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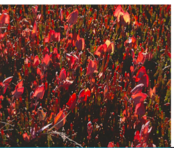

Kooragang

Ramsar Wetland

Ecological Character Description

Citation

Brereton, R., and Taylor-Wood, E., 2010, Ecological Character Description of the Kooragang Component of the Hunter Estuary Wetlands Ramsar Site. Report to the Department of Sustainability, Environment, Water, Population and Communities (SEWPAC), Canberra.

Acknowledgments

The Steering Committee provided information and support to the ECD preparation:

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The ECD development was funded by SEWPAC.

Introductory Notes

This Ecological Character Description (ECD Publication) has been prepared in accordance with the *National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands* (National Framework) (Department of the Environment, Water, Heritage and the Arts, 2008).

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) prohibits actions that are likely to have a significant impact on the ecological character of a Ramsar wetland unless the Commonwealth Environment Minister has approved the taking of the action, or some other provision in the EPBC Act allows the action to be taken. The information in this ECD Publication does not indicate any commitment to a particular course of action, policy position or decision. Further, it does not provide assessment of any particular action within the meaning of the *Environment Protection and Biodiversity Conservation Act 1999* (Cth), nor replace the role of the Minister or his delegate in making an informed decision to approve an action.

The *Water Act 2007* requires that in preparing the [Murray-Darling] Basin Plan, the Murray Darling Basin Authority (MDBA) must take into account Ecological Character Descriptions of declared Ramsar wetlands prepared in accordance with the National Framework.

This ECD Publication is provided without prejudice to any final decision by the Administrative Authority for Ramsar in Australia on change in ecological character in accordance with the requirements of Article 3.2 of the Ramsar Convention.

Disclaimer

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Note: There may be differences in the type of information contained in this ECD publication, to those of other Ramsar wetlands.

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OEH – Water and Mangroves at Kooragang wetlands, NSW

Executive summary

This ecological character description (ECD) is for the Kooragang component of the Hunter Estuary Wetlands Ramsar site which is located in the estuary of the Hunter River at Newcastle on the central coast of New South Wales. The purpose of the ECD is to provide a baseline description of the site at the time of Ramsar listing, such that changes in ecological character can be assessed. The Hunter Estuary Wetlands Ramsar site is comprised of the Kooragang component of the Hunter Wetlands National Park (formerly Kooragang Nature Reserve) which was listed in 1984 and Shortland Wetlands (now called the Hunter Wetlands Centre Australia) which was added to the Ramsar site in 2002. The Hunter Wetlands Centre Australia is a small (42 hectare) complex of wetlands located approximately 2.5 kilometres south west of Kooragang. Kooragang Nature Reserve was included in the Hunter Wetlands National Park which was gazetted in 2006.

The Kooragang component of the Hunter Estuary Wetlands Ramsar site is located approximately seven kilometres north of the Newcastle central business district on the 'North Arm' of the Hunter River and covers an area of 2926 hectares. The Ramsar site is comprised of the bed of Fullerton Cove, the northern part of Kooragang Island (including the Kooragang Dykes) and the eastern section of the Tomago Wetlands (Figure 2-1). The Tomago Wetlands are an area of former wetlands converted to grazing land by drains and levees which lie to the west of Fullerton Cove. The Ramsar site also includes the fringing mangroves and islands within Fullerton Cove and part of the North Arm, as well as Stockton Sandspit and the Kooragang Dykes.

On Kooragang Island, the site is bounded by Ash Island to the west and State owned undeveloped land to the south (Figure 2-1). The undeveloped parts of Kooragang Island which includes Ash Island and the Ramsar site are bounded by a rail line which separates them from the southern industrial area.

Ramsar listing criteria

The entire Hunter Estuary Wetlands Ramsar site (i.e. the Kooragang component and Hunter Wetlands Centre Australia) was re-assessed against the current Ramsar criteria in 2010 which identified that the wetland met Criteria 2, 4 and 6. The Kooragang component of the Hunter Estuary Wetlands contributes to all of these as outlined below:

- **Criterion 2**. One wetland bird species (Australasian bittern; *Botaurus poiciloptilus)*, listed as Endangered under both the EPBC Act and on the IUCN Red List (Version 2009.1), a fish species (Estuary Stingray; *Dasyatis fluviorum*) listed as vulnerable on the IUCN Red List (Version 2009.1) and a frog (green and golden bell frog; *Litoria aurea*) listed as Vulnerable on the EPBC Act have been recorded within the Kooragang component;

- **Criterion 4**. The Kooragang component is an important foraging and roosting site for migratory shorebirds, and supports waterbirds at critical stages in their life cycles, including breeding, migration stop-over, roosting and drought refuge; and
- **Criterion 6**. The Kooragang component regularly supports more than 1% of the East Asian-Australasian Flyway population of eastern curlew (*Numenius madagascariensis*) and more than 1% of the Australian population of red-necked avocets (*Recurvirostra novaehollandiae*).

Wetland types

The Kooragang component of the Hunter Estuary Wetland contains five Ramsar wetland types:

- estuarine waters (F)
- inter-tidal mud, sand or salt flats (G)
- Inter-tidal marshes; includes salt marshes, salt meadows, saltings, raised salt marshes; includes tidal and brackish marshes (H)
- Inter-tidal forested wetlands; includes mangrove swamps, tidal and freshwater swamp forests (I)
- tree-dominated wetlands (Xf)

Critical components and processes

The critical ecosystem components, sub-components and processes that describe the ecological character of the Kooragang component at the time of listing have been determined to be:

- waterbirds, particularly migratory shorebirds
- the green and golden bell frog (*Litoria aurea*), a nationally listed threatened species
- *Sarcocornia* saltmarsh which supports migratory shorebirds
- intertidal mudflats which provide foraging habitat for migratory shorebirds
- hydrology (tidal regime and freshwater inflows) which is a major influence on the distribution and extent of saltmarsh and mangroves

A brief description of the ecosystem components and processes present at the time of listing is provided in Table E1.

Table E1. Components and processes within the Hunter Estuary Wetlands Ramsar site

Component/process	Summary description
Geomorphology	The Hunter Estuary is a “mature barrier estuary” which is characterised by an extensive river system with a high sediment load.
Hydrology	Large catchment (22 000 kilometres^2), with stream inflows of approximately 1800GL/yr. There is no strong pattern of seasonal freshwater flows into the estuary. The majority of inflow and outflows in the estuary are tidal fluxes. The annual tidal inflow and outflow for the Hunter Estuary have been estimated to be 18 250GL.
Water quality	Water quality data at time of listing was limited, however the indications are that: • salinity is variable and typical of an estuary where salinity is affected by freshwater inflow events • estuary waters are well oxygenated and are likely to be maintained by the strong tidal movements in the lower estuary • turbidity levels in the estuary are generally moderate, with short-term increases after rain events • nutrient levels (nitrogen and phosphorus), particularly phosphorus, are relatively high in the estuary • heavy metals are not particularly concentrated in the North Arm and Fullerton Cove • the phytoplankton is typical for an estuary of the mid-east coast of Australia and is dominated by diatoms and dinoflagellates with a total of 20 taxa
Vegetation	The vegetation communities within the site are predominantly wetland types, including mangrove forests, saltmarsh, and brackish swamps. Successional changes were happening in the vegetation within the site at the time of listing, in particular, the expansion of mangroves and decline in saltmarsh.
Birds	The Hunter Estuary Wetlands supports an abundance and diversity of wetland birds including migratory and non-migratory shorebirds. The Hunter Estuary Wetlands supports waterbirds at all stages in their life cycles, including breeding, migration stop-over, roosting and drought refuge which is one of the main reasons why the Hunter Estuary Wetlands meets the criteria for listing as a Wetland of International Importance. At the time of listing in 1984, a total of 112 wetland bird species had been recorded from the Kooragang component of the Hunter Estuary Wetlands. Thirty-seven of these bird species are listed as migratory under the EPBC Act and include 29 species of Palaearctic shorebirds, 17 of which were regularly recorded within the Hunter Estuary Wetlands during the spring and summer months. At the time of listing, a maximum of 6800 migratory waders were recorded within the Hunter Estuary Wetlands, including 900 eastern curlews which was over 2% of the East Asian-Australasian Flyway population for this species. The estuary is also important for threatened waterbird species including the Australasian bittern, which is listed as Endangered under both the EPBC Act and on the IUCN red list. Important bird habitats at the site include: • saltmarsh ponds (important roosting and foraging habitat for shorebirds) • tidal mudflats and sand flats (important foraging habitat for shorebirds) • Stockton Sandspit (important roosting habitat for shorebirds) • Kooragang Dykes (important roosting and foraging habitat for shorebirds)
Frogs	The site supports the threatened green and golden bell frog (*Litoria aurea*) which is listed as Vulnerable under the EPBC Act.

Fish	The majority of fish species (63%) found in the estuary are euryhaline (i.e. they are capable of surviving across a wide range of salinities) and includes species with both freshwater and marine life-stages. The site supports the estuary stingray (*Dasyatis fluviorum*) which is listed s Vulnerable on the IUCN Red List.
Invertebrates	The aquatic invertebrate fauna is representative of an estuarine ecosystem. Invertebrate habitats include: • benthos in and around the mangrove forests • rocky reefs and artificial structures • tidal mudflats • saltmarsh and mangrove vegetation The major groups of aquatic invertebrates include prawns, oysters and benthic invertebrates (crustaceans, isopods, amphipods and copepods, crabs, marine snails and marine worms such as polychaetes). The infauna is an important food resource for shorebirds
Other fauna	Other fauna species have been recorded from the Hunter Estuary Wetlands including: • two species of native terrestrial mammals, the brush-tailed possum and the eastern grey kangaroo • ten species of insectivorous bats • three species of reptiles, the eastern water dragon, red-bellied black snake and the green tree snake

Ecosystem services

The critical ecosystem services provided by the Kooragang component of the Hunter Estuary Wetlands Ramsar site are the supporting services:

- Food webs – The food web on the intertidal mudflats supports migratory shorebirds, one of the critical components of the Ramsar site.
- Biodiversity – The Kooragang component supports a range of species and habitats, particularly migratory shorebirds*;* *Sarcocornia* saltmarsh which supports migratory shorebirds; and the intertidal mudflats which provide foraging habitat for migratory shorebirds.
- Threatened wetland species, habitats and ecosystems – The site supports two nationally and two internationally threatened species, the green and golden bell frog is listed as vulnerable and the Australasian bittern is listed as endangered under the EPBC Act, the Australasian bittern is also listed as endangered and the estuarine stingray vulnerable on the IUCN Red List.

Conceptual model

A conceptual model of the Hunter Estuary Wetlands showing the major interactions and spatial relationships between the critical components and processes has been developed. The main habitat features of the estuarine wetlands are the saltmarsh-mangrove-intertidal mudflat communities which support migratory shorebirds. The vegetation associations within the site are largely determined by the frequency and periodicity of tidal inundation as well as salinity. Saltmarshes are confined to those areas periodically tidally inundated and which are hypersaline. Mangroves fringe the tidal mudflats of Fullerton Cove and are found in areas which are inundated more frequently and have salinities close to full seawater (e.g. margins of Kooragang Island).

Threats

An evaluation of the threats to the Hunter Estuary Wetlands Ramsar site was undertaken to identify the external drivers that generate stress on the wetland and which are likely to lead to ecological effects that will irreversibly change the ecological character of the site. Two main drivers of change were identified, climate and human activities. The available information suggests that human activity is the major driver of change within the Hunter Estuary Wetlands Ramsar site. Major threats that were identified which may lead to significant changes in the ecological character of the Hunter Estuary Wetland Ramsar site are:

- changes in tidal range due to dredging and flood mitigation and drainage works and increased sedimentation (as a result of past catchment clearing) leading to mangrove expansion and resulting in saltmarsh decline; and
- changes in freshwater/saltwater balance due to changes in land drainage and exclusion of tidal waters leading to saltmarsh decline.

As saltmarsh is an important foraging and roosting habitat (diurnal and nocturnal) for migratory shorebirds, the decline in saltmarsh resulting from the changes in tidal range and changes in the freshwater/saltwater balance is likely to be linked to the decline in migratory shorebirds within the Kooragang component. The decline in the distribution and extent of saltmarsh has resulted in a loss of foraging and roosting habitat.

Limits of Acceptable Change

The “limits of acceptable change” (LACs) are broadly defined in the ECD Framework as the upper and lower bounds of variability for a measure of a particular ecosystem component, process or service (DEWHA 2008). If the particular measure exceeds these bounds (moves outside the limits of acceptable change) this may indicate unacceptable change in ecological character. Ramsar Convention (2005) refers to unacceptable change as “human induced change” that is generally negative. It is considered that the LACs for Kooragang would be exceeded if:

- It is not understood what amount of migratory species loss would constitute a change in ecological character and whilst there is some baseline data a LAC was not set. The baseline was 18 species.

- For any five year period the annual maximum summer count of migratory shorebirds is less than 5000 birds in five consecutive years.
- For any five year period the annual maximum summer count of eastern curlew is less than 600 birds in any year.
- There were no more than two years between successful breeding events (defined as the presence of a first year adult cohort) in at least one of the three known populations of the green and golden bell frog.
- The areal extent of saltmarsh falls below 466 hectares.

Current ecological condition and changes in ecological character

Although there have been no significant changes in ecosystem components and processes, such as freshwater inflows and water quality, there have been significant changes in the critical components and processes since the time of listing, namely:

- Between 1984 and 2007 there has been a decline in the maximum number of migratory shorebirds species recorded annually from 18 to 13 species. Noting that in 2006 there were 16 species, 2005 16 species, 2004 17 species and 2003 16 species. Whether this would constitute a change in ecological character for this site is unclear.
- Between 1984 and 2007 there has been an overall declining trend in the number of migratory shorebirds (from 6800 recorded at the time of listing to 3200 in 2007). Since 1999 through to the present the maximum counts of migratory shorebirds have been around 3 500 birds, ranging from a low of 3095 in 2006 and a high of 3451 in 2003, with six out the eight counts recording more than 3330 birds (Herbert 2007a). The LAC for the abundance of migratory shorebirds was set at 5000 and it has been exceeded.
- Between 1999 and 2007, 400 to 600 eastern curlews have been regularly counted in monthly surveys in the Hunter Estuary (Herbert 2007a). The LAC for the numbers of eastern curlew has not been exceeded.
- There has been a 9% increase in the area of mangrove forests and a 41% decrease in the area of saltmarsh within the Hunter Estuary Wetlands since the time of listing in 1984, which has been attributed to a change in tidal range caused by dredging, flood mitigation works (floodgates, levees) and constriction of the river channel in the upper estuary. The current areal extent of saltmarsh within the Hunter Estuary Wetland is around 339 hectares. The LAC for saltmarsh has been exceeded.

- There has also been an increase in the number of red-necked avocet from 100 in the mid 1980s to over 5,000 in 2007 possibly related to long-term drought in the inland causing avocets to move to coastal wetlands where there is permanent water.

Knowledge gaps

The main knowledge gaps with regard to the critical components, processes or services are:

Green and golden bell frog

- Breeding - There is no recent information on green and golden bell frog breeding events within the Ramsar site. Therefore it is not possible to determine if the LAC for the green and golden bell frog, "there are no more than two years between successful breeding events (defined as the presence of a new first year adult cohort) in at least one of the three known populations", has been exceeded or not.

Vegetation

- Vegetation communities - The most recent vegetation mapping that could be correlated back to the time of listing dates from 1993 (Winning 1996). While more recent vegetation mapping has been undertaken, this has been completed at a scale unsuitable for comparison to the baseline established for the Kooragang component. There is an urgent need to update the vegetation mapping to assist with validating the saltmarsh community LAC given the indicative trend (up to 1993) of a decline in the area of saltmarsh. A consistent approach to vegetation mapping (e.g. community descriptions) is required so that comparisons can be made between vegetation maps, including the identification and mapping of the distribution of inter-tidal mudflats.

Hydrology

- Tidal range - Limited information is available on changes in tidal range and the impact on mangrove expansion, saltmarsh decline and changes in the distribution of intertidal mudflats. Monitoring of tidal range changes at a range of locations associated with the Ramsar site would assist in evaluating the need for a direct LAC associated with this critical process.

Geomorphology

- Sedimentation - Sediment deposition rates and relationships with saltmarsh/mangrove vegetation/habitat changes are poorly known. As increased sedimentation has been identified as a major threat in combination with tidal changes, quantification of the rates of sedimentation associated with various sections of the Kooragang component would assist in understanding the rate and trend of this threat.

Aboriginal heritage

- Aboriginal sites and community interests - The site has a high potential to have important Aboriginal heritage values. However, the Kooragang component has not been subject to a systematic survey and not much is known about the small number of sites that have been recorded within the Ramsar site. For this reason, it is considered important to establish a baseline for this service.

Invertebrates

- Soft sediment invertebrates (infauna) - Soft sediment invertebrates are an important supporting component for shorebirds and little is known about their distribution, habitat preferences and response to changes in the estuary (e.g. changes in tidal regime, hydrological changes).

Fish

- Species present – it is important to obtain data regarding which species are breeding in the Kooragang component, in what habitats (e.g. muddy, sandy bottoms, mangroves, saltmarsh) and their associated spawning cues/requirements.

Monitoring

The recommended monitoring to measure changes in the ecological character of the Hunter Estuary Wetlands are:

- Monthly counts of migratory shorebirds during the period when they are present (September to April) to monitor diversity (number of species present) and abundance and to assess if the LAC is exceeded. Counts need to be done at the species level to monitor changes in abundance of particular species as well as total numbers.
- Monthly counts of eastern curlews within the Hunter Estuary including the Kooragang component during the period when they are present (September to April) to monitor changes in the populations and to assess if the LAC is exceeded.
- Quarterly surveys for Australasian bitterns to confirm continued presence and identify important habitats and identify threats.
- Five yearly mapping of vegetation to monitor changes in extent and distribution of saltmarsh, mangroves and intertidal mudflats to assess if shorebird habitat continues to decline.

- Biannual monitoring of the rates of sediment accretion and subsidence to help understand the process of wetland vegetation successional change and to obtain an indication of the direction of change.
- Daily monitoring of tidal height and range to assess the direction of vegetation successional change–increasing tidal range is likely lead to increasing mangrove establishment and decline in saltmarsh.
- There is evidence that the brackish ponds are a refuge for green and golden bell frogs because the slightly saline conditions are inhibiting the establishment of the chytrid fungus. Regular monitoring (yearly during breeding season) of the abundance and distribution of green and golden bell frog within the brackish wetlands would establish whether the brackish wetlands continue to be a refuge from the chytrid fungus.
- Undertake fish surveys twice a year during the breeding season to establish the continued presence of the estuarine stingray and identify important habitats/areas.

Communication and education messages

Priority communication and education messages for the Kooragang component of the Hunter Estuary Wetlands Ramsar site include:

- its importance as a site for migratory shorebirds and for local shorebirds and waterbirds
- the importance of maintaining saltmarsh habitat within the Ramsar site as foraging and roosting habitat for shorebirds
- the relationship between mangrove expansion and saltmarsh decline including the likely causes and how efforts are being made to rehabilitate saltmarsh habitat
- the efforts that have gone into maintaining Stockton Sandspit as an important high tide roost site for shorebirds
- the sensitivity of foraging and roosting shorebirds to disturbance from people on shore and in boats.

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Abbreviations

CAP	The Hunter-Central Rivers Catchment Action Plan (2007)
OEH	New South Wales Office of Environment and Heritage
SEWPAC	Australian Government Department of Sustainability, Environment, Water, Population and Communities
I & I NSW	New South Wales Department of Industry and Investment
DPI	New South Wales Department of Primary Industries (now part of I & I NSW)
ECD	Ecological Character Description
EP&A Act	New South Wales *Environmental Planning and Assessment Act 1979*
EPA	New South Wales Environment Protection Authority (now part of OEH)
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
FM Act	New South Wales *Fisheries Management Act 1994*
HBOC	Hunter Bird Observers Club
HCRCMA	Hunter-Central Rivers Catchment Management Authority
KWRP	Kooragang Wetland Rehabilitation Project
LEP	New South Wales Local Environmental Plan
MHL	Manly Hydraulics Lab
NPWS	New South Wales National Parks and Wildlife Service
NSW	New South Wales
NTU	Nephelometric Turbidity Units
NV Act	New South Wales *Native Vegetation Act 2003*

NW Act	New South Wales *Noxious Weed Act 1993*
PEP	New South Wales Protection of the Environment Policy
PVP	Property Vegetation Plan
RIS	Ramsar Information Sheet
SPCC	State Pollution Control Commission (became NSW EPA, now part of DECCW)
TSC Act	New South Wales *Threatened Species Conservation Act 1995*
WM Act	New South Wales *Water Management Act 2000*

Glossary

Change in ecological character	The human induced adverse alteration of any ecosystem component, process, and/or ecosystem benefits/service (Ramsar Convention 2005, Resolution IX.1, Annex A).
Community	A distinct assemblage of organisms (plants or animals) occupying a common environment.
Community composition	The types of taxa present in a community.
Conceptual model	A model that shows the important components and processes of a wetland ecosystem and their relationships.
Ecological character	Describes the combination of ecosystem components, processes, and benefits/services that epitomise the wetland at the time of listing.
Limits of acceptable change	The variation that is considered acceptable in a particular component or process of the ecological character of a wetland. Changes in the component or process outside these limits may lead to a reduction or loss of the criteria which support the Ramsar listing of the site.
List of Wetlands of International Importance ("the Ramsar list")	The list of wetlands which have been designated as internationally important, according to one or more of the Ramsar listing criteria.
Shorebird	A subset of the waterbirds Refers to wading birds that frequent mostly seashores and estuaries including plovers, sandpipers, stilts, avocets and oystercatchers.
Monitoring	The collection of data in response to a hypothesis postulated from assessment activities.
Ramsar convention	"Convention on Wetlands of International Importance especially as Waterfowl Habitat. Ramsar (Iran), 2 February 1971. UN Treaty Series No. 14583. As amended by the Paris Protocol, 3 December 1982, and Regina Amendments, 28 May 1987" (www.ramsar.org/)
Ramsar criteria	Criteria for identifying Wetlands of International Importance used to identify wetlands that qualify for Ramsar listing.
Ramsar Information Sheet (RIS)	The form which provides essential data on all designated Wetlands of International Importance including geological location, site area, site ownership criteria for inclusion of the Ramsar list, wetland types present, and a brief description of the ecosystem components, processes and services/benefits, and conservation measures.
Ramsar list	The List of Wetlands of international Importance (www.ramsar.org/).
Ramsar sites	Wetlands that are on the "Ramsar list" because they meet one or more of the "Ramsar criteria".
Waterbird	Birds that are dependant on wetlands. Refers to the twenty families accepted under the "Ramsar convention" and includes grebes, cormorants, pelicans, herons, egrets, bitterns, storks, ibises, spoonbills, swans, geese and ducks, rails, coots, oystercatchers, stilts, avocets, plovers, sandpipers, gulls and terns (www.environment.gov.au/biodiversity/migratory/publications/).
Wetland types	Wetlands as defined by the Ramsar Convention wetland classification system (www.ramsar.org/).
Wetlands	Areas of marsh, fen, peatland or water, either natural or artificial, with a permanent or temporary cover of water that is static or flowing, fresh, brackish or salt, including areas of marine waters where the water depth does not exceed six metres at low tide (www.ramsar.org/).

1. Introduction

1.1 Site details

Site parameter	Detail
Name	The Hunter Estuary Wetlands. The site includes what were the Kooragang Nature Reserve, and the Shortland Wetlands. The Kooragang Nature Reserve is now part of the Hunter Wetlands National Park and the Shortland Wetlands is now known as the Hunter Wetlands Centre Australia. For continuity purposes, where this document needs to refer to the Hunter Wetlands Centre Australia component of the Ramsar site it will do so using its former name of Shortland Wetlands.
Location	Latitude 32 degrees 51 minutes South, Longitude 151 degrees 46 minutes East
General location	The Kooragang component of the Hunter Estuary Wetlands Ramsar site is located in the estuary of the Hunter River which is approximately 8 kilometres north of Newcastle on the New South Wales coast north of Sydney.
Area	Kooragang component of the Hunter Estuary Wetlands Ramsar Site - 2926.3[1] hectares.
Altitude (ASL)	0 to 10 metre
Date of Ramsar site designation	1984
Ramsar criteria met	2, 4, 6
Management authority	NSW OEH is responsible for the management of what was the Kooragang Nature Reserve and is now the Hunter Wetlands National Park. The relevant contact is: The Manager, Central Coast Hunter Range Region NSW Parks and Wildlife Service PO Box 1477 Gosford NSW 2250 Phone: 02 4320 4200
Date ECD applies	1984
Status of description	This is the first Ecological Character Description (ECD) for the Kooragang component of the Hunter Estuary Wetlands Ramsar Site
Date of compilation	June 2010
Compiled by	Hydro Tasmania Consulting
RIS reference	Ramsar Information Sheet: Hunter Estuary Wetlands 2002 (http://www.environment.gov.au/water/topics/wetlands/database/pubs/24-ris.pdf0l)
Management plan reference	NSW National Parks and Wildlife Service. (1998). *Kooragang Nature Reserve and Hexham Swamp Nature Reserve Plan of Management*. NSW National Parks and Wildlife Service. Hurstville, NSW. http://www.environment.nsw.gov.au/resources/parks/pomfinalhexhamkooragang.pdf

[1] The area is from a recent land survey of the Hunter Wetlands National Park. The Hunter Wetlands Centre Australia was also surveyed at this time and the area of this component of the Hunter Estuary Wetlands Ramsar Site is 42 hectares (McDiarmid, 2009).

1.2 Purpose of the ecological character description

The purpose of the ecological character description (ECD) of the Kooragang component of the Hunter Estuary Wetlands Ramsar site is to provide a baseline description of the wetland at the time of listing in 1984. The Ramsar Convention (2005) has defined "ecological character" as "the combination of the ecosystem components, processes and benefits/services that characterise the wetlands at a given point in time". This ECD forms the baseline used to assess changes in the ecological character of the Ramsar wetland. The Convention has defined a "change in ecological character" as "the human induced adverse alteration of any ecosystem component, process and/or ecosystem benefit/service" (Ramsar Convention 2005). The ECD can also be used as a reference for:

- development and implementation of a management plan designed to maintain the ecological character of the site;
- design of a monitoring program to detect changes in ecological character;
- assessment of the likely impact on ecological character of proposed actions, as required under the EPBC Act, including environmental impact assessments; and
- reporting to the Australian Government and the Ramsar Convention about any changes in the ecological character of Ramsar sites (DEWHA 2008).

The ECD also provides a basis for updating the Ramsar Information Sheet (RIS). The RIS provides information and data about the Ramsar site and is a major component of the documentation provided when proposing a site for Ramsar listing. A RIS must be prepared for each Ramsar site at the time of listing and updated every six years if necessary (Ramsar Convention 1996, Resolution VI.1 paragraph 2.3). The ecological character description (ECD) for the Kooragang Component of the Hunter Estuary Wetlands Ramsar Site along with the ECD for Shortland Wetlands (Taylor-Wood and Jaensch 2005) will provide detailed information to update the RIS for the entire site.

McGrath (2006) outlined the aims of an ECD for Ramsar wetlands as follows:

1. 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* (Australian Government):

   (a) to describe and maintain the ecological character of declared Ramsar wetlands in Australia; and

   (b) to formulate and implement planning that promotes:

      (i) conservation of the wetland; and

(ii) 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.

2. To 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 the result of technological developments, pollution or other human interference."

3. To supplement the description of the ecological character contained in the Ramsar Information Sheet submitted under the Ramsar Convention for each listed wetland and, collectively, form an official record of the ecological character of the site.

4. To assist the administration of the EPBC Act, particularly:

   (a) 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 and 17B of the EPBC Act; or

   (b) To assess the impacts that actions referred to the Minister under Part 7 of the EPBC Act have had, will have or are likely to have on a declared Ramsar wetland.

5. To 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.

6. To inform members of the public who are interested generally in declared Ramsar wetlands to understand and value the wetlands.

1.3 Treaties, legislation and regulations

The following section outlines the treaties, legislation and regulations that are relevant to the Kooragang component of the Hunter Estuary Wetland Ramsar site. For further information regarding international, national or state legislation or policies, refer to http://www.austlii.edu.au/.

1.3.1 International

- *The Convention on Wetlands of International Importance* – an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. Negotiated through the 1960s by countries and non-governmental organisations that were concerned by the increasing loss and degradation of wetland habitat for migratory waterbirds, the treaty was adopted in the Iranian city of Ramsar in 1971 and came into force in 1975. It is the only global environmental treaty that deals with a particular ecosystem, and the Convention's member countries cover all geographic regions of the planet (Ramsar Convention, 2009)

- *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) (1974)*
- *The 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) (1986).*

The JAMBA and CAMBA are bilateral agreements relating to the conservation of migratory birds and were formed with the Government of Japan in 1974 and the People's Republic of China in 1986. They list terrestrial, water and shorebird species which migrate between Australia and the respective countries. In both cases the majority of listed species are shorebirds. Both agreements require the parties to protect migratory birds by:

  - limiting the circumstances under which migratory birds are taken or traded;
  - protecting and conserving important habitats;
  - exchanging information; and
  - building cooperative relationships.

The JAMBA agreement also includes provisions for cooperation on the conservation of threatened birds. Australian Government and non-government representatives meet every two years with Japanese and Chinese counterparts to review progress in implementing the agreements and to explore new initiatives to conserve migratory birds (DEWHA 2009).

- *The Agreement between the Government of Australia and the Republic of Korea for the Protection of Migratory Birds and their Environment (ROKAMBA) (2006)* – a bilateral migratory bird agreement similar to the JAMBA and CAMBA. In April 2002, Australia and the Republic of Korea agreed to develop ROKAMBA and the agreement was signed in Canberra on 6 December 2006. It came into force on 13 July 2007. The ROKAMBA formalises Australia's relationship with the Republic of Korea with regard to migratory bird conservation and provides a basis for collaboration on the protection of migratory shorebirds and their habitat (DEWHA 2009).
- *Convention on the Conservation of Migratory species of Wild Animals (Bonn Convention)* - The Bonn Convention adopts a framework in which countries with jurisdiction over any part of the range of a particular species co-operate to prevent migratory species becoming endangered. For Australian purposes, many of the species are migratory birds.

1.3.2 National

1.3.2.1 Legislation

- The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) – is the Australian Government's central piece of environmental legislation. It provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places - defined in the EPBC Act as matters of national environmental significance. The EPBC Act provides for protection and promotes cooperative management of Australia's Ramsar wetlands. Ramsar wetlands are recognised as a matter of national environmental significance under the EPBC Act. In Australia a 'declared Ramsar wetland' is a wetland, or part of a wetland, designated by the Commonwealth under Article 2 of the Ramsar Convention for inclusion in the List of Wetlands of International Importance kept under that Article (Section 17(1) EPBC Act). The EPBC Act also establishes criteria for declaring threatened wetlands of international importance and subordinate legislation (EPBC Regulations 2000) promotes best practice management of Ramsar wetlands through nationally consistent management principles.

1.3.2.2 Guidelines and policies

- The *National Framework and Guidance for Describing the Ecological Character of Australian Ramsar Wetlands. Module 2 of the National Guidelines for Ramsar Wetlands* (DEWHA 2008) – provides background information on ecological character, guidance on interpreting terms, the essential elements of an ecological character description, and a step-by-step guide to developing a description of ecological character for wetlands.
- The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000* – provides a framework for water resource management, and states specific water quality guidelines for each environmental value and the context within which they should be applied.
- *EPBC Act Policy Statement 1.1: Significant Impact Guidelines 2006* – provides guidance on determining whether an action is likely to have a significant impact on a matter of national environmental significance protected by the EPBC Act.

1.3.3 State

1.3.3.1 Legislation

The following New South Wales (NSW) Acts and their associated regulations apply to the Hunter Estuary Wetlands Ramsar site and may have to be considered when implementing management actions at the site (based on Act summaries from OEH - www.environment.nsw.gov.au - and NSW Legislation web sites - www.legislation.nsw.gov.au).

- The A*boriginal Land Rights Act 1983* – provides land rights for Aboriginal people and representative Aboriginal Land Councils in NSW. It allows for the vesting of land in those Councils; provides for the acquisition of land; the management of land and other assets and investments by, or for, those Councils; and the allocation of funds to, and by, those Councils. In addition, the Act provides for the provision of community benefit schemes by, or on behalf of, those Councils.
- The *Environmental Planning and Assessment Act 1979* (EP&A Act) – is the principal legislative tool governing land use in NSW. One object of the EP&A Act is to encourage the protection of the environment, including the protection and conservation of native animals and plants, including threatened species, populations and ecological communities and their habitats, as listed under the *Threatened Species Conservation Act 1995* (TSC Act) or the *Fisheries Management Act 1994* (FM Act). A second objective is to encourage the principles of ecologically sustainable development. Whilst not directly related to the Kooragang site, consideration of environmental values associated with the Kooragang component and potential impacts would be required for any developments proposed on adjacent land or for development which may affect the Kooragang component (e.g. dredging of the channel). In addition, any upgrade of existing infrastructure or development of new (e.g. tracks, shelters) by OEH within the national park would require approval prior to commencement of any works.
- The *Fisheries Management Act 1994 –* provides for the protection of all threatened fish and marine vegetation native to NSW waters. The objectives of this Act are to: conserve fish stocks and key fish habitats; conserve threatened species, populations and ecological communities of fish and marine vegetation; promote ecologically sustainable development, including the conservation of biological diversity; promote viable commercial fishing and aquaculture industries; promote quality recreational fishing opportunities; appropriately share fisheries resources between the users of those resources; and provide social and economic benefits for he wider community of NSW.
- The *Local Government Act 1993 –* is the legal framework for local government in NSW. The purposes of this Act are to regulate the relationships between the people and bodies comprising the system of local government in NSW; to encourage and assist the effective participation of local communities in the affairs of local government; to give councils the ability to manage the resources within their local government area; and to require councils, councillors and council employees to

have regard to the principles of ecologically sustainable development in carrying out their responsibilities.

- The *National Park Estate (Lower Hunter Region Reservations) Act 2006* – This Act revoked the reservation under the *National Parks and Wildlife Act 1974* as, or as part of, Hexham Swamp Nature Reserve or Kooragang Nature Reserve and reserved them under the Act as, or as part of, Hunter Wetlands National Park. The act also included approximately one hectare of crown land as part of the Hunter Wetlands National Park. The Act also made amendments to the *National Parks and Wildlife Act 1974* and the *Hunter Water Act 1991* in relation to special areas that are within national park estate, including provision for the joint preparation and implementation of plans of management. Tomago Sandbeds Catchment Area (which borders Fullerton Cove) is a Hunter Water Corporation special area as defined under the *Hunter Water (Special Areas) Regulation 2003*. The Act provides that the Hunter Water Corporation is the owner of all works on land within a special area that is also within the national parks estate. This includes the need to operate, repair, replace, maintain, remove, extend, expand, connect, disconnect, improve or do any other things that Hunter Water considers necessary or appropriate to any of its works or to construct new works and, for these purposes, to carry out any work on, below or above the surface of the land.
- The *National Parks and Wildlife Act 1974* – places the Director-General of the NPWS responsible for the care, control and management of all national parks, historic sites, nature reserves, reserves, Aboriginal areas and state game reserves. State conservation areas, karst conservation reserves and regional parks are also administered under the Act. In addition, the Director-General is responsible under this legislation for the protection and care of native fauna and flora, and Aboriginal places and objects throughout NSW.
- The *Noxious Weed Act 1993* (NW Act) – provides for identification, classification and control of weed species that have been declared 'noxious' in NSW. The NW Act aims to reduce the negative impact of weeds on the economy, community and environment of NSW by establishing control mechanisms to prevent the establishment of significant new weeds, and restricting the spread of and reducing the area of existing significant weeds. The declared noxious weeds bitou bush (*Chrysanthemoides monilifera*), lantana (*Lantana camara*), and pampas grass (*Cortaderia selloana*) occur in the Hunter Estuary Wetlands Ramsar site. The NW Act also provides for the monitoring of and reporting on the effectiveness weed management measures.
- The *Protection of the Environment Operations Act 1997* – Activities listed in Schedule 1 to the Act (broadly, activities with potentially significant environmental impacts) require a licence. Licences can also be issued to regulate water pollution from activities that are not in Schedule 1. Such licences can provide protection against prosecution for water pollution if the licence conditions are

complied with. The EPA issues all licences and licences can control the air, noise, water and waste impacts of an activity. Licences are on-going but subject to review at least once every five years and can be varied, suspended or revoked. A number of industries on Kooragang Island currently have licences for the storage and management of hazardous or other waste. While these licences do not allow discharge into water, the licences provide conditions to reduce the risk of spills into waters. If spills were to occur, there is the potential for the ecological character of Kooragang to be affected. The Act also provides for the issuing of three types of environment protection notices: clean-up, prevention and prohibition notices.

- The *Rural Fires Act 1997* – establishes the NSW Rural Fire Service (RFS). In addition to its other purposes, it defines the NSW RFS functions to make provision for the prevention, mitigation and suppression of rural fires; it repeals the Bush Fires Act 1949; and amends certain other Acts.
- The *Threatened Species Conservation Act 1995* – protects all threatened plants and animals native to NSW (with the exception of fish and marine plants). It provides for the identification, conservation and recovery of threatened species and their populations and communities. It also aims to reduce the threats faced by those species.
- The *Water Management Act 2000* – Provides for the integrated and sustainable management of the State's waters, including those provisions previously included in the *Rivers and Foreshores Improvement Act 1948* (RFI Act). The *Water Management Amendment (Controlled Activities) Regulation 2008* commenced on 4 February 2008 and repealed Part 3A of the RFI Act which related to permits to undertake works near water. These permits are now covered under the Controlled Activity Provisions of the *Water Management Act 2000*. This provisions ensure that a Controlled Activity Approval (CAA) is not granted unless the Minister is satisfied that adequate arrangements are in force to ensure minimal harm will be done to any waterfront land (i.e. land within 40 metres from top of bank) as a consequence of the carrying out of the proposed controlled activity.

1.3.3.2 Guidelines and policies

- Guidelines for Threatened Species Assessment under Part 3A [DEC/DPI 2005] – Threatened species impact assessment is an integral part of environmental impact assessment. The objective of s. 5A of the NSW EP&A Act, the assessment of significance, is to improve the standard of consideration afforded to threatened species, populations and ecological communities, and their habitats through the planning and assessment process, and to ensure that the consideration is transparent.

- ‘Policies and Guidelines for Aquatic Habitat Management and Fish Conservation’ – apply to all planning and development proposals and various activities that affect freshwater, estuarine and marine ecosystems. They assist developers, consultants, planners, local councils and other government agencies in assessing proposals and documents such as Licences, Development Applications, and Environmental Impact Statements, in order to ensure that they are sensitive to and mitigate impacts on the aquatic environment.
- The NSW *Wetlands Management Policy 2010 –* is the policy of the NSW Government to promote the conservation, sustainable management and wise use of NSW wetlands by all stakeholders for the benefit of present and future generations. Adoption of the NSW Wetlands Policy means that the Government, in its decision-making, will give explicit consideration to the biophysical requirements of wetlands with the goal of ensuring their sustainable management.
- *State Environmental Planning Policy No. 14 Coastal Wetlands –* resides under the *Environmental Planning and Assessment Act 1979.* The aim of this policy is to ensure that the coastal wetlands are preserved and protected in the environmental and economic interests of the State. It is noted that this policy does not apply to land dedicated or reserved under the NSW *National Parks and Wildlife Act 1974* as an Aboriginal area, historic site, national park, nature reserve, state game reserve or state recreation area.
- *State Environmental Planning Policy 71 Coastal Protection* – also resides under the NSW *Environmental Planning and Assessment Act 1979*. This Policy aims to ensure that the natural, cultural, recreational and economic interests of the State are protected and managed. This Policy applies to land the whole or any part of which is within the coastal zone. The coastal zone generally includes land, one kilometre inland from the coast, one kilometre landward around any bay, estuary, coastal lake or lagoon; and one kilometre along either bank of a coastal river. Restoring the Balance: Guidelines for managing floodgates and drainage systems on coastal floodplains (2003) – presents strategies to reduce the adverse impacts of coastal floodplain drainage systems on fisheries and estuarine water quality. At the same time they are designed to help land managers maintain agricultural production and prevent further degradation.
- The *Hunter - Central Rivers Catchment Action Plan 2007* (CAP) – describes the most important natural resource issues in the Hunter – Central Rivers Region and guides how natural resource management and investment should occur. It has been prepared by the Hunter-Central Rivers Catchment Management Authority (HCRCMA) to direct where effort and funding should be focussed to get the best protection and improvement for natural resources as well as providing benefits for the community. The CAP provides a coordinated plan for all natural resource work in the region and promotes partnerships and collaborations with government, industry, community

groups and individuals. The HCRCMA also has regulatory role in the application of the NSW *Native Vegetation Act 2003* and a statutory function under the NSW *Water Management Act 2000*. The CAP provides the guiding principles for the application of the *NSW Native Vegetation Act 2003* and the preparation of Property Vegetation Plans (PVPs).

1.3.4 Local government

Any proposed use or development within the Hunter Estuary Wetlands Ramsar site may require assessment and approval under the Newcastle City Council Local Environmental Plan (LEP) and/or the Port Stephens Council LEP because the site falls within both local government areas (Figure 2-1).

The Local Environmental Plans are instruments established under the NSW *Environmental Planning and Assessment Act 1979* which guide planning decisions in local government areas and establish the requirements for the use and development of land. The LEPs also refer to the Hunter Regional Plan which covers planning issues such as environmental conservation, housing and settlement, and infrastructure development. Development Control Plans, prepared in accordance with the NSW *Environmental Planning and Assessment Act 1979*, may also apply to the proposed use or development.

The Port Stephens Council area includes the Tomago Wetlands and the fringing mangroves on the western side of Fullerton Cove; it also adjoins the northern and eastern edge of Fullerton Cove (Figure 2-1). The adjacent land within Port Stephens Council is zoned as "Rural agriculture" where the planning objective is "to maintain the rural character of the area and to promote the efficient and sustainable utilisation of rural land and resources" (Reg 11 of the *Port Stephens Local Environmental Plan 2000).* There is also a narrow strip of land zoned as "Environmental protection" along the eastern shore of Fullerton Cove.

The land adjacent to the Hunter Estuary Wetland Ramsar site that is within the City of Newcastle is zoned as "Port and industry" (the "Industrial area" in Figure 2-1), "Environmental protection" (the "State Owned Land" and "Ash Island" in Figure 2-1). There is also a strip of land adjacent to the western end of the Ramsar site on Kooragang Island which is zoned as a "Special Uses Zone." This area encompasses the transmission line, water and gas pipeline easements that cross Kooragang Island.

2. Site description

2.1 Site location

The Hunter Estuary Wetlands Ramsar site is located in the estuary of the Hunter River at Newcastle on the central coast of New South Wales, Australia. Newcastle is an industrial centre known for coal mining and metal manufacturing, situated 150 kilometres north of Sydney. The Hunter River is a major coastal river that discharges to the ocean at Newcastle. It has several important tributaries, including the Goulburn River, Williams River, Paterson River, Glennies Creek and Pages Creek. The Hunter Estuary Wetlands Ramsar site is comprised of the Kooragang component of the Hunter Wetlands National Park and Shortland Wetlands (now called the Hunter Wetlands Centre Australia).

Kooragang Nature Reserve which covers an area of 2926 hectares was included in the Hunter Wetlands National Park in 2006. Shortland Wetlands is a small (42 hectare) complex of wetlands located approximately 2.5 kilometres south west of the Kooragang component of the Hunter Wetlands National Park (Figure 2-1). The Kooragang component of the Ramsar site is located approximately seven kilometres north of the Newcastle central business district on the ‘North Arm’ of the Hunter River. The Kooragang component is comprised of the bed of Fullerton Cove, and the North Arm of the Hunter River between Stockton Bridge and the Tomago Wetlands, the northern part of Kooragang Island and the eastern section of the Tomago Wetlands (Figure 2-1). The Tomago Wetlands are an area of former farmlands on drained land which lie to the west of Fullerton Cove. The Ramsar site also includes the fringing mangroves and islands within Fullerton Cove and part of the North Arm, as well as Stockton Sandspit and the Kooragang Dykes (Figure 2-1). The Stockton Bridge, which links the island to the city, forms the southern extent of the Hunter River within the Ramsar site (Figure 2-1).

In 2011, an additional 626 hectares of land adjacent to the Ramsar site, on Ash Island (which is part of Kooragang Island) was gazetted as part of the Hunter Wetlands National Park (Figure 2-1). The Hunter Wetlands National Park on Kooragang Island, is bounded by a rail line which separates the southern industrial area from the northern parts of Kooragang Island.

2.2 Site history

Kooragang Island was originally composed of a group of up to ten individual islands some of which were separated by narrow intertidal river channels of varying size (Williams et al. 2000). The original vegetation of the larger islands (Ash Island, Moscheto Island, and Dempsey Island) and area surrounding Fullerton Cove was floodplain woodland and littoral rainforest (Dames and Moore 1978) which was cleared for farming in the mid to late 1800s (Williams et al. 2000).

Reclamation works began within the Hunter Estuary in the late 1850s and continued up until the 1930s which resulted in the merging of a number of the islands. Reclamation works ceased for a time and it was not until after World War II that there was a proposal to make Kooragang Islands an industrial area (Coffey 1973). The passage of the *Newcastle Harbour Improvements Act 1953* resulted in the NSW Public Works being given ownership of the Kooragang islands and the responsibility to construct a "single land mass" and coordinate all industrial development and servicing. Land reclamation continued through the 1960s and 1970s. By 1968, the original islands had been amalgamated into one land mass predominantly through reclamation for industrial land and were gazetted as one, 'Kooragang Island' (Williams et al. 2000). Note that the name "Ash Island" has been retained for the area where it originally occurred. By 1971 over 704 hectares of wetlands had been either partly or fully reclaimed (NSW National Parks and Wildlife Service 1998).

In 1972, the Minister for Works announced that 600 hectares (19%) of Kooragang Island was to be left in its natural state (Coffey 1973). The northern part of Kooragang Island was gazetted as a Nature Reserve in 1983, covering a total area of 2926 hectares (NSW National Parks and Wildlife Service 1998).

There has also been a history of construction of drains and levees within and adjacent to the Hunter Estuary including the construction of a levee bank around Fullerton Cove and the installation of large drains between 1913 and 1928. The Williamtown - Long Bight - Tomago drainage scheme which was approved in 1968 resulted in the enlargement of the ring drain (which was constructed in 1976) and heightening of the levee bank around Fullerton Cove (Williams et al. 2000).

2.3 Site overview

The Kooragang component of the Hunter Estuary Wetlands is the much larger component of the Ramsar site; it covers 2926 hectares compared to the 42 hectare complex of freshwater wetlands that form Shortland Wetlands. The two wetland areas are connected by Ironbark Creek, the south arm of the Hunter River and Ash Island.

The Kooragang component lies in the estuary of the Hunter River and has a range of typical estuarine wetland types including open estuarine waters, intertidal sand and mudflats, intertidal saltmarshes and mangrove forests. It also supports a small remnant of Melaleuca swamp forest and blackbutt dry forest. The Kooragang component provides important feeding and roosting sites for a large number of migratory shorebirds which are present between September and April. It also provides foraging and roosting habitat for a range of non-migratory shorebirds and waterbirds all year round.

The main landscape features of the Kooragang component are Kooragang Island, and Fullerton Cove which is a large shallow embayment with a depth of less than 2 metres. Kooragang Island, and the areas fringing Fullerton Cove are predominantly covered by mangrove forests dominated by grey mangroves (*Avicennia marina*), although river mangrove (*Aegiceras corniculatum*) is also present.

There are also saltmarshes located on Kooragang Island and in the north of Fullerton Cove which are either dominated by salt couch (*Sporobolus virginicus*), glasswort (*Sarcocornia quinqueflora*) or seablite (*Suaeda australis*) (Kingsford and Ferster Levy 1997). Elevation across the Ramsar site is low ranging from sea level to approximately 10 metres above sea level.

In contrast, Shortland Wetlands is a small complex of mostly freshwater wetlands including man-made ponds, freshwater marshes and swamp forest surrounded by urban development along three boundaries. This urban wetland which was degraded has been rehabilitated through a program of wetland restoration which began in 1985[2]. The site provides habitat for a range of wetland species, including breeding, feeding and roosting habitat and drought refuge for waterbirds. A separate ECD has been prepared for Shortland Wetlands with a benchmark set at the time of listing in 2002 (Taylor-Wood and Jaensch 2005).

[2] Hunter Wetlands Australia – www.wetlands.org.au, accessed 24/2/2010.

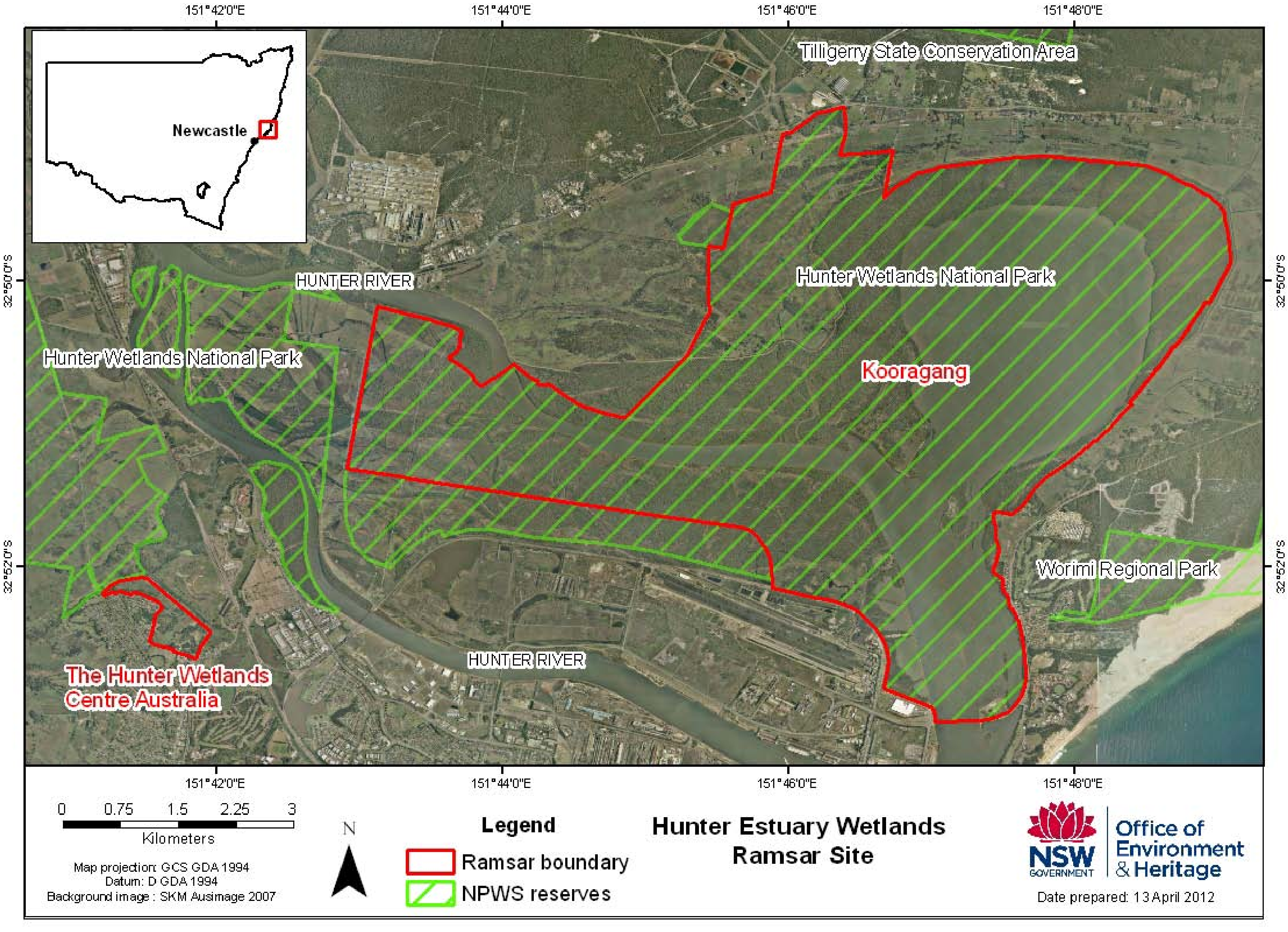


Figure 2-1: Map showing the boundaries of the Kooragang component and Shortland Wetlands in the Hunter Estuary Wetlands Ramsar site

2.4 Climate

The climate of the area is maritime with average diurnal temperatures ranging from a minimum of 8.4°C to a maximum of 25.5°C over the year (Figure 2-2). The highest temperature on record is 42°C on 23 December 1990, and the lowest temperature of 1.8°C was recorded on 27th July 1986. There is moderate variation in annual rainfall with the higher rainfall months being March through to June (approximately 120 millimetres per month) and the driest months being August to October (approximately 75 millimetres per month, Figure 2-2). Mean annual rainfall is 1139 millimetres. The wettest year on record was 1890 when 1919 millimetres of rain fell and the driest year on record was 1980 with 570 millimetres[3].

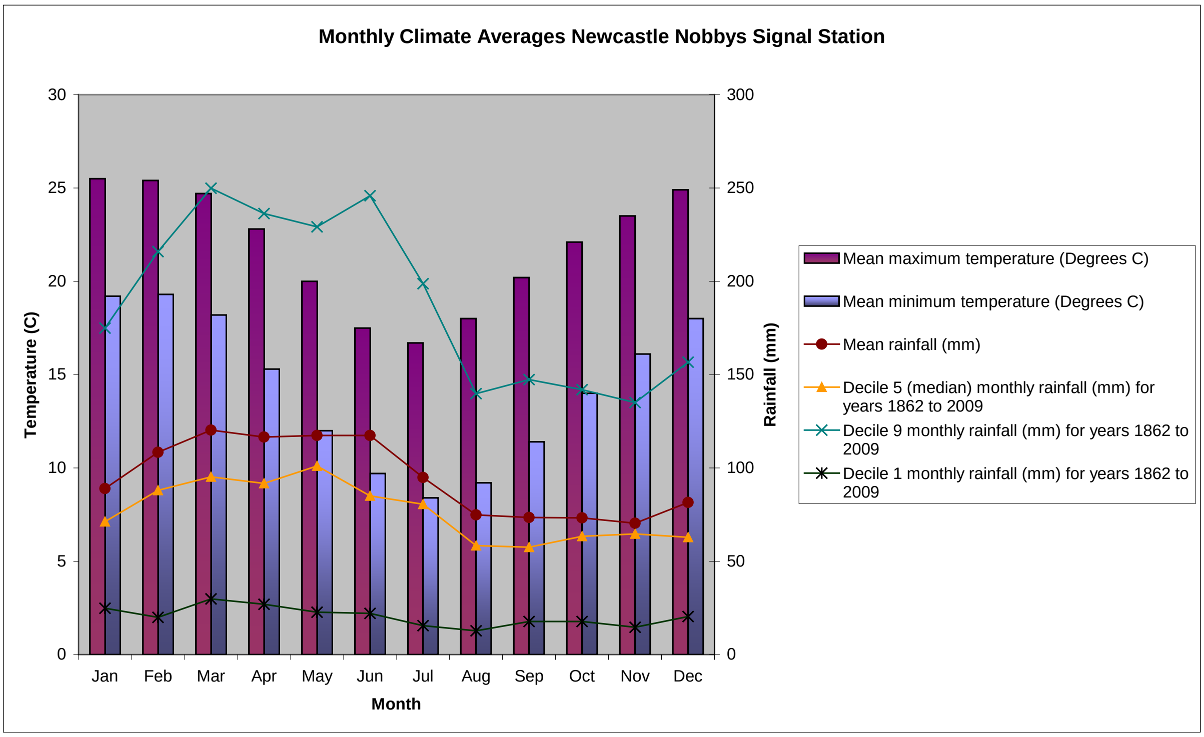


Figure 2-2
Monthly climate statistics from 'Newcastle Nobbys Signal Station AWS[3]

2.5 Biogeographic setting

In 2008, the Natural Resource Management Ministerial Council agreed to adopt the Australian Drainage Divisions system, along with IMCRA for marine ecosystems, as the best fit national regionalisation approach for aquatic ecosystems. This approach was seen as one way of reducing the difficulty in applying the Ramsar criterion relating to a system's uniqueness or representativeness. This is a change

[3]Climatic averages are from the Bureau of Meteorology station 'Newcastle Nobbys Signal Station AWS' (Site number: 061055). "Newcastle Nobbys Signal Station AWS" station has continuously recorded climate data from 1862 through to the present.

from the IBRA regions which were used for the Hunter Estuary Wetlands 2002 RIS and which are on a much finer geographic scale.

The Hunter River Basin, which encompasses an area of 21 451 square kilometres, falls within the South East Coast Drainage Division. The drainage division encompasses south-eastern coastal Australia from south of the Gold Coast in south east Queensland through New South Wales and Victoria to east of Adelaide in South Australia (Figure 2-3). The drainage division includes major river basins such as the Clarence, Macleay, Manning, Hawkesbury-Nepean, Shoalhaven, Snowy, Latrobe, Yarra, Werribee, Barwon and Glenelg Rivers and covers an area of 264 003 square kilometres (Figure 2-3). Major river estuaries within the drainage division include the Clarence, the Macleay, Manning, Hawkesbury, Shoalhaven and Crookhaven, Snowy River, and Barwon.

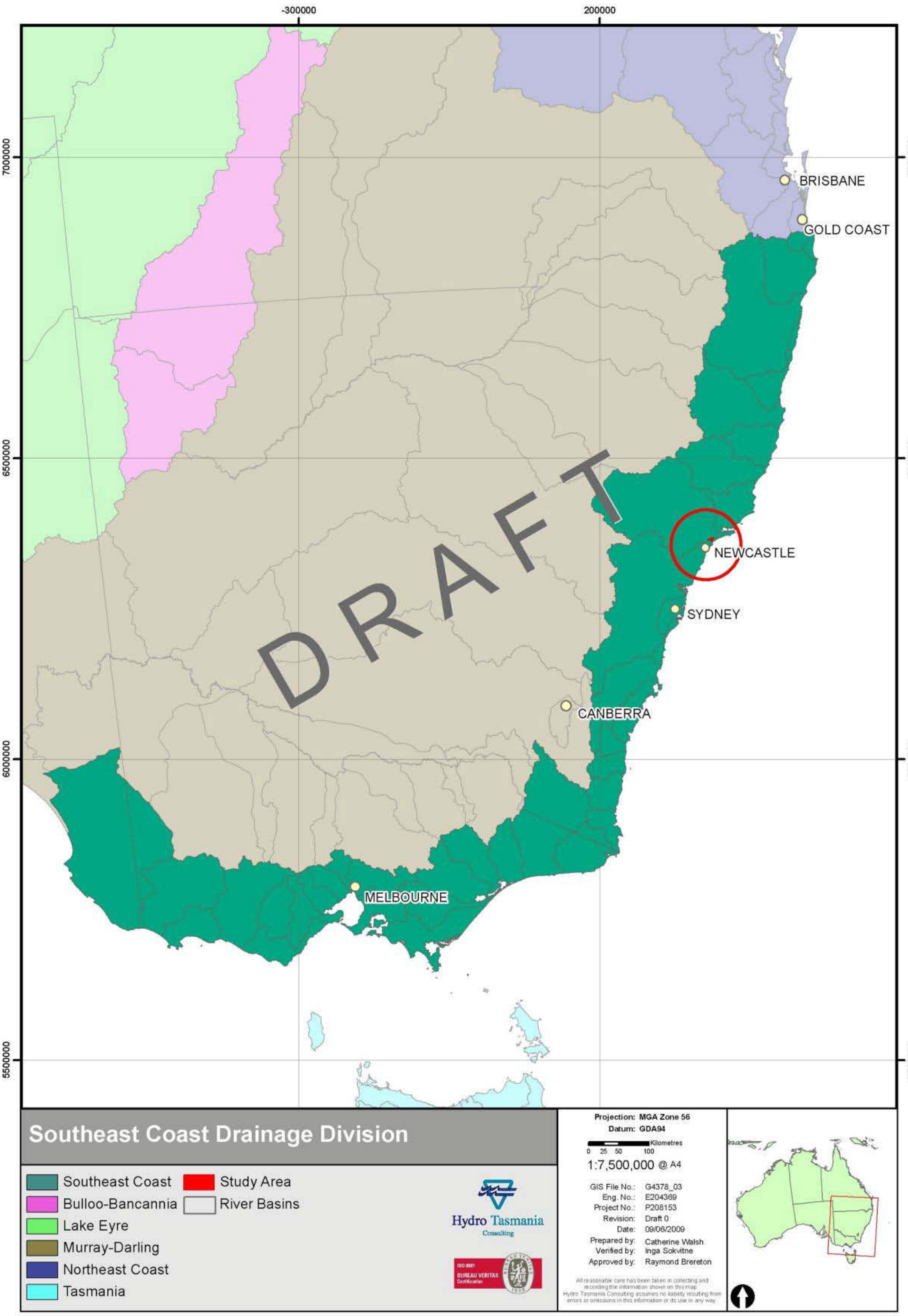


Figure 2-3
South East Coast Drainage Division (Source: Geoscience Australia ANZCW0703006043 http://www.bom.gov.au/hydro/wr/basins/index.shtml)

2.6 Land tenure

The Kooragang component of the Hunter Estuary Wetlands Ramsar site is entirely within the Hunter Wetlands National Park and is managed by the NSW Parks and Wildlife Service which is a group within the NSW OEH. The Shortland Wetlands is private land owned and managed by the Hunter Wetlands Centre Australia. Other agencies which have management responsibilities within the Hunter River Catchment that may impact on the Ramsar wetland are:

- *The Hunter–Central Rivers Catchment Management Authority (CMA)* which has responsibility for managing the native vegetation, soil and other natural resources in the catchment in conjunction with the community, local government, industry and State Government. The CMA is guided by the *Hunter–Central Rivers Catchment Action Plan* (2007) which identifies the most important natural resource issues in the region and provides a coordinated plan for all natural resource work through partnerships and collaborations with government, industry, community groups and individuals.
- *State Water* which manages all major water supply storages in NSW and supplies bulk water to irrigation authorities, town water supply authorities, mines, electricity generators and other industry by releasing water from its dams into rivers to be accessed by downstream water users. State Water also delivers water for private irrigators and stock and domestic users and is responsible for delivering environmental flows, in accordance with rules as set out in NSW Water Sharing Plans, on regulated rivers in the state. The *Water Sharing Plan for the Hunter Regulated River Water Source 2003* applies to the water source between the banks of all rivers which have been declared regulated rivers within the Hunter Basin, from the upstream limit of Glenbawn Dam water storage downstream to the estuary of the Hunter River, and from the upstream limit of Glennies Creek Dam water storage downstream to the junction with the Hunter River, and to the unconsolidated alluvial sediments underlying the waterfront land of all rivers that are declared regulated rivers as described above.
- *Hunter Water* which operates in the greater Newcastle area treating and distributing domestic water as well as collecting and treating wastewater.
- Utility companies which have easements that cross the Ramsar site include Energy Australia (electricity retailer), Transgrid (electricity transmission), Australian Rail Track Corporation (railway line), Hunter Water (water pipeline) and AGL Energy (gas pipeline).

2.7 Ramsar criteria

At the time of listing in 1984, Hunter Estuary Wetlands satisfied the former Ramsar criteria 1b, 2a, 2b, and 3. Since listing, the criteria have been revised a number of times in 1990, 1996, 1999 and 2005 when the current criteria were adopted (DEWHA 2008), see Appendix A.

In 2002, the Shortland Wetlands were added to the Hunter Estuary Wetlands Ramsar site satisfying two of the 1999 criteria, 1 and 4. A justification statement on how the site satisfied each of these criteria in 1984 and 2002 is provided in the following sections.

Those criteria met by Hunter Estuary Wetlands at the time of listing (including the inclusion of the Shortland Wetlands component of the site in 2002) equate to current criteria 1, 2, 3, 4, and 6. Where possible an assessment of how each of these criteria is currently satisfied in accordance with the Explanatory Note and Guidelines for Completing the Information Sheet on Ramsar Wetlands (RIS) (Ramsar 2009) is provided in Section 2.7.2

The Ramsar site is considered to satisfy additional criteria that were not considered at the time of listing. Justification statements as to how these criteria are met are provided in Section 2.7.3

2.7.1 Criteria met at the time of listing

The Hunter Estuary Wetlands Ramsar site which comprised the Kooragang Nature Reserve (now part of the Hunter Wetlands National Park) was designated in 1984 as a wetland of international importance because it satisfied the following four listing criteria (known as "Cagliari criteria"):

1(b) regularly supports 1% of the individuals in a population of one species or subspecies of waterfowl

- In 1983 the Kooragang component of the Ramsar site supported 14.6% of the total population of the lesser golden plover (*Charadrius hiaticula*) and 5.9% of the eastern curlew (*Numenius madagascariensis*) population.

2(a) supports an appreciable number of rare, vulnerable or endangered species or subspecies of plant or animal

- The Kooragang component of the Ramsar site was considered to meet this criterion because several rare waders have been recorded at the site including the ringed plover (*Charadrius hiaticula*), large sand plover (*Charadrius leschenaultii*), little curlew (*Numenius minutus*), pectoral sandpiper (*Charadrius melanotus*) and ruff (*Philomachus pugnax*).

2(b) is of special value for maintaining the genetic and ecological diversity of a region because of the quality and peculiarities of its fauna and flora

- The Kooragang component of the Ramsar site was considered to meet this criterion because it supports estuarine wetland habitats which are ecologically diverse and representative of the significant genetic pool of wetland species in the region.

3 is a particularly good example of a specific type wetland community characteristic of its region.

- The Kooragang component of the Ramsar site was considered to meet this criterion because it is a large area of productive estuarine wetland which is characteristic of its region.

In 2002 the Shortland Wetlands, now known as the Hunter Wetlands Centre Australia, were added to the Hunter Estuary Wetlands Ramsar site. The Shortland Wetlands were included in the Hunter Estuary Wetland site in 2002 independently satisfying criteria 1 and 4. Further details are presented below.

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.

Shortland Wetlands was considered to meet this criterion because it was considered unique in that within its 42 hectare site, it had a combination of high conservation value near-natural wetlands (melaleuca swamp forest, freshwater reed marsh, coastal estuarine mangrove-lined creek) and high conservation value artificial wetlands (constructed freshwater lagoons, coastal estuarine casuarina-lined channel, model farm dam) (Ekert 2002). The Shortland Wetlands was identified as the only complex of this type found within the Sydney Basin biogeographic region which was used as the appropriate biogeographic region at the time of listing. The melaleuca swamp forest was identified as particularly noteworthy because it represented a wetland type that was once widespread but was now poorly represented in the Sydney Basin biogeographic region.

Criterion 4: A wetland should be considered internationally important if it supports species at a critical stage in their life cycles, or provides refuge during adverse conditions.

Shortland Wetlands was considered to meet this criterion because it supported a large number of species (some in large numbers) at a critical seasonal stage of their breeding cycle and as a refuge during adverse conditions (Ekert 2002). Specifically:

- Twenty-eight bird species had been recorded breeding at Shortland Wetlands
- The great egret (*Ardea alba*), intermediate egret (*Ardea intermedia*), little egret (*Egretta garzetta*) and cattle egret (*Ardea ibis*) were seasonal migrants to the site.
- Over 1000 Australian white ibis (*Threskiornis molucca*) had been recorded using the melaleuca swamp forest as a night roost throughout the year. Numbers increased significantly over autumn and winter as migrants from inland breeding colonies arrived at the coast to forage.
- Up to 7000 straw-necked ibis (*Threskiornis spinicollis*) were recorded using the Wetlands Centre Melaleuca swamp forest for night roosting during autumn and winter. The numbers declined during August as they progressively left the site to return to the inland.

- Nankeen night herons (*Nycticorax caledonicus*) used the swamp forest for night foraging and for day roosting during the non-breeding season in variable numbers (up to 200 birds have been recorded) (Ekert 2002).
- White-faced heron (*Egretta novaehollandiae*), white-necked heron (*Ardea pacifica*), royal spoonbill (*Platalea regia*) and yellow-billed spoonbill (*Platalea flavipes*) used the swamp forest as a night roost throughout the year (ranging from single birds up to about 30).

The site also provided drought refuge for a number of bird species during prolonged inland droughts as indicated by a sudden rise in numbers coinciding with inland drought. With the breaking of the drought there was an accompanying drop in numbers of birds at the Shortland Wetlands. Species that use the site as a drought refuge include freckled duck (*Stictonetta naevosa*), pink-eared duck (*Malacorhynchus membranaceus*), Australian pelican (*Pelecanus conspicillatus*), and glossy ibis (*Plegadis falcinellus*) (Eckert 2002).

The Shortland Wetlands were also an important refuge for local resident ducks, herons and other waterbirds during dry periods, with up to 2000 ducks being recorded (Winning 1989).

2.7.2 Current criteria met at the time of listing

An assessment of the current criteria met by the Hunter Estuary Wetlands at the time of listing was undertaken in 2010. In relation to the assessment of the Hunter Estuary Wetlands Ramsar criteria, the South East Coast Drainage Division is now seen as the most appropriate biogeographic region to be applied (see Section 2.5). The assessment pertains to the criteria being applied to the site as a whole but information is provided on how each component of the site contributes to satisfying these criteria. Comments are also included under each criterion regarding information since the time of listing and how this may support the site in meeting criteria.

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.

This criterion was claimed as met for the Shortland Wetlands in the 2002 RIS; however reassessment of the Hunter Estuary Wetlands Ramsar site in the context of the South East Coast Drainage Division suggests that the site does not meet this criterion.

The 2002 RIS stated that "Shortland Wetlands" is unique in that it has, within its 42 hectare site, a combination of high conservation value near-natural wetlands (melaleuca swamp forest, freshwater reed marsh, coastal estuarine mangrove-lined creek) and high conservation value artificial wetlands (constructed freshwater lagoons, coastal estuarine casuarina-lined channel, model farm dam). It is the only complex of this type found within the Sydney Basin IBRA biogeographic region. The melaleuca swamp forest in particular represents a wetland type that, although once very widespread, is poorly represented in the Sydney Basin IBRA biogeographic region."

Melaleuca swamp forest forms part of the coastal swamp forest assemblage of communities described in Keith (2004) and "swamp sclerophyll forest on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner IBRA bioregions" which is listed as an Endangered Ecological Community on the NSW TSC Act. However, it is unlikely that the melaleuca swamp forest at Shortland Wetlands would meet this criterion as applied to the drainage division because coastal swamp forest occurs in the NSW North Coast and South East Corner IBRA bioregions as well as the Sydney Basin bioregion. All of these bioregions lie within the South East Coast Drainage Division.

The Hunter Estuary Wetlands including the Shortland Wetlands and the Kooragang component do not meet the criterion for containing a representative rare or unique type of an estuarine wetland within the South East Coast Drainage Division. This is because the drainage division includes other major river estuaries such as the Clarence River Estuary, the Macleay River Estuary, Manning Estuary, Hawkesbury River, Shoalhaven and Crookhaven Estuaries which are better examples of estuarine wetlands with similar Ramsar wetland types including inter-tidal mud flats, inter-tidal marshes (saltmarsh) and sea-grass beds that are more extensive and in better condition.

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

This criterion was not claimed as met in the 2002 RIS. However, the ECD for Shortland Wetlands (Taylor-Wood and Jaensch 2005) re-assessed the wetlands against the Ramsar criteria and found that Criterion 2 was met because the Australasian bittern (*Botaurus poiciloptilus*) was identified as occurring within the Ramsar site.

The Australasian bittern is listed as Endangered under both the EPBC Act and the IUCN Red List (Version 2009.1). The Australasian bittern has also been recorded within the Kooragang component of the Hunter Estuary Wetlands. There are records from 2000, 2007, 2008 and 2009 from the Tomago Wetlands adjacent to the Ramsar site (Ann Lindsey, HBOC pers. comm.). Herbert (2007a) considered the Australasian bittern to be a breeding resident in the Hunter Estuary as it has been recorded in all months and there are extensive areas of habitat available including within the Hunter Estuary Wetlands.

The green and golden bell frog *(Litoria aurea*) also occurs within the Kooragang component of the Hunter Estuary Wetland. The green and golden bell frog is listed as Vulnerable under the EPBC Act. Breeding populations have been recorded in ponds in the south eastern corner of the study area on Kooragang Island (Hamer et. al 2002). They have also been recorded in the Juncus Swamp at the eastern end of Kooragang Island (Hamer 1997).

The estuary stingray (*Dasyatis fluviorum*) which inhabits mangrove fringed rivers and estuaries (Cavanough et al. 2003) has been recorded from the Hunter Estuary (Ruello 1976, Gibbs et al. 1999). The estuary stingray is listed as Vulnerable on the IUCN Red List (Version 2009.1).

The presence of internationally and nationally listed threatened species demonstrates that the Kooragang component of the Hunter Estuary Wetlands contributes to the site meeting this criterion.

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.**

Although claimed as met for the Shortland Wetlands and the Kooragang component in the 2002 RIS, a reassessment of the site in the context of the South East Coast Drainage Division suggests that the Hunter Estuary Wetlands Ramsar site does not meet this criterion.

Kooragang Nature Reserve is described in the 2002 Hunter Estuary Wetlands RIS as “ecologically diverse and represents a significant genetic pool for wetland species in the Sydney Basin biogeographic region". This observation is unlikely to still be relevant if the wetland is assessed within the context of the South East Coast Drainage Division. The Kooragang component of the Hunter Estuary Wetlands supports a diverse range of native flora, with 91 species of native plants recorded on Kooragang Island which are predominantly wetland species (Winning 1996). They form a number of distinct habitats, including mangrove forest, saltmarsh, saline grasslands, freshwater wetlands and open water. These habitats support a high diversity of wetland fauna, particularly birds, with 101 species of waterbirds being recorded within the Kooragang component of the Hunter Estuary Wetlands and 63 species within the Shortland Wetlands (Appendix 4 in the RIS published in 2002).

However, other wetlands within the drainage division support larger numbers of waterbirds including the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site and the Gippsland Lakes Ramsar site. Within the Port Phillip Bay Ramsar site between 48 000 and 65 000 waders have been recorded feeding on the shores of the western shoreline of Port Phillip Bay during summer (Casanelia 1999a). This Ramsar site also holds more than 1% of the known Australian population of fourteen species of shorebirds (Casanelia 1999a). The Gippsland Lakes Ramsar site supports large numbers of waterbirds including over 7000 grey teal, 6000 chestnut teal, 10 000 black swans, 4500 Australasian grebe, 13 000 Eurasian coot and 7000 great cormorant (Casanelia 1999b).

Using the guidance provided by the Ramsar Convention (2008), Criterion 3 is not considered to be met at the time of listing because there is no information to support a case for the site maintaining the biological diversity of the biogeographic region (South East Coast Drainage Division). It may have met this criterion if the site had a number of endemic species but there is no evidence that the site has high endemism. In particular, the Hunter Estuary Wetland:

- is not a "hotspot" of biological diversity (Ramsar Convention 2008) even though it does contain a relatively high diversity of wetland birds;
- is not a centre of endemism or otherwise contains significant numbers of endemic species;
- contains subset of the range of biological diversity (including habitat types) occurring in a region (notably seagrass is absent which is a particularly high value habitat for fish and marine invertebrates); and
- does not support particular elements of biological diversity that are rare or particularly characteristic of the biogeographic region (South East Coast Drainage Division).

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

One hundred and twelve species of waterbirds (belonging to one of the 20 families that are defined as waterbirds under the Ramsar Convention on Wetlands) have been recorded from the Hunter Estuary Ramsar Wetlands, including both the Shortland Wetlands and the Kooragang component. Forty-one species of migratory birds recorded at Kooragang and 21 species at Shortland Wetlands are presently listed as migratory under the EPBC Act which includes species other than shorebirds, such as some egret species, terns, glossy ibis, and the white-bellied sea-eagle (Table 2-1; Appendix B). The EPBC Act includes birds listed under international treaties such as the JAMBA, CAMBA and ROKAMBA.

Migratory shorebirds are present for up to eight months of the year between September and April in the Hunter Estuary Ramsar site. In February 1986, 6800 migratory shorebirds were recorded in the Hunter Estuary (Herbert 2007a). In 2006, approximately 3000 migratory shorebirds were recorded in the Hunter Estuary (Herbert 2007a). The Kooragang component of the Hunter Estuary Wetlands Ramsar site regularly supports 17 species of migratory shorebirds (Herbert 2007a). The Fullerton Cove area within the Kooragang component has been identified as the most important foraging area for the majority of the migratory shorebirds in the Hunter Estuary (Herbert 2007a). Stockton Sandspit and the Kooragang Dykes which lie within the Kooragang component are also important roosting and foraging areas for migratory shorebirds (Herbert 2007a).

Shortland Wetlands regularly provides habitat for at least seven species of migratory shorebird. Kooragang and Shortland Wetlands also support a large number of species at a critical seasonal stage of their breeding cycle. Twenty-eight bird species have been recorded breeding at Shortland Wetlands and 24 bird species have been recorded breeding at Kooragang. Close to the time of listing, in 1987/88 2000 cattle egret nests were recorded in the Hunter Estuary (including Shortland Wetlands) during the breeding season, however, this number had dropped to just over 400 in the 2006/07 breeding season, (Herbert 2007a). White ibis have also been recorded breeding in the estuary, 55 nests recorded at the Shortland Wetlands in 2006/07 (Herbert 2007a). Black-winged stilts are also a breeding resident species in the Kooragang component (breeding has been recorded at Stockton Sandspit) and were common and abundant in the estuary at the time of listing with over 1000 birds recorded in 1984 (Herbert 2007a). In the 2006/07 breeding season 416 black-winged stilts were recorded (Herbert 2007a).

The Hunter Estuary Wetlands also provides refuge for a number of species during periods of inland drought. Shortland Wetlands is a drought refuge for species such as freckled duck (*Stictonetta naevosa*); pink-eared duck (*Malacorhynchus membranaceus*); Australian pelican (*Pelecanus conspicillatus*); and glossy ibis (*Plegadis falcinellus*) (Albrecht and Maddock 1985). Shortland Wetlands and the Kooragang component are also important for local resident ducks, herons and other waterbirds, with up to 2000 ducks recorded at Shortland Wetlands during dry periods (Winning 1989).

The melaleuca swamp forest at Shortland Wetlands is an important night roost for Australian white ibis (*Threskiornis molucca*), straw-necked ibis (*Threskiornis spinicollis*) and Nankeen night heron (*Nycticorax caledonicus*). Over 1000 Australian white ibis and 7000 straw-necked ibis have been recorded roosting at Shortland Wetlands. Up to 200 Nankeen night herons have been recorded night foraging and for day roosting during the non-breeding season (Eckert 2002).

The Kooragang component of the Hunter Estuary Wetland contributes to this criterion because it is an important foraging and roosting site for migratory shorebirds. The Hunter Estuary Wetlands meets Criterion 4 because it supports species at critical stages in their life cycles: breeding, migration stop-over, roosting and drought refuge.

Table 2-1
Species listed as migratory on international migratory bird treaties

Scientific Name	Common Name	International migratory bird treaty
Anas clypeata	Northern shoveler	CAMBA, JAMBA, ROKAMBA
Anas querquedula	Garganey	Bonn, CAMBA, JAMBA, ROKAMBA
Ardea alba	Great egret	CAMBA, JAMBA
Ardea ibis	Cattle egret	CAMBA, JAMBA
Plegadis falcinellus	Glossy ibis	Bonn, CAMBA
Charadrius lescenaultii	Greater sand plover	Bonn, CAMBA, JAMBA, ROKAMBA
Charadrius mongolus	Lesser sand plover	Bonn, CAMBA, JAMBA, ROKAMBA
Charadrius veredus	Oriental plover	Bonn, JAMBA, ROKAMBA
Pluvialis fulva	Pacific golden plover	Bonn, CAMBA, JAMBA, ROKAMBA
Pluvialis squatarola	Grey plover	Bonn, CAMBA, JAMBA, ROKAMBA
Chlidonias leucopterus	White-winged black tern	CAMBA, JAMBA, ROKAMBA
Sterna albifrons	Little tern	Bonn, CAMBA, JAMBA, ROKAMBA
Sterna caspia	Caspian tern	CAMBA, JAMBA
Sterna hirundo	Common tern	CAMBA, JAMBA, ROKAMBA
Rostratula australis	Australian painted snipe	CAMBA
Actitis hypoleucos	Common sandpiper	Bonn, CAMBA, JAMBA, ROKAMBA
Arenaria interpres	Ruddy turnstone	Bonn, CAMBA, JAMBA, ROKAMBA

Scientific Name	Common Name	International migratory bird treaty
Calidris acuminata	Sharp-tailed sandpiper	Bonn, CAMBA, JAMBA, ROKAMBA
Calidris alba	Sanderling	Bonn, CAMBA, JAMBA, ROKAMBA
Calidris canutus	Red knot	Bonn, CAMBA, JAMBA, ROKAMBA
Calidris ferruginea	Curlew sandpiper	Bonn, CAMBA, JAMBA, ROKAMBA
Calidris melanotus	Pectoral sandpiper	Bonn, CAMBA, JAMBA, ROKAMBA
Calidris ruficollis	Red-necked stint	Bonn, CAMBA, JAMBA, ROKAMBA
Calidris tenuirostris	Great knot	Bonn, CAMBA, JAMBA, ROKAMBA
Gallinago hardwickii	Latham's snipe	Bonn, CAMBA, JAMBA, ROKAMBA
Heteroscelus brevipes	Grey-tailed tattler	Bonn, CAMBA, JAMBA, ROKAMBA
Heteroscelus incana	Wandering tattler	Bonn, CAMBA, JAMBA,
Limicola falcinellus	Broad-billed sandpiper	Bonn, CAMBA, JAMBA, ROKAMBA
Limnodromus semipalmata	Asian dowitcher	Bonn, CAMBA, JAMBA, ROKAMBA
Limosa lapponica	Bar-tailed godwit	Bonn, CAMBA, JAMBA, ROKAMBA
Limosa limosa	Black-tailed godwit	Bonn, CAMBA, JAMBA, ROKAMBA
Numenius madagascariensis	Eastern curlew	Bonn, CAMBA, JAMBA, ROKAMBA
Numenius minutus	Little curlew	Bonn, CAMBA, JAMBA, ROKAMBA
Numenius phaeopus	Whimbrel	Bonn, CAMBA, JAMBA, ROKAMBA
Philomachus pugnax	Ruff	Bonn, CAMBA, JAMBA, ROKAMBA
Tringa glareola	Wood sandpiper	Bonn, CAMBA, JAMBA, ROKAMBA
Tringa nebularia	Common greenshank	Bonn, CAMBA, JAMBA, ROKAMBA
Tringa stagnatilis	Marsh sandpiper	Bonn, CAMBA, JAMBA, ROKAMBA
Tryngites subruficollis	Buff-breasted sandpiper	JAMBA, ROKAMBA
Xenus cinereus	Terek sandpiper	Bonn, CAMBA, JAMBA, ROKAMBA
Cuculus saturatus	Oriental cuckoo	CAMBA, JAMBA, ROKAMBA
Hirundapus caudacutus	White-throated needletail	CAMBA, JAMBA, ROKAMBA
Merops ornatus	Rainbow bee-eater	JAMBA
Hirundo rustica	Barn swallow	CAMBA, JAMBA, ROKAMBA
Motacilla flava	Yellow wagtail	CAMBA, JAMBA, ROKAMBA

Criterion 6: A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of waterbird.

Bamford et al. (2008) in "*Migratory Shorebirds of the East Asian – Australasian Flyway: Population Estimates and Internationally Important Sites*" identify the Hunter Estuary as being an internationally important site (i.e. supports more than 1% of the population) for six migratory species, eastern curlew (*Numenius madagascariensis*), black-tailed godwit (*Limosa limosa*), bar-tailed godwit (*Limosa lapponica*), Terek sandpiper (*Xenus cinereus*), ruddy turnstone (*Arenaria interpres*), and curlew sandpiper (*Calidris ferruginea*). However, a review of the available data suggests that the Hunter Estuary Wetland Ramsar site regularly supports 1% of the population of only one of these species, the eastern curlew.

The 1% threshold for the East Asian-Australasian Flyway population for eastern curlew is 380 individuals (Bamford et al. 2008). At the time of listing in 1984, 653 eastern curlews were recorded in the Hunter Estuary (Australasian Wader Studies Group data cited in Bamford et al. 2008). Since then regular wader surveys by the Australian Wader Study Group and Hunter Bird Observers Club have recorded maximum counts of between 800 and 1000 eastern curlews in the Hunter Estuary up until the late 1990s (Herbert 2007a). Between the years 2000 and 2007 the maximum numbers of eastern curlews that have been counted has regularly been between 400 and 600 (Herbert 2007a). Most of these birds roost at the Kooragang Dykes and the Stockton Sandspit which are within the Kooragang component.

Bamford et al. (2008) identified the Hunter Estuary as a site of international importance for the black-tailed godwit because a maximum count of 4000 birds had been recorded (undated, Smith 1990 cited in Bamford et. al 2008). The 1% threshold for this species is 1,600 (Bamford et al. 2008). At the time of listing in 1984 over 500 black-tailed godwits were recorded in the Hunter Estuary and between 1999/2000 and 2006/07 between 200 and 400 birds were recorded, with the largest numbers (300 to 350 birds) at the Kooragang Dykes within the Kooragang component of site (Herbert 2007a). According to the most recently available data the Hunter Estuary Wetland does not regularly support more than 1% of the black-tailed godwit population.

Bamford et al. (2008) reported a maximum count of 4000 bar-tailed godwits (undated, Smith 1990 cited in Bamford et al. 2008). The 1% threshold for this species is 3250 (Bamford et al. 2008). At the time of listing in 1983/84 over 3500 bar-tailed godwits were recorded in the Hunter Estuary and between 1983/84 and 1997/98 between 3000 and 5000 birds were recorded mostly at Kooragang Dykes within the Kooragang component of the site (Herbert 2007a). Between the years 1999/2000 and 2006/07 maximum summer counts of bar-tailed godwits have been between a high of 2019 in 1999/2000 and low of 1077 by 2006/07 (Herbert 2007a). According to the available data the Hunter Estuary Wetland site has not supported more than 1% of the population of bar-tailed godwits since 1997/98 and therefore does not regularly support more than 1% of the population of this species.

Bamford et al. (2008) reported a maximum count of 600 Terek sandpipers (undated, Smith 1990 in Bamford et al. 2008). The 1% threshold for this species is 500 (Bamford et al. 2008). At the time of listing in 1983/84, around 20 Terek sandpipers were recorded in the Hunter Estuary, however over 350 birds were recorded in the Hunter Estuary in 1991/92 and 633 in 1996/97 (Herbert 2007a). Between 1999/2000 and 2006/07 maximum summer counts of Terek sandpipers within the Hunter Estuary have been between 30 and 70 birds (Herbert 2007a). Within this period, up to 70 Terek sandpipers have been recorded foraging and roosting within Fern Bay within the Kooragang component. Based on the available data, the Hunter Estuary Wetland does not regularly support more than 1% of the population of Terek sandpipers.

Bamford et al. (2008) reported a maximum count of 520 ruddy turnstones in the Hunter Estuary. There is a record of 520 ruddy turnstones recorded on the 1/02/1986 (Australian Wader Studies Group data) but there is no reference for where they were recorded in the estuary. The 1% threshold for this species is 350 (Bamford et al. 2008). However, Herbert (2007a) records the ruddy turnstone as an uncommon summer migrant in the Hunter Estuary and there have been no more than six birds recorded within the estuary in annual counts between 1999 and 2007, mostly at Stockton Sandspit and Kooragang Dykes. Based on the available data, the Hunter Estuary Wetland site does not regularly support more than 1% of the population of ruddy turnstones. Ruddy turnstones mainly inhabit coastal rock platforms and beaches and are generally not common in estuarine habitats.

Bamford et al. (2008) records a maximum count of 4000 curlew sandpipers, (undated, Smith 1990 cited in Bamford et al. 2008). The 1% threshold for this species is 1800 (Bamford et al. 2008). At the time of listing in 1983/84 over 2000 curlew sandpipers were recorded in the Hunter Estuary. In 1985/86 over 4000 curlew sandpipers were recorded and between 1983/84 and 1997/98 there were regular counts of over 2000 birds (Herbert 2007a). Between 1999/2000 and 2006/07 maximum summer counts of curlew sandpipers have been much lower between 400 and 800 birds (Herbert 2007a). Most birds have been recorded at the Kooragang Dykes. According to the available data the Hunter Estuary Wetland site has not supported more than 1% of the population of curlew sandpipers since 1997/98 and therefore does not regularly support more than 1% of the population of this species.

One other species of waterbird has been regularly observed in numbers greater than 1% of the individuals in a population. The red-necked avocet (*Recurvirostra novaehollandiae*) is found throughout Australia and is considered to be a non-breeding resident within the Hunter Estuary. It breeds on wetlands in inland Australia when conditions are suitable. At the time of listing in 1984, only small numbers of red-necked avocets (less than 20) were recorded within the estuary (Herbert 2007a). Numbers have increased significantly since the 1980s with maximum counts of 5032 in 2006 and 7000 in 2007 (Herbert 2007a). The 1% threshold for red-necked avocet is 1100 birds (Wetlands International 2006) and these counts represent between 4.7% and 6.5% of the total red-necked avocet population. Between 1999 and 2007 over 2000 red-necked avocets have been recorded in the Hunter Estuary in all years except 2000 (Herbert 2007a). Up to 5000 birds (spring 2006) have been recorded foraging and roosting at Stockton Sandspit within the Kooragang component (Herbert 2007a).

This criterion is met because the Kooragang component of the Hunter Estuary Wetlands regularly supports more than 1% of the East Asian-Australasian Flyway population of eastern curlew and more than 1% of the Australian population of red-necked avocets.

2.7.3 Assessment against additional criteria

Criterion 5: A wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds.

There are anecdotal reports of as many as 20 000 migratory shorebirds using the Hunter Estuary prior to the 1970s (Herbert 2007a); however, these numbers have not been recorded in the Hunter Estuary since. At the time of listing in 1984, a maximum number of 6800 migratory waders were recorded in the Hunter Estuary (Herbert 2007a). There have been 7000 avocets and a number of other waterbirds including other egrets, herons, stilts, pelicans and ducks recorded within the Kooragang component and Shortland Wetlands; however, there were not 20 000 or more waterbirds regularly recorded within the Ramsar site around the time of listing (Herbert 2007a).

Criterion 7: A wetland should be considered internationally important if it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity.

Ninety-nine species of fish were recorded from the broader Hunter Estuary, including the Kooragang component around the time of listing. This fish assemblage was considered to be relatively depauperate for an estuarine system at the time of listing and is still considered to be low. The review of this criterion and an assessment of the available data from the Kooragang component and Shortland Wetlands indicates that this criterion is not met by the Hunter Estuary Wetland.

Criterion 8: A wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.

The mangrove forests within the Kooragang component of the Hunter Estuary Wetland are likely to provide shelter, food and a nursery area for local fish species and crabs. In addition the Hunter Estuary was identified as the third largest prawn fishery in 2001 (SMEC 2001). The main prawn species fished was the school prawn (*Metapenaeus macleay*). This species spawns at sea, near the coast, and the juveniles migrate into the estuaries after two to three weeks where they develop into adults. School prawns prefer the hyposaline conditions found in the open waters of the large estuaries of east coast Australia. Although the Hunter Estuary Wetland site is used by these species, there is insufficient data to assess the relative importance of the site either now or at the time of listing as a source of food for fishes, spawning ground, nursery and/or migration path on which fish, crabs and prawn stocks depend.

The review of this criterion and an assessment of the available data from the Kooragang component and Shortland Wetlands indicate that this criterion is not met by the Hunter Estuary Wetland.

Criterion 9: A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of wetland-dependent non-avian animal species.

The Kooragang component and Shortland Wetlands supports a range of wetland-dependent non-avian animal species such as frogs, including the nationally threatened green and golden frog. However, only a small area of freshwater wetland (less than one hectare) is present at Kooragang which provides suitable habitat for the green and golden bell frog. It is not considered that this area would support 1% of the population.

An attempt was made to reintroduce green and golden bell frogs at the Hunter Wetlands Centre in 2005, when 850 bell frog tadpoles were released into three ponds (Stockwell 2008). Tadpole survival was high; however, two months after the tadpoles had metamorphosed into frogs the number of green and golden bell frogs encountered during visual surveys began to decline (Stockwell 2008). This decline continued and after 13 months of the release, green and golden bell frogs appeared to have disappeared from the site (Stockwell 2008). The failure of the re-introduction was attributed to infection by the Amphibian Chytrid Fungus (*Batrachochytrium dendrobatidis*) that was acquired following the re-introduction of tadpoles into the ponds, as they were tested prior to release and appeared to be free of the disease (Stockwell 2008).

There is no evidence at this time that the Hunter Estuary Wetland site regularly supports 1% of the individuals in a population of the green and golden bell frog or any other species or subspecies of wetland-dependent non-avian animal species. This criterion was not met by the Kooragang component of the Hunter Estuary Wetland at the time of listing.

2.8 Wetland types

The Kooragang component of the Hunter Estuary Wetlands is ecologically diverse and supports a number of important wetland communities. The 2002 RIS identified eight Ramsar wetland types within the Kooragang component all within the Marine/Coastal wetland class; they included rocky marine shores (D), sand, shingle or pebble shores (E), estuarine waters (F), inter-tidal mud, sand or salt flats (G), coastal brackish/saline lagoons (brackish to saline lagoons with at least one relatively narrow connection to the sea) (J), inter-tidal marshes (H) and, inter-tidal forested wetlands (I), and coastal freshwater lagoons (K).

Close to the time of listing in 1983, eleven wetland habitats were mapped within the Kooragang component of the Ramsar site by Outhred and Buckney (1983). The habitat map of Outhred and Buckney (1983) was used to review and identify the Ramsar wetland types during the preparation of this ECD. The eleven habitats mapped by Outhred and Buckney (1983) can be equated with only four of the Ramsar wetland types identified in the 2002 RIS which are: estuarine waters (F); inter-tidal mud; sand or salt flats (G); inter-tidal marshes (H); and inter-tidal forested wetlands (I) (Table 2-2, Figure 2-4). A fifth wetland type, freshwater, tree-dominated wetlands (Xf), was identified as occurring within the site during the preparation of this ECD. There were no rocky marine shores (D); sand, shingle or pebble shores (E); coastal brackish/saline lagoons (brackish to saline lagoons with at least one relatively narrow connection to the sea) (J); or coastal freshwater lagoons (K) wetland types identified within the Kooragang component. A description of the wetland types identified within the Kooragang component is provided below.

Estuarine waters (F)

The main areas of estuarine waters in the Kooragang component are the large expanse of open water in Fullerton Cove, the northern arm of the Hunter River and the Kooragang Dyke Ponds. While the Dyke Ponds have always been open water, the construction of the associated retaining walls in the 1960s has created an area of intertidal mudflat which is an important foraging and roosting habitat for shorebirds (Herbert 2007a).

Inter-tidal mud, sand or salt flats (G)

The largest area of intertidal mudflat within the Kooragang component is within Fullerton Cove. There are smaller areas of mudflats and sandy beaches on the small islands in the North Arm of the Hunter River and on the Stockton Sandspit.

Inter-tidal marshes (H)

At the time of listing in 1984, intertidal marshes within the Kooragang component were represented by saltmarsh and saline pasture to the west of Fullerton Cove and saltmarsh on Kooragang Island (Figure 2-1). Prior to the time of listing, the installation of drains to the west of Fullerton Cove caused changes in the hydrology of the area, which resulted in saline pastures replacing much of the saltmarsh in this area (Figure 2-4). Brackish swamps occurred south of Moscheto Creek on Kooragang Island.

Inter-tidal forested wetlands (I)

At the time of listing, mangrove communities dominated by grey mangrove (*Avicennia marina*), occurred around the margins of Fullerton Cove and the banks of the North Arm of the Hunter River. The river mangrove (*Aegiceras corniculatum*) was also present and occurred as a local dominant along the margins of the tidal channels subject to regular tidal inundation (Outhred and Buckney 1983). There are also small patches of swamp oak (*Casuarina glauca*) woodland in the north and west of Fullerton Cove.

Freshwater, tree-dominated wetlands (Xf)

During the preparation of this ECD a small isolated patch of melaleuca swamp forest dominated by broad-leaved paperbark (*Melaleuca quinquenervia*) was located on the northern edge of the Kooragang component (Figure 3-10). This is a patch of remnant swamp forest that would have been present at the site in 1984 but was outside the area mapped by Outhred and Buckney (1983).

Pasture

There were also patches of freshwater pasture present on Kooragang Island at the time of listing in 1984 resulting from farming activities prior to the time of listing. These pasture areas were dominated by introduced species and are terrestrial habitats that do not fit any of the Ramsar human-made wetland types.

Table 2-2
Wetland types

Ramsar wetland type*		1983 Vegetation mapping unit (Outhred and Buckney 1983)	
Code	Description*	Code	Description
Marine coastal wetlands			
F	Estuarine waters; permanent water of estuaries and estuarine system of deltas		Open water
G	Inter-tidal mud, sand or salt flats		Bare ground
H	Inter-tidal marshes; includes salt marshes, salt meadows, saltings, raised salt marshes; includes tidal and brackish and freshwater marshes	SP SM1 SM2 SM3 SW	Saline pasture *Sarcocornia* saltmarsh *Sporobolus* saltmarsh *Juncus* saltmarsh Brackish swamp
I	Inter-tidal forested wetlands; includes mangrove swamps, nipah palm swamps and tidal freshwater swamp forests	M1 M2	Vigorous mangroves Mangroves lacking vigour *Casuarina glauca* forest
Inland wetlands			
Xf	Freshwater, tree-dominated wetlands; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils.		Not mapped in 1983, identified during the preparation of the ECD

*From Annex I. *Ramsar Classification System for Wetland Type* in the *Information Sheet on Ramsar Wetlands* (RIS) 2009-2012 version. Categories approved by Recommendation 4.7 (1990), as amended by Resolution VIII.13 of the 8th Conference of the Contracting Parties (2002) and Resolutions IX.1 Annex B, IX.6, IX.21 and IX. 22 of the 9th Conference of the Contracting Parties (2005).

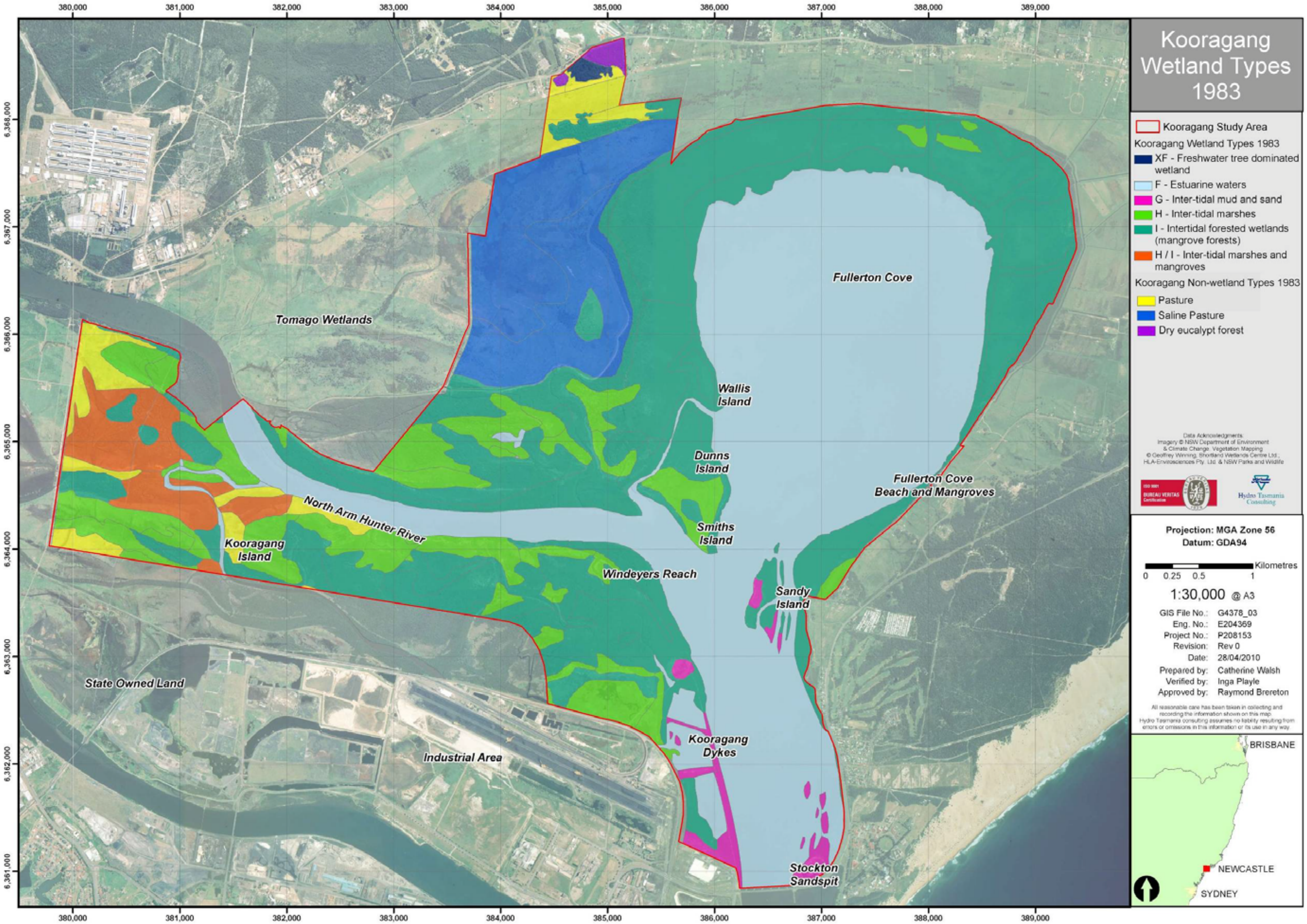


Figure 2-4: Map showing Ramsar Wetland types

3. Ecosystem components, processes and services

3.1 Components and ecosystem processes

This section describes the components and processes for the Kooragang component of the Hunter Estuary Wetlands that characterise the site at the time of listing in 1984. Geomorphology and hydrology are the underlying determinants of the type of estuarine wetland that is present at the site. In turn, geomorphology and hydrology influence the wetland biota and the physio-chemical components and processes that occur at the site.

3.1.1 Geomorphology

The river valleys along the south-east Australian seaboard that are underlain by Cainozoic deposits have evolved over millions of years, undergoing many erosion and accretion phases. The Quaternary glacial periods (2 million years ago) saw this coastal fringe displaced seaward onto the continental shelf resulting in rivers cutting new base levels into this shelf (Roy et al. 2001). Following the glacial periods, higher sea levels have resulted in coastal valleys being drowned, some forming estuaries, such as the Hunter Estuary. The Hunter Estuary has subsequently in-filled with sediment sourced both from the land and seaward margins (Roy et al. 2001).

Three major cycles of sediment fill have occurred in the Hunter Valley, during the Tertiary (1.8 million years ago), Pleistocene (140 000 years ago) and Holocene periods (10 000 years ago to present) (MHL 2003). The most recent sediment fill event in the Holocene occupies most of the estuary land surface and is evident in the Holocene swamps and floodplains (MHL 2003). There are three main groups of Holocene sediment fill in the Hunter Estuary, marine fill, central basin fill and bayhead delta/fluvial fill (MHL 2003). The marine fill consists mainly of marine sand (comprised of quartz, shell, and heavy minerals) deposited in coastal barriers (beaches and dunes) and flood tidal delta complexes (MHL 2003). The central basin fill is mainly fine-grained mud supplied to the estuary by the river when it was still open water (MHL 2003). At the time of listing, this sediment was and still is accumulating mostly in the lower estuary in areas such as Fullerton Cove. The bay head delta is the complex of sandy channels and bars formed as the river drains into the open water of the estuary as exemplified by the upper area of Kooragang Island which is within the Ramsar site (MHL 2003). The fluvial fill consists of river channels, point bars and floodplains that have formed on top of the estuary after the estuary water body was filled.

Sediment transporting mechanisms within the Hunter Estuary are dominated by local wind waves and wind-induced water movements. Wave dominated estuaries are strongly influenced by river discharge and are associated with barrier estuaries. The Hunter Estuary is classified as a “mature barrier estuary” which is characteristically formed by extensive river systems with high sediment loads (Roy et al. 2001). They occur behind sand barriers on exposed sections of the coast. These estuaries have open inlets, similar to the Hunter Estuary, which is typical of larger rivers with large catchment areas/ river discharge. The hydrological flows of these large rivers counteract the wave flux that transports beach sand entering the embayment. In the Hunter Estuary this larger system allows for a clear connection between present-day maturity and catchment size. The former water body which made up the Hunter Estuary has been estimated to have occupied an area of greater than 100 square kilometres, and has since contracted in area over the last three to four thousand years by an estimated 20 000 to 50 000 square metres per year to its current extent of 30 square kilometres (30 million square metres) (Roy et al. 2001).

The Hunter Estuary begins four kilometres upstream of Maitland at Oakhampton, some 64 kilometres from the coast (HCRCMA 2009). Upstream of this setting the geomorphic characteristics of the river are those of a typical graded alluvial river with extensive meandering across its floodplain. Between its upstream limit and the coast, the character of the Hunter Estuary transitions from river flats, to an estuarine delta below Hexham, and is bounded on the seaward side by the sandspit of the Stockton Peninsula (Coffey 1973). Closer to the coast the estuary opens into an embayment to the north called Fullerton Cove. The river exits the estuary to the south of Stockton Sandspit between the end of the spit and the rocky outcrops of Nobbys Head. Upstream of the river mouth, the Hunter River forms a typical estuarine delta where it has wandered in its course depositing sand and silt which at the time of listing was characterised by two main river channels (the North Arm and South Arm) and a network of smaller channels flowing through an area of islands, mangrove swamps and tidal mud flats.

The main island in the Hunter Estuary is Kooragang Island at the mouth of Fullerton Cove which represents the remnants of an island delta that was once comprised of up to ten other islands that have progressively been anthropogenically in-filled through a process of reclamation. The land reclamation works which created Kooragang Island had mostly been completed at the time of listing in 1984. The delta incorporating Kooragang Island was originally more extensive prior to the establishment of a permanent settlement in Newcastle. Subsequent dredging and reclamation activities, along with river stabilisation works, have cleared an ‘efficient’ channel (the South Arm) suitable for shipping purposes in the lower reaches. Much of the original silt, gravels and other deposited material has been sourced from upstream and was accelerated after settlement, although this occurred up to 70 years post disturbance (e.g. land clearing, Spink et al. 2005). In excess of 500 upstream river works have occurred since settlement and have resulted in a reduction in sediment yield (Fryirs et al. 2009).

The bathymetry of Hunter Estuary has been described based on modelling completed by Hunter Water in 1990 and more recent hydro-surveys undertaken by Newcastle Port Corporation (BMT WBM 2009). This is the only available information on bathymetry close to the time of listing. The deepest part of the estuary is in the Port area where the depth is maintained between 14 and 16 metres, decreasing upstream to four metres in the upper part of the South Arm, continuing to decline to 1 m deep at the junction with the North Arm (BMT WBM 2009). The majority of tidal flows are through the North Arm which is mostly over five metres deep and up to nine metres deep on the outside of river bends. Fullerton Cove is an extensive, flat, shallow embayment with depths of less than 2 metres (BMT WBM 2009).

3.1.1.1 Sediment

Sedimentation and erosion patterns vary within the estuary but generally erosion is the main process in the upper reaches of the estuary and deposition occurs in the lower estuary. Large floods are the major source of sediments and sediments deposited during the 1955 flood are being reworked and deposited down stream. In the North Arm there has been lateral deposition and the channel has meandered with scrolls evident on the margin of the inside bend (MHL 2003). This has largely occurred between Dunns Island and Tomago. Low energy areas of the lower estuary such as Fullerton Cove are also depositional zones characterised by the accumulation of mud, largely of fluvial origin (Boyd 2001). The major source of these sediments is from bed and bank erosion in Hunter River upstream of Oakhampton and the Paterson River upstream of Patterson. The entrance of the estuary is also a contributor of marine sediments. Deposition rates measured in Fullerton Cove estimate an accumulation rate of 2.3 millimetres per year (Boyd 2001).

3.1.2 Hydrology

3.1.2.1 Hunter River flows

The Hunter Estuary drains a catchment of 22 000 square kilometres, and mean discharge into the estuary is approximately 1 800 000 megalitres per year (MHL 2003). The catchment extends further inland than any other coastal river catchment in NSW, and as a consequence exhibits a variety of rainfall and runoff regimes. Annual rainfall ranges from 700 millimetres in the west of the catchment to 1 600 millimetres in the mountainous Barrington Tops region in the catchment's north-east. More than 40% of Hunter River flow volume is contributed by the Barrington Tops region. The Paterson, Allyn and Williams Rivers, which drain the Barrington Tops, collectively account for only about 10% of the total Hunter catchment area (MHL 2003). Flow duration curves are shown in Figure 3-1 for one of the Barrington Tops rivers (Patersons River) and for the Hunter River at Greta (approximately 50 kilometres north west of Newcastle) upstream of the Barrington Tops tributaries. These are the closest gauging stations to the estuary with available data. These illustrate that median flows in these rivers are over 100 megalitres per day for the Patersons River and approximately 500 megalitres per day for the Hunter River. There is no strong pattern of seasonal flow in the Hunter River above Greta, although the highest flows are in June (Figure 3-2). However, there is a trend of late summer-autumn peak in flows in the Barrington Tops region (Figure 3-2).

The flows in the Hunter River are heavily regulated by three large dams; Glenbawn, Glinnies Creek and Lostock dams which control some 18% of the total flow volume. A 1984 estimate concluded that more than 10 000 megalitres per year were abstracted for irrigation from the lower Hunter (and its tributaries) in the vicinity of the estuary (MHL 2003). MHL (2003) estimated average inflows to the estuary to be 1800 gigalitres per year. At the time of listing average annual abstraction was a small proportion of inflows; however, abstraction may have been a higher proportion of flow in a given season (e.g. in summer when water is abstracted for irrigation and inflows are lower).

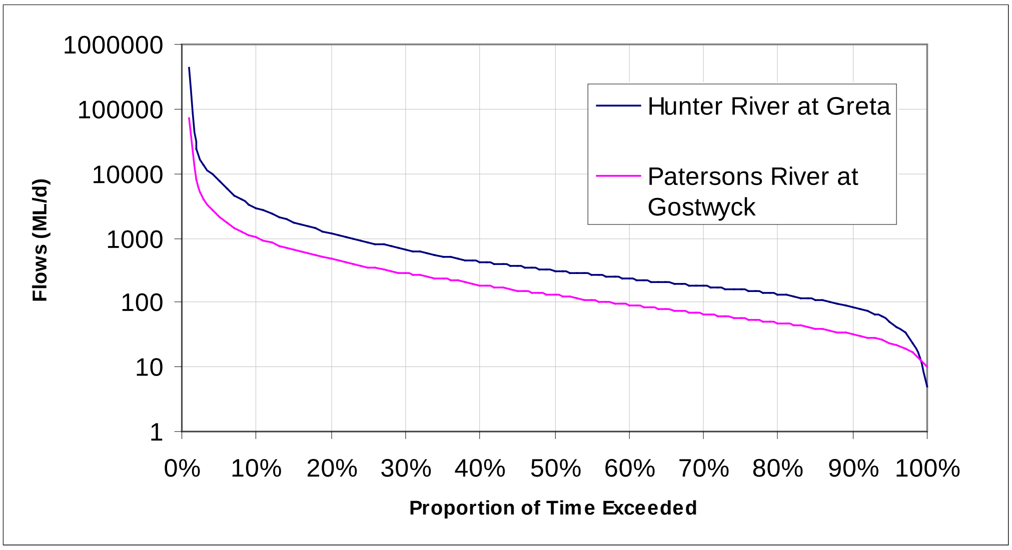


Figure 3-1
Flow durations in the Hunter River at Greta (site 210064, upstream of the Barrington Tops Tributaries) and in the Patersons River at Gostwyck (site 210079) 1978-2009 (raw timeseries flow data from DNR, 2009)

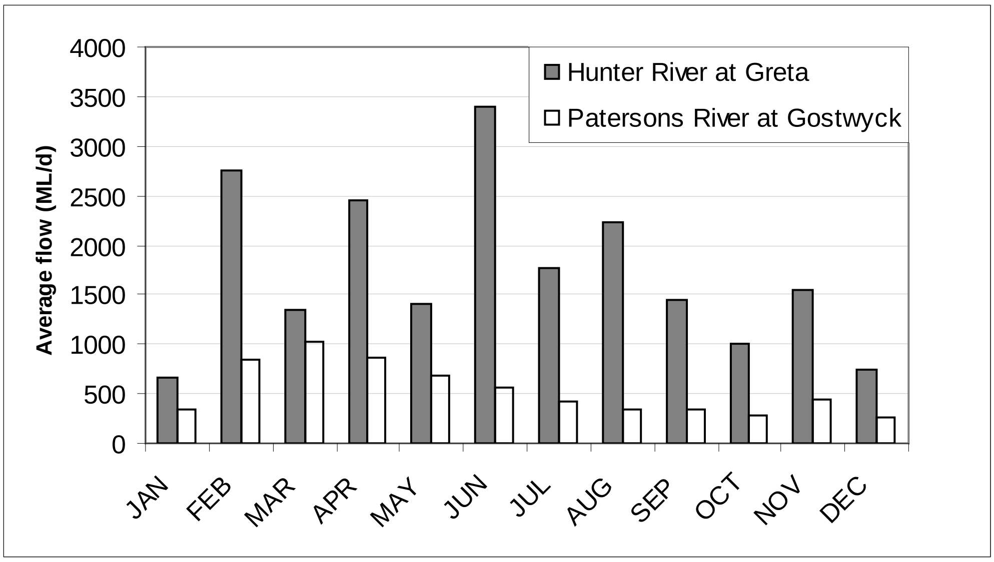


Figure 3-2
Average monthly flows from 1978 to 2009 in the Hunter River at Greta (site 210064, upstream of the Barrington Tops Tributaries) and in the Patersons River at Gostwyck (site 210079) (raw timeseries flow data from DNR, 2009)

3.1.2.2 Flooding

The Hunter River periodically experiences large floods. The largest floods are caused by large tropical depressions descending from Australia's north, and rainfall from these storms can fall catchment-wide (MHL 2003). Peak discharges during the two largest floods in the Hunter Valley (1893 and 1955) have been estimated to exceed 7000 cubic metres per second. The 1955 flood was caused by a storm that dumped an average of 270 millimetres of rain across the entire catchment in only three days, and resulted in widespread destruction of a large number of flood control structures and loss of life (MHL 2003). The 1955 flood (a 1in 200 year event) resulted in an estimated 2.1 million megalitres to discharge into the estuary over three days (compared with an annual average discharge of 1 800 000 ML). Smaller flood events are more common and have occurred in the Lower Hunter in 1971, 1972, 1977, 1978, 1985 and 1989 (Patterson, Britton & Partners 1996a cited in MHL 2003). These are likely to be the result of deep low pressure systems resulting in south-easterly airstream and heavy coastal rains which can cause these floods in the Lower Hunter River (MHL 2003). Large flood events such as these can dramatically alter the ratio of freshwater to salt water in the estuary for a short period of time.

The 1955 flood resulted in the state government establishing the *Hunter River Valley Flood Mitigation Act 1956* and the subsequent implementation of flood control structures including river diversions, levee banks, flood gates and dredging across the Hunter River Valley prior to the time of listing (MHL 2003). The scheme was designed to maintain the natural flood sequence along the floodplain, but to better protect people and property from the impacts of floods (MHL 2003). The flood mitigation works have constrained the natural river course which has resulted in an increase in flow downstream. This has resulted in a decrease in floodplain, wetland and shore habitats which was occurring at the time of listing (MHL 2003). Levees and floodgates were also restricting the natural interplay between fresh and saline water at the time of listing.

3.1.2.3 Tidal water movement

The Hunter Estuary exhibits a typical ebb dominated semidiurnal tidal cycle with two high and two low tides per day (Howe 2005). The tidal range (between High Water Solstice Springs – Indian Spring Low Water) at Stockton Bridge is 1.918 metres (MHL 2003). The tidal limit in the Hunter River occurs approximately 64 kilometres from the ocean (MHL 2003). Data from a mangrove and saltmarsh monitoring program indicated that the mangroves were inundated by approximately 43% of tides per the year and saltmarsh zones by 6% of tides per year.

The majority of the tidal flows (80%) in the Hunter River occur through the North Arm (MHL 2003). The Hunter Estuary has tidal flows characteristic of a riverine estuary system with maximum tidal flows generally recorded during the two hours after high tide and minimum tidal flows (slack water) recorded within one hour after high or low tide (MHL 2003). The annual tidal inflow and outflow for the Hunter Estuary has been estimated to be 18 250 gigalitres (MHL 2003).

Most of the creeks and waterways draining into the Hunter Estuary area have a tidal component, although the movements of tides up them may be constrained by structures such as bridges, culverts and flood gates. In 1990, there were a total of 84 structures on creeks and drains within the Kooragang component of the Hunter Estuary Wetland including those in the Fullerton Cove/Stockton area and on Kooragang Island. Comprised of 28 bridges, 46 culverts and 10 flood gates, most of these were in place at the time of listing (Williams et al. 2000).

3.1.2.4 Estuary water balance

The water fluxes at the Kooragang component of the Hunter Estuary Wetland have been divided into the following five processes to conceptualise water flows into and out of the site:

1. Inflows from the Hunter River
2. Direct rainfall over the estuary
3. Direct evapotranspiration from the estuary
4. Groundwater flows into and out of the estuary
5. Tidal water movement

These processes have been quantified for the Hunter Estuary (MHL 2003), and a schematic is presented in Figure 3-3.

The majority of water movement into and out of the estuary is due to tidal water movement. The contribution of groundwater is based on extrapolations, and consequently, is somewhat uncertain. Annual ground water inflows have been estimated to be 183 gigalitres (MHL 2003). Direct rainfall and evapotranspiration are at least an order of magnitude smaller than the other fluxes, which led MHL (2003) to conclude that these fluxes were “negligible”.

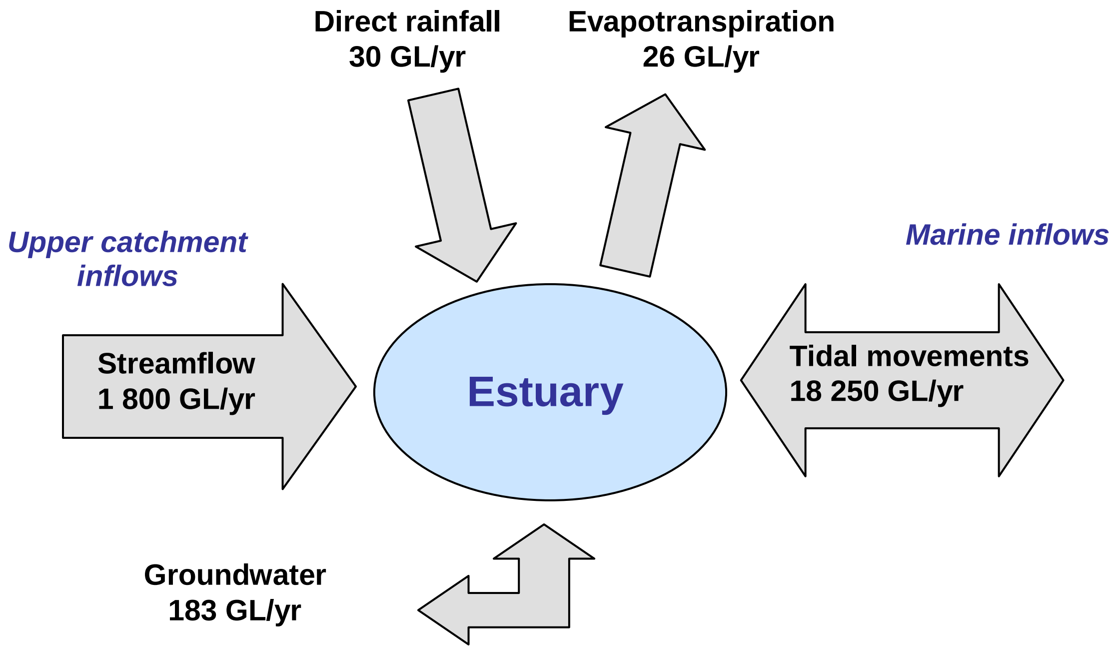


Figure 3-3
Schematic of water fluxes into the Hunter Estuary (Quantities taken from MHL 2003)

3.1.3 Water quality

Water quality data from 1979 reported in the “Investigation of the Natural Areas: Kooragang Island, Hunter River” by Moss (1983) was used in the assessment of water quality at the time of listing of the Hunter Estuary Wetland. This was the most readily available data set nearest to the time of listing. The water quality parameters that were measured in this study included salinity, dissolved oxygen, turbidity, nutrients, heavy metals and phytoplankton. Information was only available from three sampling events during one year and is therefore not wholly representative of the range of variability expected at the time of listing. Samples were taken in February and April 1979 during dry weather conditions and following wet weather in May (215 millimetres of rain fell in Paterson during the previous week).

Sampling stations designated by the State Pollution Control Commission (SPCC) are used in all subsequent data charts and shown in Figure 3-4.

Potential impacts on the Ramsar wetland from catchment influences could be evaluated from water quality data taken from sites in the Upper Estuary, although these are not shown in Figure 3-4.

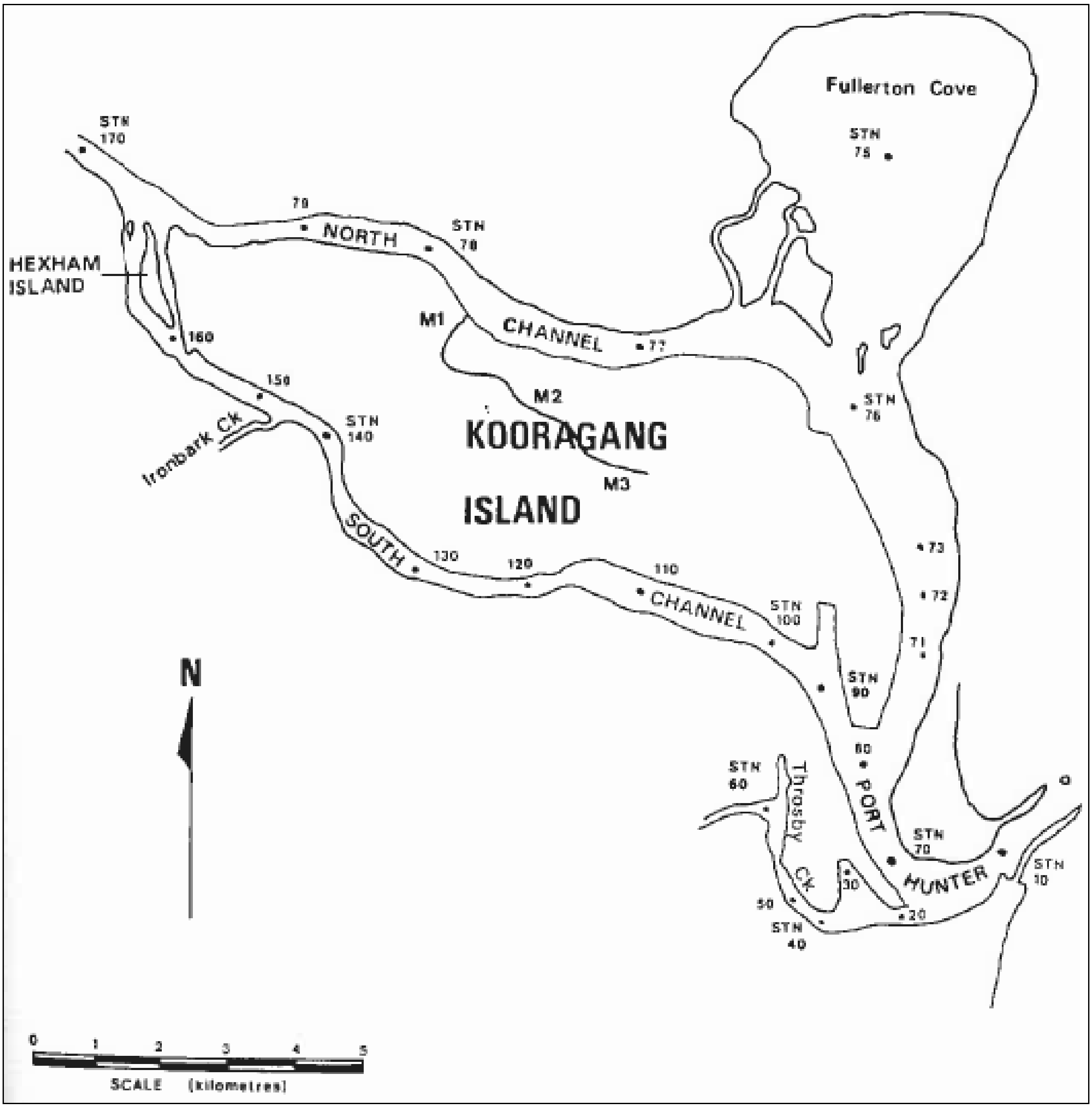


Figure 3-4
SPCC water quality sampling stations – Lower Hunter Estuary (SPCC 1979)

3.1.3.1 Salinity

Figure 3-5 shows salinity in the Hunter Estuary taken during three different sampling events in 1979. Large influxes of freshwater into the estuary cause great variability in salinity, which after rain has a very significant effect, causing vertical and horizontal stratification in the salinity gradient. The decline in salinity on 15 May 1979 can be attributed to increases in river flows as shown in Figure 3-5. The effect of freshwater input after a heavy rainfall event can be seen by the significant drop in salinity to 1.2 parts per thousand at the surface at Station 78 in the North Channel. This is compared with Stations 76 and 100 which are nearer to the Hunter River mouth (17.4 parts per thousand and 12 parts per thousand, respectively).

Data from 15 May 1979 was after a significant wet weather event. Source: SPCC (1979).

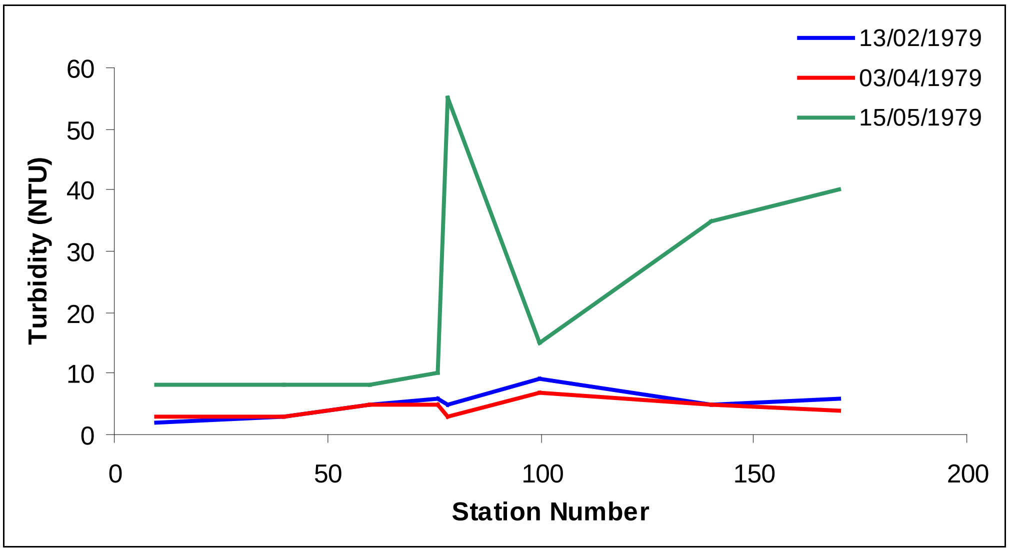
Figure 3-5
Salinity in the Lower Hunter Estuary during three samplings taken in 1979

3.1.3.2 Dissolved oxygen

The Hunter Estuary is generally well oxygenated and well mixed as a result of shallow water and high winds. Between 1973 and 1976/77, dissolved oxygen levels were near saturation in the entire Hunter Estuary from Nobbys Head to Morpeth. Data recorded in 1979 found the same conditions. Generally, dissolved oxygen concentrations were in excess of 90% saturation with a few anomalies recorded under wet weather conditions. Results suggest that typically, oxygen levels fell within accepted ranges. Strong tidal movement is known to play an important role in maintaining high oxygen levels in the lower estuary.

3.1.3.3 Turbidity

Around the time of listing, turbidity was moderate in the Hunter Estuary. As a wave-dominated estuary, there was generally a high sediment trapping efficiency with naturally low turbidity. Under normal conditions when the estuary was not in flood or recovery mode, turbidity was minimal in the lower estuary with measurements of less than 5 Nephelometric Turbidity Units (NTU). Turbidity in the estuary increased rapidly going inland from the river mouth and after rain events in the entire river system. This was due to the increase in suspended solids, especially clay particles brought in by catchment runoff. This was clearly indicated by the wet weather values recorded on 15 May 1979 in Figure 3-6 where turbidity levels reached 55 NTU at Station 78 in the North Channel. The high turbidity which affects light penetration was generally regarded as a major factor accounting for the absence of sea grasses in the Hunter Estuary (Cheng 1983). It is also a factor limiting phytoplankton productivity in the estuary.

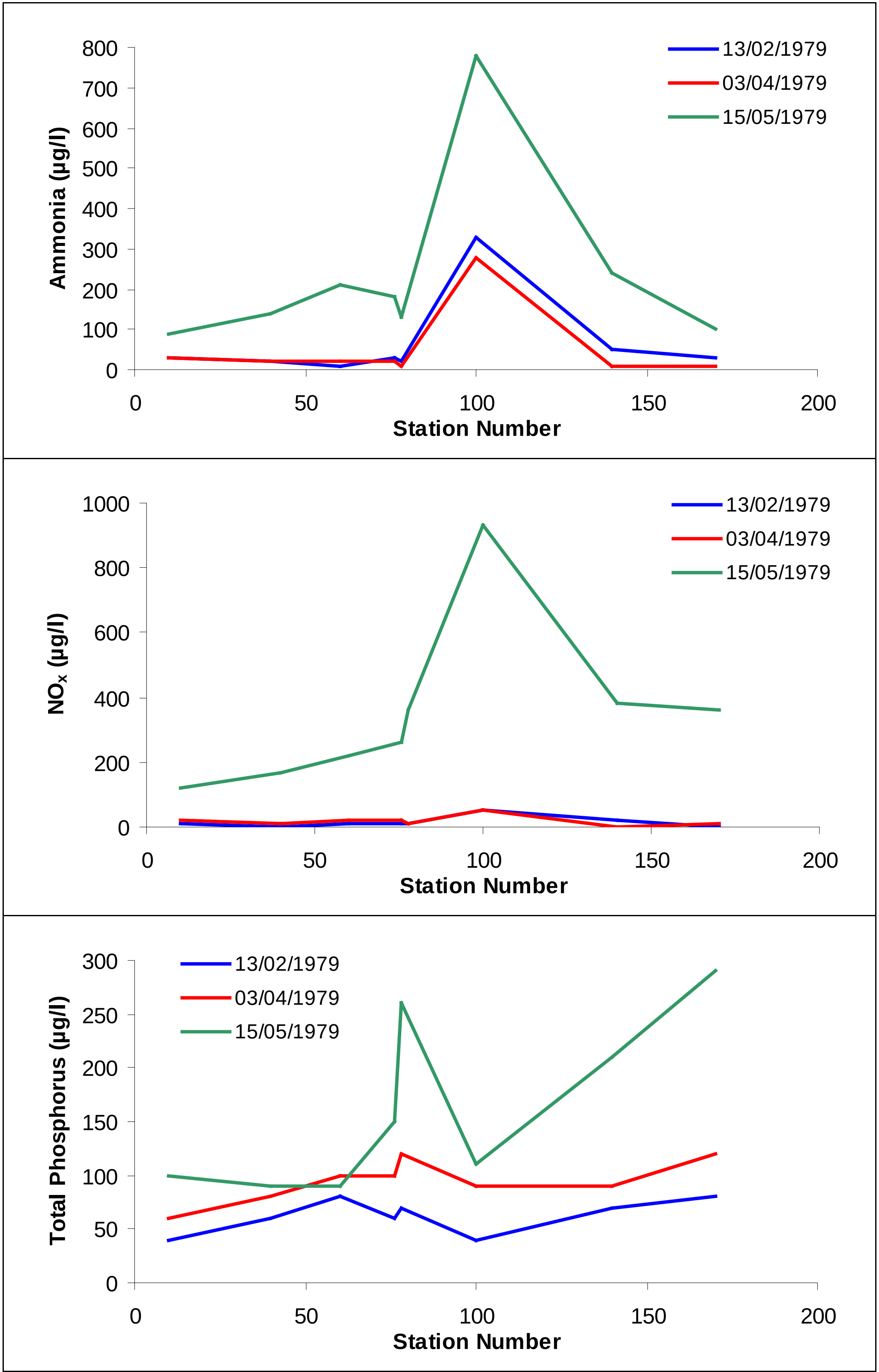


NB. Data from 15 May 1979 was after a significant wet weather event. Source: SPCC (1979)

Figure 3-6
Turbidity levels in the Lower Hunter Estuary during three samplings taken in 1979

3.1.3.4 Nutrients

A survey carried out by SPCC in 1979 showed that with the exception of stations in the South Channel which recorded mean ammonia levels of 168 micrograms per litre during dry weather conditions, total nitrogen loads in the river at the time of listing were low. Ammonia levels were consistently high in the South Channel, indicating point sources (Station Number 100 in Figure 3-7) and likely eutrophication issues at the time of listing. Total nitrogen levels were low compared to the organic matter present, indicating that much of the organic matter was derived from chemical and industrial sources (Cheng 1983). Mean total phosphorus levels in the estuary below Hexham Island were 75 micrograms per litre during dry conditions (February and April 1979) and 144 micrograms per litre following heavy rain (May 1979) which exceeds the recommended maximum level of 30 micrograms per litre for estuaries in South-east Australia (ANZECC 2000). Both nitrogen and phosphorus concentrations were known to increase markedly after heavy rain, highlighting the significance of catchment runoff as a source of nutrients for the estuary. This is shown clearly in Figure 3-7 where ammonia levels peaked at 780 micrograms per litre and oxidised nitrogen at 930 micrograms per litre at Station Number 100 in the South Channel on 15 May 1979. A total phosphorus concentration of up to 290 micrograms per litre was recorded at Station Number 170, north of Hexham Island on the same day.



NB. Data from 15 May 1979 was after a significant wet weather event. Source: SPCC (1979)

Figure 3-7
Ammonia, oxidised nitrogen and total phosphorus levels in the Lower Hunter Estuary during three samplings taken in 1979

3.1.3.5 Heavy metals

Pollution of the Hunter River from toxic substances is largely confined to the South Arm and Throsby Creek where heavy industries discharge acids, phenols, ammonia, cyanide and metals (Cheng 1983). South Arm and Throsby Creek are outside of the Hunter Estuary Wetlands Ramsar site. Throsby Creek joins the Hunter River near the river mouth, 4.5 kilometres south of the Hunter Estuary Wetlands Ramsar Site. There were markedly elevated levels of copper, chromium, zinc and iron found in the South Arm and Throsby Creek in a survey undertaken in 1977 (Cheng 1983). Data showed that the South Channel was contaminated with metals, especially zinc, lead and iron and the metals were concentrated in the top 25 to 35 centimetres of the sediments. Organic content was also high in the sediments and was largely derived from industrial, rather than natural sources.

3.1.3.6 Acid sulfate soils

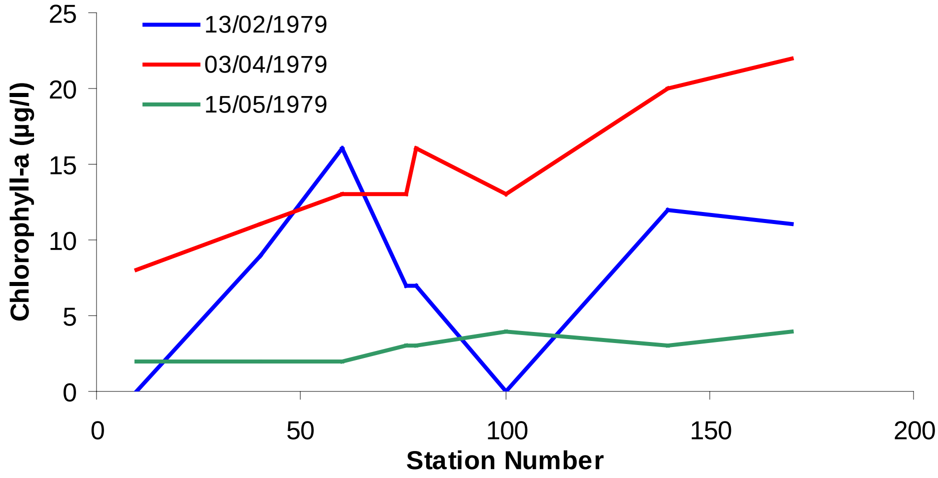
At the time of listing in 1984, acid sulfate soils had not been investigated in the Hunter Estuary. These soil layers have the potential to generate sulfuric acid when the iron sulphide material is exposed to oxygen and cause environmental harm (NSW DPI 2008a). In the lower part of the estuary downstream of Hexham, the urban area of Newcastle dominates on the southern bank. The catchment beyond the immediate foreshore zone is a mixture of urban areas, bushland and industrial activities such as coal mining and quarrying, but in the upper estuary, there is predominantly agricultural land. The Lower Hunter Valley Flood Mitigation Scheme was also passed in 1956 to undertake works designed to prevent or mitigate the flooding or inundation of land within the lower Hunter Valley by water from the river. Works to which the scheme extended included: river bank protection and stabilisation; and river regulation and diversion and dredging, all of which can lead to the oxidation of acid sulfate soils. It is possible that acid sulfate soils may have been a component of the ecosystem at that time. However, as there is no information on these sediments from this time, the discussion of this component is contained in Section 7.3.4.

3.1.3.7 Phytoplankton

The effects of eutrophication from an excess of nutrients leads to excessive growth of phytoplankton and cyclic algal blooms in the estuary. Measurements taken around the time of listing revealed that many of the chlorophyll-a values taken in the Hunter Estuary exceeded 10 micrograms per litre during the drier, warmer periods in February and April (Figure 3-8). The chlorophyll-a data indicated that the estuary supported a significant phytoplankton crop and in the upper section it was moderately eutrophic. The highest value recorded in February

1979 was in Throsby Creek (Station Number 60) which is the location for many heavy industries which are known to discharge nutrients into the water (Cheng 1983). Wet weather values observed on 15 May 1979 were all below 5 micrograms per litre, with a mean value of 3.3 micrograms per litre. During the colder months of the year, increased flow of water, more rapid changes in salinity, colder temperatures and shorter day lengths restrict rapid algal growth and a reduction in phytoplankton crop is expected.

Prior to the time of listing, there was little published information on details of the phytoplankton community of the Hunter Estuary. However, studies were conducted in December 1981 and February 1982 which compared the North Channel and South Channels (SPCC 1983). They found that significant phytoplankton biomass existed in the Hunter Estuary and Moscheto Creek (Cheng 1983). Species composition was found to be typical for an estuary of the mid-east coast of Australia and concluded that phytoplankton was dominated by diatoms and dinoflagellates with a total of 20 taxa. The most important plankton was *Skeletonema costata*, a filamentous diatom which made up 90% of the total cell counts in most samples, with the highest count recorded upstream of Kooragang Island, with a total cell count of 19 300 cells per millilitre. Both South and North Channels had essentially the same phytoplankton flora, and cell counts were also comparable. There was a trend for cell counts to increase progressively going from downstream to upstream stations in both the South and North Channels, which could be explained by a number of processes including a spatial shift from freshwater species upstream to saltwater species downstream, coupled with the effects of dilution in the lower reaches.



NB. Data from 15 May 1979, after a significant wet weather event. Source: SPCC (1979)

Figure 3-8
Chlorophyll-a levels in the Lower Hunter Estuary during three samplings taken in 1979

A conceptual model of the nutrient cycling processes and factors controlling phytoplankton biomass has been derived from previous detailed studies in northern NSW rivers (Eyre 1998) and adapted for the Hunter Estuary for this report (Figure 3-9). The processes and factors controlling phytoplankton biomass in the Hunter Estuary are driven by freshwater discharge and its effects on salinity concentrations, stratification and catchment inputs. Many processes affect the nutrient concentrations in estuarine environments. Nutrient sources, such as river inflows, industrial inputs, stormwater drainage and sewerage inputs, have magnitudes that fluctuate greatly with changing seasons and weather conditions. Biological utilisation and recycling of nutrients is sometimes important, as may be various sedimentary processes.

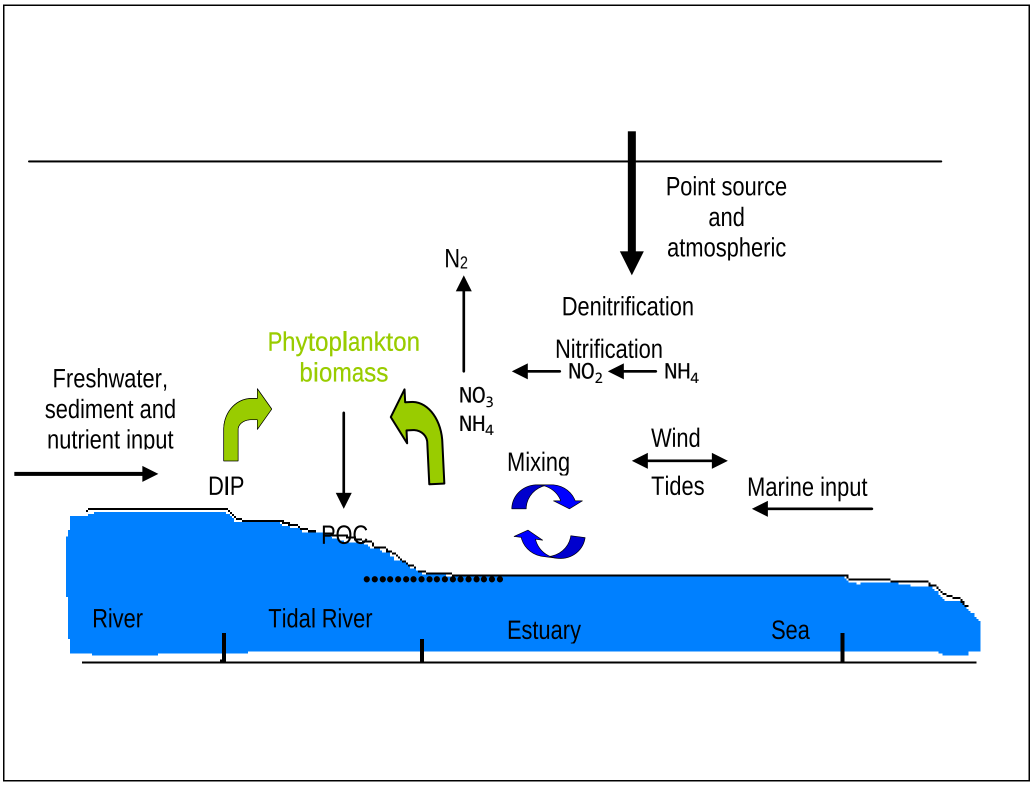


Figure 3-9
Water quality conceptual model for the Hunter Estuary

3.1.3.8 Summary

The available water quality data around the time of listing can provide an adequate picture of the chemical environment in the Hunter Estuary. However, the low sampling frequency means that the magnitude and effects of toxic pollution could not be assessed. Nutrient levels especially phosphorus are relatively high in the estuary which are likely to be driving productivity.

3.1.4 Vegetation

Vegetation types identified within the study area at the time of listing were mapped by Outhred and Buckney (1983) and are shown in Figure 3-10. The vegetation types that characterised the Hunter Estuary at this time included:

Mangrove

Mangrove forests which were dominated by grey mangrove (*Avicennia marina*) with a shrub layer of river mangrove (*Aegiceras corniculatum*) occurring along the margins of tidal channels which are subject to regular tidal flows and was most prevalent around the headwaters of Moscheto Creek. This community formed a low closed to low open forest and had a sparse understorey.

Mangrove forests which were comprised of only grey mangrove were widespread and common in the Kooragang component of the Hunter Estuary Wetland in areas subject to tidal inundation. More stunted and less vigorous mangrove swamps occurred in areas that were less regularly inundated and these areas had occasional saltmarsh plants including bearded glasswort (*Sarcocornia quinqueflora*), Austral seablite (*Suaeda australis*) and saltwater couch (*Sporobolus virginicus*).

Saltmarsh

Saltmarsh dominated by beaded glasswort (*Sarcocornia quinqueflora*) and saltwater couch occurred extensively within the site while sea rush (*Juncus kraussii*) salt marsh was more restricted and occupied areas that are not subject to daily tidal inundation and where salinity was high. The saltmarsh community west of Fullerton Cove was once the largest in the region prior to the time of listing (Moss 1983). Several distinct sub communities were identified by Outhred and Buckney (1983) from within these communities and included:

(a) *Sarcocornia* saltmarsh

- o *Sarcocornia quinqueflora* saltmarsh
- o *Sarcocornia quinqueflora/Suaeda australis* saltmarsh

(b) *Sporobolus* saltmarsh

- o *Sporobolus/Suaeda/Sarcocornia* saltmarsh
- o *Sporobolus/Triglochin/Sarcocornia* saltmarsh

(c) *Juncus* saltmarsh

Brackish swamps

These swamps were dominated by sedges (*Scirpus* spp.) as well as arrowgrass (*Triglochin* spp.) and broad leaved cumbungi (*Typha orientalis*). The largest area of this habitat was found in the south of the study area north of the railway line. Fennel pondweed (*Potamogeton pectinatus*) and manyfruit seatassel (*Ruppia polycarpa*) occurred in the large tidal pools within this habitat.

Casuarina glauca woodland

Patches of this woodland community which is dominated by swamp oak (*Casuarina glauca*) were found in the north of the Ramsar site where it occupied areas that are intermittently flooded after heavy rainfall but still brackish due to the presence of saline groundwater (Keith 2004). These patches are likely to be remnants of a vegetation community that was more widespread in the region which had been cleared and drained for pasture. The swamp paperbark (*Melaleuca ericifolia*) and broad-leaved paperbark (*Melaleuca quinquenervia*) are also found within this community.

There are two disturbance induced vegetation communities within the Ramsar site and although they are not critical to the character of the site they are included because they occupy reasonably large areas within the Kooragang component. These vegetation types are described below.

Saline pasture

This vegetation type was generally found in the west and north of the study area occupying areas that had been modified and drained, and supported a mixture of pasture and saltmarsh species. Beaded glasswort and saltwater couch were common and widespread. In areas where salinity was low enough to allow their establishment, the introduced grasses, blown grass (*Agrostis avenacea*), couchgrass (*Cynodon dactylon*) and buffalo grass *(Stenotaphrum secundum*) were present.

Pasture

This vegetation type was predominantly found in the west and north of the Ramsar site occupying modified and drained areas with low salinity. Typical grasses present were the introduced kikuyu (*Pennisetum clandestinum*), couchgrass, paspalum (*Paspalum dilatatum*), buffalo grass, as well as broadleaf weed species such as spear thistle (*Cirsium vulgare*), blackberry (*Rubus fruticosus*) and boneseed (*Chrysanthemoides monilifera*).

The vegetation mapping by Outhred and Buckney (1983) in some instances mapped mosaics of communities and so determination of exact areas of communities was not possible. However, an estimation of total areas was undertaken by combining similar vegetation types and comparing them with pre and post 1984 mapping (Table 3-1).

Table 3-1
Estimation of areas of vegetation types in the Ramsar site in 1983 (derived from vegetation mapping of Outhred and Buckney 1983)

Vegetation type	Area (ha)
Water	1286
Bareground	39.9
Mangroves	1127.9
Saltmarsh	577.4
Brackish swamp	23.8
Saline pasture and pasture	233.2
Casuarina glauca woodland	3.42
Extension area to nature reserve not mapped in 1983 which contained melaleuca swamp forest and blackbutt dry forest	56.4
Total area	3348.02

The Outhred and Buckney (1983) mapping did not include the northern most part of the Ramsar site which adjoins Cabbage Tree Road. This area included a small six hectare remnant of broad-leaved paperbark (*Melaleuca quinquenervia*) dominated coastal swamp forest and an eight hectare remnant of dry sclerophyll forest on coastal sands which was dominated by blackbutt (*Eucalyptus pilularis*) with tall saw banksia (*Banksia serrata*) in the understorey.

West et. al (1985) in an inventory of estuarine vegetation for NSW recorded 15.3 hectares of seagrass (*Ruppia* spp) for the Hunter River. There is no indication in the report where the *Ruppia* spp. occurred in the river. However, MHL (2003) observed patches of *Ruppia* spp. in the Hunter River, Paterson River in the upper estuary outside of the Ramsar site. *Ruppia* species generally inhabit brackish waters like those found in the upper estuary and would be excluded from the saline waters of the lower estuary and the Kooragang component of the Hunter Estuary Wetlands Ramsar site. There are no records of other seagrass species which inhabit saline waters in the Ramsar site at the time of listing (West et al. 1985).

3.1.4.1 Wetland succession

At the time of listing there is evidence that successional changes were happening in the estuary, particularly the expansion of mangroves and a subsequent decline in saltmarsh. This was reported in Moss (1983) and continues to happen, according to Williams et al. (2000). A number of factors have been proposed to have caused the changes in the extent of the two main estuarine wetland types (mangrove forest and saltmarsh). They include an increase in flood frequency, drainage works within and adjacent to the Ramsar site, altered tidal regimes and a change in sediment deposition caused by the installation of flood mitigation structures, dams and weirs on the Hunter River and its tributaries.

Erskine (1981) suggested that there has been an increase in flood frequency in the Hunter Valley over the past 50 years because of changes to the seasonal pattern and total rainfall in eastern Australia, namely an increase in summer rainfall as well as a smaller increase in winter rainfall (Tucker 1975, Cornish 1977). This may have caused a lowering of salinity in the estuary which has favoured the expansion of mangroves into areas that were previously hypersaline, resulting in a loss of saltmarsh.

A ring drain was built around Fullerton Cove in 1976 which is likely to have resulted in the drying of the saltmarshes. The drying of the saltmarsh combined with an increase in fresh water runoff resulted in a decline in salinity and allowed the colonisation of salt tolerant grasses and the subsequent transition of saltmarsh to saline pasture. This change in vegetation was occurring at the time of listing as evidenced by the mapping of these vegetation types by Outhred and Buckney (1983).

An increase in the tidal range within the Hunter Estuary caused by dredging and deepening of channels, construction of levees and construction of floodgates both prior to and after the time of listing has been implicated in mangrove expansion (Herbert 2007b, Howe 2005). An increase in tidal range increases the degree and frequency of tidal inundation which can reduce the hypersalinity of saltmarsh environments and allow the colonisation of mangroves (Herbert 2007b).

Monitoring of sediment accretion and surface elevation of mangrove and saltmarsh habitats in the study area by Rogers and Saintilan (2004) also suggested that there is a relationship between the increase in saltmarsh surface elevation and the rate of mangrove incursion. They describe the following two processes that affect mangrove/saltmarsh distribution and which are related to changes in tidal inundation:

- Increased frequency of inundation leading to sediment accretion in saltmarshes causes increased surface elevation (and subsequent decreased frequency of inundation and increased salinity) and allows saltmarsh expansion (Rogers and Saintilan 2009)
- Reduced frequency of inundation of saltmarsh lowers the rates of sediment build up which combined with subsidence because of below ground processes (e.g. compaction, ground water volume changes, biomass changes), can lead to increased inundation frequency (due to lowering of the saltmarsh) resulting in a decline in salinity which favours mangrove expansion (Rogers and Saintilan 2009).

Rogers and Saintilan (2004) found that salt marshes within the Ramsar site are subsiding at a rate greater than is being replenished by sediment accretion while build up of sediments is occurring at a higher rate in mangrove areas which leads to an increase in mangroves, both to the landward and seaward direction. Much of mangrove progradation is also related to the pattern of sedimentation which has occurred in low energy areas such as Fullerton Cove (See Section 3.1.1).

Significant flora species

No nationally listed species were known from the site at the time of listing. There is a record of the eyebright *Euphrasia arguta* which is listed as extinct under the EPBC Act from within the Ramsar site (NSW Wildlife Atlas) however it has a poor accuracy (10 000 metre) and was recorded in 1886. It is considered unlikely that this species occurs within the study area.

Zannichellia palustris (horned pondweed) which is listed as endangered on the TSC Act has been recorded from the western part of the Kooragang component of the Hunter Estuary Wetland and may still occur on the site.

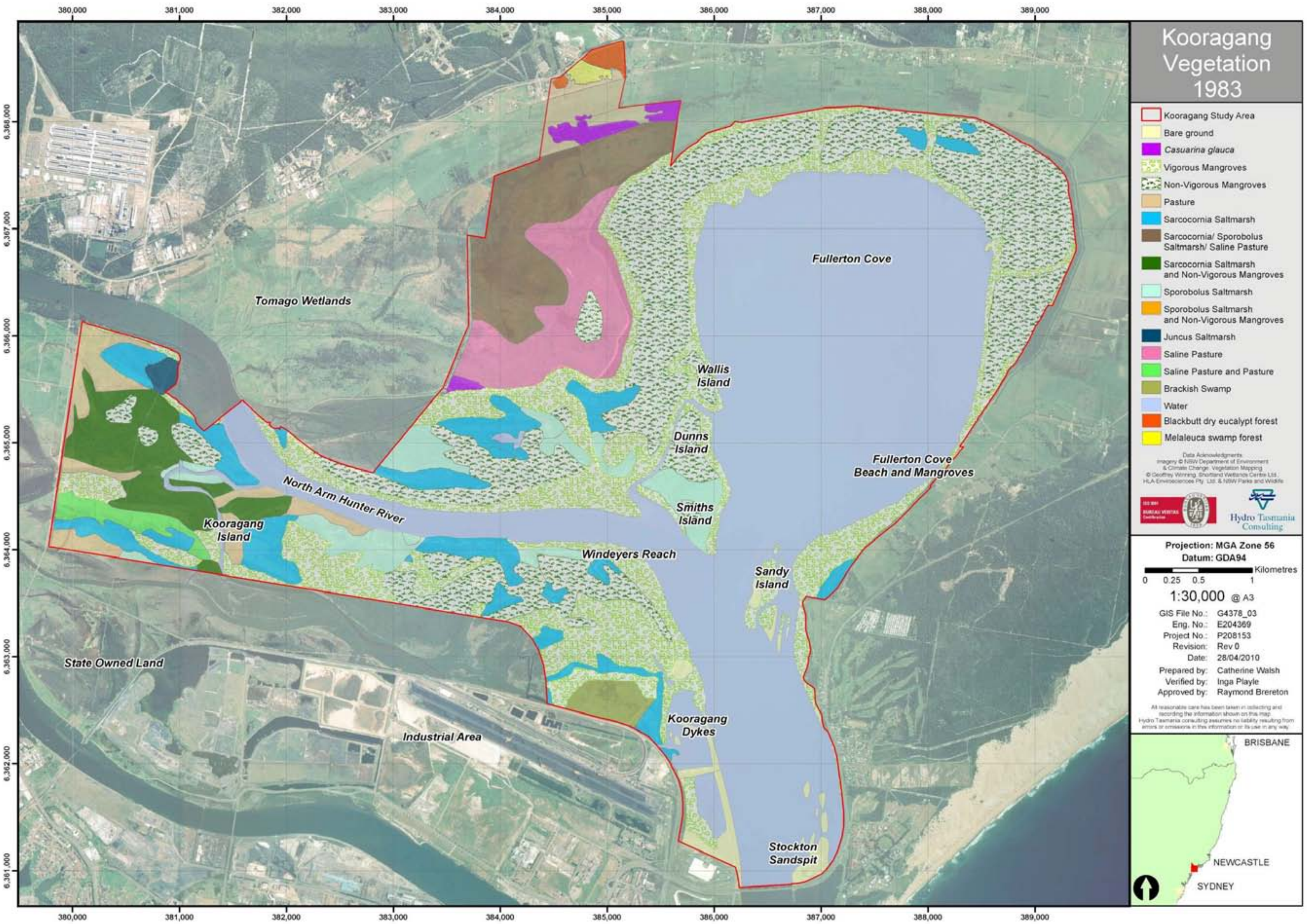


Figure 3-10: Vegetation map of the Kooragang component of the Hunter Estuary Wetlands at the time of listing (1984)

3.1.5 Birds

The abundance and diversity of wetland birds are two of the main factors for the Hunter Estuary Wetlands meeting the criteria for listing as a Wetland of International Importance (see Section 2.7). A full list of bird species recorded at the site, including common and scientific names, is provided in Appendix B. At the time of listing in 1984 a total of 100 species of waterbirds had been recorded from the Kooragang component of the Hunter Estuary Wetlands (See Appendix B). Thirty-seven of these waterbird species are listed as migratory under the EPBC Act, 29 of which are Palaearctic waders. The existing Hunter Estuary Wetlands RIS indicates that 15 species of migratory shorebirds were regularly recorded within the Ramsar site at the time of listing. However, a review of the distribution, abundance and status of birds in the Hunter Estuary by Herbert (2007a) identified 17 species of migratory shorebirds which were regularly recorded within the Hunter Estuary Wetlands during the spring, summer and autumn months (Herbert 2007a). A review of annual migratory shorebird data for the period 1970-1989 identified an annual median maximum of 18 species (Herbert 2011, unpublished data) The extra (18^{th}) species is the common sandpiper, which have been recorded in low numbers in the Ramsar site around the time of listing, however, Herbert (2007a) considers them to be an uncommon summer migrant.

Close to the time of listing in 1986, a maximum of 6800 migratory waders were recorded within the Hunter Estuary Wetlands (Herbert 2007a). The variation in abundance for the period 1970 to 1989 was approximately 10,000 migratory shorebirds in 1970 and 5000 migratory shorebirds in 1989 (Herbert 2007a).

Table 3-2
Migratory shorebirds regularly recorded within the Hunter Estuary in 1984, from Herbert (2007a)

Common name	Scientific name
Black-tailed godwit	*Limosa limosa*
Bar-tailed godwit	*Limosa lapponica*
Whimbrel	*Numenius phaeopus*
Eastern curlew	*Numenius madagascariensis*
Marsh sandpiper	*Tringa stagnatilis*
Common greenshank	*Tringa nebularia*
Terek sandpiper	*Actitis hypoleucos*
Grey-tailed tattler	*Heteroscelus brevipes*
Ruddy turnstone	*Arenaria interpres*
Great knot	*Calidris tenuirostris*
Red knot	*Calidris canutus*
Red-necked stint	*Calidris ruficollis*
Sharp-tailed sandpiper	*Calidris acuminata*

Common name	Scientific name
Curlew sandpiper	*Calidris ferruginea*
Pacific golden plover	*Pluvialis fulva*
Lesser sand plover	*Charadrius mongolus*
Broad-billed sandpiper	*Limicola falcinellus*

The site supported significant numbers of wader species at the time of listing, including 900 eastern curlews which were recorded within the Hunter Estuary in the summer of 1984 (Herbert 2007a). This was over 2% of the East Asian-Australasian Flyway population for this species. The 1% population threshold for this species is 380 individuals (Bamford et al. 2008).

In the spring of 1984, over 1000 red knot (0.5% of the flyway population) were recorded in the estuary (Herbert 2007a). The Hunter Estuary is used as a staging area by red knots. Large numbers arrive in September and feed in the estuary for a short time before most birds move south to Victoria by October (Herbert 2007a). The 1% threshold for this species is 2200 (Bamford et al. 2008).

Bar-tailed godwits have also been recorded in large numbers with maximum counts of 3500 recorded in 1983 and 4000 in 1985 and 1986 (Herbert 2007a). At the time of listing in 1984 a maximum count of 1800 bar-tailed godwits was recorded in the estuary (Herbert 2007a). However, since the time of listing the maximum counts of bar-tailed godwits have declined. Between 1999/2000 and 2006/07 maximum summer counts have been between 1000 and 2000 birds (Herbert 2007a). The 1% population threshold for the bar-tailed godwit is 3250 (Bamford et al. 2008).

The Hunter Estuary Wetlands are also important for other waterbirds, including non-migratory shorebirds (e.g. red-necked avocet, black-winged stilt), ducks (e.g. chestnut teal), grebes, pelicans, cormorants, darters, herons, ibis, egrets, spoonbills, crakes, rails, water hens, coots, gulls and terns.

Black-winged stilts are a breeding resident species and were common and abundant in the estuary at the time of listing with over 1000 birds recorded in 1984 (Herbert 2007a). The estuary is also an important site for chestnut and grey teal, with a mixed flock of over 1300 teal recorded foraging in Fullerton Cove in autumn 2002 (Herbert 2007a). Both species are breeding residents within the Hunter Estuary.

Overall twenty species of waterbirds have been recorded breeding in the Kooragang component (see Appendix B). Breeding waterbirds include ducks, crakes, moorhens, swamphens, coot, masked lapwings, red-capped plover and black fronted dotterel. Breeding habitat for these waterbird species is mostly associated with freshwater swamps with open water and dense vegetation. Freshwater habitats are limited in the Kooragang component. Most of the swamps are brackish (e.g. Juncus Swamp). The Kooragang component provides mainly foraging and roosting habitat for waterbirds.

The estuary is also important for threatened waterbird species including the Australasian bittern, which is listed as endangered on both the EPBC Act and the IUCN red list. The Australasian bittern has been recorded within the Kooragang component of the Hunter Estuary Wetland. There were five Australasian bitterns observed in 1974 in the Juncus Swamp from within the Ramsar site on Kooragang Island (Figure 3-10, Herbert 2007a). There are more recent records after the time of listing in 2000, 2007, 2008 and 2009 from *Sarcocornia* and *Sporobolus* saltmarsh and saline pasture (Figure 3-10) from within the site adjacent to Tomago Wetlands. Herbert (2007a) considered the Australasian bittern to be a breeding resident in the Hunter Estuary because it has been recorded in all months and there are extensive areas of suitable wetland habitat available, namely freshwater or brackish wetlands with a dense cover of *Phragmites, Juncus* or *Typha* species.

The little tern (*Sterna albifrons*) formerly occurred in significant numbers within the Hunter Estuary, 600 were recorded in the late 1970s (Gosper 1981) and were recorded breeding during the 1970s (Herbert 2007a). The little tern is listed as threatened on the TSC Act and migratory under the EPBC Act. By the time of listing of the Hunter Estuary Wetlands Ramsar site, little terns had begun to decline. Little terns still forage in the estuary and are generally observed in groups of one to five birds (Herbert 2007a).

The Hunter Estuary is also home to wetland birds other than waterbirds including the raptors, the white-bellied sea-eagle, swamp harrier, and the wetland passerines, the mangrove gerygone, tawny grassbird, little grassbird, Australian reed warbler and golden-headed cisticola. The white-bellied sea-eagle is one of the most commonly observed birds of prey in the estuary, where they occur over all wetland habitats. The mangrove gerygone is restricted to mangrove habitats, whereas the grassbirds, reed warbler and cisticola occur in dense grassland and sedgeland habitats (e.g. *Phragmites* and *Typha* swamps).

3.1.5.1 Bird habitats

At the time of listing, a habitat classification scheme was prepared for Kooragang Island which included the Kooragang component of the Hunter Estuary Wetland (Moss 1983). The habitat classifications which included mangroves, saltmarsh, brackish swamps, saline pastures, pasture, tidal mudflats and open water also included a description of the bird assemblages that used them. These habitats and their bird assemblages are described below. Other important foraging and roosting habitats for shorebirds within the Kooragang component of the Hunter Estuary Wetlands have also been included in the habitat descriptions, such as Stockton Sandspit and Kooragang Dykes. The importance of these habitats for birds is summarised in Table 3-3 (e.g. whether they are used for foraging, breeding or roosting).

Mangroves. Two mangrove communities have been mapped based on vegetation and habitat descriptions in Outhred and Buckney (1983), (see section 3.1.4 and Figure 3-10). One is a vigorous mangrove community with an open tree layer of *Avicennia marina* (grey mangrove). The other is a mangrove forest lacking vigour (Outhred and Buckney1983) which is characterised by large trees of *Avicennia marina* growing amongst stunted mangroves with occasional occurrences of saltmarsh plants, *Sarcocornia quinqueflora* and *Suaeda australis*. There are extensive mangrove forests surrounding Fullerton Cove, fringing the North Arm of the Hunter River and on Kooragang Island (Figure 3-10).

The mangrove community supports a large number of bird species; up to 40 species have been recorded including two species which are restricted to mangroves and adjacent wetlands, mangrove gerygone and the striated heron (Moss 1983). The mangrove gerygone feeds throughout the mangrove forests but appears to breed only in *Aegiceras* scrub (Moss 1983). The striated heron is a shy, elusive species that is uncommon in the Hunter Estuary, where it feeds along the creeks in the dense mangroves (Clarke and Van Gessel 1983). Clarke and Van Gessel (1983) recorded it as breeding in vigorous mangrove forests in the Hunter Estuary.

The tall mangrove trees within the vigorous forest provide nest sites for 12 bird species, including the great egret, intermediate egret and white-faced heron; and roost sites for other birds including four species of Palaearctic waders (Moss 1983). The whimbrel, common sandpiper, grey-tailed tattler and Terek sandpiper have been regularly recorded roosting in mangroves.

Table 3-3
Habitats and their importance for birds

Habitat	Importance for birds
Mangroves	Foraging, roosting, breeding
Saltmarsh	Foraging, roosting
Brackish swamp	Foraging, breeding
Intertidal mudflats	Foraging
Open water	Foraging
Swamp oak woodland	Foraging, breeding
Saline pasture and pasture	Foraging, breeding
Stockton Sandspit	Foraging, roosting, breeding
Kooragang Dykes	Foraging, roosting

Saltmarsh. *Sarcocornia* dominated saltmarsh occurs on the western shore of Fullerton Cove and the northern edge of Kooragang Island (Figure 3-10). Moss (1983) stated that *Sarcocornia* dominated saltmarsh is one of the most important habitats for migratory and non-migratory waders which use this habitat for feeding and roosting. Waders forage in the inundated saltmarsh for invertebrates in the mud (infauna). The *Sarcocornia* saltmarsh provides important secondary feeding areas, after the tidal mudflats, for the sharp-tailed sandpiper, Pacific golden plover, Lathams snipe, greenshank, marsh sandpiper and wood sandpiper (Moss 1983).

The areas of *Sarcocornia* saltmarsh used as roosts are open with shallow salt scalds, ponds and sandspits. However, prior to listing in 1984, areas of shallow water in *Sarcocornia* saltmarsh in the west of Fullerton Cove had been the main night roost site (Tomago Wetlands). However, the installation of floodgates and construction of a ring drain prior to the time of Ramsar listing had resulted in the drying of these saltmarshes and the subsequent loss of this habitat for roosting waders. They had become, at the time of listing in 1984, a mosaic of saline pasture, *Sarcocornia* saltmarsh and *Sporobolus* saltmarsh and had been abandoned by shorebirds (Clarke and Van Gessel 1983), (Figure 3-10). The most used saltmarsh roost sites at the time of listing were in *Sarcocornia* saltmarsh, to the east of the mouth of Moscheto Creek on the northern edge of Kooragang Island (known as Windeyers Reach Nocturnal Roost, Herbert 2007a) and the Stockton Sandspit, to the north of Stockton Bridge on the east side of the river (Clarke and Van Gessel 1983).

Sporobolus saltmarsh which is dominated by *Sporobolus virginicus* also occurs on site. Other salt tolerant plants commonly present in this community include *Suaeda australis, Sarcocornia quinqueflora* and *Triglochin striata* (Moss 1983). This habitat occurs around Fullerton Cove and on Kooragang Island. This habitat is generally unsuitable for waders because of the low inundation and dense cover of vegetation, although it is used for feeding by the grey-tailed tattler (Moss 1983). However, when the drier areas are inundated or there are more open areas of this habitat with associated shallow water, for example in some parts of Fullerton Cove, they are used for feeding by egrets and ibis and as roosting sites for waders (Moss 1983).

The other saltmarsh habitat on site is *Juncus* saltmarsh which is characterised by a dense cover of *Juncus kraussii* with *Sporobolus virginicus* also likely to be present (Outhred and Buckney 1983). This habitat is restricted within the Ramsar site to the western end of Kooragang Island (Figure 3-10). The dense vegetation cover is used by wetland-dependent passerines such as the Australian reed-warbler, little grass-bird, tawny grassbird and golden-headed cisticola for feeding and breeding (Moss 1983).

Brackish swamps. Brackish swamps are dominated by the sedges *Scirpus fluviatilis* and *Scirpus littoralis* (Outhred and Buckney 1983). The largest occurrence of this habitat was in the Juncus Swamp, adjacent to the railway line at the eastern end of Kooragang Island, although there are smaller ephemeral areas of brackish swamps at the western end of Kooragang Island within the Ramsar site.

In 1983, Juncus Swamp was considered the most important bird habitat on Kooragang Island with 19 species of birds breeding in the swamp and others feeding and roosting (Moss 1983). Ducks (chestnut teal, grey teal, pacific black duck) and the clamorous reed warbler, little grass-bird, tawny grassbird and golden headed cisticola have been recorded breeding in Juncus Swamp (Moss 1983). Five Australasian bitterns were observed in Juncus Swamp in 1974 (Herbert 2007a) prior to listing and it was considered prime breeding and foraging habitat for this species at the time of listing. Brackish swamps also provide feeding and breeding habitat for crakes and rails.

Intertidal mudflats. The intertidal mudflats of Fullerton Cove, fringing the north-eastern end of Kooragang Island and the east bank of the North Arm of the Hunter River (Fern Bay, North Arm Sandflats) upstream of Stockton Bridge are the major feeding areas for migratory and non-migratory shorebirds (Moss 1983). At low tide, shorebirds forage over the mudflats feeding on invertebrates in the mud and sand substrates (infauna). Each species has a particular foraging behaviour, which is influenced by the length of the beak (how deep into the substrate they can forage) and leg length (determines the depth of the water they can forage in). Consequently, the intertidal mudflats can support large numbers of various migratory and non-migratory shorebirds including bar-tailed godwit, black-tailed godwit, whimbrel, eastern curlew, great knot, red knot, Terek sandpiper, curlew sandpiper, common greenshank, marsh sandpiper, pacific golden plover and double-banded plover, black-winged stilt, pied oystercatcher, masked lapwing and great egret (Herbert 2007a).

Open water. The open water of the North Arm of the Hunter River and Fullerton Cove provides habitat for waterbird species which feed and rest in deeper waters including cormorants, terns and pelicans which feed on fish; and ducks (e.g. chestnut teal, grey a teal). Herbert (2007a) reported that 1 325 chestnut teal and grey teal had been observed foraging in the north-west corner of Fullerton Cove.

Swamp oak woodland. There are patches of swamp oak woodland north of Fullerton Cove in the Tomago Wetlands. This habitat is not significant for waterbirds and is used by common terrestrial bird species including willie wagtail, Australian magpie, grey shrike-thrush, grey butcher bird and Australian raven.

The remaining habitats are human induced through the clearing and draining of the original native vegetation, and include pasture and saline pasture. There were also two man made structures within the estuary which were important sites for shorebirds and waterbirds at the time of listing, the Stockton Sandspit and Kooragang Dykes.

Saline pasture and pasture. Saline pasture is characterised by a mixed cover of saltmarsh plants and introduced pasture grasses. This habitat occurs in the drained areas to the west of Fullerton Cove (Figure 3-10). Saline pasture grades into pasture, which occurs in areas of low salinity that are not tidally inundated. Pasture within the Ramsar site occurs mainly in the western end of Kooragang Island (Figure 3-10).

The saline pasture and pasture habitats are too dry for waders and most wetland birds although they are used by ibis and herons, brown quail and masked lapwing for feeding (Moss 1983). There are also terrestrial bird species that use these habitats including Richards's pipit, brown songlark, and singing bushlark.

Stockton Sandspit. Stockton Sandspit is located to the north of Stockton Bridge at its eastern end (Figure 2-1). It was created during the late 1960s from dredge spoil to support the abutments of Stockton Bridge (Herbert 2007a). It was mapped as bare ground in at the time of Ramsar listing (see Figure 3-10). It was identified at the time of listing as an important migratory shorebird daytime roost site (Clarke and Van Gessel 1983).

Kooragang Dykes. The Kooragang Dykes is a 1.5 kilometre long series of rock retaining walls built at the eastern end of Kooragang Island to reclaim land for industrial use (Figure 2-1). The dykes are mapped as bare ground in the vegetation map (see Figure 3-10). The dykes were built in the 1960s, but the land reclamation project did not proceed beyond the construction of the rock walls (Herbert 2007a). The dykes were continuous when first constructed but over time the rock walls have been breached allowing tidal flow into the flats behind them and mangroves have begun to grow on the dykes (Herbert 2007a).

The dykes are an important high tide roost for shorebirds and the intertidal flats and ponds they enclose also provide significant foraging habitat (Herbert 2007a). At times, during the summer months between1999 and 2007, over 5 000 shorebirds have been recorded roosting on the dykes at high tide, including bar-tailed godwit, eastern curlew, red knot, curlew sandpiper, Pacific golden plover and red-necked avocet (Herbert 2007a).

There is also important shorebird foraging and roosting habitat adjacent to the Kooragang component of the Hunter Estuary Wetland outside of the Ramsar site, including Ash Island which has similar saltmarsh, saline pasture, pasture and mangrove habitats.

3.1.5.2 Variability

Herbert (2007a) indicates that 17 species of migratory shorebirds regularly visited the Hunter Estuary Wetlands Ramsar site between 1970 and 1990, the years around the time of listing in 1984. There is limited available data to assess the variability in the migratory shorebird abundance around the time of listing. However, data presented in Herbert (2007a) for the period 1970 to 1989 has been used to assess natural variability in the abundance of migratory shorebirds for the time of Ramsar listing. Within this period maximum shorebird counts ranged between a high of approximately 10 000 in 1970 and a low of approximately 5000 in 1988 (Herbert 2007a). The range of variation in maximum shorebird numbers between counts is considered to represent natural variability. There is no data to suggest that there were any major events in the estuary at the time of these counts that may have affected wader numbers. However, migratory shorebirds are exposed to factors outside the site at their breeding grounds and on their migration routes which may affect the abundance at the site.

There was sufficient data to assess the variability in the abundance of some individual shorebird species. For example, there was available data in Herbert (2007a) for the eastern curlew for 18 separate years in a 27 year period around the time of listing, between 1970 and 1997. Fourteen years before listing a maximum count of 600 eastern curlews was recorded in 1970 and thirteen years after listing in 1997 a maximum count of 900 eastern curlews was recorded (Herbert 2007a, Figure 3-12). The lowest recorded maximum count of eastern curlews was 200 in 1973. There were other low maximum counts of around 300 birds in 1971, 1989, and 1991 (Herbert 2007a). Herbert (pers. comm. 2011) suggests that these lower counts are a result of survey method and underestimate the population in the estuary at that time. The highest recorded maximum count was 1000 birds in 1975 and 1996.

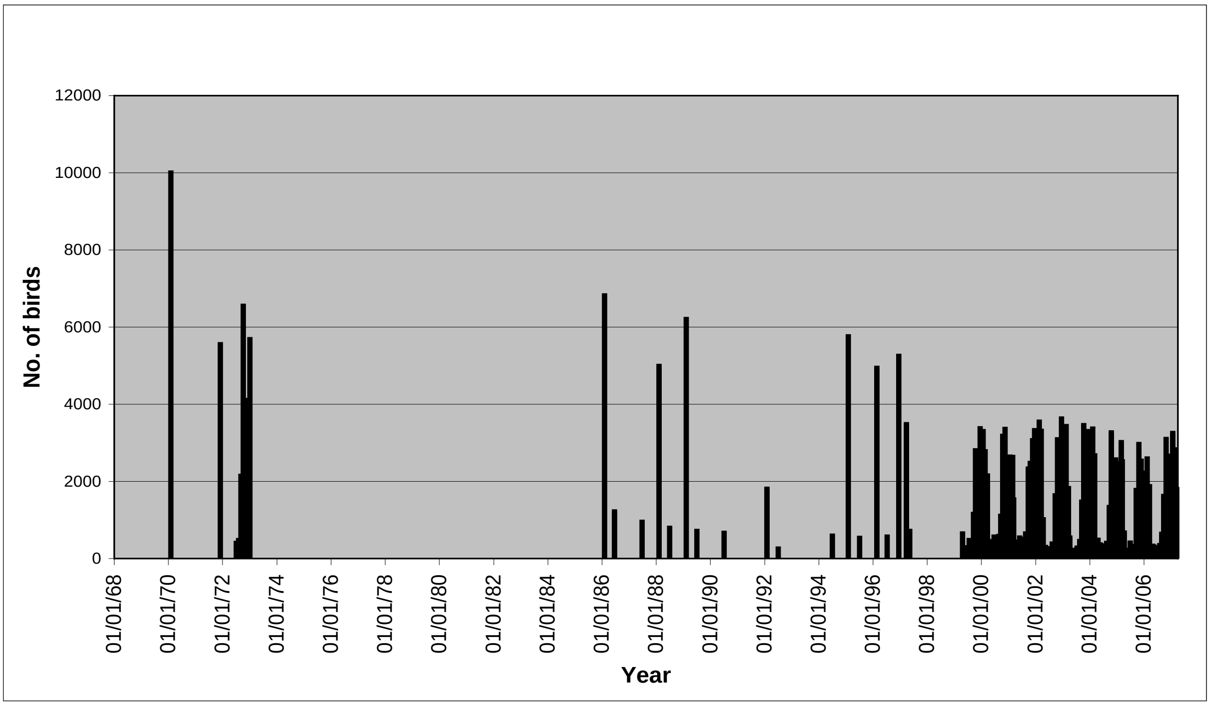


Figure 3-11

Total migratory shorebirds recorded in the Hunter Estuary between 1970 and 2007 (from Herbert 2007a).

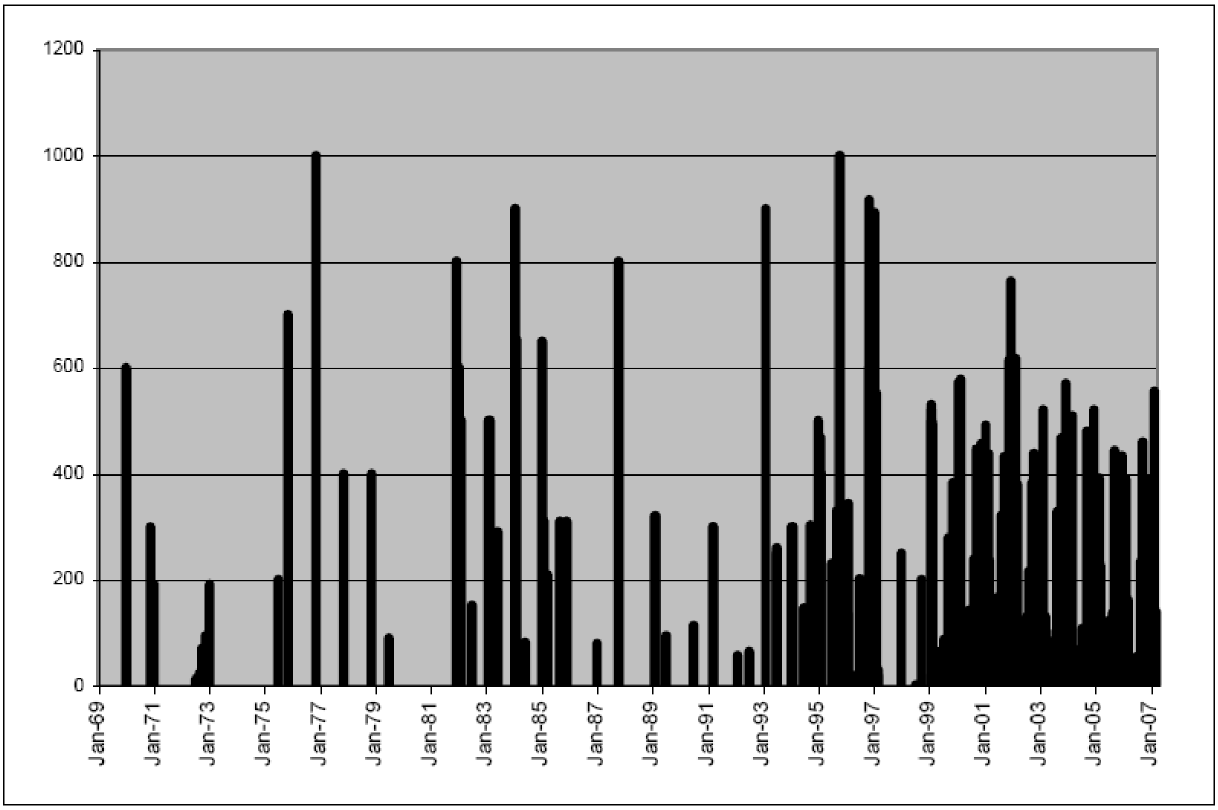


Figure 3-12
Abundance of eastern curlews within the Hunter Estuary, 1999 to 2007 (Herbert 2007a)

3.1.6 Frogs

Seven species of frogs are currently known from the Kooragang component of the Hunter Estuary Wetlands (Table 3-4) and these were most likely present at the time of listing in 1984. There is limited suitable habitat for the frogs within the Ramsar site and it is predominantly restricted to freshwater and brackish wetlands in an area of pasture in the south western corner of the Ramsar site and the Juncus Swamp at the eastern end of Kooragang Island (Table 3-4).

The frog fauna of the study area includes the green and golden bell frog (*Litoria aurea*) which is listed as Vulnerable under the EPBC Act. The green and golden bell frog was first reported on Kooragang Island in 1971 when Gosper (1974) reported extraordinary breeding concentrations of bell frogs had attracted large feeding assemblages of ibis, herons and egrets. There are no further observations reported until 1996 when the green and golden bell frog was recorded during fauna surveys carried out for a proposed coal loader development (Hamer *et. al* 2002). Subsequent studies have identified breeding populations of this species in the south western corner of the Ramsar site on Kooragang Island (Hamer *et. al* 2002). Hamer (1997) also recorded green and golden bell frogs in the Juncus Swamp at the eastern end of Kooragang Island. There are no population estimates for the green and golden bell frog at the time of listing. However, out of the 21 water bodies on Kooragang Island that were inhabited by green and golden bell frogs, only three occur within the Kooragang component of the Hunter Estuary Wetland (Hamer *et. al* 2002). Thus, the population of green and golden bell frogs within the Ramsar site was probably not large because of the limited suitable habitat.

The remaining six species of frogs are restricted to the same wetland habitats within the Kooragang component as the green and golden bell frog. There is little available information about them regarding population size and breeding status at the time of listing but their presence indicates that they were likely to be breeding residents.

Table 3-4
Frogs[4] recorded from the Kooragang component of the Hunter Estuary Wetland

Common name	Scientific name	EPBC Act
Hylidae		
Green and golden bell frog	*Litoria aurea*	Vulnerable
Green tree trog	*Litoria caerulea*	
Eastern dwarf tree frog	*Litoria fallax*	
Peron's tree frog	*Litoria peronii*	
Myobatrachidae		
Common froglet	*Crinia signifera*	
Striped marsh frog	*Limnodynastes peronii*	
Spotted marsh frog	*Limnodynastes tasmaniensis*	

3.1.7 Fish

The fish community of Kooragang Wetland was not assessed as part of the initial Ramsar listing and only one study pre-dating the time of listing has been published, Ruello (1976). Based on ten years of data collection, Ruello (1976) identified 59 fish species from the Hunter Estuary including the estuary stingray (*Dasyatis fluviorum*) which is listed Vulnerable on the IUCN Red List (Version 2009.1) (Appendix D). Ruello (1976) considered the fish community in the estuary to be depauperate when compared to communities from other temperate zone estuaries in Eastern Australia.

Ruello (1976) reported that the fish community in the Hunter Estuary was highly impacted prior to listing, with significant pollution from industries on Kooragang Island. The estuary was heavily polluted with highly turbid, low oxygen water discoloured by industrial effluent (Ruello 1976). At least one fish kill was caused by the discharge of acid effluent from Kooragang Island (Ruello 1976). Chronic pollution sources included sewerage output, arsenic, cyanide and zinc from industrial processes and wood pulp and sugars

[4] List derived from Hamer (2007) and data held by the Kooragang Rehabilitation Project (P. Svoboda pers. comm.)

from timber processing (Ruello 1976). The estuary had also been significantly modified though dredging, land reclamation and harbour works, resulting in a significant loss of fish habitat (Ruello 1976). Despite this poor condition, a diminished commercial fishery remained (Ruello 1976). At least 21 commercial or recreational fish species were known prior to the time of listing (Ruello 1976).

Two introduced fish species were recorded from the Hunter Estuary around the time of listing, eastern gambusia (*Gambusia holbrooki*) and the yellowfin goby (*Acanthogobius flavimanus*) (Ruello 1976, Copeland 1993).

The Hunter Estuary, including Kooragang Island, provides fish habitats across a range of salinities, ranging from sea water to fresh, although brackish water habitats dominate. Eight species of small, native freshwater fish were present in tributaries, moving further into the estuary on freshwater plumes during high flow events. Similarly, several obligate marine species have been recorded in the estuary, particularly during extended periods of low flow and subsequent increased salinity. The majority of fish species (63%) found in the estuary are euryhaline, capable of surviving across a wide range of salinities, including species with both freshwater and marine life-stages.

Euryhaline fish are generally obligate estuary inhabitants for at least part of their life-cycle, and are thus indicative of the long term condition and ecosystem function of the Hunter Estuary, including the Kooragang Wetlands component.

Fish populations in the Hunter Estuary are influenced by a range of processes, predominantly the availability of suitable food, habitat and water quality. An important part of estuarine food webs, fish predator-prey dynamics help to regulate populations of birds and aquatic invertebrates, as well as influencing estuarine vegetation communities.

The key processes maintaining fish populations in the Hunter Estuary are reproduction and migration. Mangrove swamps and estuarine wetlands, like those found in Kooragang Wetlands, are spawning and nursery habitats for a number of fish species, including fishery species. It is probable that Kooragang Wetlands provided key habitats for fish reproduction for the fish community of Hunter Estuary at the time of listing, however there is insufficient available data to verify this. The quality and extent of these reproductive habitats, in combination with water quality and food availability, limit the amount of successful fish reproduction within the estuary.

Catadromus fish species such as the short-fin eel (*Anguilla australis*), long-fin eel (*Anguilla reinhardtii*), and the anodromous species, the Australian bass (*Macquaria novemaculeata*) have been recorded in the estuary before and after the time of listing indicating they were present at time of listing (Ruello 1976; Copeland 1993). The presence of these species which migrate between fresh and marine waters to complete their lifecycles indicates that they likely migrate through the estuary at some point in their life cycles. The open waters of the Kooragang component provide barrier-free movement between marine, estuarine and upstream freshwater environments in the Hunter River and other streams that enter the estuary. However, at the time of listing there were many barriers to upstream movement including weirs, flood gates and concrete culverts on the Hunter River and streams flowing into the estuary which are likely to have impeded these species attempts to complete their lifecycle (Williams et al. 2000).

3.1.7.1 Physical processes

A natural tidal regime is essential to support diverse and abundant fish communities in the wetland. Tidal inundation provides access to wetland areas, as well as refreshing and maintaining water quality, replenishing dissolved oxygen, regulating water temperature and removing wastes. Tidal activity balances with freshwater inflows to maintain the availability of habitats and conditions to support fish populations, including the estuary's salinity regime. Climate change, including changes in the timing and extent of rainfall events, and water extraction can alter the tidal balance of the estuary. The presence of flood gates in the Hunter Estuary currently modifies the natural tidal regime, reducing the amount of suitable fish habitat available (Ruello 1976).

Channel morphology also impacts on fish communities, with channel depth and hydraulic forces limiting the area of fish habitat. Prior to the time of listing, dredging and channel deepening in the Hunter Estuary is thought to have caused significant reductions in fish habitat in parts of the Hunter Estuary, including channel works around Kooragang Island (Ruello 1976).

3.1.7.2 Variability

There is a paucity of quantitative information about fish populations, associations and habitats within the Ramsar site at the time of listing. A review of the available published data has identified a total of 99 fish species (listed in Appendix D) that have been recorded in the Hunter Estuary in studies between 1976 and 2005 (Ruello 1976; Copeland 1993; Shepherd 1994; Williams et al. 1995; Gibbs et al. 1999; The Ecology Lab 2006). However, this number may be an over-estimation due to taxonomic changes and inaccuracies in identification. At least 30 of these species have been considered commercial or recreational fishing species during this period. There is no reliable information available on the abundances of these species, although fish numbers do appear to fluctuate greatly, with large variations between studies in the species of fish caught (Appendix D). This variation is also likely to reflect the variation in sampling methods used by each of the studies.

3.1.8 Invertebrates

At the time of listing in 1984 the Kooragang component of the Hunter Estuary Wetland supported a range of habitats. These were predominantly aquatic habitats including saline, brackish and limited areas of freshwater; and terrestrial habitats which supported a range of invertebrate communities. An intensive survey of Kooragang Island invertebrate habitats by the NSW Department of Environment and Planning (Moss 1983) was conducted for insects, snails and crabs. Spiders and insects were sampled from vegetation foliage. Of the adult insects found, numerous taxa where identified that have an aquatic larval stage. Therefore, it is likely that insects are common and diverse in the immediate aquatic environment.

The southern sentinel crab (*Macrophthalmus latifrons*) has been recorded on Kooragang Island and may be a new species for NSW; previously it was only known from Victoria (Harris 1994).

Kooragang Island has also been shown to have a diverse community of 29 non-marine snails, from saltmarsh, brackish, freshwater and terrestrial habitats, with at least 13 being aquatic (Shea 1999). Hutchins (1983) suggests that the molluscan fauna becomes richer within the saltmarsh zone, with two species being particularly common, and attribute this to the change in vegetation structure and associated habitat. Hutchins (1983) also found that the epifauna that encrust the mangrove roots was limited to a single group, the barnacles. The low diversity of epifauna was attributed to the extreme hydrological and salinity regimes within the mangrove forests (Hutchins 1983).

The major groups of aquatic invertebrates within the Hunter Estuary including the Kooragang component that had been recorded after the time of listing but were likely to be present at the time of listing include prawns, oysters and benthic invertebrates (crustaceans, isopods, amphipods and copepods, crabs, marine snails and marine worms such as polychaetes) (MHL 2003). Of the pelagic invertebrate fauna, copepods are dominant, however, a shift from estuarine to freshwater invertebrates occurs when salinity drops to between approximately 10 and 0 parts per million (Genders 2001).

The benthos in and around the mangrove forests on Kooragang Island also supported aquatic invertebrates such as crabs, marine snails, marine worms, and crustaceans (Clarke and Miller 1983; The Ecology Lab 2001). Mangroves also provide a source of vegetative material used as a food source by many taxa including prawns (Ruello 1976). Rocky reefs and artificial structures such as the Kooragang Dykes provide habitat for oysters, barnacles, sea squirts and crabs; however, detailed presence and abundance surveys had not been conducted on these habitats at the time of listing (The Ecology Lab 2001).

The studies conducted by Hutchins (1983) and Hodda and Nicholas (1985) provide information on benthic infauna that occurred along transects from the lower intertidal mudflat margins, through the mangrove forest and saltmarsh upper intertidal margins in Fullerton Cove. Hutchins (1983) found that 26 species represent the infauna of Fullerton Cove; however, five species were most abundant within the community (three polychaetes, one bivalve mollusc and one amphipod). In contrast, Hodda and Nicholas (1985) found that nematode worms and copepod crustaceans represented 90% of the individuals sampled. It is unclear why these two studies provide such different results, but it may be attributed to the sampling methods. These two studies show that there are a variety of size classes within the infauna community. This is further supported by the Hodda and Nicholas (1985) survey which also sampled a number of polychaete and oligochaete worm taxa, a single mite and larval insects from the Dipteran families Ceratopogonidae and Tipulidae.

These two studies provide little evidence of spatial distribution of taxa of benthic infauna; however, there is some evidence of gradients in species along the transects (Hodda and Nicholas 1985). These studies demonstrate that the infauna of Fullerton Cove within the Kooragang component of the Hunter Estuary Wetlands Ramsar site is typical of south-east Australian estuarine infauna and also characteristic of intertidal meiofauna worldwide at higher taxonomic resolutions.

Although the available data suggests that the invertebrate fauna did not contribute significantly to the unique character of the Hunter Estuary Wetland Ramsar site at the time of listing, they do provide an important food resource for the bird assemblages within the site, particularly the infauna. The infauna (e.g. polychaete worms, molluscs and copepods) in the intertidal mudflats and saltmarshes are the main food resource for the large number of migratory and non-migratory shorebirds that occur within the Kooragang component (e.g. Fullerton Cove, Kooragang Island).

The Hunter Estuary supported a prawn fishery at the time of listing. The school prawn (*Metapenaeus macleayi*) comprised most of the catch. The other prawn that was also caught was the eastern king prawn (*Pennaeus plebejus*). In 1977/78 the prawn catch from the Hunter River was 22 803 kilograms (Montgomery and Winstanley 1982). There was also a small crab fishery for blue swimmer crab (*Portunus pelagicus*) and mud crab (*Scylla serrata*) in the estuary (Ruello 1976).

School prawns have a life cycle which includes both estuarine and oceanic waters. The adults spawn in nearshore ocean waters between February and May and after a larval stage of two to three weeks the juvenile prawns move into the estuary (NSW DPI 2008c). School prawns prefer soft muddy substrates and can be found well upstream in brackish water to freshwater (NSW DPI 2008c). They also move into mangrove forests when the forests are inundated by high tides to shelter and feed on small invertebrates and detritus.

3.1.9 Other fauna

Two species of native terrestrial mammals have been recorded on Kooragang Island, the brush-tailed possum (*Trichosurus vulpecula*) and the eastern grey kangaroo (*Macropus giganteus*)[5]. Ten species of bats have been recorded on Kooragang Island which are likely to forage over the Ramsar site (Table 3-5). Eight of these species roost in tree hollows. There is potential roosting habitat for bats within the blackbutt dry forest remnant on the northern edge of the Ramsar site (Figure 3-10) which contains large trees with potential hollows. The two species of bent-wing bat, the little bent-wing bat (*Miniopterus australis*) and the large bent-wing bat (*Miniopterus schreibersii oceanensis*), roost in caves. Although they may forage for flying insects over the site, there are no roost sites within the Hunter Estuary Wetland Ramsar site for these species.

Three species of reptiles have been recorded from Kooragang Island, the eastern water dragon (*Physignathus lesueurii* ssp. *lesueurii*), red-bellied black snake (*Pseudechis porphyriacus*) and the green tree snake (*Dendrelaphis punctulata*). These reptiles are widespread across eastern Australia in a range of habitats, particularly where there is water present including streams, rivers, lakes and wetlands.

Table 3-5
Bat species recorded on Kooragang Island[6]

Common name	Scientific name	Conservation Status
White-striped mastiff bat	*Tadarida australis*	
Little freetail bat	*Mormopterus sp. 2*	
Gould's wattled bat	*Chalinolobus gouldii*	
Chocolate wattled bat	*Chalinolobus morio*	
Little bent-wing bat	*Miniopterus australis*	Vulnerable NSW TSC Act
Large bent-wing bat	*Miniopterus schreibersii oceanensis*	Vulnerable NSW TSC Act
Fishing bat	*Myotis adversus*	
Gould's long-eared bat	*Nyctophilus gouldi*	
Eastern broad-nosed bat	*Scotorepens orion*	
Little forest bat	*Vespadelus vulturnus*	

[5] http://www.hcr.cma.nsw.gov.au/kooragang/9_MiscellaneousFaunaAshIsland.pdf accessed 28 April 2010
[6] http://www.hcr.cma.nsw.gov.au/kooragang/7_BatsKooragangIsland.pdf accessed 28 April 2010

3.1.10 Critical components and ecosystem processes

This section describes what are considered to be the critical components and processes for the Kooragang component of the Hunter Estuary Wetland at the time of listing in 1984.

These components have been chosen because they determine, or strongly influence the ecological character of the site. They have been assessed as critical because:

- they are important determinants of the site's unique character;
- they are important for supporting the Ramsar criteria under which the site was listed;
- change is reasonably likely to occur over the short, medium or long term (<100 years); and
- if change occurs to them, they will cause significant negative consequences to the ecological character of the site.

Of the components and processes described previously, the critical components, sub-components and processes have been determined to be:

- waterbirds, particularly migratory shorebirds;
- the green and golden bell frog (*Litoria aurea*), a nationally listed threatened species;
- *Sarcocornia* saltmarsh which supports migratory shorebirds;
- intertidal mudflats which provide foraging habitat for migratory shorebirds; and
- hydrology (tidal regime and freshwater inflows) which is a major influence on the distribution and extent of saltmarsh and mangroves.

3.1.10.1 Migratory shorebirds

The Kooragang component of the Hunter Estuary Wetland is an important site for migratory shorebirds which are present for up to eight months of the year between September and April. Around the time of listing 6800 migratory shorebirds were recorded in the Hunter Estuary (Herbert 2007a). At this time the site regularly supported 17 species of migratory shorebirds (Herbert 2007a). The presence of these migratory shorebirds is one of the main reasons the site was listed as a Wetland of International Importance; it supports wetland migratory shorebirds at a critical stage of their life cycle. The Hunter Estuary Wetland provides foraging and roosting habitat for populations of migratory shorebirds during their non-breeding season (Ramsar Criterion 4).

The site also supports significant numbers of non-migratory shorebirds such as the red-necked avocet, black-winged stilt, red-capped plover, black-fronted dotterel, red-kneed dotterel, masked lapwing, pied oystercatcher, sooty oystercatcher and 5 species of terns (Herbert 2007a). It is also important for individual shorebird species. For example, it supports more than 1% of the East Asian-Australasian Flyway population of eastern curlew (Ramsar Criterion 6). There is evidence that migratory shorebirds have declined significantly in numbers (Figure 7-7) and diversity over the last 40 years which is likely to be ongoing and may result in the site no longer being an important site for migratory shorebirds leading to a change to the ecological character of the site.

3.1.10.2 Green and golden bell frog

There are breeding populations of the green and golden bell frog in the south western corner of the Ramsar site on Kooragang Island and in the Juncus Swamp at the eastern end of the island. The green and golden bell frog is listed under the EPBC Act as Vulnerable (Ramsar Criterion 2). The chytrid fungus which can severely impact frog populations has been introduced to Kooragang Island since the time of listing and has affected the distribution and abundance of the green and golden bell frog on the island. There is some evidence that the green and golden bell frogs are persisting in the brackish wetlands within the Hunter Estuary Wetland Ramsar site because the chytrid fungus is inhibited in brackish conditions (Stockwell et al. 2008). If the salinity within the brackish wetlands changes so that they become fresher, then there is the potential for the green and golden bell frog populations to be affected resulting in the loss of the populations at the site.

3.1.10.3 Sarcocornia saltmarsh

Sarcocornia saltmarsh has been identified as one of the most important habitats for migratory and non-migratory shorebirds. The *Sarcocornia* saltmarsh provides important feeding areas for migratory shorebirds after intertidal mudflats. The salt scalds, ponds and sandspits within the saltmarsh also provide important roosting habitat for shorebirds.

Saltmarsh is characteristic of estuaries in south eastern Australia; however they have been declining over the past 40 years, including saltmarsh within the Hunter Estuary Wetland (Saintilan and Williams 2000). The decline has been associated with invasion by mangroves, which is also happening in the Hunter Estuary. The decline in saltmarsh has resulted in the loss of roost sites and foraging habitat for migratory shorebirds.

3.1.10.4 Intertidal mudflats

The intertidal mudflats are the major feeding areas for migratory and non-migratory shorebirds. At low tide shorebirds forage over the flats foraging on invertebrates in the mud and sand substrates (infauna). The mudflats are used by a diversity of shorebirds because different species forage at different depths within the substrate determined by bill length, and at different water depths depending on the length of their legs.

There are anecdotal reports that the mudflats are changing in character. Deposits of fine silts on the mudflats (e.g. at Kooragang Dykes and in Fullerton Cove) has led to a muddier substrate which may be becoming less suitable as foraging habitat for the smaller shorebirds such as curlew sandpiper and lesser sand plover because of their shorter bills not penetrating to where the infauna are located and shorter legs making it more difficult to get around on the mud flats (Ann Lindsay, HBOC, pers. comm.). In addition, the area of mapped open water within the Kooragang component, which includes the intertidal areas, has declined over the last 60 years. This has been attributed in part to the expansion of mangroves leading to a decrease in the area of intertidal mudflat.

3.1.10.5 Hydrology (tidal regime and freshwater inflows)

The hydrological regimes (tidal and freshwater inflows) are the main determinants of the distribution and extent of the vegetation communities within the Hunter Wetland Ramsar site, particularly the saltmarsh and mangrove communities. Changes in tidal inundation can lead to changes in the distribution of saltmarsh and mangroves. An increase in frequency and depth of tidal inundation reduces the salinity of saltmarsh environments and allows the colonisation of mangroves (Herbert 2007b). This process has been implicated in the expansion of mangroves within the site and the consequent loss of saltmarsh.

The freshwater inflows into the site also determine the distribution and extent of vegetation communities. For example a ring drain was built around Fullerton Cove in 1976 which has resulted in the drying of the saltmarshes by draining water away. The drying of the saltmarsh combined with an increase in fresh water runoff has resulted in a decline in salinity resulting in a change in floristic composition. Salt tolerant grasses have colonized the saltmarsh and it has become a saline pasture.

3.2 Ecosystem benefits and services

A summary of the ecosystem benefits and services provided by the Hunter Estuary Wetland Ramsar site is provided in Table 3-6. The ecosystem services are described in greater detail in the following sections.

Table 3-6
Ecosystem benefits and services provided by the Hunter Estuary Wetland

Ecosystem benefit or service	Description
Provisioning services — products obtained from the ecosystem such as food, fuel and fresh water	
Wetland products (fisheries)	The school prawn trawl fishery using otter nets is the major fishery within the Hunter Estuary. Prawn fishing areas in the estuary include the North Arm and deeper areas of Fullerton Cove within the Ramsar site. There is also a commercial fin fishery in the estuary
Cultural services — benefits people obtain through spiritual enrichment, recreation, education and aesthetics	
Recreation and tourism	The Hunter Estuary is an important recreational fishery. The Kooragang component is an important bird watching area, particularly on Stockton Sandspit and Kooragang Dykes. Tourist boats cruise through the Kooragang component watching birds and viewing the estuarine habitats.
Spiritual and inspirational	There are four known Aboriginal sites within the boundaries of the Ramsar site and a further seven are along the site boundary. The local Aboriginal community are likely to consider these sites to be very important, but that would need to be confirmed and information would need to be gathered through community consultation with the Worimi people and possibly the Awabakal people. The spiritual importance of the Kooragang wetland to local Aboriginal people is as yet unknown; however, it has the potential to be great. Aboriginal people may have a variety of special attachments to this place, for example in the form of totemic (or 'kinship') ties. Aboriginal groups in the past would have obtained products from the estuary such as food (plants, animals, birds, fish, shellfish, etc), fuel, fibre, fresh water and indigenous medicines. The value to local Aboriginal groups is likely to be both in the form of ancestral use as well as present day use.
	There are historic sites recorded within the boundary of the Hunter Wetland Ramsar site which are important to the local Newcastle community.

Ecosystem benefit or service	Description
Scientific and educational	The Kooragang component of the Hunter Estuary Wetlands Ramsar site has been used for a range of scientific studies including: long term counts of migratory shorebirds (Herbert 2007a); studies of the interactions between the hydrodynamics, geomorphology and vegetation and the implications for roost availability for migratory shorebirds (Howe 2008); migratory shorebird ecology (Spencer 2010); and the ecology of the green and golden bell frog (Hamer 1998). The Kooragang component of the Hunter Estuary Wetlands site is also an important area for bird watching. Stockton Sandspit is readily accessible to the public and migratory shorebirds can be observed feeding and roosting. The sandspit is an important educational site for the public, particularly regarding the migratory shorebirds that visit the Ramsar site. There is a bird-watching viewing area at Stockton Sandspit with interpretation signs highlighting the natural features of the sandspit including information on the migratory shorebirds.
Supporting services — services necessary for the production of all other ecosystem services such as water cycling, nutrient cycling and habitat for biota. These services will generally have an indirect benefit to humans or a direct benefit over a long period of time	
Food webs	The food web on the intertidal mudflats supports migratory shorebirds, one of the critical components of the Ramsar site. Microbes in the mud decompose detritus and form the basis of the food chain. The microbes, detritus and algae in turn support an abundant infauna comprised predominantly of polychaete and oligochaete worms, bivalve molluscs, and amphipods. When the tide is out and the mudflats are exposed, the infauna are a food source for shorebirds. When the tide returns and the mudflats are covered in water, the infauna provides a source of food for fish which are also food for other waterbirds such as cormorants, pelicans, terns and gulls.
Biodiversity	The Hunter Estuary Wetland Ramsar site has a range of biodiversity values and supports: • A range of estuarine vegetation communities including intertidal sand and mud flats, saltmarsh, and freshwater/brackish wetlands which are important foraging and roosting habitat for migratory birds. • Infauna in intertidal mudflat areas which provide food for migratory waders. • Seventeen species of migratory shorebirds which are regular summer visitors to the Hunter Estuary, and constitutes more than 1% of the threshold for the East Asian-Australasian Flyway population of eastern curlew. • More than 1% of the Australian population of red-necked avocet. • A high diversity of flora and fauna including 112 species of vascular plants (Kooragang Island) and 101 species of waterbirds birds including 38 bird species which are listed as migratory under the EPBC Act.
Threatened wetland species, habitats and ecosystems	The site supports two nationally and two internationally threatened species; the green and golden bell frog is listed as Vulnerable and the Australasian bittern is listed as Endangered under the EPBC Act. The Australasian bittern is also listed as Endangered and the estuarine stingray Vulnerable on the IUCN Red List. Coastal saltmarsh and *Melaleuca* swamp forest (Swamp sclerophyll forest on coastal floodplains) are listed as Endangered Ecological Communities on the NSW TSC Act.

3.2.1 Provisioning services

3.2.1.1 Fisheries

Prawns

At the time of listing in 1984, the school prawn trawl fishery was the principle fishery within the Hunter Estuary (Ruello 1976; MHL 2003) and was one of five estuary prawn fisheries in NSW around the time of listing; the others being the Clarence, Hawkesbury, Port Jackson and Botany Bay. The fishery used otter nets and occurred within the deeper channel of the North Arm and deeper areas of Fullerton Cove within the Hunter Estuary Wetlands Ramsar site. In 1977/78, six years prior to listing, the prawn catch from the Hunter River was 22 803 kilograms (Montgomery and Winstanley 1982). In 1998/99, prawns comprised 99% of the commercial trawl catch, of which 97% was the school prawn, and 2% was eastern king prawn (NSW Fisheries 2002). A small crab fishery for blue swimmer crab (*Portunus pelagicus)* and mud crab *(Scylla serrata*) using traps also existed within Fullerton Cove prior to the time of listing (Ruello 1976).

Fish

The Hunter Estuary provides fish as a food source to local residents and the wider community. The wetland provides spawning, nursery and adult habitat for fish species valued for human consumption.

The estuary supports the tenth-largest commercial fishery in NSW (fish and invertebrates), with approximately 140 000 kilograms of fish harvested per annum (The Ecology Lab 2006). The estuary also provides recreational fishing opportunities. Data from a recreational fishing survey done in early 2000 suggested that recreational fishermen catch around 114 000 fish per annum of which about 60% are kept and the rest are returned to the water (MHL 2003). The major species targeted by commercial fisherman and recreational anglers are listed in Table 3-7. The main commercial fish species in the Hunter Estuary is sea mullet with 140 000 kilograms of fish caught per year (MHL 2003). Other commercial fish species that are caught include eels, fantail mullet, silver biddy and bream (MHL 2003). Most fish are caught using gill nets which are set in Fullerton Cove within the Hunter Estuary Ramsar site (Ruello 1976).

Some fish species recorded from the Hunter Estuary, such as gobies, are popular in the aquarium trade; however no information is currently available on aquarium fish harvesting in NSW, so it is not possible to assess whether fish are collected from the estuary for this purpose.

Table 3-7
Major fishery species of the Hunter Estuary (source: NSW DPI 2008b, The Ecology Lab 2006)

Scientific name	Common name	Commercial	Recreational
Invertebrates			
Metapenaeus macleayi	School prawn	✓	
Penaeus plebejus	Eastern king prawn	✓	
Portunus pelagicus	Blue swimmer crab	✓	
Scylla serrata	Mud crab	✓	
Fish			
Acanthopagrus australis	Yellowfin bream	✓	✓
Anguilla australis	Short-fin eel	✓	
Anguilla reinhardtii	Long-fin eel	✓	
Argyrosomus japonicus	Mulloway		✓
Gerres subfasciatus	Silver biddy	✓	
Girella tricuspidata	Luderick	✓	✓
Liza argentea	Flat-tail mullet		✓
Macquaria colonorum	Estuary perch		✓
Macquaria novemaculeata	Australian bass		✓
Mugil cephalus	Sea mullet	✓	✓
Myxus elongatus	Sand mullet		✓
Paramugil georgii	Fantail mullet		✓
Platycephalus arenarius	Flag-tail flathead		✓
Platycephalus bassensis	Sand flathead		✓
Platycephalus fuscus	Dusky flathead	✓	✓
Pomatomus saltatrix	Tailor		✓
Pseudorhombus arsius	Large-tooth flounder		✓
Pseudorhombus jenynsii	Small-tooth flounder		✓
Rhabdosargus sarba	Tarwhine		✓
Sillago ciliata	Sand whiting	✓	✓
Sillago maculata	Trumpeter whiting		✓

3.2.2 Cultural services

3.2.2.1 Recreation and tourism

Recreation opportunities within Kooragang component of the Hunter Estuary Wetlands are mainly limited to water based activities such as fishing and boating because access to the saltmarsh and mangrove areas on Kooragang Island and west of Fullerton Cove are difficult. The Hunter Estuary is an important recreational fishery with at least 30 000 recreational fishing events recorded in the Hunter region each year (The Ecology Lab 2006). Recreational fish species are listed in Table 3-7. Recreational fishing is more commonly done from boats in the lower estuary, particularly in the North Arm at the mouth of Fullerton Cove, and upstream and downstream of this section of river within the Kooragang component of the Hunter Estuary Wetlands site. Recreational fishing also occurs in the North Arm near Stockton Bridge and in Moscheto Creek on Kooragang Island (MHL 2003). Shore based fishing occurs at Kooragang Island and Stockton Bridge (MHL 2003).

The Kooragang component of the Hunter Estuary Wetlands site is also an important area for bird watching as demonstrated by the Hunter Bird Observers Club regular monthly monitoring of wetland birds at survey sites within the Hunter Estuary including Stockton Sandspit, Kooragang Dykes Fullerton Cove and Kooragang Island (Herbert 2007a).

3.2.2.2 Aboriginal heritage

Aboriginal community interests

Aboriginal people have connections to land on many levels. The Aboriginal heritage sites made by their ancestors will be important, not least for the stories that such places allow people to tell about their land. The land contains other values for Aboriginal people including the natural resources their ancestors used, and in many cases that the people still use today for food, craft and medicines such as, shellfish, waterbirds, and plants[7]. There may be surviving Creation stories connected with landscape features such as wetlands, estuaries, and hills.

The local aboriginal groups which will have an interest in the Kooragang component of the Hunter Estuary Wetlands Ramsar site are local Worimi groups[8] on the northern side of the estuary and the Awabakal people[9]. Traditionally the Awabakal area has been on the southern side of the Hunter estuary, and includes

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[7] Totemic (or 'kinship') associations with animal and bird species may have also survived. It should be stressed here that Indigenous relationships with what we term as the 'natural world' are complex, and Indigenous people do not necessarily split their world into 'natural' and 'cultural' heritage.
[8] The Worimi Local Aboriginal Land Council; Maaiangal Aboriginal Heritage Inc; Mur-roo-ma Inc.; and, Nur-run-gee Inc (which also represents the Worimi Traditional Aboriginal Elders Group Inc).
[9] The Awabakal Newcastle Aboriginal Co-op.

Newcastle, Lake Macquarie and the Hunter Valley. The famous Creation story Tittalik comes from these people, and describes how the Hunter River (or 'Coquon') came to be formed (Maynard 2004).

Aboriginal heritage sites

There are 96 Aboriginal objects and Aboriginal places[10] recorded in and around the Hunter Estuary; however most of these are outside the Ramsar site. A sub-set of these sites is shown in Table 3-8. All of the recorded Aboriginal sites are open sites (that is, they are not within rock shelters and caves), and are mainly stone artefact scatters, shell middens and isolated stone artefacts. There is one scarred tree recorded in bushland adjacent to Tomago Road, Tomago.

There are four known Aboriginal sites within the boundaries of the Ramsar site and a further seven are along the edge of the site boundary. These numbers are not definite due to the varying accuracy in Aboriginal site recordings; however, they do give an indication of the known extent of Aboriginal heritage sites within the Kooragang wetland.

Table 3-8
Aboriginal heritage sites[11] in the Hunter Estuary

No.	Site ID	Site name	Site type	Recorder
1	38-4-0050	Moscheto Island	Open camp site	ASRSYS
2	38-4-0895	Fern Bay Complex	None	McCardle
3	38-4-0676	Tomaree/Tomago A10	None	McCardle
4	38-4-0647	A1 - Tomaree/Tomago	None	McCardle
5	38-4-0052	Moscheto Island / Newcastle Bight	Open camp site	Starling
6	38-4-0051	Moscheto Island / Newcastle Golf Club	Open camp site	Dyall
7	38-4-0700	Newcastle Golf Club 3	None	Mayers
8	38-4-0699	Newcastle Golf Club 2	None	Mayers
9	38-4-0065	Fullerton Cove	Midden	Sullivan
10	38-4-0702	Newcastle Golf Club 5	None	Mayers
11	38-4-0679	PAD 1: Tomaree to Tomago	None	McCardle

[10] Under the *National Parks and Wildlife Act 1974* (*NPW Act 1974*), Part 6, an Aboriginal object is any deposit, object or material evidence relating to Aboriginal habitation of the area that comprises New South Wales. An Aboriginal place is defined as a place which has been declared so by the Minister administering the *NPW Act 1974* because he or she believes that the place is or was of special significance to Aboriginal culture. All Aboriginal objects and places are protected, and Part 6 of the *NPW Act 1974* requires people to seek permission from the Department of Environment and Climate Change (DECC) if they are proposing disturbance.
[11] Registered sites from the Aboriginal Heritage Information Management System (AHIMS) supplied by the DECC

When the Plan of Management was prepared for Kooragang Nature Reserve and neighbouring Hexham Swamp Nature Reserve in 1998, only one Aboriginal site, a shell midden, was mentioned and described as being 'north of the training dykes' (NSW National Parks and Wildlife Service 1998:31).

The management plan assumes that Aboriginal occupation sites have nearly all been destroyed due to river bank works, land reclamation, industrialisation and urbanisation. However, site 38-4-0050 has survived on Moscheto Island despite the area having been subject to land reclamation works, and is now part of Kooragang Island.

There have been numerous Aboriginal heritage assessments of neighbouring areas, which have recorded a number of sites. The recent environmental assessment for the Fern Bay Seaside Village which is located some 700 metres south east of Fullerton Cove has been the most detailed and informative Aboriginal heritage study closest to the Kooragang (Environmental Resources Management (ERM) 2009). This assessment followed numerous other surveys from the late 1980s onwards which categorised the area as having a high archaeological value and sensitivity. It was also stated that the area had a high social value to the local Aboriginal community (ERM 2009, Annex I).

Five known sites have been excavated and archaeologically sensitive landforms augur-tested to check previous models for Aboriginal land use. These investigations confirmed and refined previous findings. A predictive Aboriginal site model was developed for the area around the Hunter Estuary (ERM 2009, Annex I: 14) which identifies that:

- open artefact scatter sites are found across the landscape where original soils have been preserved;
- open artefact scatter sites increase in frequency, size and complexity near creeks, rivers and swamps;
- isolated artefacts are found anywhere;
- midden sites are found near estuaries and coastlines;
- burials are often found in soft substrates such as sand, and often in occupation middens; and
- scarred and carved trees are found in remnant bushland with old growth trees.

The ERM report also notes that most archaeological sites are subsurface due to cyclical flooding events and are only exposed as a result of erosion (ERM 2009: Annex I). The Aboriginal artefact scatters and shell middens in the Fern Bay area are mainly located on elevated ground (but not on dune crests) and near to swamps and swamp forests. They mainly contain stone artefacts made from local sources of stone found at Nobbys Head and Tomago and artefact types include the 'Worimi Cleaver' thought to be used to process edible starch from Bungwall Fern, found in the swamp forests. The main shellfish types found in middens are estuarine species, dominated by Rock Oyster (found at the margins of estuaries and within mangroves), with lower proportions of Mud Whelk (found on estuary mud flats), Cockle and Blue Mussel. The ERM report concludes that: “This indicates they (the shellfish) were gathered from the Hunter Estuary, probably in Fullerton Cove, approximately 600 metres to the west of the study area. They were gathered and brought back to the site [Fern Bay Estate Site C – 38-4-0790] for consumption.”(ERM 2009, Annex I: 48).

The large number of known sites that have been recorded in and around the Hunter Estuary, and that are still being discovered, indicate that there will be more Aboriginal sites within the Ramsar boundaries which have not yet been recorded. The small number of known sites within the Hunter Estuary Wetlands Ramsar site is most likely a consequence of the fact that there has never been a systematic survey for Aboriginal heritage and/or because Aboriginal sites are buried beneath the ground surface.

3.2.2.3 Historic heritage

The *Kooragang Nature Reserve and Hexham Swamp Nature Reserve Plan of Management* (NSW National Parks and Wildlife Service 1998) identifies four historic structures that occur within the Kooragang component of the Hunter Estuary Wetland (Table 3-9). These sites are also listed on the NSW National Parks and Wildlife Service’s Historic Register and under the NSW *Heritage Act 1979*, which is responsible for the preservation of significant items of non-Aboriginal heritage.

Table 3-9
Listed historic heritage within the Kooragang component of the Hunter Estuary Wetland

No.	Site
1	Tongues Tree Fig (a mature Moreton Bay fig associated with early farming)
2	Concrete footing of an old dairy farm - Sandy Island
3	Timber bridge
4	Half-submerged wooden drogher (a slow moving fishing boat)

The Tongues Tree Fig occurs within the Kooragang component of the Ramsar site boundaries. There is little information on the heritage register regarding the Tongues Tree Fig. No additional information could be found on the concrete footings of the early dairy farm, the timber bridge or the wooden drogher.

The most significant historic site in the area is the School Master’s House which lies outside the boundary of the Kooragang component of Hunter Estuary Wetland Ramsar site. The School Master's House is located on Ash Island within the City Farm complex on the western boundary of the Ramsar site. The School Master’s House was used from the 1890s until 1934 and serviced the Ash Island School. The house has since been restored through the Kooragang Wetland Rehabilitation Project.

3.2.2.4 Scientific and educational

The Hunter Estuary Wetlands Ramsar site has been the subject of many scientific investigations; in particular, long term studies on migratory and non-migratory shorebirds. For example the HBOC has been carrying out monthly bird counts since 1999 at 21 sites around the Hunter Estuary (Herbert 2007a). Four of these sites are within the Ramsar site: Stockton Sandspit, Fern Bay, Kooragang Dykes and Fullerton Cove Beach. Stockton Sandspit, Kooragang Dykes and Dyke Ponds are the most important sites for roosting and foraging shorebirds within the estuary. They support the largest number of shorebirds within the estuary; as many as 5 000 birds have been recorded at times (Herbert 2007a). There have also been studies on the ecology of migratory shorebirds within the Hunter Estuary (Spencer 2010).

The mangroves and saltmarsh have also been studied to understand the processes of mangrove expansion and saltmarsh decline (Rogers and Saintilan 2004). There has also been a study of the hydrodynamics, geomorphology and vegetation of the Hunter Estuary wetlands and the implications for migratory shorebird high tide roost availability (Howe 2008).

3.2.3 Supporting services

3.2.3.1 Food webs

The food web of the intertidal mudflats supports migratory shorebirds which are one of the critical components of the Kooragang component of the Hunter Estuary Wetland Ramsar site. Intertidal mudflats occur within Fullerton Cove, Fern Bay, Kooragang Dykes and at the Stockton Sandspit. Microbes within the mud decompose detritus and form the basis of the mudflats food chain. The microbes, detritus and algae on the mudflats in turn support an abundant invertebrate infauna comprised predominantly of polychaete and oligochaete worms, bivalve molluscs, and amphipods. The infauna are the source of food for shorebirds which forage across the exposed mudflats when the tide is out. At low tide, the intertidal mudflats provide the major feeding area for shorebirds within the estuary (Herbert 2007a). When the tide returns and the mudflats are covered in water, the infauna also provides a food source for fish which are also food for other shorebirds such as cormorants, pelicans, terns and gulls.

3.2.3.2 Biodiversity

The Kooragang component of the Hunter Estuary Wetlands Ramsar site supports vegetation communities and habitats which are important for supporting biodiversity at the site including:

- Saltmarsh which is an important foraging and roosting habitat for migratory and non-migratory shorebirds, 41 species of shorebirds have been recorded within the Kooragang component.
- Mangroves which support the mangrove gerygone and striated heron that breed and forage almost

exclusively in this habitat.

- Brackish/freshwater swamps are important for frog populations, seven species have been recorded from within the Ramsar site including the green and golden bell frog (*Litoria aurea*) which is listed as Vulnerable under the EPBC Act. The brackish swamps also support populations of breeding waterbirds (ducks, moorhens, swamphens) as well as other wetland dependant birds such as the little grassbird and clamorous reed-warbler. The brackish swamps support a population Australasian bittern (*Botaurus poiciloptilus*) which is listed as Endangered under both the EPBC Act and on the IUCN Red List (Version 2009.1).
- The intertidal mud and sand flats at Fullerton Cove, Fern Bay and Stockton Sandspit support an invertebrate infauna comprised mostly of polychaete worms, copepods and molluscs that are an important food source for migratory and non-migratory shorebirds.
- The open waters of the estuary support a variety of ducks (chestnut teal, grey teal) in numbers of up to 2000 and also the estuary stingray (*Dasyatis fluviorum*) which is listed as Vulnerable on the IUCN Red List (Version 2009.1).
- Kooragang Dykes and Stockton Sandspit are also important roosting and foraging sites for shorebirds. More than 1% of the East Asian-Australasian Flyway population of eastern curlew has been recorded at Kooragang Dykes. More than 1% of the Australian population of red-necked avocet has been recorded at Kooragang Dykes and Stockton Sandspit.
- The wetland also supports a relatively high diversity of flora species (112 species).

3.2.3.3 Threatened wetland species, habitats and ecosystems

As noted above under biodiversity, the Kooragang component of the Hunter Estuary Wetlands Ramsar site supports one nationally and two internationally threatened species.

The green and golden bell frog which is listed as Vulnerable under the EPBC Act occurs in brackish/freshwater wetlands in the south east of the site on Kooragang Island.

The Australasian bittern which is listed as Endangered under the EPBC Act and on the IUCN Red List has been recorded from brackish/freshwater swamps on Kooragang Island and on the Tomago in the Juncus Swamp from within the Ramsar site on Kooragang Island and *Sporobolus* saltmarsh and saline pasture adjacent to the Tomago Wetlands. The estuarine stingray which is listed as Vulnerable on the IUCN Red List has been recorded from the Hunter Estuary.

Coastal saltmarsh is listed as an Endangered Ecological Community on the NSW TSC Act. *Melaleuca* swamp forest is one of the vegetation types included in Coastal Swamp Sclerophyll Forest on coastal floodplains which is a listed threatened ecological community on the NSW TSC Act.

3.2.4 Critical ecosystem benefits and services

Of the benefits and services described above, the critical ones have been determined to be:

- **Food webs** on the intertidal mudflats which support migratory shorebirds.
- **Biodiversity,** particularly migratory shorebirds*; Sarcocornia* saltmarsh which supports migratory shorebirds; and the intertidal mudflats which provide foraging habitat for migratory shorebirds. The Kooragang Dykes and Stockton Sandspit are also important roosting and foraging sites for shorebirds, more than 1% of the East Asian-Australasian Flyway population of eastern curlew has been recorded at the Kooragang Dykes.
- **Threatened wetland species, habitats and ecosystems** particularly the green and golden bell frog (*Litoria aurea*) which inhabits brackish/freshwater wetlands within the Ramsar site.

These services have been chosen because they determine, or strongly influence the ecological character of the site. They have been assessed as critical because:

- they are important determinants of the site's unique character;
- they are important for supporting the Ramsar criteria under which the site was listed;
- change is reasonably likely to occur over the short, medium or long term (<100 years); and
- if change occurs to them, they will cause significant negative consequences to the ecological character of the site.

4. Interactions and conceptual model

A conceptual model of the Hunter Estuary Wetland showing the major interactions and spatial relationships between the key components and processes is presented in Figure 4.1.

The main habitat features of the estuarine wetland range from the deepest waters in the river channel in the North Arm of the Hunter River to the *Casuarina glauca* woodlands which occur along the inland edge of the wetland on the drier, least saline soils.

The estuary bed rises from the river channel of the North Arm to form the extensive intertidal mudflats of Fullerton Cove. These mudflats support an abundant invertebrate infauna comprised predominantly of polychaete and oligochaete worms, bivalve molluscs, and amphipods. The invertebrate infauna of the intertidal mudflats provides the major feeding area for shorebirds within the estuary (Herbert 2007a).

Mangroves fringe the intertidal mudflats of Fullerton Cove and are also widespread on Kooragang Island (Figure 3-10). The mangrove communities support invertebrate species such as crabs and marine snails as well as smaller invertebrates such as marine worms, bivalve molluscs and crustaceans. At high tide, the mangroves provide foraging and sheltering habitat for prawns which feed on detritus and invertebrates (NSW DPI 2008c). Fish also utilise the mangroves at high tides for foraging (feeding on invertebrates) and shelter and these areas are also important as nurseries for juvenile fish (Bell et al. 1984, Laegdsgaard and Johnson 1995). Two species of birds, the mangrove gerygone and the striated heron breed and forage almost exclusively in the mangroves (Moss 1983).

Saltmarshes dominated by samphire and saltwater couch occur on Kooragang Island and to the west of Fullerton Cove (Figure 3-10). Most of the saltmarshes are subject to periodic intertidal inundation and are hypersaline. They support a diverse range of invertebrates including an infauna of crabs, marine snails, polychaete and oligochaete worms. The saltmarsh vegetation also supports spiders, insects and a diverse community of non-marine snails (29 species) (Shea 1999). The invertebrate populations within the saltmarshes are an important food source for shorebirds. The combination of bare areas and low vegetation cover provide important roosting habitat for shorebirds (Moss 1983).

The vegetation associations within the site are largely determined by the frequency and periodicity of tidal inundation as well as salinity. Saltmarshes are confined to those areas that are periodically tidally inundated and which are hypersaline. Channel dredging and flood mitigation measures have increased the volume of tidal flows into the estuary and therefore the area regularly inundated has increased. This, combined with increased surface runoff of freshwater and landward drains, has lead to the decrease in area of hypersalinity currently occupied by saltmarsh vegetation which is being replaced either by mangroves (seaward) or saline pasture (landward).

In conjunction with changes in tidal influence, sedimentation is also leading to vegetation changes in the estuary. In modern times increased sediment is being supplied to the Hunter Estuary due to deforestation and overgrazing in the upper catchment (Boyd 2001). Sediment is generally transported in major floods; however, flood mitigation measures such as levee banks enhance erosion processes upstream and supply higher sediment loads to downstream areas. Increased sedimentation is occurring in flatter areas of the estuary around the margins of Kooragang Island and Fullerton Cove (MHL 2003) and these areas are being colonised by mangroves. On a smaller scale, drainage of saltmarshes has decreased the amount of flooding and so sediment accretion leading to a loss of saltmarsh habitat (Rogers and Saintilan 2004).

Freshwater inflows provide nutrients from the breakdown of terrestrial and aquatic plant material (detritus) which are required for algal and microbial growth. This in turn provides the main food source for aquatic invertebrates. Aquatic invertebrates are an important food source for many fish species in the estuary, as well as shorebirds. Fish eggs, larvae, juveniles and the adults of smaller fish species provide a food source for larger, predatory fish, particularly marine species. Juvenile and smaller adult fish are also an important food source for waterbirds such as cormorants and terns which dive from the surface (cormorants) or the air (terns) to catch fish in the open waters of the estuary. Fin fish and prawns within the river channel also support commercial and recreational fisheries.

There are brackish wetlands on Kooragang Island within the Ramsar site and to the west of Fullerton Cove (Figure 3-10) which are dominated by sedges, arrowgrass and broad leaved cumbungi. The brackish wetlands on Kooragang Island support populations of frogs including the threatened green and golden bell frog. The brackish wetlands also provide foraging habitat for waterbirds such as ibis, herons, egrets and the threatened Australasian bittern (Clarke and Van Gessel 1983).

The Hunter Estuary Wetland Ramsar site does contain areas of modified habitats namely the saline pastures which occur on Kooragang Island and the Tomago Wetlands on areas that have been drained and cleared for pasture. These areas support a mixture of pasture and saltmarsh species. Salt couch and glasswort have re-established in more saline areas but where salinity is low, blown grass, couch, and buffalo grass are present. In the drained area on Kooragang Island and to the west and north of Fullerton Cove which were once used as grazing lands, pasture grasses are the dominant vegetation cover and include kikuyu, couch, paspalum and buffalo grass. Common reed *(Phragmites australis)* is also present.

The vegetation in the saline pasture and pasture areas is too dense and generally too dry to provide suitable habitat for shorebirds; however, they do support foraging habitats for some wetland species such as ibis, herons, Australasian bittern, brown quail and masked lapwing as well as terrestrial bird species including swamp harrier, Richards pipit, brown songlark, and singing bushlark (Clarke and Van Gessel 1983).

There are patches of other habitats within the study area on higher ground where the soils are not saline, including broad-leaved paperbark swamp forest and blackbutt dry sclerophyll forest.

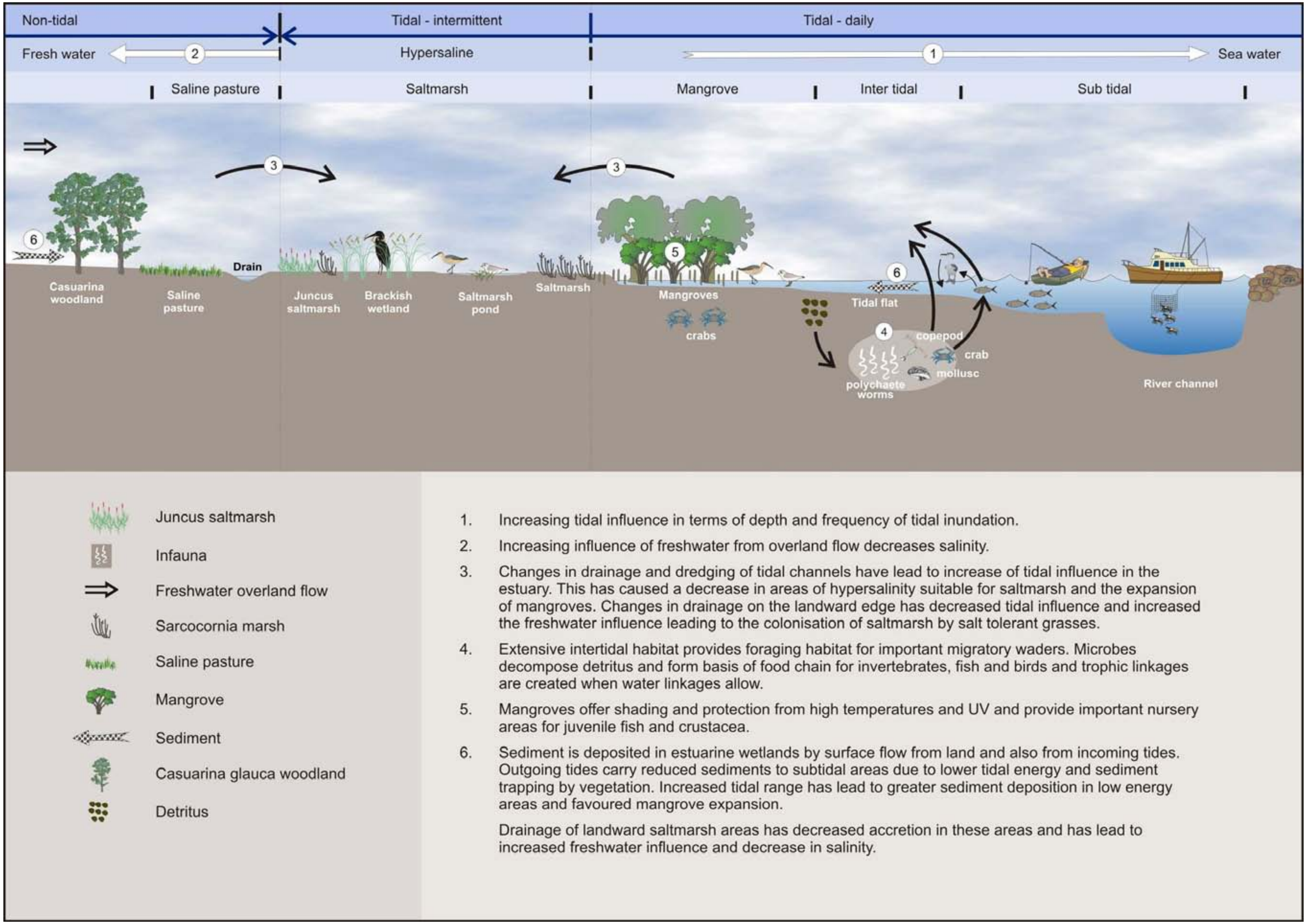


Figure 4-1: Conceptual model showing the relationship between ecological components, processes, benefits and services

5. Threats to the ecological character of the Hunter Estuary Wetlands Ramsar site

5.1 Identification of threats

Threats to the Hunter Estuary Wetlands Ramsar site are presented in Table 5-1. Note that this table only includes those threats which have the potential to affect the ecological character. For each threat identified, the likelihood (probability) of the threat occurring and timing of the threat (i.e. when the threat will actually result in an adverse impact to the ecological character of the wetland) is also included. The following categories have been used to define the likelihood of a threat occurring:

- Already occurring – threat is currently known to occur
- Almost certain – threat is expected to occur in the short term (one to two years)
- Possible - threat may occur in the short term
- Unlikely - threat not expected in the short term but may occur in medium (three to five years) or long term (more than five years)
- Rare - Threat may only occur in extreme and/or exceptional circumstances

In order to further evaluate these threats a stressor model was developed to assist in the identification of external drivers that generate stress on the wetland, leading to ecological effects that can irreversibly change the ecological character of the site (Figure 5-1). The stressor model shows that there are two main drivers of change: climate and human activities. The available information suggests that human activity is the major driver of change within the Hunter Estuary Wetlands Ramsar site. Major threats that were identified by the stressor model which may lead to significant changes in the ecological character of the Hunter Estuary Wetland Ramsar site are:

- changes in tidal range due to dredging and flood mitigation and drainage works and increased sedimentation (as a result of past catchment clearing) leading to mangrove expansion and resulting in saltmarsh decline; and
- changes in freshwater/saltwater balance due to landward drainage leading to saltmarsh decline.

Each of these threats and their implications are outlined below.

5.1.1 Changes in tidal range

The regular annual dredging of the harbour and entrance to remove silt and increase the depth of the river channel for shipping has contributed to the increase in tidal range by increasing the inflow of tidal waters into the estuary (MHL 2003; Herbert 2007b). The construction of a weir between Hexham Island and Ash Island has resulted in a reduction of channel width in the South Arm of the Hunter River due to lateral accretion of sediments along the channel margins which restricts the upstream incursion of tidal flows. Tidal flows are also constrained from spreading out over the floodplain by floodgates and levee banks which have been installed to mitigate flooding. Floodgates are placed across waterways flowing into the estuary to moderate lateral dispersion of flood flows from the main channel while levee banks help to confine flood flows to the main channel, so that flood flows are delivered to the ocean rather than over the floodplain. The effect of channel constriction (natural and human induced) and flood mitigation on tidal flows in the estuary is to confine them to the main channel and limit their upstream extent resulting in an increase in tidal range in the lower estuary.

In addition, in some areas drainage channels through saltmarsh areas have changed tidal movements and reduced the frequency of tidal inundation of saltmarsh areas. A ring drain built around Fullerton Cove in 1976 has resulted in a reduction in tidal inundation of the saltmarshes on the inland side of the drain. These saltmarshes have become under greater influence of freshwater inflows from the land and have changed into saline pastures where salt tolerant grasses are dominant.

Two processes relating to the frequency and depth of tidal inundation have been identified which can result in the expansion of mangrove communities and the decline of saltmarsh communities:

1. Increased frequency and depth of tidal inundation in parts of the estuary (particularly Fullerton Cove and North Arm) reduces the salinity of saltmarsh environments and allows the colonisation of mangroves (Herbert 2007b).
2. A reduced frequency of tidal inundation of saltmarsh because of the closing of flood gates lowers the rate of sediment build up, which, combined with subsidence because of below ground processes (e.g. compaction, ground water volume changes, biomass changes), can lead to increased frequency and depth of inundation (due to lowering of the saltmarsh) resulting in a decline in salinity which favours mangrove expansion (Rogers and Saintilan 2009).

Rogers and Saintilan (2004) generally found that saltmarshes within the Ramsar site are subsiding at a rate greater than is being replenished by sediment accretion, while build up of sediments is occurring at a higher rate in mangrove areas which leads to an increase in mangrove extent both to the landward and seaward directions.

5.1.2 Changes in freshwater/saltwater balance

Changes in drainage are also likely to be affecting saltmarshes through changes in the freshwater/saltwater balance. A decrease in tidal influence due to the ring drain around Fullerton Cove has resulted in fresh water runoff being the dominant hydrological process influencing salinity, causing a decline in salinity. This has allowed the colonisation of salt-tolerant grasses and the transition of saltmarsh to saline pasture. This was occurring at the time of listing as evidenced by the mapping of vegetation types by Outhred and Buckney (1983) and is still likely to be occurring.

5.1.3 Consequence of saltmarsh decline

Saltmarsh is an important foraging and roosting habitat (diurnal and nocturnal) for migratory shorebirds. The decline in saltmarsh from the changes in tidal range and changes in the freshwater/saltwater balance has been linked to the decline in migratory shorebirds within the Kooragang component. The decline in the distribution and extent of saltmarsh has resulted in a loss of foraging and roosting habitat.

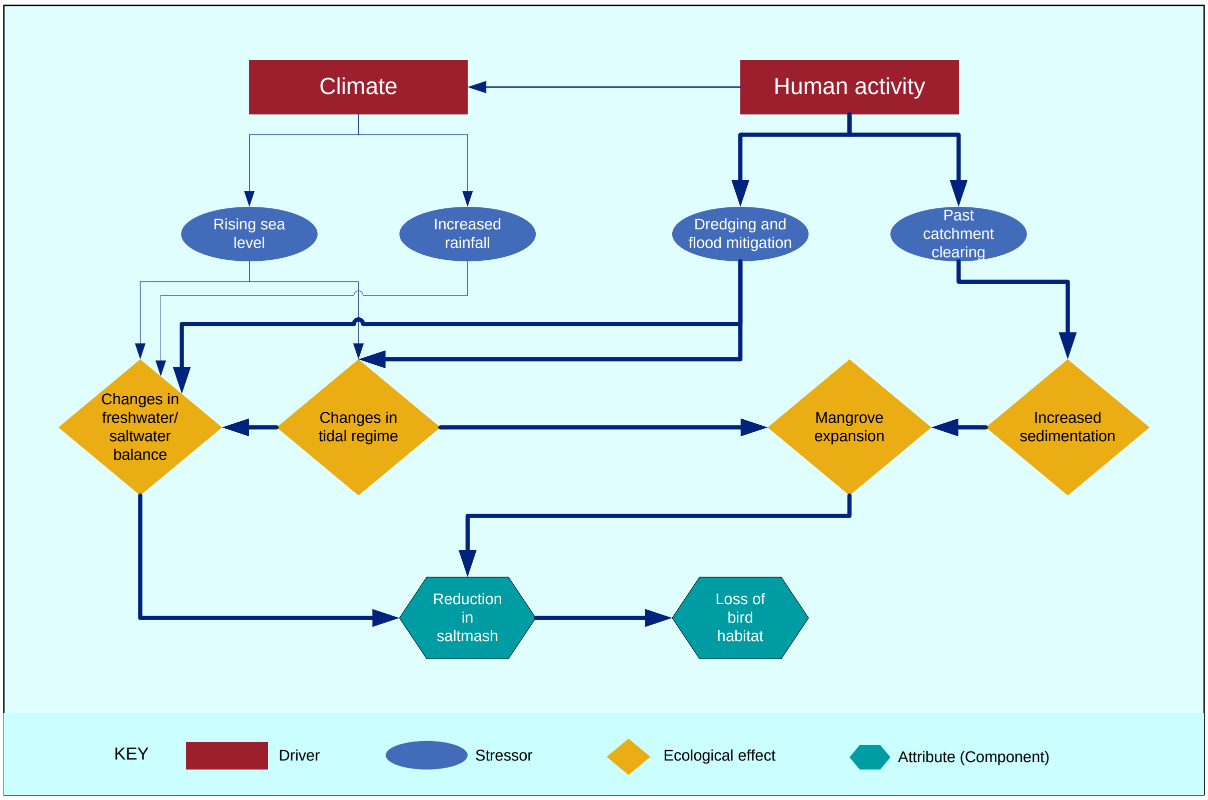


Figure 5-1
Stressor model showing major threats and critical components and processes

Table 5-1
Threats to the ecological character of the Hunter Estuary Wetlands Ramsar site (Kooragang component)

Actual or likely threat or threatening activities	Potential impact(s) to wetland components, processes and/or services	Affected ecosystem service	Related components and processes	Likelihood	Timing of threat	Significance of impact to ecological character (and extent)
Harbour, river channel and river mouth dredging	Opening of harbour mouth and deepening of the river channel cause increase in tidal range and consequent expansion of mangroves resulting in decline in saltmarsh and loss of shorebird foraging and roosting habitat. Reduction in available fish habitat and increased turbidity, leading to gill abrasion and increased fish mortality. Dredging of sediments can release contaminants, increase turbidity, cause habitat disturbance, migration of pelagic invertebrates and may cause changes in the community composition.	Biodiversity Pollution control and detoxification Recreation and tourism Scientific and educational Spiritual and inspirational Wetland products (fisheries)	Hydrology Water quality Vegetation Birds Fish Invertebrates	Already occurring	Immediate to long term	High (widespread)
Shipping traffic in South Arm	Decline in water quality due to pollution from ship traffic, including oil spills. Introduction of pest aquatic species from ballast water.			Rare	Immediate to long term	Low to medium (widespread)
Bank erosion and stabilisation	Increased sedimentation impacting wetland communities and key faunal habitats (as discussed above). Bank erosion could expose and damage Aboriginal heritage sites.	Biodiversity Scientific and educational Recreational and tourism Spiritual and inspirational	Geomorphology Water quality Vegetation Birds Frogs	Already occurring	Immediate to long term	Medium (widespread)

Actual or likely threat or threatening activities	Potential impact(s) to wetland components, processes and/or services	Affected ecosystem service	Related components and processes	Likelihood	Timing of threat	Significance of impact to ecological character (and extent)
Flood mitigation	Changes in tidal regime and subsequent impacts on wetland communities (as discussed above).	Biodiversity Recreation and tourism Spiritual and inspirational	Hydrology Water quality Vegetation Birds Fish Frogs Invertebrates	Already occurring	Short to long term	High (widespread
	The species *Metapenaeus macleayi* school prawn (an important fishery species) which prefers hyposaline conditions is susceptible to prolonged droughts exacerbated by decreased freshwater flows due to culverts and floodgates. This can result in reduced populations as a result of higher salinity levels in the estuary. Also resulting in a reduction in nursery areas and nutrient sources for prawns.	Biodiversity Wetland products (fisheries)	Hydrology Water quality Macroinvertebrates	Already occurring	Immediate to medium term	Low (widespread)
Changes in freshwater/saltwater balance	Reduced freshwater inflows, increase in saltwater intrusion into estuary restricting brackish and freshwater species and changing wetland communities.	Pollution control and detoxification Flood control Biodiversity Recreation and tourism Food webs Spiritual and inspirational	Hydrology Water quality Fish Invertebrates	Already occurring	Immediate – long term	High (widespread)
Introduced eastern gambusia	Predation of tadpoles (including green and golden bell frog) resulting in a decline in breeding success.	Biodiversity Scientific and educational	Fish Frogs	Already occurring	Immediate to long term	Medium (localised to freshwater pools)
Introduction of chytrid fungus	Impact on frog populations (abundance and distribution) including green and golden bell frog, causing mortality of frogs and decrease recruitment and decline in available habitat.	Biodiversity Scientific and educational Spiritual and inspirational	Frog	Already occurring	Immediate to long term	Medium (localised to freshwater pools)

Actual or likely threat or threatening activities	Potential impact(s) to wetland components, processes and/or services	Affected ecosystem service	Related components and processes	Likelihood	Timing of threat	Significance of impact to ecological character (and extent)
Introduced weeds: bitou bush (*Chrysanthemoides monilifera*), lantana (*Lantana camara*), pampas grass (*Cortaderia selloana*) and spiny rush (*Juncus acutus*).	Introduced weeds may impact on the use of habitats by wetland birds, for roosting and nesting, particularly freshwater and brackish wetlands.	Biodiversity Scientific and educational Recreational and tourism Spiritual and inspirational	Vegetation Birds	Already occurring	Immediate to long term	Low (localised infestation, limited to specific habitats)
Introduced animals: red fox (*Vulpes vulpes*)	Red foxes prey on frogs and ground nesting, roosting and feeding birds.	Biodiversity Scientific and educational Recreational and tourism Spiritual and inspirational	Birds Frogs	Already occurring	Immediate to long term	Medium (widespread)
Commercial and recreational fishing	Overfishing of prawn and fish stocks leading to decline in abundance and diversity of species. May lead to a reduction of prey items for waterbirds.	Biodiversity Scientific and educational Recreational and tourism Wetland products Spiritual and inspirational	Fish Birds	Already occurring	Medium to long term	Low (widespread)
Recreation	Disturbance of migratory birds by dogs, boats, and people, particularly at readily accessible sites such as Stockton Sandspit.	Biodiversity Scientific and educational Recreational and tourism Spiritual and inspirational	Birds	Already occurring	Immediate to long term	Medium (high impact at localised sites)
Industrial development adjacent to site leading to air pollution and runoff pollution to the estuary from the industrial area. Also see flood mitigation	Toxic effects from industrial wastes in estuary (e.g. slag heaps used as fill on Kooragang Island) – fish kills, bird kills, lowered spawning success and deformities. Pollutants can be concentrated through the food chain to shorebirds. Pollution can affect the abundance and density of infauna taxa.	Biodiversity Wetland products (fisheries) Pollution control and detoxification Recreation and tourism Scientific and educational Food webs Spiritual and inspirational	Vegetation Fish Birds Water quality Invertebrates	Already occurring	Immediate to long term	Low to Medium (widespread)

Actual or likely threat or threatening activities	Potential impact(s) to wetland components, processes and/or services	Affected ecosystem service	Related components and processes	Likelihood	Timing of threat	Significance of impact to ecological character (and extent)
Oil spill	An oil spill is likely to affect waterbirds and seabirds within the estuary. It will also affect foraging and roosting areas for shorebirds on islands and around the shore of the estuary. It will also affect fish populations within the estuary.	Biodiversity Wetland products (fisheries) Pollution control and detoxification Recreation and tourism Scientific and educational Food webs Spiritual and inspirational	Vegetation Fish Birds Water quality Invertebrates	Rare	Immediate to short term	Medium (localised)
Acid sulfate soils	The soils at Kooragang Island have been ranked as medium risk. The impacts associated with acid sulfate soils are wide-ranging and severely damaging to the surrounding environment. Discharges of acidic water cause harmful effects on vegetation, fish, oysters and other aquatic species. Aquatic habitats are also damaged as a result of acid water discharges.	Biodiversity Wetland products (fisheries) Recreation and tourism Scientific and educational Nutrient cycling Spiritual and inspirational	Vegetation Fish Birds Water quality Invertebrates	Unlikely	Immediate to short term	Medium (localised)
Turbidity	Water clarity has decreased since the time of listing due to an excess of sediment being supplied to the upper Hunter estuary from catchment land use changes including historical deforestation and overgrazing. Increased turbidity reduces light entering the waters of the estuary resulting in a loss of productivity.	Biodiversity Wetland products (fisheries) Recreation and tourism Scientific and educational Food webs Spiritual and inspirational	Vegetation Fish Water quality Invertebrates	Already occurring	Immediate to long term	Low (widespread)
Agricultural use of adjacent land • Past catchment clearing • Livestock grazing • Cropping/horticulture	Increased sedimentation as a result of catchment clearing.	Food webs Biodiversity Scientific and educational Recreation and tourism Pollution control and detoxification Spiritual and inspirational	Water quality Birds Fish Frogs Vegetation Invertebrates	Already occurring	Immediate – medium term	High (widespread)
	Loss of fish habitats from native stream-side vegetation loss and spread of riparian weeds. Declining water quality through agricultural runoff (sediments, fertilizers, pesticides & herbicides). Increased turbidity from erosion, leading to gill abrasion and increased fish mortality.			Already occurring	Immediate – medium term	Low (widespread)

Actual or likely threat or threatening activities	Potential impact(s) to wetland components, processes and/or services	Affected ecosystem service	Related components and processes	Likelihood	Timing of threat	Significance of impact to ecological character (and extent)
Climate change • Changed rainfall patterns • Changed frequency and intensity of flood events	Changes to hydrology and tidal regime leading to changes in wetland communities and associated species. Changes to breeding and migration cues and success.	Climate regulation Biodiversity Scientific and educational Recreation and tourism Food webs	Geomorphology Hydrology Water quality Vegetation Birds Fish Frogs Invertebrates	Almost certain	long term	High (widespread)

6. Limits of acceptable change

The “limits of acceptable change” (LACs) are defined in the ECD Framework (DEWHA 2008) broadly as the upper and lower bounds of variability for a measure of a particular ecosystem component, process or service.

Limits of acceptable change have been developed for the critical components, sub-components, processes and services that were identified in Sections 3.1.10 and 3.2.4 as required by the ECD Framework (DEWHA 2008) and are presented in Table 6-1.

It is noted that for some critical components and processes, there is limited baseline information with which to develop quantitative Limits of Acceptable Change (e.g. freshwater inflows). In these cases it will be noted that there is minimal or no data that currently exists to set a Limit of Acceptable Change with any level of confidence. This will be treated as a key knowledge gap. Where a Limit of Acceptable Change can be created from comparative studies from other sites which are representative of Kooragang or where indirect measures can be identified against the critical components or processes, these will be used to develop Limits of Acceptable Change where limited direct baseline information is available. Where there is no data to develop a Limit of Acceptable Change for a critical component or process, recommendations will be made under knowledge gaps and monitoring to obtain direct baseline information relating to the critical component or process.

Additional explanatory notes for Limits of Acceptable Change

Limits of Acceptable Change are a tool by which ecological change can be measured. However, Ecological Character Descriptions are not management plans and Limits of Acceptable Change do not constitute a management regime for the Ramsar site.

Exceeding or not meeting Limits of Acceptable Change does not necessarily indicate that there has been a change in ecological character within the meaning of the Ramsar Convention. However, exceeding or not meeting Limits of Acceptable Change may require investigation to determine whether there has been a change in ecological character.

While the best available information has been used to prepare this Ecological Character Description and define Limits of Acceptable Change for the site, a comprehensive understanding of site character may not be possible as in many cases only limited information and data is available for these purposes. The Limits of Acceptable Change may not accurately represent the variability of the critical components, processes, benefits or services under the management regime and natural conditions that prevailed at the time the site was listed as a Ramsar wetland.

Users should exercise their own skill and care with respect to their use of the information in this Ecological Character Description and carefully evaluate the suitability of the information for their own purposes.

Limits of Acceptable Change can be updated as new information becomes available to ensure they more accurately reflect the natural variability (or normal range for artificial sites) of critical components, processes, benefits or services of the Ramsar wetland.

Table 6-1

Limits of acceptable change for critical components and processes for the Kooragang component of the Hunter Estuary Wetlands

Critical ecological components, processes and services	Baseline condition and range of natural variation where known	Limits of acceptable change (based on baseline and natural variability)	Basis of LAC	Level of confidence
Significant species and communities components, processes and services				
Maximum number of species of migratory shorebirds recorded at site annually	There is median confidence in the maximum number of shorebirds species that regularly visited the Kooragang part of the Ramsar site around the time of listing. Data provided by the Hunter Bird Observers Club (Herbert 2007a and Herbert pers. comm. 2011), summarises all available records of bird counts from 1970 to 2007 from a range of sources (Van Gessel and Kendall 1974, Gosper 1981, AWSG, Phil Straw, Geering and Winning 1993, Kingsford et al, HBOC). It is noted that data count methods and sites may not be consistent across all these surveys. To establish a baseline for 1984, we have taken the median of the maximum annual counts of migratory shorebird species for the period 1970 to 1989. This is 18 species and the range was 17 to 18 species. Noting the maximum number of migratory species in the years 2003 to 2007 were 16, 17, 16, 16 and 13 species respectively.	No LAC has been set. It is not well understood what would constitute a substantial loss of diversity, leading to a change of ecological character at this site and it is recommended that this LAC be set in future.		

Critical ecological components, processes and services	Baseline condition and range of natural variation where known	Limits of acceptable change (based on baseline and natural variability)	Basis of LAC	Level of confidence
Abundance of migratory shorebirds recorded at the site in summer	Maximum counts (n=6) either side of 1984 (1970-1989) of migratory shorebirds have been used to represent natural variability in abundance. In this period the range of maximum counts was between 10,000 migratory shorebirds in 1970 and 5000 migratory shorebirds in 1988 (Figure 7-7) (Herbert 2007a). The variability between these counts is considered to represent natural variability. There is no data to suggest that there were any major events in the estuary at the time of these counts that may have affected shorebird numbers. However, migratory shorebirds are exposed to factors outside the site at their breeding grounds and on their migration routes which may affect the abundance at the site. There is low confidence in the maximum counts of migratory shorebirds data because the methods that were used to carry out the surveys were not recorded in detail, including the extent of coverage of shorebird areas within the Hunter Estuary Ramsar site and the timing of the counts (i.e. did they coincide with the peak wader period in the year of the count). For the years 2003 to 2007 the maximum summer counts have been: • 2003 – 3451 • 2004 – 3403 • 2005 – 3009 • 2006 – 3095 • 2007 – 3252	For any five consecutive years there will be no instance of all years recording a maximum summer annual count of migratory shorebirds of less than 5000 birds. This LAC is based on the range of variability shown in the counts between 1970 and 1989 and if there is consistently less than 5000 migratory shorebirds recorded in maximum summer counts this would indicate a change in ecological character. This estimate should be reviewed as better understanding of limits of acceptable change is derived.	Available data (C. Herbert pes. Comm. 2011 and Herbert 2007a)+ expert opinion	Low

Critical ecological components, processes and services	Baseline condition and range of natural variation where known	Limits of acceptable change (based on baseline and natural variability)	Basis of LAC	Level of confidence
Eastern curlew	A maximum count of 900 eastern curlews was recorded for the Hunter estuary at the time of listing in 1984. Fourteen years before listing a maximum count of 600 eastern curlews was recorded in 1970 and thirteen years after listing in 1997 a maximum count of 900 eastern curlews was recorded (Herbert 2007a). There is available data for the eastern curlew for 18 separate years in this 27 year period. The lowest recorded maximum count was 200 birds in 1973 and the highest recorded maximum count was 1000 eastern curlews in 1975 and 1996 and the lowest maximum counts were around 300 birds in 1971, 1989, and 1991 (Herbert 2007a). Three hundred eastern curlews have been adopted arbitrarily as the low point of natural variability around the time of Ramsar listing. The variability between these 18 counts is considered to represent natural variability. However, it is likely that the lower counts may have been a result of in-complete surveys and are therefore under-estimates (C. Herbert, pers. comm. March 2011). Herbert (pers.comm 2011) suggests 600 would be a more realistic low maximum count. There is no data to suggest that there were any major events in the estuary at the time of these counts that may have affected wader numbers. However, migratory shorebirds are exposed to factors outside the site at their breeding grounds and on their migration routes which may affect the abundance at the site. There is low confidence in the maximum counts of the eastern curlews data because the methods that were used to carry out the surveys were not recorded in detail, including the extent of coverage of wader areas within the Hunter Estuary Ramsar site and the timing of the counts (i.e. did they coincide with the peak wader period in the year of the count). However, counts of eastern curlews were carried out in most years in the 27 year period being considered around the time of listing which gives some level of confidence that natural variability is being detected.	For any five year period there will be no instance of all years recording a maximum summer annual count of eastern curlew for the Hunter estuary of less than 600 birds. This estimate should be reviewed as better understanding of limits of acceptable change is derived.	Available data, scientific literature (Herbert 2007a) + expert opinion	Low

Critical ecological components, processes and services	Baseline condition and range of natural variation where known	Limits of acceptable change (based on baseline and natural variability)	Basis of LAC	Level of confidence
Number of migratory shorebird roost sites	Five regularly used roost sites are known for the time of listing: • Stockton Sandspit (bare ground) • Fern Bay • Kooragang Dykes • Fullerton Cove Beach • Windeyers Reach Nocturnal Roost (Herbert 2007a) Changes prior to listing have resulted in the loss or reduction in area of some roost sites due to changes in vegetation (type and distribution).	The LAC for this critical component is linked to vegetation changes and as such an indirect LAC is specified. See LAC for saltmarsh.	NA	NA
Green and golden bell frog	Breeding populations of green and golden bell frogs are known from three permanent wetlands within the Ramsar site on Kooragang Island. There are no population estimates available for the green and golden bell frog at the time of listing. There is high confidence that all of the wetlands with breeding populations of the green and golden bell frogs within the Ramsar site have been identified.	There are no more than two years between successful breeding events (defined as the presence of a first year adult cohort) in at least one of the three known populations. The LAC is based on the known life history of green and golden bell frogs, they breed at one year of age and they have a life span of three to four years (Glenn Moir Australian Museum Business Services pers. comm.) Therefore the failure of a successful breeding event at a wetland for more than two successive breeding seasons could lead to the local extinction of a breeding population. However, mark –recapture studies have shown that frogs move between wetlands on Kooragang Island (Hamer and Mahony 2007) so that breeding failure at one wetland may not result in local extinction if there is recruitment from other nearby wetlands.	Available data, scientific literature + expert opinion	Low given the absence of long-term data regarding: 1. Breeding events at the three green and golden bell frog breeding sites within the Ramsar site on Kooragang Island 2. Population and movement dynamics between the three breeding sites.

Critical ecological components, processes and services	Baseline condition and range of natural variation where known	Limits of acceptable change (based on baseline and natural variability)	Basis of LAC	Level of confidence
Saltmarsh community	Saltmarsh at the time of listing in 1984 covered approximately 582 ha. Saltmarsh has steadily declined in the estuary since 1954 because of changing hydrology and mangrove expansion. In 1954 it is estimated that there were 947 ha of saltmarsh within the Ramsar site; 788 ha in 1966; 667 ha in 1976; 582 ha in 1986; and 339 ha in 1993 (representing a decline of 41% since close to the time of listing in 1984) (Figure 7-7). This is consistent with Saintilan and Williams (2000) who found that there has been a general decline in saltmarsh in south east Australia since the 1940s. In the 28 estuaries they included in their study they reported declines of between 15% and 100%. Studies on the accuracy of vegetation mapping have indicated that error rates of between 20% and 40% are not uncommon (Edwards et al. 1998; Schmidt et. al 2004). However, a comparison of mapping of saltmarsh and mangroves between 1983 (Outhred and Buckney 1984) and 1986 (Williams et al. 1996) showed that the differences in mapping of saltmarsh and mangroves over this relatively short time (3 years) are less than 10%, indicating that in a relatively small well known area like the Hunter Estuary, vegetation mapping errors are likely to be lower.	The areal extent of saltmarsh does not fall below 466 ha i.e. the areal extent at the time of listing (582 ha) minus a 20% mapping error.	Available data + expert opinion	Low
Food webs	The intertidal mudflats of Fullerton Cove, fringing the north-eastern end of Kooragang Island and the east bank of the North Arm of the Hunter River (including Fern Bay, North Arm Sandflats) upstream of Stockton Bridge, support a food web which is a critical supporting service for migratory and non-migratory shorebirds; they are a major feeding area (Herbert 2007a) There is little information about the intertidal mudflat food webs at the time of listing and therefore it is difficult to describe the baseline condition and the variability.	This critical service is linked to changes in the presence of migratory shorebirds. Therefore no direct LAC has been developed and instead the critical service will be assessed indirectly through changes in the abundance and diversity of migratory shorebirds. See LAC for shorebirds.	NA	NA

Critical ecological components, processes and services	Baseline condition and range of natural variation where known	Limits of acceptable change (based on baseline and natural variability)	Basis of LAC	Level of confidence
Biodiversity	This critical service relates to the important biodiversity components of Ramsar site including: migratory shorebirds; *Sarcocornia* saltmarsh which supports migratory shorebirds; and the intertidal mudflats which provide foraging habitat for migratory shorebirds.	Migratory shorebirds, saltmarsh and the intertidal mudflats have also been identified as critical components and LACs have been developed for them. See LACs for shorebirds, salt marsh and intertidal mudflats.	NA	NA
Threatened wetland species, habitats and ecosystems	This critical service relates mainly to the presence of the nationally listed threatened green and golden bell frog (*Litoria aurea*). Breeding populations of the green and golden bell frog are known from three permanent wetlands within the Ramsar site on Kooragang Island. There are no population estimates available for the green and golden bell frog at the time of listing.	The green and golden bell frog has been identified as a critical component and a LAC has been developed for it (see above).	NA	NA

Critical ecological components, processes and services	Baseline condition and range of natural variation where known	Limits of acceptable change (based on baseline and natural variability)	Basis of LAC	Level of confidence
Biophysical and hydrological components, processes and services				
Intertidal mudflats	The intertidal mudflats of Fullerton Cove, fringing the north-eastern end of Kooragang Island and the east bank of the North Arm of the Hunter River (including Fern Bay, North Arm Sandflats) upstream of Stockton Bridge, are the major feeding areas for migratory and non-migratory shorebirds (Herbert 2007a). There is little information about the extent and the condition of the intertidal mudflats at the time of listing and therefore it is difficult to describe the baseline condition and the variability.	As this critical component is linked to changes in the presence of migratory shorebirds, no direct LAC has been developed. See LACs for migratory shorebirds abundance and diversity.	NA	NA
Tidal range	The current baseline indicates that there has been an increase in tidal range since 1955 and this has continued from the time of listing to the present. This increase in tidal range is related to flood mitigation works, channel dredging and potentially, climate change	As this critical process is linked to changes in saltmarsh coverage, no direct LAC has been developed and instead will be assessed indirectly through changes in saltmarsh coverage. See saltmarsh LAC.	NA	NA
Freshwater inflow	Analysis of hydrological trends and variability using data from the time of listing indicates a gradual decline in overland freshwater flows and slight increase in evapotranspiration, along with seasonal and temporal variation (depending on climatic events – rain/drought). Given the timescale of data required to evaluate trends or significant changes, the creation of a direct LAC for this critical process is not recommended.	As this critical process is linked to changes in saltmarsh coverage, no direct LAC has been developed and instead will be assessed indirectly through changes in saltmarsh coverage. See saltmarsh LAC.	NA	NA

7. Current ecological condition and changes in ecological character since listing

7.1 Geomorphology

7.1.1 Sedimentation

Whilst there is indirect evidence of changes in sediment loads associated with the Hunter Estuary as evident by the need for continual dredging of the port section, there has been no ongoing monitoring of sediment baseloads. It has been recorded that there are high siltation rates associated with the harbour and entrance of the estuary. The estimate of sediment input to the lower estuary at Hexham is 1 million tonnes of sediment, with annual dredging currently removing around 414 000 cubic metres per year. Based on a long-term average accumulation rate of 2.3 millimetres per year for Fullerton Cove, it is estimated that approximately 100 000 tonnes accumulate while the remainder of 489 000 are discharged out of the system where they accumulate on the middle shelf (MHL 2003).

7.2 Hydrology

7.2.1 Hydrological trends 1984-2009

In order to determine any changes to hydrological characteristics since the listing of the Kooragang component, trend analyses of time series data were undertaken. However, it should be noted that the 25 year period (1984 to 2009) analysed is not long enough to control for natural variability, and the analyses undertaken only provide an indication of the hydrological changes that may have occurred since the time of listing.

In summary, there is no strong evidence for a reduction in stream flow since the time of listing and based on the available data it is not possible to determine whether stream flow has changed since the time of listing. There is no groundwater timeseries data readily available to assess whether there have been any changes since listing. However, an analysis of groundwater movement in the Hunter Estuary by Hughes et al. (1998) demonstrated that groundwater fluxes are influenced by tidal movement, meaning that a description of both tidal and groundwater hydraulics is required to accurately quantify changes in groundwater inflows.

Rainfall and evapotranspiration data (Penman-Monteith) were available for the period since listing as this data has been synthesised as part of the SILO project and then generated at 0.05 degree geographic grid points across Australia (http://www.bom.gov.au/silo/ accessed 4 June 2009). SILO rainfall and evaporation trends were analysed for Kooragang Island for the period 1984 to 2009. Rainfall showed no strong trend over the period 1984 to 2009 (Figure 7-2), while evapotranspiration shows an increasing trend (Figure 7-1), as well as higher absolute values of evapotranspiration in 1984 and 2007. Although, increasing evapotranspiration has the potential to increase salt crusting and hypersalinity in salt marshes (Hughes et al. 1998), there is no available data to determine that this has led to a change in the character of site.

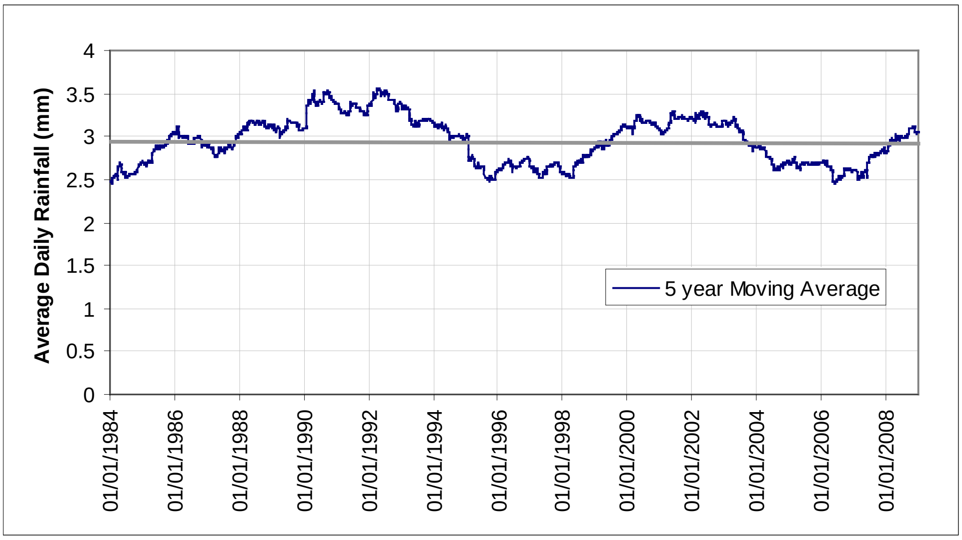


Figure 7-1
Five-year moving average of SILO synthesised rainfall on Kooragang Island

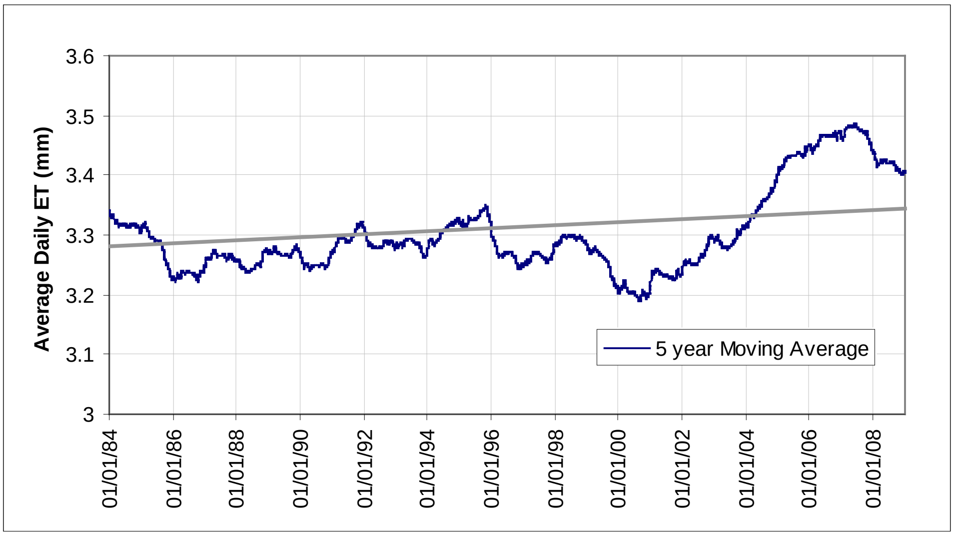


Figure 7-2
Five-year moving average of SILO synthesised Penman-Monteith evapotranspiration on Kooragang Island

7.2.1.1 Tidal movements

The main change with regard to tidal movements since the time of listing in 1984 has been the change in the tidal range. MHL (2003) compared the tidal range from 1955 and 2002 and found that the spring tide had increased in range upstream over this time period which includes the period since the time of listing. Umwelt (2002) in Herbert (2007b) reported that the solstice tidal range in the Hunter Estuary has increased by 100 millimetres at Stockton Bridge and 250 millimetres at Hexham Bridge in the last 50 years. The cause of the change in tidal range has been attributed to dredging of the entrance channel and the harbour which has allowed more water to enter the estuary Umwelt (2002) in Herbert (2007b). Umwelt (2002) in Herbert (2007b) estimated that there has been an approximately 5% increase in tidal exchange volume over the last 50 years. MHL (2003) suggested that other factors are also implicated in the increase in tidal range including the construction of levees and floodgates which confine the tidal prism to the main river channel and do not allow the tide to spread out over the floodplain as it would under natural conditions. All three mechanisms, dredging, levees and floodgates have been implicated as contributing to the increase in tidal range which has been identified as one of the factors resulting in mangrove expansion at the expense of saltmarsh (Herbert 2007b, MHL 2003), therefore resulting in a change to the ecological character of the wetland.

There is no clear evidence that rising sea levels may be contributing to a change in tidal range. MHL (2003) reported that there has been an approximately 4.5 centimetre rise in sea level between 1995 and 2000. Herbert (2007b) looked at changes in sea levels over a longer period, between 1915 and 2000 and noted that the sea levels had not significantly changed over the longer term and that there appeared to be an 80 year cycle in sea levels. For example, the five-year-mean sea-level in 1998 was only about 1 centimetre higher than it was in 1915 and that the sea-level during the latter 1900s was, for most of the time, less than the sea-level in 1915 (Herbert 2007b).

7.3 Water quality

7.3.1 Water quality

Water quality monitoring measurements made by the Hunter Water Corporation, EPA and Maitland City Council in the Hunter Estuary included 25 water quality variables, measured at irregular locations and times from 1972 to early 2000. Details of the water quality analysis are presented in Sanderson and Redden (2001a). The analysis highlights spatial patterns of nutrients and biota within the estuary and also provides a qualitative assessment of changes in the nutrient status of the estuary during the last 25 years (Sanderson and Redden 2001a). However, the quantity of data is limited and therefore only an estimate can be made of how water quality characteristics have changed since the time of listing.

Generally, water quality has shown little change from the time of listing. Sanderson and Redden (2001b) profiled the salinity structure along the length of the Hunter Estuary between January and April 2001. In general, gradients were found to be fairly uniform along the length of the estuary, with salinity at the ocean entrance around 35 parts per thousand which is similar to the salinity recorded at the time of listing. Dissolved oxygen levels can sometimes be sufficiently low to stress fish, even in the main branches of the Hunter Estuary but in general results show that dissolved oxygen levels have not changed since the time of listing and that the estuary is well oxygenated throughout (Sanderson and Redden 2001a). Throughout the study area, pH measurements varied from a minimum of 6.0 to a maximum of 9.0, which suggests that overall pH is a not a water quality parameter of concern in the estuary. Around the time of listing, an average pH of 8.2 was recorded suggesting no discernible change in pH in the estuary.

7.3.2 Turbidity

Water clarity has decreased since the time of listing due to an excess of sediment being supplied to the upper Hunter Estuary because of deforestation and overgrazing. Currently mean turbidity is 15 NTU with a maximum of 260 NTU. At the time of listing, turbidity was minimal in the lower estuary (less than 5 NTU) when the estuary was not in flood or recovery mode with values greater than 50 NTU only recorded following wet weather events. Currently, turbidity is higher in the upper estuary than in the lower estuary, mostly due to dilution with low turbidity seawater near the ocean. Comparing turbidity results from the time of listing with more recent data, shows that while there has been an increase in turbidity, it is not sufficient to be considered a change in ecological character at the site scale or likely to cause such a change.

7.3.3 Nutrients

There has been a long-term increase in oxidised nitrogen since the time of listing in all zones analysed, although part of that increase can be attributed to a wet weather bias of the measurement program after 1985 (Sanderson and Redden 2001a). Total phosphorus appears to have been steady. Ammonia levels have not statistically increased in these areas and have been stable through the 25 year period to 2000, with increasing concentrations towards the lower end of the estuary. The majority of measurements (90%) were at least 25 micrograms per litre and 10% were at least 640 micrograms per litre.

7.3.4 Acid sulfate soils

Post 1984, acid sulfate soils have been investigated in the Hunter Estuary. In 1995, as a first step towards identification and future management of acid sulfate soils in NSW coastal areas, a series of Acid Sulfate Soil Risk Maps were prepared by a team of soil surveyors from the Department of Land and Water Conservation (now part of NSW OEH) (NSW DPI 2008a). In 2008 the NSW DPI published a report which detailed an on-ground assessment of the distribution and effects of acid sulfate soils in the Lower Hunter Estuary (NSW DPI 2008a). Fullarton Cove and the Tomago Wetland areas were ranked as being at high risk of acid sulfate soils (NSW DPI 2008a). The study found that there was a high level of stored acidity in the subsoil profile around Fullarton Cove and that at some locations the acid sulfate soils layer was within 0.3 metres of the soil surface NSW DPI (2008a). The results of the NSW DPI (2008a) study suggested that acid was also leaching from the soil into the main drains at the Tomago Wetland particularly the Fullerton Cove Ring Drain resulting in drain water which is slightly acidic.

The NSW DPI (2008a) study ranked all soil sample sites in wetland areas on Kooragang Island as medium risk. This was due to the deeper nature of acid sulfate soil at most sites, the natural water regime of the site and the absence of artificial drainage lines (NSW DPI 2008a). The lack of artificial drains was regarded as an advantage because most of the potential acid sulfate soil layer has never, and was unlikely to be (under the current wetland management), oxidised. Although the study did find that it was likely that sites in the central area of Ash Island which is adjacent to the Kooragang component were exporting some acid through ground water seepage (NSW DPI 2008a).

Although risks have been established for sites in the Hunter Estuary including the Kooragang component, the detailed distribution of acid sulfate soils is still largely unknown, as is the impact these soils are having on the estuary, including the Hunter Estuary Wetlands site.

7.3.5 Phytoplankton

Seasonal cycles of phytoplankton counts and chlorophyll-a concentrations suggest peaks in late summer and early spring. Zooplankton counts peak about a month afterwards, suggesting grazing might influence the phytoplankton population. The combined effect of high turbidity and strong vertical mixing suggests that phytoplankton is probably also light limited. Chlorophyll-a levels are similar to those reported around the time of listing and information on phytoplankton suggests little change to the algal community.

7.4 Vegetation

The most current vegetation mapping available is from 1993; Winning (1996) mapped similar communities to Outhred and Buckney (1983) but in slightly more detail. A number of mosaics originally mapped by Outhred and Buckney were subsequently mapped into separate components by Winning (1996). This means direct comparison between the mapping is difficult; however the vegetation types are broadly comparable. The areas of each community mapped in 1993 are presented in Table 7-1. It should be noted that this mapping is not directly comparable to Outhred and Buckney (1993) because there are differences between the mapping boundaries of the communities and the Ramsar site boundary. The Outhred and Buckney mapping did not include the northernmost extent of the Hunter Estuary Ramsar site adjacent to Cabbage Tree Road (Figure 3-10). Therefore some areas within the study area have not been mapped, particularly small slivers along boundaries and areas around drains. Also the mapping undertaken by Winning (1996) did not include a small portion in the north of Ramsar site. This was completed using the information from the Lower Hunter Catchment vegetation map layer provided by OEH but using the classifications of Winning (1996).

Table 7-1
Comparison of vegetation mapping units mapped by Winning (1996) and Outhred and Buckney (1983)

1983 Vegetation mapping types (Outhred and Buckney 1983)	Area mapped in 1983 (ha)	1993 Vegetation mapping types (Winning 1996)	Area mapped in 1993 (ha)
Open water	1286	Open Water	1289.8
Bare ground	39.9	Dunal scrub / weeds or bare sand	9.3
Vigorous mangroves (M1) Mangroves lacking vigour (M2)	1127.9	Mangrove forest / scrub	1293.5
Sarcocornia saltmarsh (SM1) *Sporobolus* saltmarsh (SM2)	570.1	*Sarcocornia quinqueflora, Sporobolus virginicus* saltmarsh	309
Juncus saltmarsh (SM3)	7.5	*Juncus kraussii* saltmarsh	12.5
Brackish swamp (SW)	23.8	*Typha orientalis, Phragmites australis, Schoenoplectus* spp, *Bolboschoenus* spp. brackish swamp	2.2
		Phragmites australis brackish swamp	62.4
Casuarina glauca woodland	3.4	*Casuarina glauca* woodland	28.7*
Saline Pasture (SP) *Sarcocornia* and *Sporobolus* Saltmarsh and saline pasture (SM1), (SM2), (SP) pasture (P)	233.2	*Agrostis avenacea, Sporobolus* saline pasture.	257*
		Pasture	9.1
		Pasture, dry grassland, dry herbland or cleared land	73.6*
Total areas	3291.8		3347.1

Some of the discrepancy between the mapping is likely to be due to issues of scale and detail; however, a number of changes to the vegetation within the study area are likely be real and the result of various changes to the wetland habitats and their surrounds, including upstream changes. Considerable work has been undertaken documenting the vegetation changes, particularly the transgression of mangrove into saltmarsh and loss of open water habitat in the Lower Hunter River (Buckney 1987; Williams et al. 2000).

Williams et al. (2000) using various maps and aerial photographs determined the changes in vegetation boundaries over the course of 40 years from 1954 to 1993. Generally they found that a decrease in open water is occurring, with mangroves expanding at the expense of saltmarsh communities. The decrease in open water is partially due to a direct infilling for industrial land but also due to sedimentation processes. Mangroves are colonising newly deposited sediments but are also expanding into areas of saltmarsh.

The expansion of mangroves has been attributed to an increase in the tidal range within the Hunter Estuary caused by dredging and deepening of channels, construction of levees and construction of floodgates (Herbert 2007b; Howe 2005). An increase in tidal range increases the degree of tidal inundation and can reduce the hypersalinity of saltmarsh environments and allow the colonisation of mangroves (Herbert 2007b). Rogers and Saintilan (2004) also found that salt marshes within the Ramsar site are subsiding at a rate greater than is being replenished by sediment which also has the potential to lead to a landward incursion of mangrove and a progradation of mangrove at the seaward interface.

Over the course of the 39 year period between 1954 and 1993 the amount of open water present within the study area decreased by 145 hectares or approximately 10% of the area present in 1954 (Table 7-2). Between the time of listing and 1993, the rate of change decreased and there approximately 1.5% decline in the area of open water over this period (Table 7-2). Mangroves have increased in extent over the 39 year period between 1954 and 1993 by a total of 492 hectares, with a large increase between 1954 and 1966 (195 hectares) and at least a further 109 hectares since the listing of the site in 1984 (Table 7-2, Figure 7-4). The loss of saltmarsh from the study area has almost mirrored the expansion of mangroves. There has been a significant decline in the area of saltmarsh since 1954, from 947 hectares to 339 hectares in 1993. Between the time of listing and 1993, there has been a decline in the area of saltmarsh of 41% (Table 7-2, Figure 7-4). The LAC for saltmarsh is exceeded if the areal extent of saltmarsh falls below 466 hectares. The most recent mapping of the saltmarsh indicates that it occupies an area of around 339 hectares therefore the LAC for this critical component is exceeded.

Table 7-2
Change in areas vegetation types and open water within the Hunter Estuary Wetlands Ramsar site between 1954 and 1993 (adapted from Williams et al. 2000)

Habitat	Area (ha) 1954	Area (ha) 1966	Area (ha) 1976	Area (ha) 1986	Area (ha) 1993	% change in area 1954-1993	% change since time of listing
Open water	1434	1364	1300	1308	1289	-10%	-1.5%
Mangrove	820	1015	1180	1203	1312	+60%	+9%
Saltmarsh	947	788	667	582	339	-64%	-41%

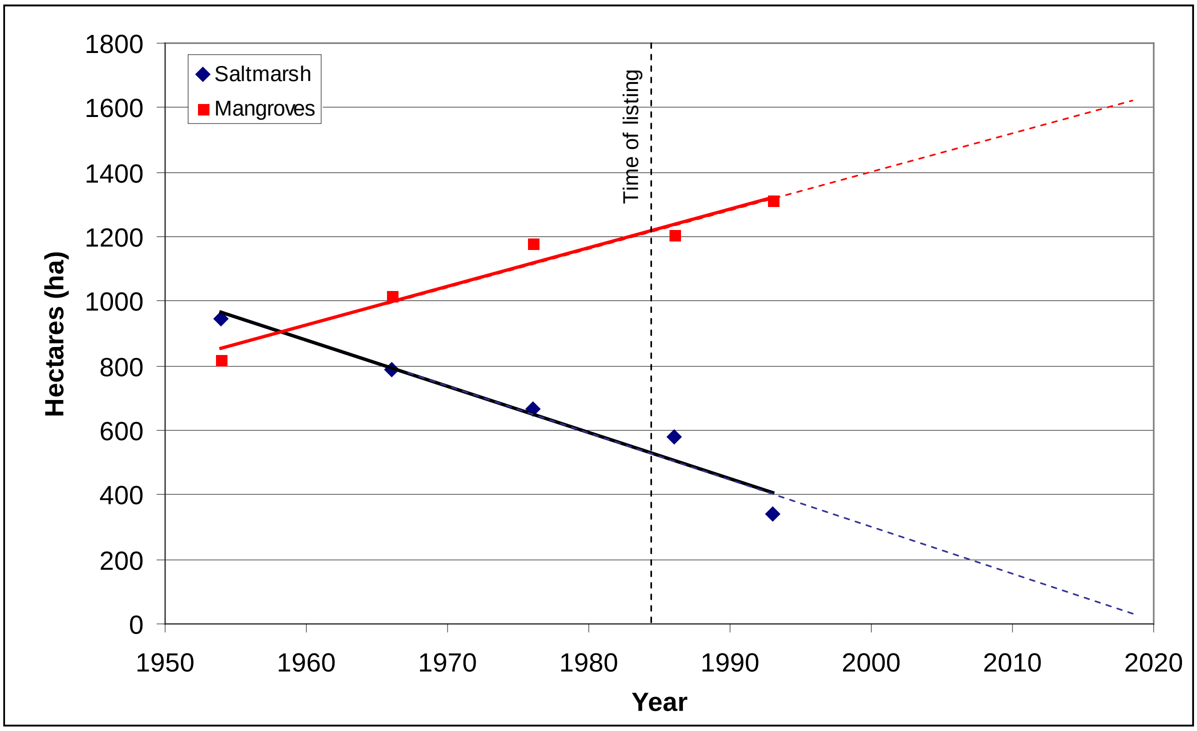


Figure 7-3
Changes in saltmarsh and mangrove distribution over time (dotted line is extension of trend (solid) line)

The other main vegetation change has been the expansion of common reed *(Phragmites australis*) within the brackish swamp communities. There was no common reed mapped as a vegetation community in 1983 (Outhred and Buckney 1983) although they did record it as a component of the Pasture community. Winning (1996) mapped 62.4 hectares of common reed in the 1993 vegetation map mostly in the Juncus swamp south east of the Ramsar site on Kooragang Island (Figure 7-4). The increase in area of common reed has been attributed to the decline in salinity in the soils due to the absence of saltwater inflows because of the installation of flood mitigation structures (e.g. floodgates, and levees) during the 1970s (Greenwood and MacFarlane 2006). The expansion of common reed has changed the community composition of the brackish swamps but has not changed the wetland type. *P. australis* brackish swamp is still considered as a Ramsar wetland type (intertidal brackish marsh).

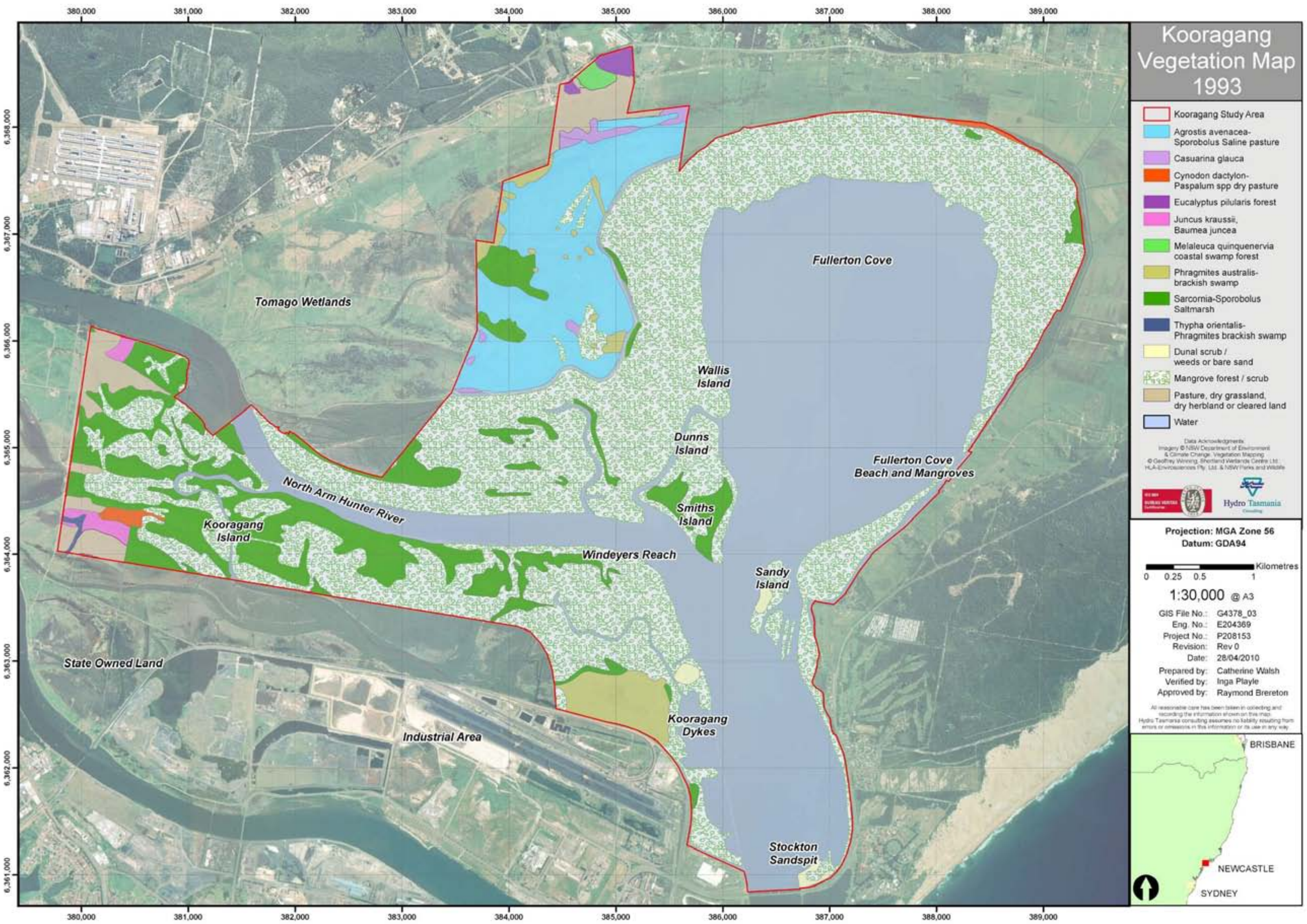


Figure 7-4: Vegetation map of the Kooragang component of the Hunter Estuary Wetlands Ramsar Winning 1996)

7.5 Birds

Herbert (2007a) has collated migratory shorebird survey data for the Hunter Estuary from the 1970s through to 2007 (Figure 7-5) which showed that there was an overall decline in the number of migratory shorebirds of more than 60% in the Hunter Estuary during this time. There are no data available for the time of listing in 1984, but in 1986 there were 6800 migratory shorebirds recorded in the estuary and by 1999 the number of shorebirds had declined by about 50% to around 3500 (Herbert 2007a, Figure 7-5). The maximum counts of migratory shorebirds recorded in the estuary has remained relatively stable from 1999 through to the present at around 3500, ranging from a low of 2 967 in 2005/06 to a high of 3626 in 2002/03, with six out of the eight counts recording more than 3330 birds (Herbert 2007a). The LAC for migratory shorebird abundance is for any five year period there will be no instance of all years recording a maximum summer annual count of migratory shorebirds of less than 5 000 birds. Between 1999 and 2007, a period of nine years, the maximum summer count of migratory shorebirds has not exceeded 3626 birds therefore the LAC for numbers of migratory shorebirds has been exceeded.

The decline in migratory shorebirds in the Hunter Estuary has been linked to the decline in saltmarsh in the estuary (Section 7.4). The decline in saltmarsh has been attributed to the expansion of mangrove forests which has been associated with a number of factors including: changes in rainfall, changes in sediment deposition and nutrient loads within the estuary; increased tidal range caused by harbour, river channel and mouth dredging combined with the construction of rock training walls for land reclamation; and the construction of flood gates on tidal creeks and rivers within the Hunter Estuary. Herbert (2007b) argues that it is the increase in tidal range caused by deepening of the harbour and channels, together with the closure of floodgates that has resulted in the expansion of mangroves throughout the Hunter Estuary. The HBOC has also reported that deposits of finer silts on the mudflats (e.g. at Kooragang Dykes and in Fullerton Cove) has led to a muddier substrate which may be becoming less suitable as foraging habitat for the smaller shorebirds such as curlew sandpiper and lesser sand plover (Ann Lindsay, HBOC, pers. comm.).

Associated with the decline in saltmarsh and the consequent loss of shorebird habitat since the 1970s, has been an overall decline in many species of migratory shorebirds within the East Asian – Australasian Flyway (Bamford et al. 2008) including the curlew sandpiper and red-necked stint. Bamford et al. (2008) also noted that there has been a localised decline in eastern curlews in Australia. The lesser sand-plover has also declined at the site to the point where it has not been recorded in the last 10 years (Herbert 2007a). In the 1970s, up to 800 birds were recorded in the Hunter Estuary but by 1984 this had declined to around 150. Between April 1999 and 2007, lesser sand-plovers were only recorded on a few occasions with the maximum number being three compared to 150 at the time of listing (Herbert 2007a). Three other species that were regularly recorded at the time of listing have also declined to the point where they have been rarely recorded over the past ten years – the ruddy turnstone, great knot, and broad-billed sandpiper (Herbert 2007a). Other species of migratory shorebirds that have showed declines since 1984 include the black-tailed godwit, bar-tailed godwit, whimbrel, eastern curlew, grey-tailed tattler, Terek sandpiper, and Pacific golden plover (Herbert 2007a). At the time of listing 17 species of migratory shorebirds were regularly recorded at the Hunter Estuary Wetland; between 1999 and 2007, bird surveys have recorded between 13 and 18 species of migratory shorebirds (Hunter 2007a). However, four species of shorebirds (the lesser sand plover, ruddy turnstone, great knot, broad-billed sandpiper) have declined to the point where they are recorded in significantly lower numbers in annual counts and classified by Herbert (2007a) as rarely recorded.

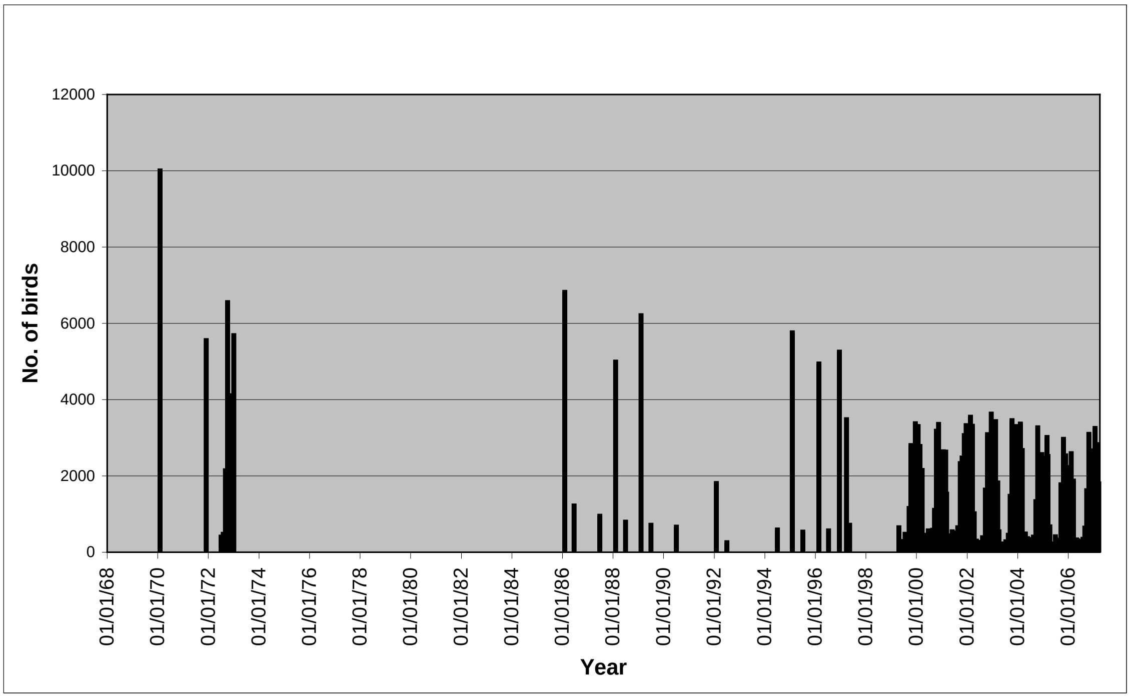
The LAC for shorebird diversity was based on available records of shorebird counts for the Hunter estuary (Herbert pers. comm. 2011). The baseline range for the period 1970 to 1989 was 17 to 18 species and the median maximum count was 18 species (Herbert, unpublished data 2011). What would constitute a significant decline in species richness resulting in a change in ecological character is not well understood. However, the data for the years 2003 to 2007, shows that the maximum species richness has been declining and was 16, 17, 16, 16 and 13 species in respective years.

Despite the decline in migratory shorebirds, the Hunter Estuary is still considered an important site for migratory shorebirds. Bamford et al. (2008) identified the Hunter Estuary as internationally important. The site still supports more than 1% of the East Asian-Australasian Flyway population of eastern curlews. The 1% threshold for this species is 380 individuals (Bamford et al. 2008). Between 1999 and 2007, 400 to 600 eastern curlews have been regularly counted in monthly surveys in the Hunter Estuary (Herbert 2007a). Most of these birds roost at the Kooragang Dykes and the Stockton Sandspit within the Kooragang component. The LAC for eastern curlew numbers is that for any five year period there will be no instance of all years recording a maximum summer annual count of eastern curlew of less than 300 birds. The LAC for the numbers of eastern curlew has not been exceeded.

In contrast to the declines of migratory waders noted above, a local shorebird, the red-necked avocet, has significantly increased in numbers. In the mid 1980s there were less than 100 red-necked avocets recorded but by 2007 the number had risen to over 5000 (Figure 7.6) (Herbert 2007a). They mostly forage in Fullerton Cove and roost at the lagoon at Stockton Sandspit, Kooragang Dykes and Dyke Ponds (Herbert 2007a). The red-necked avocet breeds at inland wetlands when conditions are suitable and it has been suggested that the increase in numbers in the Hunter Estuary may be due to the ongoing dry period in inland Australia and birds have moved to the estuary where there is water and feeding habitat. When the interior wetlands become wet the birds may disperse away from the coast; however, they return to the coast as the wetlands dry out (Herbert 2007a).

In 2002, rehabilitation works were carried out on the Stockton Sandspit which included the removal of fringing mangroves to provide a clear line-of-sight to the open water of the estuary (Herbert 2007a). Prior to its rehabilitation, its suitability as a roosting site had declined because of the establishment of mangroves. Herbert (2007a) records that the Stockton Sandspit is now one of the most important high tide roosts for shorebirds within the Hunter Estuary. Both the lagoon and saltmarsh on the sandspit are used for roosting and foraging. Twenty-three species of migratory shorebirds including up to 12 species that regularly use the sandspit, and ten species of non-migratory shorebirds have been recorded using the sandspit (Herbert 2007a), some in large numbers. For example up to 1000 bar-tailed godwits have often been recorded at the sandspit in recent years. In addition, the black-winged stilt and pied oystercatcher have been recorded breeding at Stockton Sandspit since the time of listing. At high tide as many as 5 000 red-necked avocet have been recorded roosting in the lagoon at the Stockton Sandspit (Herbert 2007a).

There has also been a change in the brackish swamp habitat at Juncus Swamp. When the vegetation of the area was mapped in 1983, Juncus Swamp was classed as a brackish swamp (Moss 1983). The termination of tidal flow along Moscheto Creek from the development of the industrial area to the south and the construction of the railway prior to the 1970s has caused Juncus Swamp to become a freshwater swamp dominated by common reed (*Phragmites australis*), broad leaved cumbungi (*Typha orientalis*) and spiny rush (*Juncus acutus*) (Herbert 2007a). It is still considered important habitat for Australian bitterns and bar-tailed godwits which have been recorded roosting in open water at the Juncus Swamp during winter (Herbert 2007a).



Data gaps in the graph indicate that count data is not available for those years

Figure 7-5

Total migratory shorebirds recorded in the Hunter Estuary between 1970 and 2007 (from Herbert 2007)

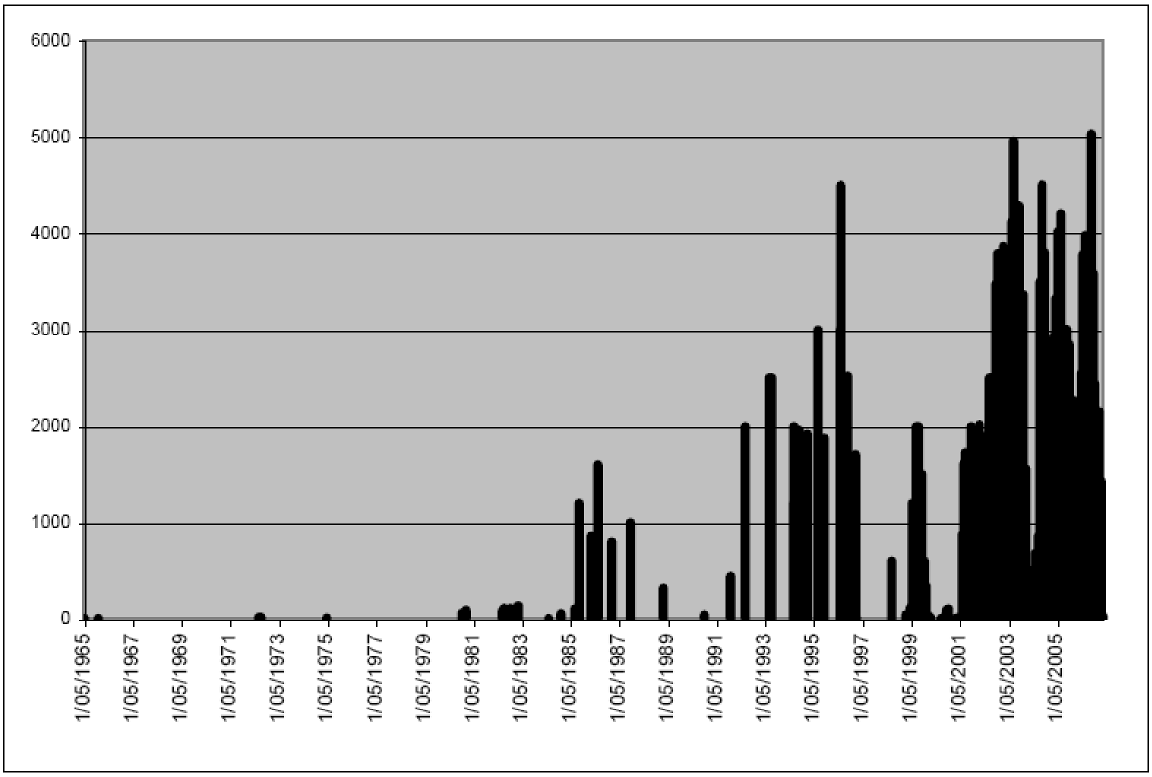


Figure 7-6

Red-necked avocet recorded within the Hunter Estuary (reproduced from Herbert 2007a)

7.5.1 Saltmarsh and migratory shorebird decline

Since 1954, the area of saltmarsh within the Kooragang component of the Hunter Estuary Ramsar site wetland has been declining with a subsequent increase in mangroves (Figure 7-7). This decline has been related to changes in tidal range, sediment fluxes and salinity regime. Migratory shorebird counts since 1970 (where data was available) show a similar declining trend (brown dashed line in Figure 7-7) as the area of saltmarsh (blue dashed line) up until 1999 when migratory shorebird abundances dropped significantly. Since this time migratory shorebirds have remained relatively stable. Since 1993, no comparative mapping of saltmarsh has been undertaken to assess its current coverage. Therefore validation of the current extent of saltmarsh within Kooragang is required to identify whether the rate of saltmarsh loss is continuing, or a stable regime has been established, and whether there may be further declines in shorebird numbers because of habitat loss. The error bars around the saltmarsh and mangrove points indicate the 20% accuracy limits of the vegetation mapping.

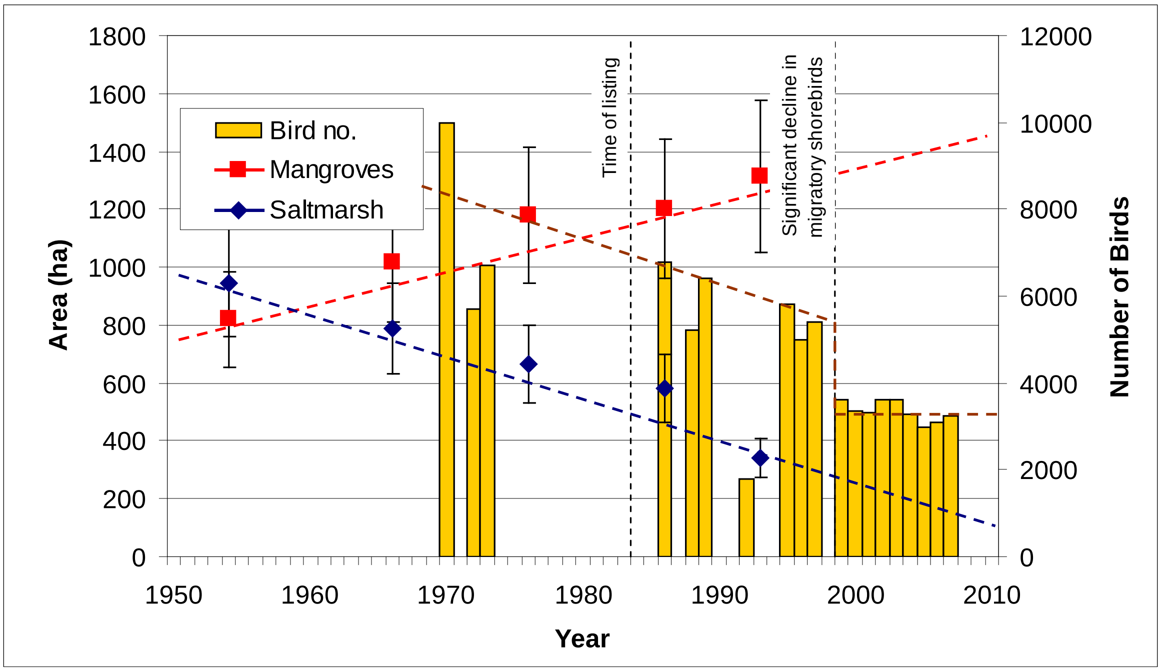


Figure 7-7
Changes in saltmarsh and mangrove distribution over time, with corresponding migratory bird counts (Herbert 2007a; dashed lines = trend lines)

7.6 Frogs

There is little data on the ecology of the frogs within the Kooragang component of the Hunter Estuary Wetland at the time of listing. However, there have been a number of recent studies on the green and golden bell frog. Hamer et al. (2002) in a study on the habitat determinants of the green and golden bell frog found that it had a preference for waterbodies with an abundance of the sedges *Juncus kraussii*, *Schoenoplectus littoralis* and salt couch, *Sporobolus virginicus*. The erect emergent sedges were thought to provide suitable micro-habitats for basking and foraging (Hamer et al. 2002). These sedges are indicative of brackish conditions although Hamer et al. (2002) found that none of the water chemistry parameters they measured, including salinity, were significant predicators of the presence of the green and golden bell frog. Hamer et al. (2002) recorded salinity levels ranging in water bodies inhabited by frogs ranging from 0.02 to 18.34 parts per thousand. The freshwater/brackish ponds inhabited by green and golden bell frog within the Ramsar site existed at the time of listing and therefore there have probably been no significant changes in available habitat.

There is no available data on the abundance of green and golden bell frogs within the Ramsar site at the time of listing or since the time of listing. However, a study of the population dynamics of the green and golden bell frog on Kooragang Island (part of which is included within the Ramsar site boundaries) estimated the population to be over 1 000 individuals in 21 occupied wetlands (Hamer et al. 2002).

Chytrid fungus has been introduced to Kooragang Island since the time of listing and has affected the distribution and abundance of the green and golden bell frog. Stockwell et al. (2008) in a study on the effects of chytrid fungus (*Batrachochytrium dendrobatidis*) on the green and golden bell frog found evidence that the frog’s preference for brackish wetland habitats on Kooragang Island may be influenced by the distribution of chytrid fungus. Stockwell et al. (2008) found that chytrid fungus growth was inhibited by the salt concentration in the wetlands. This suggested that chytrid fungus was infecting green and golden bell frog in freshwater wetlands on Kooragang Island resulting in their exclusion from these wetlands (Stockwell et al. 2008). However, green and golden bell frogs were persisting in brackish wetland habitats, as indicated by their habitat preference because the chytrid fungus did not flourish in brackish conditions. Therefore, chytrid fungus is likely to be suppressing the green and golden bell frog population within the Kooragang component of the Hunter Estuary Ramsar site.

A LAC for the green and golden bell frog has been developed, “there are no more than two years between successful breeding events (defined as a new first year adult cohort) in at least one of the three known populations”. There is no recent information on green and golden bell frog breeding events within the Ramsar site and therefore it is not possible to determine if the specified LAC for green and golden bell frog has been exceeded or not.

7.7 Fish

The results of fish studies since the time of listing cannot be compared to assess changes in the fish community as each study sampled in different parts of the estuary, using different sampling methods and equipment (Gibbs et al. 1999, The Ecology Lab 2006). To date there has been no consistent, replicated survey work that has been published. Gibbs et al. (1999) found a total of 68 fish species in the Hunter Estuary in 1999 compared to 59 species recorded by Ruello (1976) between 1966 and 1976. These two data points do not provide any indication of trends. Note that water quality in the estuary has remained much the same over the past 30 years apart from turbidity which has increased, therefore it would be unlikely that fish assemblages would have changed significantly. However, survey data on the extent of key fish habitats within the Ramsar site indicate that there have been changes in estuarine spawning and nursery habitat. A small increase in mangrove forest cover and a significant decline in saltmarsh (Table 7-3) have been observed which may have affected fish diversity and abundance.

Table 7-3
Extent of estuarine spawning and nursery habitats at time of listing and current

Habitat	Area (ha)	
	At time of listing	Current
Mangrove forest (*Avicennia marina* & *Aegiceras corniculatum*)	1203	1312
Saltmarsh	582	339

Despite the current environmental condition of the Hunter Estuary it presently supports a moderate diversity of euryhaline fish, with some of those species present in high numbers at various times (Appendix D). Further monitoring is required to measure abundances over time and thus ascertain the importance of the estuary in general, and Kooragang Wetlands in particular, as fish habitat.

The Hunter Estuary is a known habitat for two or three fish species of conservation significance (Table 7-4). At the time of the Ramsar listing of the site, the estuary stingray was the only threatened fish species recorded from the estuary. Targeted monitoring effort is required to determine the abundance and distribution of these species, and to clarify the importance of Hunter Estuary Wetlands in supporting communities of threatened and protected fish species.

Table 7-4
Species of conservation significance in the Hunter Estuary (sources: Ruello 1976; Shepherd 1994; Gibbs et al. 1999; IUCN Redlist version 2009.1)

Scientific name	Common name	Ecological significance
Dasyatis fluviorum	Estuary stingray	Vulnerable (IUCN)
*Psammogobius biocellatus**	Sleepy goby	Near-threatened (IUCN)
Vanacampus phillipi	Port Phillip pipefish	Protected in NSW

* Species identification is uncertain and may actually be *Glossogobius giuris* (Tank goby), which is considered to be common.

Four introduced fish species have been recorded from the Hunter Estuary (Table 7-5), compared with two species at the time of listing. Since then the goldfish and the oriental goby have been added to the list of introduced fish that occur within the Hunter Estuary Ramsar site.

Table 7-5
Introduced fish species in the Hunter Estuary (source: Ruello 1976; Copeland 1993; Shepherd 1994; Williams et al. 1995; Gibbs et al. 1999; The Ecology Lab 2006)

Scientific name	Common name	Ecology
Carassius auratus	Goldfish	Freshwater, tolerates some salinity short-term
Cyprinus carpio	European carp	Freshwater, tolerates some salinity short-term
Gambusia holbrooki	Mosquito fish	Freshwater, but capable of surviving salinities up to sea water for short periods
Acanthogobius flavimanus	Oriental goby	Marine euryhaline species, tolerating marine and brackish environments

7.8 Invertebrates

There is insufficient data to assess whether there has been any change in invertebrate diversity or abundance since the time of listing, with the exception of the school prawn. Data on commercial landings of school prawns in the years between 1978/79 and 2006/07 indicate that the catch rates were highly variable but stable, with no clear trends evident (NSW DPI 2008c). Even though there were no clear trends, the prawn fishery in NSW was considered to be growth overfished in some areas (NSW DPI 2008c). Note that is the total estuary prawn landings from the five coastal estuaries that were open to prawn trawling, the Clarence River, Hunter River, Hawkesbury River, Port Jackson and Botany Bay over this time. There was no indication that there were significant differences in trends in prawn landings between the estuaries (NSW Fisheries 2002). There were no long term data available for the Hunter Estuary but in 1999/2000 total reported landing of school prawn in the Hunter Estuary was 40 406 kilograms compared to 22 803 kilograms in 1978/79.

7.9 The current status of the LACs

The assessment of the current ecological condition indicates that the LACs for the numbers of migratory shorebirds recorded at the site annually and the saltmarsh community have been exceeded (Table 7-6).

Table 7-6
The current status of the limits of acceptable change for critical components, processes and services for the Kooragang component of the Hunter Estuary Wetlands

Critical ecological components, processes and services	Limits of acceptable change (Based on baseline and natural variability)	Current status of LAC
Significant species and communities components, processes and services		
Maximum number of species of migratory shorebirdsrecorded at site annually	A LAC was not set, but should be in future as better knowledge becomes available	The most recent available data is for 2003-2007 (Data provided by Herbert 2011) and shows that there is a declining trend in species richness from the baseline (18 species). 2003 - 16 species 2004 - 17 species 2005 – 16 species 2006 – 16 species 2007 - 13 species
Maximum number of migratory shorebirds recorded at the site annually	For any five year period there will be no instance of all years recording a maximum summer annual count of migratory shorebirds (of less than 5000 birds.	Between 1999 and 2007, a period of nine years, the maximum summer count of migratory shorebirds has been between 3090 and 3600. Therefore this LAC is exceeded.
Eastern curlew	For any five year period there will be no instance of all years recording a maximum summer annual count of eastern curlew of less than 600 birds.	Between 1999 and 2007, 400 to 600 eastern curlews have been regularly counted in monthly surveys in the Hunter Estuary (Herbert 2007a). The LAC for the numbers of eastern curlew has not been exceeded.
Green and golden bell frog	There are no more than two years between successful breeding events (defined as a new first year adult cohort) in at least one of the three known populations.	There is no recent information on green and golden bell frog breeding events within the Ramsar site and therefore it is not possible to determine if the specified LAC for green and golden bell frog has been exceeded or not.
Saltmarsh community	The areal extent of saltmarsh does not fall below 466 ha.	The most recent mapping of the saltmarsh in 1993 indicates that the area occupied is around 339 hectares. Therefore the LAC for this critical component is exceeded.

8. Knowledge gaps

The knowledge gaps linked to the components, processes or services that describe the ecological character of the Kooragang component of the Hunter Estuary Wetland Ramsar site are identified in Table 8-1. Where possible the knowledge gaps have been prioritised based on their importance to understanding critical components, processes or services of the ecological character and determining limits of acceptable change or major threats. Those knowledge gaps that have been identified as high (i.e. directly related to critical components or process, or major threats) which can be addressed through monitoring are discussed further in Section 9.

Table 8-1
Knowledge gaps for the Kooragang component of the Hunter Estuary Wetlands Ramsar site

Component, Process or Service	Sub-component or process	Knowledge gap	Recommended action	Priority
Green and golden bell frog	Breeding	There is no recent information on green and golden bell frog breeding events within the Ramsar site. Therefore it is not possible to determine if the LAC for the green and golden bell frog, "there are no more than two years between successful breeding events (defined as the presence of a new first year adult cohort) in at least one of the three known populations", has been exceeded or not.	Monitoring	High
Vegetation	Habitat for migratory waders	The most recent vegetation mapping that could be correlated back to the time of listing dates from 1993 (Winning 1996). While more recent vegetation mapping has been undertaken, this has been completed at a scale unsuitable for comparison to the baseline established for the Kooragang component. There is an urgent need to update the vegetation mapping to assist with validating the saltmarsh community LAC given the indicative trend (up to 1993) of a decline in the area of saltmarsh. A consistent approach to vegetation mapping (e.g. community descriptions) is required so that comparisons can be made between vegetation maps, including the identification and mapping of the distribution of inter-tidal mudflats.	Monitoring	High
Hydrology	Tidal range	Limited information is available on changes in tidal range and the impact on mangrove expansion, saltmarsh decline and changes in the distribution of intertidal mudlflats. Monitoring of tidal changes at a range of locations associated with the Ramsar site would assist in evaluating the need for a direct LAC associated with this critical process.	Research/Monitoring	Medium

Component, Process or Service	Sub-component or process	Knowledge gap	Recommended action	Priority
Geomorphology	Sedimentation	Sediment deposition rates and relationships with saltmarsh/mangrove vegetation/habitat changes are poorly known. As increased sedimentation has been identified as a major threat in combination with tidal changes, quantification of the rates of sedimentation associated with various sections of Kooragang component would assist in understanding the rate and trend of this threat.	Research /monitoring	Medium
Aboriginal heritage	Aboriginal sites and community interests	The site has a high potential to have important Aboriginal Heritage values. However, the Kooragang component has not been subject to a systematic survey and not much is known about the small number of sites that have been recorded within the Ramsar site. For this reason, it is considered to be important to establish a baseline for this service.	Research/consultation into Aboriginal heritage values within Kooragang (needs to be driven by the local Aboriginal communities) including: • re-visit the known Aboriginal sites and accurately describe their extent and condition • carry out a systematic survey for Aboriginal heritage places within the Ramsar site • improve knowledge of local Aboriginal spiritual and other attachments to this landscape and heritage sites within it	Medium
Invertebrates (infauna)	Soft sediment invertebrates	Soft sediment invertebrates are an important supporting component for shorebirds and little is known about their distribution, habitat preferences and response to changes in the estuary (e.g. changes in tidal regime, sediments, hydrological changes).	Research into the distribution and habitats of soft sediment biota, their role as a food source for shorebirds and their response to changing environmental conditions	Low
Fish	Species present	Obtain data on what species are breeding in Kooragang component, in what habitats (e.g. muddy, sandy bottoms, mangroves, saltmarsh) and the associated spawning cues/requirements.	Research into breeding requirements	Low

9. Monitoring needs

Recommendations for monitoring to measure changes in the ecological character of the Kooragang component of the Hunter Estuary Wetlands are outlined in Table 9-1. The recommendations are targeted at measuring changes in those critical components and processes or major threats that may indicate that the "Limits of Acceptable Change", identified in Section 6, are likely to be exceeded and that a change in ecological character may be occurring. The recommendations also include the monitoring of the presence of those threatened species that have been identified under Ramsar Criterion 2 for which the site is listed but for which limited data is available (green and golden bell frog, Australasian bittern and estuary stingray). Although these species may not have been identified as critical components of the ecological character, they are important to the site in meeting the Ramsar listing criteria.

Table 9-1
Recommended monitoring in the Kooragang component of the Hunter Estuary Wetlands Ramsar site

Overarching component, process, benefit or service	Specific component, process, benefit or service	Objective of the monitoring	Indicator/measure	Frequency	Priority
Biodiversity	Saltmarsh, mangroves and intertidal mudflats	To map vegetation changes to monitor decline in saltmarsh and loss of shorebird habitat over time	Areal extent of key vegetation communities and habitats i.e. saltmarsh, mangroves, intertidal mudflats	Five yearly	High
	Birds	To assess changes in the diversity and abundance of migratory shorebirds	Diversity and abundance of migratory shorebirds	Monthly (between September and April)	High
		To monitor changes in the populations of eastern curlews that visit the Hunter Estuary between September and April	Abundance of eastern curlew	Monthly (between September and April)	High
		To assess the presence of threatened species and identify important habitats (e.g. Australasian bittern)	Presence/absence of threatened species Habitats used by threatened species	Quarterly	Medium

Overarching component, process, benefit or service	Specific component, process, benefit or service	Objective of the monitoring	Indicator/measure	Frequency	Priority
Biodiversity	Frogs	To develop population estimates (abundance, distribution and presence of juvenile frogs) of green and golden bell frog to establish whether the brackish wetlands continue to be a refuge from the chytrid fungus	Presence and abundance of threatened species Presence of juvenile frogs to indicate successful breeding events Presence of chytrid fungus	Yearly during breeding season	Medium
	Fish	To assess the presence of threatened species and identify important habitats (i.e. estuary stingray)	Presence/absence of threatened species Habitats used by threatened species	Twice a year, especially during breeding season	Medium
Geomorphology	Sedimentation	To monitor sediment accretion and subsidence to help understand the process of wetland successional changes and to obtain an indication of the direction and rate of change	Sediment deposition/subsidence	Biannual	Medium
Hydrology	Tidal Range	To measure the tidal height and range to understand the process of wetland successional change and to monitor the direction and rate of change (increasing tidal range means increasing mangrove establishment and decline in saltmarsh).	Tidal height and range	Daily	Medium

10. Communication and education messages

Currently there are few communication, education, participation or awareness activities that have been developed specifically for the Hunter Wetlands National Park or the Kooragang component of the Hunter Estuary Wetlands Ramsar site. This is in part because public access to the park is limited and there are few opportunities for activities within the park because it is mostly wetland, saltmarsh and mangroves. These habitats are difficult habitats to provide access to and are sensitive to disturbance, particularly saltmarsh. There are two main points of public access, through the Kooragang Wetland Rehabilitation Project area on Ash Island, and the bird-watching viewing area at Stockton Sandspit under the Stockton Bridge. There are interpretation signs pointing out the natural features of the sandspit including the migratory shorebirds that visit the Hunter Estuary.

The Kooragang Wetland Rehabilitation Project (KWRP) which is based on Ash Island adjacent to the Hunter Estuary Wetland Ramsar site has a strong emphasis on community involvement through an education and extension program. The KWRP is a project of the Hunter-Central Rivers Catchment Management Authority (HCRCMA). The KWRP is involved in rehabilitation and restoration works on three sites in the Hunter River Estuary - Ash Island Tomago Wetlands and Stockton Sandspit. The last two sites are co-operative projects with the NSW OEH as they form part of Hunter Estuary Wetlands National Park. The KWRP community program aims to:

- facilitate community involvement and training activities through an education and extension program that features Kooragang City Farm;
- encourage the use of Kooragang and Tomago wetlands for educational purposes;
- enhance opportunities for outdoor recreation and nature appreciation;
- promote the Hunter Estuary as a centre of excellence in sustainable wetland management;
- maintain the international profile of wetlands of the Hunter Estuary; and
- maintain access and infrastructure for visitors.

The KWRP activities and the existing information provide a base from which to develop communication and education messages for the Hunter Estuary Wetlands Ramsar site. Those that could be given priority for the Kooragang component for the Hunter Estuary Wetlands Ramsar site include:

- its importance as a site for migratory shorebirds and for local shorebirds and waterbirds;

- the importance of maintaining saltmarsh habitat within the Ramsar site as foraging and roosting habitat for shorebirds;
- the relationship between mangrove expansion and saltmarsh decline including the likely causes and the efforts being made to rehabilitate saltmarsh habitat, e.g.:
  - opening floodgates in the Tomago Wetland Rehabilitation area to allow salt water flushing to create saltmarsh to provide roosting and foraging habitats for shorebirds, and
  - removing culverts on Ash Island and replacing them with bridges and flow-control structures to restore tidal flows in the creeks while minimising the encroachment of mangroves on saltmarsh;
- the efforts that have gone into maintaining Stockton Sandspit as an important high tide roost site for shorebirds including:
  - the creation of the inter-tidal lagoon on Stockton Sandspit,
  - the removal of mangroves, and
  - the maintenance of bare areas on the sandspit; and
- the sensitivity of foraging and roosting shorebirds to disturbance from boats and people particularly at areas which are readily accessible on foot such as Stockton Sandspit, and by boat (e.g. Kooragang Dykes, the intertidal flats in Fullerton Cove and North Arm) – how to minimise disturbance to wetland birds and other biota (e.g. the collection of pondweed at Stockton Sandspit).

11. References

Albrecht, G. and M. Maddock (1985). Avifauna of Shortland Wetlands. *Wetlands (Australia) 5*(2): 53-69.

ANZECC. (2000). *Australian Water Quality Guidelines for Fresh and Marine Waters.* Australian and New Zealand Environment and Conservation Council.

Bamford M., Watkins D., Bancroft, W., Tischler, G. and Wahl, J. (2008). *Migratory Shorebirds of the East Asian - Australasian Flyway; Population Estimates and Internationally Important Sites*. Wetlands International - Oceania. Canberra, Australia.

Bell, J.D., Pollard, D.A., Burchmore, J.J., Pease, B.C. and Middleton, M.J. (1984). *Structure of a fish community in a temperate tidal mangrove creek in Botany Bay, New South Wales*. Australian Journal of Marine and Freshwater Research 35, 33–46.

BMT WBM. (2009). *Hunter Estuary Management Study*. BMT WBM Pty Ltd, Prepared for Newcastle City Council.

Boyd, R. (2001). Geology and Soils of the Hunter Catchment and Evolution and Sedimentation of the Hunter Estuary. A report for Manly Hydraulics Laboratory as part of the Hunter Estuary Processes Study.

Buckney, R.T. (1987). *Three Decades of Habitat Change: Kooragang Island, New South Wales.* In *Nature Conservation: The Role of Remnants of Native Vegetation.* (eds). D.A. Saunders, G.W. Arnold, A.A. Burbidge and A.J.M. Hopkins. Pages 227-232. Surrey Beatty and Sons Pty Ltd, Sydney.

Casanelia, S. (1999a). *Port Phillip Bay (Western Shoreline) and Bellarine Peninsula – 18*. Information Sheet on Ramsar Wetlands (RIS). http://www.environment.gov.au/water/topics/wetlands/database/pubs/21-ris.pdf

Casanelia, S. (1999b). *Gippsland Lakes – 21*. Information Sheet on Ramsar Wetlands (RIS). http://www.environment.gov.au/water/topics/wetlands/database/pubs/21-ris.pdf

Cheng, D.M.H. (1983). *Water chemistry and biology of the Hunter River Estuary*. In *Investigation of the Natural Areas of Kooragang Island.* Department of Environment and Planning, Sydney. pp. 86-106.

Clarke, C.J. and Miller, P.F. (1983). *Habitat evaluation – invertebrates*. In J Moss. (ed). *An investigation of the natural areas: Kooragang Island, Hunter River.* 1983. Report prepared by C.D. Field and Associates and Insearch Ltd. Department of Environment and Planning, Sydney.

Clarke, C.J. and Van Gessel, F.W.C. (1983). *Habitat evaluation – birds*. In J Moss. (ed). *An investigation of the natural areas: Kooragang Island, Hunter River.* 1983. Report prepared by C.D. Field and Associates and Insearch Ltd. Department of Environment and Planning, Sydney.

Coffey, E.J. (1973). *Inquiry into Pollution: Kooragang Island, Report and findings of the Commissioner*. State Pollution Control Commission. 72pp.

Copeland C.A. (1993). *The Ironbark Creek Ecosystem - Section 2: Ecosystems Task Group Report*. Hunter Catchment Management Trust, Maitland, NSW, Australia.

Cornish, P.M. (1977). Changes in seasonal and annual rainfall in New South Wales. *Search* 8:38-40.

Dames and Moore (1978). *An assessment of the effect on the environment of the proposed Stage II landfill scheme at Kooragang Island, Newcastle, New South Wales*. Report to the NSW Dept. of Public Works

Department of Natural Resources (DNR). (2009). *New South Wales Department of Natural Resources Provisional River data* URL: http://waterinfo.nsw.gov.au - accessed 11 June 2009.

Department of the Environment, Water, Heritage and the Arts (DEWHA). (2008). *National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands.* Module 2 of the National Guidelines for Ramsar Wetlands— Implementing the Ramsar Convention in Australia. Australian Government Department of the Environment, Water, Heritage and the Arts, Canberra.

Department of the Environment, Water, Heritage and the Arts (DEWHA), (2009). 'Bilateral bird agreements' in *Biodiversity: Migratory Species in Australia*, accessed 12 January 2010, from http://www.environment.gov.au/biodiversity/migratory/waterbirds/bilateral.html

Edwards, T. C., Jr., G. G. Moisen, and D. R. Cutler. (1998). Assessing map uncertainty in remotely-sensed, ecoregion-scale cover-maps. Remote Sensing and Environment 63:73-83.

Ekert, P. (2002). Shortland Wetlands - Site Management Plan 2002 – 2009. The Wetlands Centre Australia, Wallsend NSW.

Environmental Resources Management. (2009). *Fern Bay Seaside Village Environmental Assessment - Annex I. Aboriginal Heritage Report.* Prepared for Aspen Group Pty Ltd.

Erskine, W.D. (1981). Effects of recent increases in rainfall on floods and runoff in the Upper Hunter Valley. *Search* 12:82–83

Eyre, B. (1998). Transport, retention and transformation of material in Australian estuaries. *Estuaries*. 21(4A): 540-551.

Fryirs, K., Spink, A. and Brierley, G. (2009). Post-European settlement response gradients of river sensitivity and recovery across the upper Hunter catchment, Australia. *Earth Surface Processes and Landforms*. 34(7): 897-918

Genders, A.J. (2001). Distribution and abundance of larval fishes and invertebrates along the Hunter River estuary, New South Wales, Australia, with specific reference to the effects of floodgates, MSc thesis, University of Newcastle.

Gibbs, P., McVea, T. and Louden, B. (1999). *Utilisation of Restored Wetlands by Fish and Invertebrates.* NSW Final Report Series No.16, NSW Fisheries. Pyrmont, NSW, Australia.

Gosper, D. G. (1981). Birds of the Hunter and Richmond Rivers, NSW. *Corella* 5(1): 1-18.

Gosper, D.G. (1974). A survey of avifauna utilizing wetland habitats on the N.S.W. Northern Rivers: Part 1. Estuarine Wetlands. Report to the NSW Parks and Wildlife Service.

Greenwood M.E. and G.R. MacFarlane, (2006). Effects of Salinity and Temperature on the Germination of *Phragmites australis*, *Juncus kraussii* and *J. acutus*: Implications for Estuarine Restoration Initiatives. *Wetlands* 26(3): 854–861

Hamer A.J. (1998) .*Aspects of the ecology of the green and golden bell frog (*Litoria aurea*) on Kooragang Island, New South Wales, Australia*. Masters of Environmental Science thesis, Dept. Geography and Environmental Science, University of Newcastle Callaghan, NSW, Australia.

Hamer, A. (1997). *The distribution of frog fauna in the Kooragang Wetland Rehabilitation Project Area, Ash Island, new South Wales*. Report for the Kooragang Wetland Rehabilitation Project

Hamer, A.J., and Mahony, M.J. (2007). Life history of an endangered amphibian challenges the declining species paradigm. *Australian Journal of Zoology* 55:79-88

Hamer, A.J., Lane, S.J. and Mahony, M.J. (2002). Management of freshwater wetlands for the endangered green and golden bell frog (*Litoria aurea*): roles of habitat determinants and space. *Biological Conservation* 106:413-424

Harris, V.A. (1994). New species belonging to the family Porcellidiidae (Harpacticoida: Copepoda) from Kioloa, New South Wales, Australia. *Records of the Australian Museum* 46: 303–340

HCRCMA (Hunter-Central Rivers Catchment Management Authority). (2009). http://www.hunterriverexplorer.com.au/hunter-catchment.html accessed March 2009.

Herbert, C. (2007a). *Distribution, Abundance and Status of Birds in the Hunter Estuary*. Report to Newcastle City Council. Hunter Bird Observers Club. Special Publication No. 4.

Herbert, C. (2007b). Mangrove proliferation and saltmarsh loss in the Hunter Estuary. *The Whistler* 1(1): 1-9.

Hodda, M., Nicholas, W.L. (1985). Meiofauna associated with mangroves in the Hunter River estuary and Fullerton Cove. *Australian Journal of Marine and Freshwater Research* 36: 41-50.

Howe, A. (2005). Effect of hydraulic manipulation on migratory shorebird habitat availability at an Australian coastal wetland. *XXXI Congress of the International Association of Hydraulic Engineering and Research Congress Proceedings*, Seoul, September 12-16, 2005, COEX, Seoul, Korea.

Howe, A. (2008). *Hydrodynamics, geomorphology and vegetation of estuarine wetlands in the Hunter, Australia: implications for migratory shorebird high tide roost availability*. PhD thesis. School of Engineering, University of Newcastle.

Hughes, C. H., Binning, P., Willgoose, G. R. (1998). Characterisation of the hydrology of an estuarine wetland. *Journal of Hydrology* 211, 34-49.

Hutchins, P. (1983). The Wetlands of Fullerton Cove, Hunter River, New South Wales, Wetlands: Journal of the Coast and Wetland Society 3:12-21.

Keith, D. (2004). *Ocean shores to desert dunes: the native vegetation of New South Wales and the ACT*. New South Wales Department of Environment and Conservation, Hurstville.

Kingsford, R.T. and Ferster Levy, R. (1997). Changes to the Hunter River Estuary, 1801 - 1996, and their Implications for Migratory Wading Birds and other Waterbirds. Report prepared for Environment Australia, National Parks and Wildlife Service, Hurstville, NSW.

Kooragang Wetland Rehabilitation Project. (undated). Fish and Crustacean Species of the Hunter River estuary (http://www.hcr.cma.nsw.gov.au/kooragang/5_FishCrustaceansSpeciesHRE.pdf, accessed 28 May 2009.

Laegdsgaard, P. and Johnson, C.R. (1995). Mangrove habitats as nurseries: unique assemblages of juvenile fish in subtropical mangroves in eastern Australia. *Marine Ecology Progress Series* 126 67-81 1995.

McDiarmid, G. (2009). *Survey and Mapping the Boundary of the Shortland Wetland Component of the Hunter River Estuary Ramsar Wetland–Draft Boundary Description and Mapping.* Unpublished Report to the Australian Government Department of the Environment, Water, Heritage and the Arts. GHD, Newcastle, NSW.

McGrath C (2006). Unpublished Legal review of the framework for describing the ecological character of Ramsar wetlands to support implementation of the EPBC Act. Report to the Department of the Environment and Heritage, Unpublished.

MHL (Manly Hydraulics Laboratory). (2003). *Hunter Estuary Processes Study.* NSW Department of Commerce, Manly Hydraulics Laboratory. Report No. MHL1095

Montgomery. S., and Winstanley, R.H. (1982. *Fishery Situation Report 6. Prawns (East of Cape Otway).* CSIRO Marine Laboratories, Cronulla NSW.

Moss, J. (ed). (1983). *An investigation of the natural areas: Kooragang Island, Hunter River.* Report prepared by C.D. Field and Associates and Insearch Ltd. Department of Environment and Planning, Sydney.

NSW DPI (Department of Primary Industries). (2006). *Reducing the impact of road crossing on aquatic habitat in coastal waterways* - *Hunter / Central Rivers, NSW.* New South Wales Government, Flemington NSW Australia.

NSW DPI (Department of Primary Industries). (2008a). *Acid Sulfate Soils: Priority Investigations for the Lower Hunter River Estuary*. Report to the Department of Environment, Water, Heritage and the Arts. NSW Department of Primary Industries (Aquatic Habitat Rehabilitation), Port Stephens.

NSW DPI (Department of Primary Industries). (2008b). *Primefact 825: Commercial Fishing in New South Wales*. State of New South Wales; Sydney NSW Australia.

NSW DPI (Department of Primary Industries). (2008c). *Status of Fisheries Resources in NSW, 2006/07. School prawn (*Metapenaeus macleayi*)*. Wild Fisheries Research Program. NSW Department of Primary Industry.

NSW Fisheries. (2002). *Estuary Prawn Trawl Fishery Environmental Impact Statement*: Public Consultation Document. NSW Fisheries, Cronulla NSW.

NSW National Parks and Wildlife Service. (1998). *Kooragang Nature Reserve and Hexham Swamp Nature Reserve Plan of Management.* NSW National Parks and Wildlife Service. Hurstville, NSW.

Outhred, R.K., and Buckney, R.T. (1983). Vegetation survey. In, J. (ed). *An investigation of the natural areas: Kooragang Island, Hunter River.* 1983. Report prepared by C.D. Field and Associates and Insearch Ltd. Department of Environment and Planning, Sydney.

Ramsar Convention. (1996). Resolution VI.1. Annex to Resolution VI.1. Working Definitions, Guidelines for Describing and Maintaining Ecological Character of Listed Sites, and Guidelines for Operation on the Montreux Record. http://www.ramsar.org/

Ramsar Convention. (2005). Resolution IX.1 Annex A. A Conceptual Framework for the wise use of wetlands and the maintenance of their ecological character. http://www.ramsar.org/

Ramsar Convention. (2008). Strategic Framework and guidelines for the future development of the List of Wetlands of International Importance of the Convention on Wetlands (Ramsar, Iran, 1971) 16/11/2008. Third edition, as adopted by Resolution VII.11 (COP7, 1999) and amended by Resolutions VII.13 (1999), VIII.11 and VIII.33 (COP8, 2002), IX.1 Annexes A and B (COP9, 2005), and X.20 (COP10, 2008). http://www.ramsar.org/

Ramsar Convention. (2009). The Ramsar Convention on Wetlands. www.ramsar.org (Accessed October 2009).

Rogers, K and Saintilan, N. (2004). *Monitoring the loss of saltmarsh at Kooragang Island. Progress Report 2004.* Centre for Environmental Restoration and Stewardship. Australian Catholic University National.

Rogers, K and Saintilan, N. (2009). *Predicting the response of coastal wetlands of south eastern Australia to sea-level rise*. Paper presented at the 18th NSW Coastal Conference 2009. (http://www.coastalconference.com/2009/default.asp , accessed 4/3/10)

Roy, P. S., Williams, R. J., Jones, A. R., Yassini, R., Gibbs, P. J., Coates, B., West, R. J., Scanes, P. R., Hudson, J. P., and Nichol, S. (2001). Structure and function of south-east Australian estuaries. *Estuarine, Coastal and Shelf Science* 53:351-384

Ruello, N.V. (1976). Environmental and biological studies of the Hunter River. *Operculum*, pp. 76-84.

Saintilan, N., and Williams, R.J. (2000). The decline of saltmarsh in south east Australia: Results of recent surveys. Wetlands (Australia) 18(2): 49-53

Sanderson, B and Redden, A. (2001a). *Hunter River Estuary Water Quality Data Review and Analysis*. Submitted to Manly Hydraulics Laboratory.

Sanderson, B and Redden, A. (2001b). *Salinity Structure of the Hunter River Estuary*. A report prepared for Newcastle Council.

Schmidt, K.S., Skidmore, A.K., Kloosterman, E.H., Van Oosten, H., Kumar, L., and Janssen, J.A. (2004). Mapping coastal vegetation using an expert system and hyperspectral imagery. Photogrammetric Engineering and Remote Sensing 70(6): 703-715

Shea, M. (1999). *A preliminary List of Non-Marine Molluscs of Ash Island (Kooragang Island) 1999.* Kooragang Wetland Rehabilitation Project.

Shepherd, M. (1994). *A Report to the Ecosystem Group of Ironbark Creek Catchment Management Committee on the Effects of Flood Mitigation Structures of Ironbark Creek on the Fish and Prawn Populations of the Mangrove Swamp Community*. Macquarie University, Macquarie NSW Australia.

SMEC. (2001). *Estuary Prawn Trawl EIA Report*. Prepared for NSW Fisheries. SMEC Australia Pty. Ltd. http://www.environment.gov.au/coasts/fisheries/nsw/prawntrawl/pubs/smec.pdf (accessed 19/2/10)

SPCC (State Pollution Control Commission). (1978). *Report of the State Pollution Control Commission for the year 1978*.

SPCC (State Pollution Control Commission). (1983). Hydrological study of Kooragang Island. In C.D. Field and Associates. 1983. *An investigation of the natural areas: Kooragang Island, Hunter River.* Ed. J. Department of Environment and Planning, Sydney.

Spencer, J. (2010). Migratory Shorebird Ecology in the Hunter Estuary, South-eastern Australia. PhD thesis. Centre for Environmental Restoration and Stewardship, Australian Catholic University: North Sydney, NSW.

Spink, A., Fryirs, K. and Brierley, G.J. (2005). *An assessment of the implementation and evolution of riverworks within the upper Hunter catchment.* International Association of Geomorphologists Conference, Zaragossa, Spain, September, 2005.

Stockwell, M.P., Clulow, S., Clulow, J. and Mahony. M. (2008). The impact of the Amphibian Chytrid Fungus *Batrachochytrium dendrobatidis* on a Green and Golden Bell Frog *Litoria aurea* reintroduction program at the Hunter Wetlands Centre Australia in the Hunter Region of NSW. *Australian Zoologist* 34(3): 379-

Taylor-Wood, E. and Jaensch, R. (2005). *Ecological Character of Shortland Wetlands - A Privately Managed* Ramsar *Site in NSW.* Report for the NSW Department of Environment and Conservation. Biosis Research Pty. Ltd, Chippendale, NSW.

The Ecology Lab. (2001). Hunter Estuary Processes Study: Aquatic Ecology. Report to Manly Hydraulics Laboratory, Final Draft June 2001.

The Ecology Lab. (2006). *Third Crossing of Hunter River - Aquatic Ecology*. Report to RTA Environmental Technology. The Ecology Lab Pty Ltd, Brookvale NSW Australia.

Tucker, G.B. (1975). Climate: Is Australia's Changing? *Search* 6(8): 323-328

West, R.J., Thorogood, C.A., Walford, T.R., and Williams, R.J. (1985). Fisheries bulletin 2: An estuarine inventory for New South Wales, Australia; Department of Agriculture New South Wales, Sydney, Australia.

Wetlands International. (2006). *Waterbird Population Estimates 4th edition.* Wetlands International, The Netherlands.

Williams, R.J., Hannan, J. and Balashov, V. (1995). *Kooragang Wetland Rehabilitation Project: Fish, Decapod Crustaceans and their habitats*. First Interim Report, summer 1993/94. Prepared for: Kooragang Wetland Rehabilitation Project. NSW Fisheries, Fisheries Research Institute, Cronulla.

Williams, R.J., Watford, F.A. and Balashov V. (2000). *Kooragang Wetland Rehabilitation Project: History of changes to Estuarine Wetlands of the Lower Hunter River*. NSW Fisheries Final Report Series Number 22. NSW Fisheries Office of Conservation, Cronulla.

Winning, G. (1989) *The Wetlands Centre: Site Management Plan 1990-1994*, The Wetlands Centre, Shortland Wetlands, NSW. Unpublished,

Winning, G. (1996). *Vegetation of Kooragang Nature Reserve and Hexham Swamp Nature Reserve and adjoining land.* Report for NSW National Parks and Wildlife Service. The Wetlands Centre, Shortland, NSW.

Appendices

Appendix A Criteria for Identifying Wetlands of International Importance

Appendix B Wetland birds recorded within the Kooragang component of the Hunter Estuary Wetlands

Appendix C Fish recorded within the Hunter Estuary

Appendix D Methods used to compile the Ecological Character Description

Appendix E Curricula vitae for authors

A Criteria for identifying wetlands of international importance*

Group A of the Criteria. Sites containing representative, rare or unique wetland types	
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[12].
Group B of the Criteria. Sites of international importance for conserving biological diversity	
Criteria based on species and ecological communities	
Criterion 2:	A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.
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.
Criterion 4:	A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.
Specific criteria based on waterbirds	
Criterion 5:	A wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds.
Criterion 6:	A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of waterbird.

[12] The Australian Government considers that the appropriate biogeographic region for the assessment of the Ramsar criteria is the drainage division, note that this is a change from the IBRA regions which were used for the RIS and which are on a much finer geographic scale.

Specific criteria based on fish	
Criterion 7:	A wetland should be considered internationally important if it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity.
Criterion 8:	A wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.
Specific criteria based on other taxa	
Criterion 9:	A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of wetland-dependent non-avian animal species.

*Adopted by the 7th (1999) and 9th (2005) Meetings of the Conference of the Contracting Parties

B Wetland birds recorded within the Kooragang component of the Hunter Estuary Wetlands

Compiled from Herbert (2007a), Clarke and Van Gessel (1983), RIS 2002

Key

(w) One of the 20 families of birds that are defined as waterbirds under the Ramsar Convention on Wetlands

Scientific Name	Common Name	NSW TSC Act	EPBC Act	IUCN Red List	Status	
					Resident / migrant	Breeding record
GALLIFORMES	OLD WORLD QUAIL AND PHEASANT					
Phasianidae						
Coturnix ypsilophora	Brown quail				Resident	Breeding
ANSERIFORMES	WATERFOWL					
Anatidae (w)	Ducks					
Biziura lobata	Musk duck				Resident	Breeding
Cygnus atratus	Black swan				Resident	Breeding
Tadorna tadornoides	Australian shelduck				Occasional visitor	
Chenonetta jubata	Australian wood duck				Resident	
Stictonetta naevosa	Freckled duck	Vulnerable			Rare resident	
Anas superciliosa	Pacific black duck				Resident	Breeding
Anas rhynchotis	Australasian shoveler				Resident	
Anas castanea	Chestnut teal				Resident	Breeding
Anas gracilis	Grey teal				Resident	Breeding
Malacorhynchus membranaceus	Pink-eared duck				Nomadic	
Aythya australis	Hardhead				Resident	Breeding

Scientific Name	Common Name	NSW TSC Act	EPBC Act	IUCN Red List	Status	
					Resident / migrant	Breeding record
PODICEPIDIFORMES	GREBES, DARTERS, CORMORANTS					
Podicepididae (w)	Grebes					
Podiceps cristatus	Great crested grebe				Resident	
Poliocephalus poliocephalus	Hoary-headed grebe				Nomadic	
Tachybaptus novaehollandiae	Australasian grebe				Resident	Breeding
Anhingidae (w)	Darters					
Anhinga melanogaster	Darter				Resident	
Pelecanidae (w)	Pelicans					
Pelecanus conspicillatus	Australian pelican				Resident	
Phalacrocoracidae (w)	Cormorants					
Phalacrocorax carbo	Great cormorant				Resident	
Phalacrocorax melanoleucos	Little pied cormorant				Resident	
Phalacrocorax sulcirostris	Little black cormorant				Resident	
Phalacrocorax varius	Pied cormorant				Resident	
CICONIIFORMES	HERONS, STORKS AND IBIS					
Ardeidae (w)	Herons and egrets					
Ardea alba	Great egret		Migratory		Resident	
Ardea ibis	Cattle egret		Migratory		Resident	
Ardea intermedia	Intermediate egret				Resident	
Ardea pacifica	White-necked heron				Resident	
Botaurus poiciloptilus	Australasian bittern	Vulnerable	Endangered	Endangered	Resident	
Butorides striatus	Striated heron				Resident	Breeding
Egretta garzetta	Little egret				Resident	
Egretta novaehollandiae	White-faced heron				Resident	Breeding
Ixobrychus flavicollis	Black bittern	Vulnerable			Rare resident	

Scientific Name	Common Name	NSW TSC Act	EPBC Act	IUCN Red List	Status	
					Resident / migrant	Breeding record
Ixobrychus minutus	Little bittern				Rare resident	
Nycticorax caledonicus	Nankeen night heron				Resident	
Ciconiidae (w)	Storks					
Ephippiorhynchus asiaticus	Black-necked stork	Endangered			Nomadic	
Threskiornithidae (w)	Ibis and spoonbills					
Platalea flavipes	Yellow-billed spoonbill				Nomadic	
Platalea regia	Royal spoonbill				Resident	
Plegadis falcinellus	Glossy ibis		Migratory		Nomadic	
Threskiornis molucca	Australian white ibis				Winter migrant[13]	
Threskiornis spinicollis	Straw-necked ibis				Winter migrant	
FALCONIORMES	DIURNAL BIRDS OF PREY					
Accipitridae	Hawks, eagles and kites					
Circus approximans	Swamp harrier				Resident	Breeding
Haliaeetus leucogaster	White-bellied Sea-Eagle		Migratory		Resident	
Haliastur indus	Brahminy Kite				Occasional visitor	
Falconidae	Falcons					
Falco cenchroides	Nankeen Kestrel				#	#
Falco longipennis	Australian Hobby				#	#
Falco peregrinus	Peregrine falcon				#	#
Falco subniger	Black falcon				#	#
GRUIFORMES	RAILS, CRANES AND BUSTARDS					
Rallidae (w)	Rails, crakes and gallinules					
Gallirallus philippensis	Buff-banded rail				Resident	
Rallus pectoralis	Lewin's rail				Resident	

[13] White ibis now breeding in the estuary (Herbert 2007a), 55 nests recorded in 2006/07 at the Hunter Wetlands Centre

Scientific Name	Common Name	NSW TSC Act	EPBC Act	IUCN Red List	Status	
					Resident / migrant	Breeding record
Porzana pusilla	Baillon's crake				Resident	Breeding
Porzana fluminea	Australian Spotted crake				Resident	Breeding
Porzana tabuensis	Spotless crake				Resident	
Porphyrio porphyrio	Purple swamphen				Resident	Breeding
Gallinula tenebrosa	Dusky moorhen				Resident	Breeding
Fulica atra	Eurasian coot				Resident	Breeding
CHARADRIIFORMES	WADERS AND GULLS					
Burhinidae	Thick-knees					
Esacus neglectus	Beach stone-curlew	Endangered				
Charadriidae (w)	Plovers and lapwings					
Charadrius bicinctus	Double-banded plover				Winter migrant	
Charadrius lescenaultii	Greater sand plover	Vulnerable	Migratory		Occasional summer migrant	
Charadrius mongolus	Lesser sand plover	Vulnerable	Migratory		Summer migrant	
Charadrius ruficapillus	Red-capped plover				Resident	Breeding
Charadrius veredus	Oriental plover		Migratory		Occasional summer migrant	
Elseyornis melanops	Black-fronted dotterel				Resident	Breeding
Erythrogonys cinctus	Red-kneed dotterel				Nomadic	
Pluvialis fulva	Pacific golden plover		Migratory		Summer migrant	
Pluvialis squatarola	Grey plover		Migratory		Occasional summer migrant	
Vanellus miles	Masked lapwing				Resident	Breeding
Vanellus tricolor	Banded lapwing				Occasional visitor	
Haematopodidae (w)	Oystercatchers					
Haematopus longirostris	Pied oystercatcher	Vulnerable			Resident	Breeding

Scientific Name	Common Name	NSW TSC Act	EPBC Act	IUCN Red List	Status	
					Resident / migrant	Breeding record
Haematopus fuliginosus	Sooty oystercatcher	Vulnerable			Resident	
Laridae (w)	Gulls, skuas					
Larus novaehollandiae	Silver gull				Resident	
Sterna nilotica	Gull-billed tern				Resident	
Sterna striata	White-fronted tern				Uncommon winter migrant	
Chlidonias hybridus	Whiskered tern				Nomadic	
Chlidonias leucopterus	White-winged Black tern		Migratory		Summer migrant	
Sterna albifrons	Little tern	Endangered	Migratory		Summer migrant	
Sterna bergii	Crested tern				Resident	
Sterna caspia	Caspian tern		Migratory		Resident	
Sterna hirundo	Common tern		Migratory		Summer migrant	
Recurvirostridae (w)	Stilts and avocets					
Cladorhynchus leucocephalus	Banded stilt				Occasional visitor	
Himantopus himantopus	Black-winged stilt				Resident	Breeding
Recurvirostra novaehollandiae	Red-necked avocet				Resident	
Rostratulidae	Snipe					
Rostratula benghalensis	Painted snipe		Migratory		Rare resident	
Scolopacidae (w)	Sandpipers					
Actitis hypoleucos	Common sandpiper		Migratory		Uncommon summer migrant	
Arenaria interpres	Ruddy turnstone		Migratory		Uncommon summer migrant	
Calidris acuminata	Sharp-tailed sandpiper		Migratory		Occasional summer migrant	
Calidris alba	Sanderling	Vulnerable	Migratory		Summer migrant	
Calidris canutus	Red knot		Migratory		Summer migrant	

Scientific Name	Common Name	NSW TSC Act	EPBC Act	IUCN Red List	Status	
					Resident / migrant	Breeding record
Calidris ferruginea	Curlew sandpiper		Migratory		Summer migrant	
Calidris melanotus	Pectoral sandpiper		Migratory		Summer migrant	
Calidris ruficollis	Red-necked Stint		Migratory		Summer migrant	
Calidris tenuirostris	Great knot	Vulnerable	Migratory		Summer migrant	
Gallinago hardwickii	Latham's snipe		Migratory		Summer migrant	
Heteroscelus brevipes	Grey-tailed tattler		Migratory		Summer migrant	
Heteroscelus incanus	Wandering tattler		Migratory		Occasional summer migrant	
Limicola falcinellus	Broad-billed sandpiper	Vulnerable	Migratory		Occasional summer migrant	
Limnodromus semipalmatus	Asian dowitcher		Migratory		Occasional summer migrant	
Limosa haemastica	Hudsonian godwit		Migratory		Rare summer migrant	
Limosa lapponica	Bar-tailed godwit		Migratory		Summer migrant	
Limosa limosa	Black-tailed godwit	Vulnerable	Migratory		Summer migrant	
Numenius madagascariensis	Eastern curlew		Migratory		Summer migrant	
Numenius minutus	Little curlew		Migratory		Occasional summer migrant	
Numenius phaeopus	Whimbrel		Migratory		Summer migrant	
Philomachus pugnax	Ruff		Migratory		Occasional summer migrant	
Tringa glareola	Wood sandpiper		Migratory		Occasional summer migrant	
Tringa nebularia	Common greenshank		Migratory		Summer migrant	
Tringa stagnatilis	Marsh sandpiper		Migratory		Summer migrant	
Tryngites subruficollis	Buff-breasted sandpiper		Migratory		Occasional summer migrant	
Xenus cinereus	Terek sandpiper	Vulnerable	Migratory		Summer migrant	

Scientific Name	Common Name	NSW TSC Act	EPBC Act	IUCN Red List	Status	
					Resident / migrant	Breeding record
PSITTACIFORMES	COCKATOOS, PARROTS AND LORIKEETS					
Psittacidae	Parrots and Lorikeets					
Platycercus eximius	Eastern Rosella				Resident	
CUCULIFORMES	CUCKOOS AND COUCALS					
Cuculidae	Cuckoos					
Chrysococcyx basalis	Horsfield's Bronze-Cuckoo					
Cuculus saturatus	Oriental Cuckoo		Migratory			
STRIGIFORMES	OWLS					
Tyto capensis	Grass Owl	Vulnerable				
CORACIIFORMES	KINGFISHERS					
Alcedinidae	Water kingfishers					
Alcedo azurea	Azure kingfisher				Resident	
Halcyonidae	Tree kingfishers					
Dacelo novaeguineae	Laughing Kookaburra				Resident	
Todiramphus macleayii	Forest Kingfisher					
Todiramphus sanctus	Sacred kingfisher				Summer migrant	
PASSERIFORMES	SONGBIRDS					
Artamidae	Woodswallows, Magpies, Butcherbirds and Currawongs					
Artamus leucorynchus	White-breasted Woodswallow				Summer visitor	
Gymnorhina tibicen	Australian Magpie				Resident	
Campephagidae	Cuckoo-shrikes and Trillers					
Coracina novaehollandiae	Black-faced Cuckoo-shrike				Summer migrant	
Corvidae	Ravens					
Corvus coronoides	Australian Raven				Resident	

Scientific Name	Common Name	NSW TSC Act	EPBC Act	IUCN Red List	Status	
					Resident / migrant	Breeding record
Dicruridae	Monarchs, Fantails, Magpielarks and Drongos					
Grallina cyanoleuca	Magpie-lark				Resident	
Myiagra inquieta	Restless Flycatcher				Summer migrant	
Rhipidura fuliginosa	Grey Fantail				Summer migrant	
Rhipidura leucophrys	Willie Wagtail				Resident	
Hirundo neoxena	Welcome Swallow				Resident	
Maluridae	Fairy-wrens					
Malurus cyaneus	Superb Fairy-wren				Resident	
Meliphagidae	Honeyeaters					
Ephthianura albifrons	White-fronted chat				Resident	
Lichmera indistincta	Brown Honeyeater				Resident	
Plectorhyncha lanceolata	Striped Honeyeater				Resident	
Motacillidae	Pipits and Wagtails					
Anthus novaeseelandiae	Richard's Pipit				Resident	
Motacilla flava	Yellow wagtail		Migratory		Rare summer migrant	
Acrocephalidae	Marsh- and tree-warblers					
Acrocephalus stentoreus	Clamorous reed-warbler				Summer migrant	Breeding
Cisticolidae	Cisticolas					
Cisticola exilis	Golden-headed cisticola				Resident	Breeding
Sylviidae	Old World Warblers					
Cincloramphus cruralis	Brown Songlark				Nomadic	
Cincloramphus mathewsi	Rufous Songlark				Summer migrant	
Megalurus gramineus	Little grassbird				Resident	Breeding
Megalurus timoriensis	Tawny grassbird				Resident	Breeding
Pardalotidae	Pardalotes, gerygones,					

Scientific Name	Common Name	NSW TSC Act	EPBC Act	IUCN Red List	Status	
					Resident / migrant	Breeding record
	scrubwrens and thornbills					
Acanthiza chrysorrhoa	Yellow-rumped Thornbill				Resident	
Acanthiza nana	Yellow Thornbill				Resident	
Gerygone levigaster	Mangrove gerygone				Resident	
Passeridae	House Sparrows and Grass Finches					
Lonchura castaneothorax	Chestnut-breasted Mannikin				Nomadic	
Taeniopygia bichenovii	Double-barred Finch				Nomadic	
Taeniopygia guttata	Zebra Finch				Nomadic	
Zosteropidae	White-eyes					
Zosterops lateralis	Silvereye				Resident	

C Fish recorded within the Hunter Estuary

KEY

F = freshwater FE = Freshwater euryhaline * = protected species in NSW

n/e = Not evalutated M = Marine ME = Marine euryhaline

						Source:	Kooragang Wetland Rehabilitation Project (undated)[14]	Ruello (1976)[15]	Copeland (1993)[16]	Shepherd (1994)[16]	Williams, Hannan & Balashov (1995)[14]	Gibbs, McVea & Louden (1999)[14]	The Ecology Lab (2006)
Family	Species	Common Name	Salinity class	IUCN status	EPBC Act status	Fishery species	<date>	1976	1993	1994	1995	1996	2005
Anguillidae	*Anguilla australis*	Short-fin eel	FE	n/e		Y	✓	✓	✓	✓		4	
Anguillidae	*Anguilla reinhardtii*	Long-fin eel	FE	n/e		Y	✓	✓	✓	✓	✓	3	
Antennariidae	*Antennarius striatus*	Striped anglerfish	M	n/e		-	✓	✓				2	
Atherinidae	*Atherinosoma microstoma*	Smallmouth hardyhead	FE	n/e		-						2	
Blenniidae	*Omobranchus anolius*	Oyster blenny	ME	n/e		-						7	
Callionymidae	*Callionymus limiceps*	Rough-headed dragonet	ME	n/e		-						2	
Carangidae	*Caranx sansun*	Papuan trevally	M	n/e		?		✓					
Carangidae	*Pseudocaranx dentex*	White travally	M	n/e		Y		✓				1	
Carangidae	*Trachurus novaezelandiae*	Yellowtail scad	M	n/e		Y		✓					
Chandidae	*Ambassis jacksoniensis*	Port Jackson glassfish	ME	n/e		-	✓	✓	✓	✓	✓	7319	?

[14] Kooragang Wetland Rehabilitation Project area on Ash Island
[15] Hunter River and estuary
[16] Ironbark Creek

						Source:	Kooragang Wetland Rehabilitation Project (undated)[14]	Ruello (1976)[15]	Copeland (1993)[16]	Shepherd (1994)[16]	Williams, Hannan & Balashov (1995)[14]	Gibbs, McVea & Louden (1999)[14]	The Ecology Lab (2006)
Family	Species	Common Name	Salinity class	IUCN status	EPBC Act status	Fishery species	<date>	1976	1993	1994	1995	1996	2005
Chandidae	*Ambassis marianus*	Estuary/Ramsay's glassfish	ME	n/e		-	✓	✓	✓	✓	✓	28	?
Clupeidae	*Herklotsichthys castelnaui*	Southern/Castelnau's herring	M	n/e		-	✓		✓	✓			
Clupeidae	*Hyperlophus translucidus*	Glassy sprat	M	n/e		-						1	✓
Clupeidae	*Hyperlophus vittatus*	Sandy sprat	M	n/e		-	✓		✓	✓	✓	21292	✓
Clupeidae	*Potamalosa richmondia*	Freshwater herring	FE	n/e		-		✓	✓	✓			✓
Clupeidae	*Sardinops sagax neopilchardus*	Australian sardine	M	n/e		-		✓					
Cynoglossidae	*Paraplagusia bilineata*	Lemon tongue-sole	M	n/e		-		✓					
Cyprinidae	*Carassius auratus*	Goldfish	F	n/e	EXOTIC	-	✓						
Cyprinidae	*Cyprinus carpio*	European carp	F	n/e	EXOTIC	-							✓
Dactylopteridae	*Dactyloptena orientalis*	Flying gurnard	M	n/e		-						1	
Dasyatididae	*Dasyatis fluviorum*	Estuary stingray	ME	Vulnerable		-		✓				4	
Diodontidae	*Dicotylichthys punctulatus*	Three-bar porcupinefish	ME	n/e		-		✓					
Eleotrididae	*Gobiomorphus australis*	Striped gudgeon	F	n/e		-	✓	✓	✓	✓		298	
Eleotrididae	*Gobiomorphus coxii*	Cox's gudgeon	F	n/e		-	✓						
Eleotrididae	*Hypseleotris compressa*	Emprie gudgeon	FE	n/e		-	✓		✓	✓		965	
Eleotrididae	*Philypnodon grandiceps*	Flathead gudgeon	F	n/e		-	✓	✓	✓	✓	✓	1055	
Eleotrididae	*Philypnodon sp. A*	Dwarf flathead gudgeon	F	n/e		-	✓		✓	✓		543	

						Source:	Kooragang Wetland Rehabilitation Project (undated)[14]	Ruello (1976)[15]	Copeland (1993)[16]	Shepherd (1994)[16]	Williams, Hannan & Balashov (1995)[14]	Gibbs, McVea & Louden (1999)[14]	The Ecology Lab (2006)
Family	Species	Common Name	Salinity class	IUCN status	EPBC Act status	Fishery species	<date>	1976	1993	1994	1995	1996	2005
Elopidae	*Elops hawaiensis*	Giant herring	ME	n/e		Y	✓	✓	✓	✓	✓		
Engraulidae	*Engraulis australis*	Australian anchovy	M	n/e		-	✓	✓				299	✓
Enoplosidae	*Enoplosus armatus*	Old wife	M	n/e		?		✓					
Galaxiidae	*Galaxias maculatus*	Common jollytail	FE	n/e		-	✓					2	
Gerreidae	*Gerres subfasciatus*	Silver biddy	ME	n/e		?	✓	✓				935	
Gobiidae	*Acanthogobius flavimanus*	Oriental goby	ME	n/e	EXOTIC	-	✓		✓	✓		53	
Gobiidae	*Afurcagobius tamarensis*	Tamar river goby	ME	n/e		-	✓				✓	3989	
Gobiidae	*Arenigobius bifrenatus*	Bridled goby	ME	n/e		-	✓	✓	✓	✓	✓	1965	
Gobiidae	*Arenigobius frenatus*	Half-bridled goby	ME	n/e		-	✓		✓	✓	✓	12	
Gobiidae	*Bathygobius krefftii*	Krefft's Frillgoby	ME	n/e		-		✓				5	
Gobiidae	*Cristatogobius gobioides*	Crested oyster goby	ME	n/e		-	✓			✓		13	
Gobiidae	*Favonigobius exquisitus*	Exquisite sand goby	ME	n/e		-	✓					4389	ü
Gobiidae	*Favonigobius lentiginosus*	Eastern long-finned goby	ME	n/e		-		✓				105	
Gobiidae	*Glossogobius biocellatus*[17]	Sleepy goby	ME	Near threatened?		-						1	
Gobiidae	*Gobiopterus semivestitus*	Glass goby	ME	n/e		-	✓	✓	✓	✓	✓	4123	
Gobiidae	*Mugilogobius paludis*	Mangrove goby	ME	n/e		-	✓		✓	✓	✓	179	

[17] This species name is not in current use, it may refer to *Psammogobius biocellatus* (sleepy goby), which is listed as near-threatened on the IUCN red list or it may be *Glossogobius giuris* (tank goby), which is common.

						Source:	Kooragang Wetland Rehabilitation Project (undated)[14]	Ruello (1976)[15]	Copeland (1993)[16]	Shepherd (1994)[16]	Williams, Hannan & Balashov (1995)[14]	Gibbs, McVea & Louden (1999)[14]	The Ecology Lab (2006)
Family	Species	Common Name	Salinity class	IUCN status	EPBC Act status	Fishery species	<date>	1976	1993	1994	1995	1996	2005
Gobiidae	*Mugilogobius stigmaticus*	Checkered mangrove goby	ME	n/e		-	✓				✓		
Gobiidae	*Pseudogobius sp. 9*	Blue-spot goby	FE	n/e		-	✓		✓	✓	✓	5570	
Gobiidae	*Redigobius macrostoma*	Large-mouth goby	ME	n/e		-	✓	✓		✓	✓	5117	✓
Gobiidae	*Taenioides mordax/purpurascens*	Eel goby	ME	n/e		-	✓	✓		✓			
Hemiramphidae	*Hyporhamphus regularis*	River garfish	ME	n/e		Y	✓	✓			ü	2	
Kyphosidae	*Girella tricuspidata*	Luderick / Blackfish	ME	n/e		Y	✓	✓				4	
Lutjanidae	*Lutjanus argentimaculatus*	Mangrove jack	ME	n/e		Y		✓					
Monacanthidae	*Meuschenia freycineti*	Six-spine leatherjacket	M	n/e		Y	✓						
Monacanthidae	*Meuschenia trachylepis*	Yellow-finned leatherjacket	M	n/e		?	✓					2	
Monodactylidae	*Monodactylus argenteus*	Silver batfish	ME	n/e		-	✓	✓					
Mugilidae	*Liza argentea*	Flat-tail mullet	ME	n/e		Y	✓	✓	✓	✓	✓	192	
Mugilidae	*Mugil cephalus*	Sea mullet	ME	n/e		Y	✓	✓	✓	✓	✓	301	ü
Mugilidae	*Myxus elongatus*	Sand mullet	ME	n/e		Y	✓	✓			✓	471	
Mugilidae	*Paramugil georgii*	Fantail mullet	ME	n/e		Y	✓			✓	✓	3	
Muraenescocidae	*Muraenesox cinereus*	Pike eel	ME	n/e		-		✓					

						Source:	Kooragang Wetland Rehabilitation Project (undated)[14]	Ruello (1976)[15]	Copeland (1993)[16]	Shepherd (1994)[16]	Williams, Hannan & Balashov (1995)[14]	Gibbs, McVea & Louden (1999)[14]	The Ecology Lab (2006)
Family	Species	Common Name	Salinity class	IUCN status	EPBC Act status	Fishery species	<date>	1976	1993	1994	1995	1996	2005
Paralichthyidae	*Pseudorhombus arsius*	Large-tooth flounder	ME	n/e		Y	✓					105	
Paralichthyidae	*Pseudorhombus jenynsii*	Small-tooth flounder	ME	n/e		Y	✓	✓				38	
Percichthyidae	*Macquaria colonorum*	Estuary perch	FE	n/e		Y		✓					
Percichthyidae	*Macquaria novemaculeata*	Australian bass	FE	n/e		Y		✓	✓	✓		1	ü
Platycephalidae	*Platycephalus arenarius*	Flag-tail flathead	M	n/e		Y						2	
Platycephalidae	*Platycephalus bassensis*	Sand flathead	M	n/e		Y		✓					
Platycephalidae	*Platycephalus fuscus*	Dusky flathead	M	n/e		Y	✓	✓	✓	✓		78	
Pleuronectidae	*Ammotretis rostratus*	Longsnout flounder	ME	n/e		Y						2	
Plotosidae	*Cnidoglanis macrocephalus*	Estuary catfish	ME	n/e		-	✓			✓		1	
Plotosidae	*Euristhmus lepturus*	Longtailed catfish	ME	n/e		-		✓					ü
Poeciliidae	*Gambusia holbrooki*	Mosquitofish	F	n/e	EXOTIC	-	✓	✓	✓	✓	✓	43	
Pomatomidae	*Pomatomus saltatrix*	Tailor	M	n/e		Y	✓	✓				109	
Priacanthidae	*Priacanthus macracanthus*	Spotted big-eye	M	n/e		Y		✓				1	
Pseudomugilidae	*Pseudomugil signifer*	Southern blue-eye	FE	n/e		-	v		✓	✓	✓	110	
Retropinnidae	*Retropinna semoni*	Smelt	F	n/e		-		✓					
Scatophagidae	*Scatophagus argus*	Tiger/Spotted scat	ME	n/e		-		✓					
Scatophagidae	*Selenotoca multifasciata*	Striped/Banded scat, butterfish	ME	n/e		-	✓	✓					

						Source:	Kooragang Wetland Rehabilitation Project (undated)[14]	Ruello (1976)[15]	Copeland (1993)[16]	Shepherd (1994)[16]	Williams, Hannan & Balashov (1995)[14]	Gibbs, McVea & Louden (1999)[14]	The Ecology Lab (2006)
Family	Species	Common Name	Salinity class	IUCN status	EPBC Act status	Fishery species	<date>	1976	1993	1994	1995	1996	2005
Sciaenidae	*Argyrosomus japonicus*	Jewfish/Mulloway (juveniles)	M	n/e		Y		✓					
Scorpaenidae	*Centropogon australis*	Fortescue	M	n/e		-	✓	✓		✓	✓	199	
Scorpaenidae	*Notesthes robusta*	Bullrout	FE	n/e		-		✓	✓	✓		3	
Sillaginidae	*Sillago ciliata*	Sand whiting	ME	n/e		Y	✓	✓				912	
Sillaginidae	*Sillago maculata*	Trumpeter whiting	ME	n/e		Y		✓				1	
Soleidae	*Aseraggodes macleayanus*	Narrow banded sole	M	n/e		Y		✓					
Soleidae	*Synaptura nigra*	Black sole	ME	n/e		Y	✓					3	
Sparidae	*Acanthopagrus australis*	Yellowfin Bream	ME	n/e		Y	✓	✓	✓	✓	✓	1087	✓
Sparidae	*Rhabdosargus sarba*	Tarwhine	M	n/e		Y	✓		✓	✓		50	
Sphyraenidae	*Sphyraena novaehollandiae*	Short finned sea pike	M	n/e		Y		✓					
Sphyraenidae	*Sphyraena obtusata*	Striped sea pike	ME	n/e		Y						1	
Syngnathidae	*Vanacampus phillipi*	Port Phillip Pipefish*	M	n/e		-				✓			
Terapontidae	*Pelates quadrilineatus*	Trumpeter	M	n/e		Y	✓						
Terapontidae	*Pelates sexlineatus*	Eastern striped trumpeter	M	n/e		?						15	
Terapontidae	*Terapon jarbua*	Crescent perch	ME	n/e		Y	✓	✓	✓	✓		1	
Tetraodontidae	*Marilyna pleurosticta*	Toadfish	ME	n/e		-						1	
Tetraodontidae	*Tetractenos glaber*	Smooth toadfish	ME	n/e		-						4	
Tetraodontidae	*Tetractenos hamiltoni*	Common toadfish	ME	n/e		-	✓	✓				98	
Tetraodontidae	*Torquigener pleurogramma*	Weeping toado	ME	n/e		-						4	

						Source:	Kooragang Wetland Rehabilitation Project (undated)[14]	Ruello (1976)[15]	Copeland (1993)[16]	Shepherd (1994)[16]	Williams, Hannan & Balashov (1995)[14]	Gibbs, McVea & Louden (1999)[14]	The Ecology Lab (2006)
Family	Species	Common Name	Salinity class	IUCN status	EPBC Act status	Fishery species	<date>	1976	1993	1994	1995	1996	2005
Tetraodontidae	*Torquigener squamicauda*	Brushtail toadfish	ME	n/e		-						2	
Triglidae	*Chelidonichthys kumu*	Red gurnard	ME	n/e		Y		✓				1	
Urolophidae	*Trygonoptera testacea*	Common stingaree	ME	Least concern		-		✓					

D Methods used to compile the Ecological Character Description (ECD)

The Ecological Character Description (ECD) for the Hunter Estuary Wetlands Ramsar site was compiled by Hydro Tasmania Consulting (HTC). HTC has compiled this ECD in accordance with the *National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands* Module 2, (DEWHA 2008). This document refers to the character and condition of the wetland at the time of listing (1984), although much of the data is drawn from more recent research and documentation. The process for the development of this ECD is outlined below:

1. Inception meeting:

- Discussions on what constituted the Kooragang component of the Hunter Estuary Wetland Ramsar Site
- Discussions and suggestions on the methods to describe the ecological character in the ECD and the changes since time of listing
- Identification and provision of relevant information held by the key stakeholders (e.g. reports, GIS layers, files)
- Identification of additional stakeholders for further consultation

2. Literature review and consultation

- The current Ramsar Information Sheet and Management Plan for the site
- Information provided by key stakeholders
- Available literature (see Section 11), databases (EPBC protected matters, BioNet), spreadsheets, GIS layers and other information relevant to the ecological character of the Ramsar site (as defined by its boundaries)
- Consultation with relevant experts/stakeholders, research institutions and government agencies
- Key references for flows and water management, including papers and reports that specifically address the wetland and any available modelling and/or flow/rainfall data
- Experience and knowledge of the project team including independent research.

3. Field visit and ecological assessment

- Clarification of the ecological character of the site based on the information gained from review of the literature, available data, and the general understanding of stakeholders
- Undertaken by Raymond Brereton from HTC in June 2009 who used the opportunity to further meet with local stakeholders and liaise with local ecologists.

4. Conceptual models

- Developed by the project team following completion of the literature review and field assessment

5. Reporting

- Based on the guidelines for describing the ecological character of Australian Ramsar wetlands (DEWHA 2008)

Internal and external review

E Curricula vitae for authors

Short curricula vitae for the authors of this version of the ECD are provided below:

Short curricula vitae for the authors of the ECD are provided below:

Raymond Brereton

Raymond Brereton is a Senior Ecologist for Hydro Tasmania Consulting. His role requires Raymond to be a technical specialist and project manager being responsible for conducting and managing environmental impact assessments and development approvals for wind farm developments, and other energy and water infrastructure projects. Raymond also has a technical specialist and project management role in natural resource planning and management projects for government agencies.

Raymond has expertise in performing environmental assessments and approvals and assessing the impacts of developments on fauna, flora and their habitats, providing advice on policy and prescriptions for fauna and flora conservation and providing guidance and training on fauna and flora conservation and management.

Raymond has had over twenty years previous experience working for natural resource management agencies in the field of fauna and flora conservation, addressing the impacts of developments on fauna, flora and their habitats; providing advice on policy and prescriptions for fauna and flora conservation; providing guidance and training on fauna and flora conservation and management; monitoring implementation of management prescriptions; and supervising fauna research projects.

Eleni Taylor-Wood

Dr Eleni Taylor-Wood is a Principal Consultant with Hydro Tasmania Consulting and has over ten years experience in project management and terrestrial and aquatic ecology. Eleni specialises in aquatic plants having studied seagrasses, marine and estuarine macroalgae, aquatic freshwater macrophytes and phytoplankton (freshwater and marine) both as a research scientist and environmental consultant. While working as an environmental consultant, Eleni has been involved in a diverse range of studies including: terrestrial flora and fauna assessments; aquatic surveys and impact assessment; environmental flow studies; design and implementation of monitoring programs; instream, riparian and wetland management; and investigations into the transportation pests (aquatic and terrestrial).

Eleni was a member of the Independent Expert Panel assisting the Hawkesbury-Nepean Management Forum from 2001 - 2005. Eleni's role on this panel was to provide advice on matters relating to vegetation (aquatic and riparian) especially in regards to environmental flow regimes, monitoring programs and management of the riverine environment. Eleni has considerable experience with successfully project managing large-scale, complex projects that run over several years. Eleni also has experience in providing expert advice and critically reviewing reports.

Stephen Casey

Stephen Casey is a Senior Consultant with Hydro Tasmania Consulting with expertise in the areas of environment impact assessments and ecological surveys and assessments. This role requires Stephen to provide advice on environmental impact assessments for major projects, undertake flora and fauna habitat surveys, and develop mitigation strategies for clients. This involves engaging with stakeholders and liaising and negotiating with regulatory authorities.

Stephen has an excellent knowledge of Tasmania's conservation values, including threatened species and vegetation communities and is involved in ecological assessment surveys for wind farm development in Australia.

Dax Noble

Dax Noble is an Environmental Scientist with Hydro Tasmania Consulting and is responsible for carrying out environmental impact assessments, preparing environmental management plans and seeking environmental approvals for infrastructure development. This role requires Dax to carry out contaminated site assessments and field investigations including site selection and analysis.

Dax has over three years experience in coastal and fluvial geomorphology, environmental/land and water management. Dax has worked both overseas and within Australia on varying projects including participating in an exchange program in the Netherlands undertaking field work on fen meadows focusing on water quality, ground water, ecohydrology and disturbed area restoration.

Dax has presented the 'Transition from Study to Work - Over three years of Reflection' to the 'Industry Connect Seminar Series' in New Zealand at the Environment Institute of Australia and New Zealand.

Brad Smith

Brad Smith is an Environmental Scientist and is responsible for Aquatic Ecology including aquatic macroinvertebrate taxonomy and ecology, low lake level management and assessing the impacts of development on the aquatic environment. This role requires Brad to undertake scientific investigations into impact assessments and conduct surveys and monitoring of the aquatic environment. Brad also provides advise on the mitigation and monitoring of the aquatic environment as a result of past and recent developments. Brad has over five years professional experience in water management, field logistics, stakeholder liaison and lab processing. Brad currently participates and manages various projects within Hydro Tasmania's Aquatic Environment Program and has published a paper on the 'Changes in benthic macroinvertebrate communities in upper catchment streams in Tasmania across a gradient of catchment forest operation history' in a respected, peer reviewed journal.

Jen Smith

Jen Smith is a Senior Environmental Consultant with Hydro Tasmania Consulting. Jen has over Fifteen years professional experience in providing technical experience in field archaeology and specialises in Aboriginal heritage in Tasmania.

Caroline Whalley (Water Quality)

Caroline Whalley is an Aquatic Scientist with Hydro Tasmania Consulting and is responsible for undertaking project management within the aquatic ecology and water quality fields. This role requires Caroline to undertake report writing, data interpretation and field surveys.

Caroline undertook a project called 'Watercheck' as lead Marine Biologist which involved testing the water quality of twenty-five recreational areas around Europe. The project was ship-based for four months, with analysis undertaken using onboard laboratory facilities. As well as building a picture of the overall beach and water quality throughout Europe, the aim of the study was to allow recommendations to be made on how the methodology and monitoring strategy could be incorporated into the revised EC Bathing Water Directive. Caroline's PhD research involved monitoring the water quality of waste stabilisation ponds in variable climates. Continuous and spot measurements were taken for chlorophyll-a, nutrients, dissolved oxygen, pH, temperature and turbidity. This was followed by data analysis and interpretation. Using the results, potential improvements to the design of cold climate ponds were discussed with the emphasis on enabling the re-use of treated wastewater.

James Bennett (Hydrologist)

James Bennett is a Hydrologist with Hydro Tasmania Consulting and is responsible for hydrological modelling. James is experienced in building, running and calibrating hydrological models using a variety of software. James has worked on both inflows and flood forecasting, including statistical analyses of these forecasts. James is experienced with Geographic Information Systems (GIS) software and its use in hydrology.

James is an able communicator and is able to synthesise complex methods and results in clear and concise reports and presentations. James has written technical reports for a variety of clients and his academic background is in environmental hydrology, including soils and geomorphology, biology, politics and mathematics.

James has worked on a variety of statewide hydrological projects within Tasmania including Tasmania Sustainable Yields and Climate Futures for Tasmania. These world leading studies utilise the most recent development in climate modelling to assess hydrological impacts in Tasmania. These projects have involved building large river system models to assess water yield under climate change.

James is currently pursuing a Masters in Climate Change Hydrology.

Toni Radcliff (Fish)

Toni Radcliffe in an Aquatic Scientist with Hydro Tasmania Consulting and is responsible for the management and delivery of projects is freshwater ecology. This role requires Toni to undertake field and desktop based ecological assessments, to provide scientific advice and to communicate with and reporting to clients and key stakeholders.

Toni has over five years of professional expertise and has undertaken a range of work including ecosystem condition monitoring and assessments, environmental flow assessments, impact assessments and integrated ecology studies. Toni has supported scientific monitoring by community-based groups, developing resources, providing training and expert advice to stakeholders and clients. She is skilled in freshwater fish ecology, having worked on projects involving fish behavioural ecology, community monitoring, movement studies, dietary studies and critical flow requirements. She is experienced in electrofishing, bait trapping, seining and other fish survey techniques, as well as fish husbandry, aquarium maintenance and experimental systems design and operation.