengelia sprengelioides		U
	Trochocarpa laurina	Tree Heath	U
	Woollsia pungens		U
Euphorbiaceae			
	Alchornea ilicifolia	Native Holly	U
	Amperea xiphoclada		U
	Amperea xiphoclada var.		U
	Baloghia inophylla	Brush Bloodwood	U
	Breynia oblongifolia	Coffee Bush	U
	Claoxylon australe	Brittlewood	U
	Cleistanthus	Cleistanthus	U
	Glochidion ferdinandi	Cheese Tree	U
	Glochidion ferdinandi var.	Cheese Tree	U
	Homalanthus populifolius		U
	Mallotus philippensis	Red Kamala	U
	Poranthera microphylla	Small Poranthera	U
	Pseudanthus orientalis		U
	Ricinocarpos pinifolius	Wedding Bush	U
	Ricinus communis*	Castor Oil Plant	U
Eupomatiaceae			
	Eupomatia laurina	Bolwarra	U
Fabaceae			
	Senna pendula var.		U
	Senna septemtrionalis*	Arsenic Bush	U
Fabaceae			
	Aotus ericoides		U
	Bossiaea ensata	Sword Bossiaea	U
	Bossiaea heterophylla	Variable Bossiaea	U
	Desmodium gunnii	Slender Tick-trefoil	U
	Desmodium		U
	Desmodium varians	Slender Tick-trefoil	U
	Dillwynia floribunda		U
	Dillwynia glaberrima		U
	Dillwynia retorta		U
	Dillwynia spp.		U
	Glycine clandestina	Twining glycine	U
	Glycine microphylla	Small-leaf Glycine	U
	Glycine tabacina	Variable Glycine	U
	Gompholobium	Dainty Wedge Pea	U

	Gompholobium latifolium	Golden Glory Pea	U
	Gompholobium pinnatum	Pinnate Wedge Pea	U
	Gompholobium virgatum	Leafy Wedge Pea	U
	Hardenbergia violacea	False Sarsaparilla	U
	Indigofera australis	Australian Indigo	U
	Kennedia rubicunda	Dusky Coral Pea	U
	Lotus subbiflorus*	Hairy Birds-foot Trefoil	U
	Medicago spp.*	A Medic	U
	Phyllota phylicoides	Heath Phyllota	U
	Pultenaea blakelyi		U
	Pultenaea retusa		U
	Pultenaea villosa	Hairy Bush-pea	U
	Trifolium fragiferum*	Strawberry Clover	U
	Trifolium repens*	White Clover	U
	Viminaria juncea	Native Broom	U
Fabaceae			
	Acacia baileyana	Cootamundra Wattle	U
	Acacia baueri subsp.	Tiny Wattle	U
	Acacia binervata	Two-veined Hickory	U
	Acacia echinula	Hedgehog Wattle	U
	Acacia elongata	Swamp Wattle	U
	Acacia implexa	Hickory Wattle	U
	Acacia irrorata	Green Wattle	U
	Acacia irrorata subsp.	Green Wattle	U
	Acacia longifolia		U
	Acacia longifolia subsp.	Sydney Golden Wattle	U
	Acacia longifolia subsp.	Coastal Wattle	U
	Acacia maidenii	Maiden's Wattle	U
	Acacia melanoxylon	Blackwood	U
	Acacia myrtifolia	Red-stemmed Wattle	U
	Acacia quadrilateralis		U
	Acacia spp.	Wattle	U
	Acacia suaveolens	Sweet Wattle	U
	Acacia ulicifolia	Prickly Moses	U
	Pararchidendron	Snow Wood	U
Flacourtiaceae			
	Scolopia braunii	Flintwood	U
Geraniaceae			
	Geranium homeanum		U
	Geranium retrorsum	Cranesbill Geranium	U
	Geranium solanderi	Native Geranium	U
	Pelargonium spp.*		U
Goodeniaceae			
	Dampiera stricta		U
	Dampiera sylvestris		U
	Goodenia gracilis		U
	Goodenia heterophylla		U

	Goodenia paniculata		U
	Goodenia stelligera	Spiked Goodenia	U
	Scaevola calendulacea		U
	Scaevola ramosissima	Purple Fan-flower	U
Haemodoraceae			
	Haemodorum		U
Haloragaceae			
	Gonocarpus micranthus		U
	Gonocarpus salsoloides		U
	Gonocarpus tetragynus	Poverty Raspwort	U
	Gonocarpus teucrioides	Germander Raspwort	U
Hydrocharitaceae			
	Ottelia ovalifolia subsp.	Swamp Lily	U
Icacinaceae			
	Citronella moorei		U
Iridaceae			
	Freesia hybrid*	Freesia	U
	Patersonia glabrata	Leafy Purple-flag	U
	Patersonia sericea	Silky Purple-Flag	U
Juncaceae			
	Juncus articulatus*	A Rush	U
	Juncus bufonius*	Toad Rush	U
	Juncus cognatus*		U
	Juncus continuus		U
	Juncus fockei		U
	Juncus kraussii subsp.	Sea Rush	U
	Juncus mollis		U
	Juncus planifolius		U
	Juncus prismatocarpus		U
	Juncus spp.	A Rush	U
	Juncus subsecundus	Finger Rush	U
	Juncus usitatus		U
Juncaginaceae			
	Triglochin procera	Water Ribbons	U
Lamiaceae			
	Chloanthes parviflora		U
	Chloanthes stoechadis		U
	Clerodendrum	Hairy Clerodendrum	U
	Gmelina leichhardtii	White Beech	U
	Plectranthus parviflorus		U
	Stachys arvensis*	Stagger Weed	U
	Westringia fruticosa	Coastal Rosemary	U
Lauraceae			
	Cassytha glabella		U
	Cassytha glabella f.		U
	Cassytha pubescens	Downy Dodder-laurel	U
	Cinnamomum camphora*	Camphor Laurel	U

	Cryptocarya glaucescens	Jackwood	U
	Cryptocarya microneura	Murrogun	U
	Cryptocarya obovata	Pepperberry	U
	Cryptocarya rigida	Forest Maple	U
	Endiandra sieberi	Hard Corkwood	U
	Neolitsea dealbata	Hairy-leaved Bolly Gum	U
Lentibulariaceae			
	Utricularia lateriflora	Small Bladderwort	U
Lobeliaceae			
	Lobelia anceps		U
	Pratia purpurascens	Whiteroot	U
Loganiaceae			
	Logania albiflora		U
	Mitrasacme polymorpha		U
Lomandraceae			
	Lomandra filiformis	Wattle Matt-rush	U
	Lomandra filiformis		U
	Lomandra glauca	Pale Mat-rush	U
	Lomandra longifolia	Spiny-headed Mat-rush	U
	Lomandra multiflora	Many-flowered Mat-rush	U
	Lomandra spicata		U
Loranthaceae			
	Benthamina alyxifolia		U
Luzuriagaceae			
	Eustrephus latifolius	Wombat Berry	U
	Geitonoplesium cymosum	Scrambling Lily	U
Lycopodiaceae			
	Lycopodiella lateralis	Slender Clubmoss	U
Malvaceae			
	Hibiscus heterophyllus	Native Rosella	U
	Modiola caroliniana*	Red-flowered Mallow	U
	Sida rhombifolia*	Paddy's Lucerne	U
Meliaceae			
	Dysoxylum fraserianum	Rosewood	U
	Melia azedarach	White Cedar	U
	Synoum glandulosum	Scentless Rosewood	U
Menispermaceae			
	Sarcopetalum	Pearl Vine	U
	Stephania japonica	Snake vine	U
	Stephania japonica var.	Snake Vine	U
Menyanthaceae			
	Villarsia exaltata	Yellow Marsh Flower	U
Monimiaceae			
	Palmeria scandens	Anchor Vine	U
	Wilkiea huegeliana	Veiny Wilkiea	U
Moraceae			
	Ficus coronata	Creek Sandpaper Fig	U

	Ficus fraseri	Sandpaper Fig	U
	Ficus obliqua	Small-leaved Fig	U
	Ficus rubiginosa	Port Jackson Fig	U
	Maclura cochinchinensis	Cockspur Thorn	U
	Streblus brunonianus	Whalebone Tree	U
	Trophis scandens	Burny Vine	U
Myrsinaceae			
	Aegiceras corniculatum	River Mangrove	U
	Embelia australiana		U
	Myrsine howittiana	Brush Muttonwood	U
	Myrsine variabilis		U
Myrtaceae			
	Acmena smithii	Lilly Pilly	U
	Angophora costata	Sydney Red Gum	U
	Backhousia myrtifolia	Grey Myrtle	U
	Baeckea diosmifolia	Fringed Baeckea	U
	Baeckea imbricata		U
	Callistemon citrinus	Crimson Bottlebrush	U
	Callistemon linearis	Narrow-leaved Bottlebrush	U
	Callistemon pachyphyllus	Wallum Bottlebrush	U
	Callistemon pallidus	Lemon Bottlebrush	U
	Callistemon rigidus	Stiff Bottlebrush	U
	Callistemon salignus	Willow Bottlebrush	U
	Calytrix tetragona	Common Fringe-myrtle	U
	Choricarpia leptopetala	Brush Turpentine	U
	Corymbia maculata	Spotted Gum	U
	Eucalyptus acmenoides	White Mahogany	U
	Eucalyptus canaliculata	Large-fruited Grey Gum	U
	Eucalyptus capitellata	Brown Stringybark	U
	Eucalyptus fergusonii		U
	Eucalyptus globoidea	White Stringybark	U
	Eucalyptus grandis	Flooded Gum	U
	Eucalyptus microcorys	Tallowwood	U
	Eucalyptus paniculata	Grey Ironbark	U
	Eucalyptus pilularis	Blackbutt	U
	Eucalyptus propinqua	Small-fruited Grey Gum	U
	Eucalyptus robusta	Swamp Mahogany	U
	Eucalyptus saligna	Sydney Blue Gum	U
	Eucalyptus signata	Scribbly Gum	U
	Eucalyptus tereticornis	Forest Red Gum	U
	Eucalyptus umbra	Broad-leaved White	U
	Euryomyrtus ramosissima		U
	Leptospermum	Prickly Tea-tree	U
	Leptospermum	Coast Teatree	U
	Leptospermum liversidgei	Olive Tea-tree	U
	Leptospermum	Tantoon	U
	Leptospermum		U

	Leptospermum	Slender Tea-tree	U
	Lophostemon confertus	Brush Box	U
	Melaleuca ericifolia	Swamp Paperbark	U
	Melaleuca linariifolia	Flax-leaved Paperbark	U
	Melaleuca nodosa		U
	Melaleuca quinquenervia	Broad-leaved Paperbark	U
	Melaleuca sieberi		U
	Melaleuca styphelioides	Prickly-leaved Tea Tree	U
	Melaleuca thymifolia	Thyme Honey-myrtle	U
	Ochrosperma lineare		U
	Rhodamnia rubescens	Scrub Turpentine	U
	Syzygium oleosum	Blue Lilly Pilly	U
Nymphaeaceae			
	Nymphaea caerulea	Cape Waterlily	U
Ochnaceae			
	Ochna serrulata*	Mickey Mouse Plant	U
Oleaceae			
	Jasminum volubile		U
	Ligustrum sinense*	Small-leaved Privet	U
	Notelaea longifolia	Large Mock-olive	U
	Notelaea longifolia f.		U
	Notelaea ovata		U
	Olea europaea subsp.	African Olive	U
	Olea paniculata	Native Olive	U
Onagraceae			
	Ludwigia peploides subsp.	Water Primrose	U
Ophioglossaceae			
	Ophioglossum pendulum		U
Orchidaceae			
	Caladenia carnea	Pink Fingers	P13
	Calanthe triplicata	Christmas Orchid	P13
	Calochilus paludosus	Red Beard Orchid	P13
	Cryptostylis erecta	Tartan Tongue Orchid	P13
	Cryptostylis subulata	Large Tongue Orchid	P13
	Dendrobium aemulum	Ironbark Orchid	P13
	Genoplesium littorale	Tuncurry Midge Orchid	E4A
	Plectorrhiza tridentata	Tangle Orchid	P13
	Pterostylis baptistii	King Greenhood	P13
	Pterostylis spp.	Greenhood	P13
Oxalidaceae			
	Oxalis corniculata*	Creeping Oxalis	U
	Oxalis exilis		U
	Oxalis perennans		U
Passifloraceae			
	Passiflora edulis*	Common Passionfruit	U
	Passiflora herbertiana		U
	Passiflora herbertiana	Native Passionfruit	U

	Passiflora subpeltata*	White Passionflower	U
Philydraceae			
	Philydrum lanuginosum	Frogsmouth	U
Phormiaceae			
	Dianella caerulea	Blue Flax-lily	U
	Dianella caerulea var.		U
	Dianella caerulea var.		U
	Dianella congesta		U
	Dianella longifolia	Blueberry Lily	U
	Dianella spp.		U
Phytolaccaceae			
	Phytolacca octandra*	Inkweed	U
Pinaceae			
	Pinus elliottii*	Slash Pine	U
Piperaceae			
	Piper novae-hollandiae	Giant Pepper Vine	U
Pittosporaceae			
	Billardiera scandens	Hairy Apple Berry	U
	Hymenosporum flavum	Native Frangipani	U
	Pittosporum multiflorum	Orange Thorn	U
	Pittosporum revolutum	Rough Fruit Pittosporum	U
	Pittosporum spinescens	Wallaby Apple	U
	Pittosporum undulatum	Sweet Pittosporum	U
Plantaginaceae			
	Plantago lanceolata*	Lamb's Tongues	U
	Plantago major*	Large Plantain	U
Poaceae			
	Andropogon virginicus*	Whisky Grass	U
	Arundo donax*	Giant Reed	U
	Axonopus fissifolius*	Narrow-leafed Carpet Grass	U
	Briza maxima*	Quaking Grass	U
	Briza minor*	Shivery Grass	U
	Bromus catharticus*	Praire Grass	U
	Chloris gayana*	Rhodes Grass	U
	Chloris spp.		U
	Chloris ventricosa	Tall Chloris	U
	Cynodon dactylon	Common Couch	U
	Dichelachne crinita	Longhair Plumegrass	U
	Dichelachne micrantha	Shorthair Plumegrass	U
	Digitaria ciliaris*	Summer Grass	U
	Digitaria didactyla	Queensland Blue Couch	U
	Digitaria parviflora	Small-flowered Finger Grass	U
	Digitaria ramularis	Finger Panic Grass	U
	Digitaria spp.	A Finger Grass	U
	Echinochloa crusgalli*	Barnyard Grass	U
	Echinopogon caespitosus	Bushy Hedgehog-grass	U
	Echinopogon caespitosus	Tufted Hedgehog Grass	U

	Echinopogon ovatus	Forest Hedgehog Grass	U
	Ehrharta erecta*	Panic Veldtgrass	U
	Eleusine indica*	Crowsfoot Grass	U
	Entolasia marginata	Bordered Panic	U
	Entolasia stricta	Wiry Panic	U
	Eragrostis brownii	Brown's Lovegrass	U
	Eragrostis curvula*	African Lovegrass	U
	Eragrostis elongata	Clustered Lovegrass	U
	Eragrostis leptostachya	Paddock Lovegrass	U
	Eragrostis spp.	A Lovegrass	U
	Eragrostis tenuifolia*	Elastic Grass	U
	Eriochloa procera	Spring Grass	U
	Hemarthria uncinata	Matgrass	U
	Hemarthria uncinata var.		U
	Imperata cylindrica	Blady Grass	U
	Lolium rigidum*	Wimmera Ryegrass	U
	Lolium spp.	A Ryegrass	U
	Melinis repens*	Red Natal Grass	U
	Microlaena stipoides	Weeping Grass	U
	Microlaena stipoides var.	Weeping Grass	U
	Oplismenus aemulus		U
	Oplismenus imbecillis		U
	Ottochloa gracillima		U
	Panicum simile	Two-colour Panic	U
	Paspalum dilatatum*	Paspalum	U
	Paspalum distichum	Water Couch	U
	Paspalum spp.		U
	Paspalum urvillei*	Vasey Grass	U
	Paspalum wettsteinii	Broad-leaved Paspalum	U
	Pennisetum	Kikuyu Grass	U
	Phalaris minor*	Lesser Canary Grass	U
	Phragmites australis	Common Reed	U
	Poa annua*	Winter Grass	U
	Poa labillardierei var.	Tussock	U
	Setaria distans		U
	Setaria gracilis*	Slender Pigeon Grass	U
	Setaria pumila*	Pale Pigeon Grass	U
	Setaria sphacelata*	South African Pigeon Grass	U
	Setaria spp.		U
	Spinifex sericeus	Hairy Spinifex	U
	Sporobolus africanus*	Parramatta Grass	U
	Sporobolus creber	Slender Rat's Tail Grass	U
	Sporobolus fertilis*		U
	Sporobolus virginicus var.	Marine Couch	U
	Stenotaphrum	Buffalo Grass	U
	Themeda australis	Kangaroo Grass	U
	Zoysia macrantha	Prickly Couch	U

Podocarpaceae			
	Podocarpus elatus	Plum Pine	U
Polygalaceae			
	Comesperma ericinum	Pyramid Flower	U
Polygonaceae			
	Acetosella vulgaris*	Sheep Sorrel	U
	Persicaria decipiens	Slender Knotweed	U
	Persicaria hydropiper	Water Pepper	U
	Persicaria lapathifolia	Pale Knotweed	U
	Persicaria praetermissa		U
	Persicaria strigosa		U
	Polygonum arenastrum*	Wireweed	U
	Rumex crispus*	Curled Dock	U
Polypodiaceae			
	Platycerium bifurcatum	Elkhorn Fern	P13
Posidoniaceae			
	Posidonia australis	Seagrass	U
Primulaceae			
	Samolus repens	Creeping Brookweed	U
Proteaceae			
	Banksia aemula	Wallum Banksia	U
	Banksia ericifolia	Heath-leaved Banksia	U
	Banksia ericifolia subsp.		U
	Banksia integrifolia	Coast Banksia	U
	Banksia integrifolia subsp.	Coastal Banksia	U
	Banksia oblongifolia	Fern-leaved Banksia	U
	Banksia serrata	Old-man Banksia	U
	Banksia spinulosa var.		P13
	Conospermum taxifolium		U
	Grevillea robusta	Silky Oak	U
	Hakea teretifolia	Needlebush	U
	Hakea teretifolia subsp.		U
	Helicia glabriflora		U
	Isopogon anemonifolius	Broad-leaf Drumsticks	P13
	Persoonia katerae		P13
	Persoonia lanceolata	Lance Leaf Geebung	P13
	Persoonia levis	Broad-leaved Geebung	P13
	Persoonia linearis	Narrow-leaved Geebung	P13
	Persoonia virgata		P13
	Petrophile pulchella	Conesticks	P13
Pteridaceae			
	Pteris tremula	Tender Brake	U
Putranjivaceae			
	Drypetes deplanchei	Yellow Tulipwood	U
Ranunculaceae			
	Clematis aristata	Old Man's Beard	U
	Clematis glycinoides	Headache Vine	U

	Clematis glycinoides var.		U
	Ranunculus inundatus	River Buttercup	U
	Ranunculus lappaceus	Common Buttercup	U
	Ranunculus plebeius		U
	Ranunculus repens*	Creeping Buttercup	U
	Ranunculus spp.		U
Restionaceae			
	Baloskion pallens		U
	Baloskion tetraphyllum		U
	Coleocarya gracilis		U
	Empodisma minus		U
	Eurychorda complanata		U
	Hypolaena fastigiata		U
	Leptocarpus tenax		U
	Lepyrodia scariosa		U
	Sporadanthus caudatus		U
	Sporadanthus interruptus		U
Rhamnaceae			
	Alphitonia excelsa	Red Ash	U
	Pomaderris elliptica		U
	Pomaderris intermedia		U
Ripogonaceae			
	Ripogonum brevifolium	Small-leaved Supplejack	U
	Ripogonum fawcettianum	Small Supplejack	U
Rosaceae			
	Rubus fruticosus sp. agg.*	Blackberry complex	U
	Rubus moluccanus var.	Molucca Bramble	U
	Rubus moluccanus*		U
	Rubus parvifolius	Native Raspberry	U
	Rubus rosifolius	Rose-leaf Bramble	U
	Rubus spp.		U
Rubiaceae			
	Asperula asthenes	Trailing Woodruff	V
	Atractocarpus		U
	Canthium coprosmoides	Coast Canthium	U
	Galium propinquum	Maori Bedstraw	U
	Morinda jasminoides	Sweet Morinda	U
	Pomax umbellata	Pomax	U
	Richardia brasiliensis*	Mexican Clover	U
Rutaceae			
	Acronychia oblongifolia	Common Acronychia	U
	Boronia falcifolia		P13
	Boronia parviflora	Swamp Boronia	P13
	Boronia pinnata		P13
	Correa reflexa	Native Fuschia	U
	Eriostemon australasius		P13
	Melicope micrococca	Hairy-leaved Doughwood	U

	Nematolepis squamea	Satinwood	U
	Phebalium squamulosum	Scaly Phebalium	P13
	Philotheca salsolifolia		P13
	Zieria laxiflora		U
	Zieria smithii	Sandfly Zieria	U
Salviniaceae			
	Salvinia molesta*		U
Santalaceae			
	Exocarpos cupressiformis	Native Cherry/Cherry Ballart	U
	Leptomeria acida	Sour Currant Bush	U
Sapindaceae			
	Alectryon subcinereus	Wild Quince	U
	Arytera divaricata	Coogera	U
	Cupaniopsis	Tuckeroo	U
	Diploglottis cunninghamii		U
	Dodonaea triquetra	Large-leaf Hop-bush	U
	Guioa semiglauca		U
	Mischocarpus pyriformis	Yellow Pear-fruit	U
Sapotaceae			
	Pouteria australis	Black Apple	U
Scrophulariaceae			
	Bacopa monnieri		U
	Lindernia alsinoides	Noah's False Chickweed	E1
	Verbascum virgatum*	Twiggy Mullein, Green	U
	Veronica plebeia	Trailing Speedwell	U
Selaginellaceae			
	Selaginella uliginosa	Swamp Selaginella	U
Smilacaceae			
	Smilax australis	Lawyer Vine, Wait-a-while,	U
	Smilax glyciphylla	Sweet Sarsparilla	U
Solanaceae			
	Cestrum parqui*	Green Cestrum	U
	Datura stramonium*	Common Thornapple	U
	Physalis peruviana*	Cape Gooseberry	U
	Physalis spp.		U
	Solanum aviculare	Kangaroo Apple	U
	Solanum capsicoides*	Devil's Apple	U
	Solanum mauritianum*	Wild Tobacco Bush	U
	Solanum nigrum*	Black-berry Nightshade	U
	Solanum prinophyllum	Forest Nightshade	U
	Solanum	Madeira Winter Cherry	U
	Solanum spp.		U
	Solanum stelligerum	Devil's Needles	U
Stackhousiaceae			
	Stackhousia nuda		U
Stylidiaceae			
	Stylidium graminifolium	Grass Triggerplant	U

Surianaceae			
	Guilfoylia monostylis		U
Thelypteridaceae			
	Christella dentata		U
Thymelaeaceae			
	Pimelea linifolia	Slender Rice Flower	U
	Pimelea linifolia subsp.		U
Typhaceae			
	Typha orientalis	Broad-leaved Cumbungi	U
Ulmaceae			
	Trema tomentosa var.	Native Peach	U
Uvulariaceae			
	Tripladenia cunninghamii		U
Verbenaceae			
	Lantana camara*	Lantana	U
	Verbena bonariensis*	Purpletop	U
	Verbena rigida var.	Veined Verbena	U
	Verbena spp.		U
Violaceae			
	Hybanthus monopetalus	Slender Violet-bush	U
	Viola hederacea	Ivy-leaved Violet	U
Vitaceae			
	Cayratia clematidea	Slender Grape	U
	Cissus antarctica	Water Vine	U
	Cissus hypoglauca	Giant Water Vine	U
	Tetrastigma nitens		U
Xanthorrhoeaceae			
	Xanthorrhoea fulva		P13
	Xanthorrhoea spp.		P13
Xyridaceae			
	Xyris complanata		U
	Xyris juncea	Dwarf Yellow-eye	U
	Xyris operculata		U
Zingiberaceae			
	Alpinia caerulea	Native Ginger	U

Legal status:

E1 - Endangered (Threatened Species Conservation Act, 1995)

E2 - Endangered Population (Threatened Species Conservation Act, 1995)

E4 - Presumed Extinct (Threatened Species Conservation Act, 1995)

E4A - Critically Endangered (Threatened Species Conservation Act, 1995)

V - Vulnerable (Threatened Species Conservation Act, 1995)

FE- Endangered (Fisheries Management Act, 1994)

FEP- Endangered Population (Fisheries Management Act, 1994)

FV - Vulnerable (Fisheries Management Act, 1994)

FX - Presumed Extinct (Fisheries Management Act, 1994)

P - Protected (National Parks and Wildlife Act, 1974)

P13 - Protected Plants (National Parks and Wildlife Act, 1974)

U – Unprotected

Appendix 4a: Biomass of finfish and invertebrates caught commercially in Wallis Lake during the 2008/2009 financial year (Data Source: I&I NSW ComCatch database).

Species	**Weight (kg0**
Sea mullet	102,718
Blue swimmer crab	57,254
Luderick	32,964
Dusky flathead	27,457
Sand whiting	22,722
Yellowfin bream	19,441
School prawn	18,550
Giant mud crab	13,004
Greentail prawn	11,698
Eastern king prawn	10,960
River garfish	5,278
Goldspot mullet	3,461
Sand mullet	2,766
Common silverbiddy	2,359
Tailor	1,889
Catfish	1,373
Trumpeter whiting	1,339
Brown tiger prawn	1,196
River eels	782
Cockles	730
Tarwhine	553
Octopus	526
Leatherjackets	445
Bonito	381
Diamondfish	335
Eastern sea garfish	333
Shovelnose rays	326
Southern calamari	162
Estuary squid	153
Mulloway	135
Cuttlefish	115
Bluespotted flathead	115
Mackerel tuna	83
Flounders	72
Striped grunters	51
Wobbegong sharks	28
Silver trevally	27
Yellowfin tuna	25
Hammerhead sharks	24
Australian sardine	18
School shark	12
Whaler shark	12
Yellowtail kingfish	8
Dart	8
Snapper	5
Yellowtail scad	4
Australian salmon	2
Soles	1
Goatfish	1

Appendix 4b: Commercial fishing catch data averaged over 2004-2009 and number of fishing businesses in the 2008/2009 financial year (Source: I&I NSW ComCatch database).

Estuary	Average weight (kg)	Average # Days Fished	#Licensed Fishing Businesses
Wallis Lake	64.2	114	51
Tweed Cobaki Broadwater Terranora	44.8	113.4	22
Richmond River North Creek R Ck	100.9	64.3	28
Clarence R Iluka Maclean Yamba Wooloweyah	66.2	109.5	101
Lake Wooloweyah	59.7	55.9	56
Macleay River, Spencers Creek, Trial Bay	37.5	93.1	20
Lake Innes, Lake Cathie	36.1	75.4	9
Camden Haven R, Queens Lake, Watson Taylors Lake, Nth Haven, Laurieto	33.2	151.1	21
Manning River, Crowdy Heads	72.5	76.1	16
Smiths Lake	67.7	51.9	12
Port Stephens/ Myall Lakes, Myall River, Tea Gardens	77	97.9	60
Hunter River	69.6	59.2	34
Tuggerah Lakes, Munmorah, Budgewoi	68.8	123.3	45
Hawkesbury River, Broken Bay, Brisbane Water, Pittwater, Patonga	77.1	105	56
Lake Illawarra, Wollongong	93.1	88.9	18
Shoalhaven River, Crookhaven River	78.1	95.7	17
Lake Wollumboola	68.7	19.9	7
Coila Lake	69.8	30.8	7
Corunna Lake	54.8	30.5	9
Wallaga Lake	94.3	53.4	13
Average of all NSW Estuaries	66.7	80.5	30